

Another Giant Leap: Potentials of the Nascent Private Commercial Space Industry

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*“It is difficult to say what is impossible, for the dream of yesterday
is the hope of today and the reality of tomorrow”*

-Robert H. Goddard

Many of the defining and shaping moments across the timeline of human existence have come from entering and utilizing new frontiers. These moments, of pushing and subsequently moving the limits, do not come often, but when they do, they expand the horizons of mankind. Though it is not without overcoming risk and enduring struggles that each frontier is utilized, and its enormous benefits are reaped. History has shown this pattern time and time again. In 1000 B.C, the Ancient Greek and Phoenician traders of the Mediterranean, after years of following established, secure routes, decided to venture beyond where they or their fathers ever had traveled, risking the safety of their cargo. Ultimately, they were victorious; they discovered new people with new resources to trade with (Cordiner). Later, Leif Erickson, the great viking explorer, through a perilous journey arrived at the capacious American continent, but “apparently the Vikings did not have the vision to see anything worthwhile on that vast, empty continent, and so history waited another half millennia” until Columbus and the European nations saw the potential in this new world (Cordiner). The impacts of utilizing this new frontier for the European countries were momentous. It gave them immense land, power, wealth, resources and influence, which is still felt today. Even the western United States at one time seemed so unpromising that Napoleon sold it to the United States. Thomas Jefferson bought it, not fully knowing what was in it or what benefits and challenges it might bring. Yet, his single purchase “doubled the size of the United States and changed the course of history. Thomas Jefferson did not know what he bought, but he sent Lewis and Clark to find out, and private traders, homesteaders, and businessmen followed in their path to turn the empty wilderness into the heartland of a great nation” (Cordiner). Once again making use of a frontier brought immense impacts and changed history forever. But, surely there are no frontiers today. A quick glance at a globe will show there is no land to colonize, no new regions to discover, no people to find. But why should our frontiers be limited to the globe? The next frontier is beyond our planet. Space, with all its magnitude and potential, may not be the final frontier, but it surely is the next for mankind. In fact during the Space Race, we caught a glimpse of what benefits space might bring, and it truly captivated the world. However, within 15 years, we stopped dreaming, and let our hopes come back down to earth. We closed up the pin-prick which we had made into the pool of

benefits that is space, and brought our eyes back to the miniature globe we call home; to such a point that today youth care more about the amount of megapixels on their five inch smartphones more than the overwhelmingly majestic and impressive expanse of outer space. Burt Rutan, an innovator and advocate for increased activity in outer space summed up our predicament well when he said:

Houston, we have a problem. We're entering a second generation of no progress in terms of human flight in space. In fact, we've regressed. We stand a very big chance of losing our ability to inspire our youth to go out and continue this very important thing that we as a species have always done. They need to look forward to exploration; they need to look forward to colonization; they need to look forward to breakthroughs. We need to inspire them, because they need to lead us and help us survive in the future. (Rutan)

Recently however, there has been a rejuvenation of space activity. A newly founded private commercial space industry is beginning to reopen the eyes of the world which for too long have squinted at our tiny earth in frustration. This innovative and audacious industry seeks to return to space and open it up for good as a commercially available and accessible field of private travel, as well as a region for global commerce and business. They strive to, as the movers of history before them, unlock and utilize the next frontier.

Many of these companies fall under the umbrella of NewSpace. NewSpace is a term used in the private space industry. It does not have concrete parameters as to what it describes and is thus challenging to define. However, it refers to private space companies, often backed by the personal funds of wealthy investors and entrepreneurs, who seek to create revenue through innovative, unique approaches and technologies. NewSpace companies receive, or plan to receive, a sizeable portion of their income from private business as opposed to governmental contracts. Often driven in large part by personal intrigue in space, NewSpace companies seek to further the industry, generate profit, and open space to commercial success and private access.

There are various sectors of the private commercial space industry, each with a different business model, strategy and market. First, there are satellite companies, which are mainly involved with

telecommunications, television broadcasting, and GPS capacities through satellites, e.g.: SES, Intelsat, DirecTV, Garmin, and Magellan. In this paper, I will not focus on this sector of the space industry, as it is already an established and fairly stable market. Rather the focus of this paper will be on up-and-coming innovative private space companies and their potentials.

The regions of the nascent private commercial space industry which I will discuss are: First, space tourism and private travel companies which will take civilian passengers on flights into near-space or low earth orbit. The prices for a trip will range from 95,000 to 20 million USD (FAA), depending on the company. Some of these companies are: Virgin Galactic, XCOR, Space Adventures, and Zero2Infinity. Second, there are companies whose focus is liftoff and transportation services. These services include transporting cargo, satellites, and passengers to low earth orbit, the International Space Station (from now ISS) and beyond. Examples of companies in this sector include: Space Exploration Technologies (or Space X), Boeing, Blue Origin, Orbital ATK, and Sierra Nevada Corporation. There are also several smaller regions of the private commercial space industry including: creating and operating extra-terrestrial habitats, servicing global Wi-Fi broadcasting, conducting space burials, taking private images, harvesting resources from extraterrestrial objects, and providing alternative energy sources.

Over the course of this journey of research and investigation, I sought to answer: Why has there been a recent rise in interest and activity surrounding space travel and technology in the private sector? What are the impacts and effects of this new industry moving into the future?

To answer these complex questions, I interviewed Nathan P. Wong, a consultant at X PRIZE working on the Google Lunar X PRIZE, which is a capital incentive prize created to further innovation in space technology, and Carissa Christensen, the managing director of the Tauri Group, an organization which provides analysis, planning and strategic consulting to space companies and government agencies. Additionally, I studied and reviewed governmental agencies' statistical publications, companies' descriptions and goals, commentary by people employed in NewSpace companies, news articles, economic and strategic market analysis reports, and TED talks by those leading in the field.

As I learned about this fascinating topic, I discovered that I had decided to look at private space during one of the most interesting and exciting times. I was inspecting the private commercial space industry as it began to refine itself and become a robust section of the global economy, in turn providing positive impacts all across the board, from education, inspiration and innovation to the overall mentality of humankind. Ultimately I found: **Although it still has hurdles to clear, the private commercial space industry will certainly continue its emergence and flourish into a full-fledged sector of the world economy, bringing colossal positive impacts to the entire global society.**

All along, it has been a part of human nature to explore and test boundaries. From the time we are born, we constantly are exploring and pushing ourselves beyond what we previously could. From crawling, to walking, and eventually to talking and beyond, we as a species are on a constant quest to explore, discover and go beyond what we currently can. The European Space Agency declared, “Humanity’s quest to explore has existed for as long as history has been recorded. This desire to go further, to explore new frontiers, to make new discoveries, is never ending. It is part of the essence of being human. Only the pace and actors have changed over time” (ESA). Similarly, Burt Rutan remarked, “instinctively we've gone out and climbed over difficult places, went to more hostile places, and found out later, maybe to our surprise, that that's the reason we survived” (Rutan). Indeed, our instinct of pushing the boundaries can be attributed to our progression as a species from cave-dwelling people to agriculture villages, to diverse nations, to putting a man on the moon, and, I believe, will be what drives us to becoming a multi-planetary species. Often in our striving for new places, new ideas, and new activities, we put ourselves through challenges and immense danger, but what for? Likewise many ask, why do companies risk enormous investment, and human lives, all to reach an empty vacuum? The answer is perhaps best put by George Mallory, the first man to climb Mt. Everest, who when asked why he did it, famously responded, “Because it is there.” Climbers, athletes, toddlers, and NewSpace employees are all alike; they, propelled by human instinct, strive to surpass anything that has been done before.

As with most movements, the rejuvenation of activity in private commercial space was not caused by a single event or source, but initiated by a combination of forces. One of the major forces which helped to kickstart the private space industry was incentive competition prizes. These prizes, such as The Google Lunar X Prize, The Ansari X Prize, NASA's Centennial Challenges program, and The Heinlein Prize, are competitions which give large sums of capital to the first group able to achieve the competition's rigorous and ambitious achievement. Monetary incentives have a long history of leading to innovation and technological advancement. One of the most prime examples is the Orteig Prize which was won by Charles Lindbergh flying the Spirit of St. Louis in 1927. For aviation, the industry which the prize looked to kickstart, the impact was incredible: "there was an increase in U.S. airline passengers from 5,782 to 173,405 in three years, 1926-1929, a 300% increase in applications for pilot's licenses, and a 400% increase of licensed aircrafts in the United States in one year" (Goel Insights). In private space, prizes have been structured similarly with the hope of bringing about similar results. The X PRIZE Foundation, one of the main providers of these innovative prizes states:

We believe in the power of competition. That it's part of our DNA. Of humanity itself. That tapping into that indomitable spirit of competition brings about breakthroughs and solutions that once seemed unimaginable. Impossible. We believe that you get what you incentivize....Rather than throw money at a problem, we incentivize the solution and challenge the world to solve it.
(XPRIZE.org)

By offering an incentive, the XPRIZES, along with other incentive competition prizes, drive groups to innovate and develop new solutions and ideas with a target in sight. In the space industry, these prizes have resulted in flushed out, functional private space groups which in turn have brought their ideas and products into the private commercial industry.

Additionally, recent technological advancements have made space activity more efficient and thus have made businesses models more profitable. One of these technological advancements that has helped the space industry is the growth of the internet, Ms. Christensen remarked, "the data processing and analysis capability that [came] with the revolution in information sciences and computing

technology [has enabled] more efficient activities and different kinds of products and services in space.” (Christensen, Interview). Besides the data processing capacities, the miniaturization of pieces used in space products has allowed more commercial space businesses to come about. Mr. Wong said, “instead of very, very large telecommunications satellites, and very large science instruments, you can get a lot of powerful things inside of a small satellite form factor. Something on the order of 100-500kg today and do what a five ton satellite could have done ten years ago. And so it has allowed a lot more people to get into the industry” (Wong, Interview). More efficient activities means less expenses, and therefore more profitability, which has in turn brought more interest and investment in private space.

As with any commercial venture, profitability and potential for lucrative revenue are factors which helped bring about the growth of the space industry. In fact, both of my interviewees had nearly identical views that a combination of potential business success and personal interest of those involved were major reasons for the rise in commercial space businesses. They said, “In the last couple years we have seen a lot of very wealthy and influential people getting into space [such as Elon Musk, Jeff Bezos and Richard Branson]...It’s really people who have a passion for space coming in [and being] willing to put their money on the line because they think space is one, important for humanity, but two, they think economic benefits are there as well. They think they can make money from it” (Wong), Ms. Christensen echoed, saying, “It’s this combination of the money plus a community who is really interested and enthusiastic about space” [that has brought about the recent rise in private commercial space companies] (Christensen, Interview). Many experts have drawn parallels between NewSpace’s current status and previous economic booms of automobiles, airplanes or the internet. In fact, NewSpace Global analysts predict that the NewSpace industry’s growth and path will be similar to the Internet industry’s in 1994 (NSG Analysts). Burt Rutan, instead sees it to be analogous with the aviation boom of the early 1900s (Rutan). Regardless of how NewSpace companies’ stocks will appear on graphs, there is no doubt that profitability is a major influence for many of the companies. All in all, through a combination of various pushes, the private commercial space industry, something that many that would never come to be, began to roll and pick up speed. Through incentive prizes, better technology, and business models now

showing more green than red, the private commercial space industry has budded. Yet the question remains: will it blossom?

The NewSpace industry, while on the rise, faces many impediments which, although standing as potential stumbling blocks, can, and will, remain as merely hindrances which will not halt the growth of the industry. One of the many challenges the space industry faces is the negative impact which current space activity and technology have on the environment. Rockets, the current method of movement for space companies, have a negative effect on the environment. Most notably in that they damage the ozone layer and deplete the atmosphere. However, because there are so few launches currently they, as of today, do not play a very significant role in global warming or atmospheric depletion (Rastogi). “Researcher Martin Ross and three co-authors estimated that rocket launches are responsible for roughly one percent of the total ozone depletion that can be attributed to human causes” (Rastogi). If the space industry grows though, its negative environmental impact will become a larger concern, and may become a significant dilemma for the entire space industry.

Another obstacle for NewSpace is that the current cost of going into space makes having a profitable business challenging. Because it is such a new and risky industry, investments are hard to come by. “Wall Street investors may drop in to visit, but the big institutional money isn't ready to gamble on New Space. They still face very, very long odds. The vast majority of these ventures will fail. That's just the way new ventures are” (Achenbach). Limited investment and cautious sponsors are especially challenging for NewSpace because going into space is such an expensive process. Indeed, “Earthlings vs. gravity is an enduring David vs. Goliath story...even a low Earth orbit still costs upward of \$5,000 per pound. It's hard to come up with a reasonable business plan as long as launch costs are that high, which is why the government still dominates the space industry” (Achenbach). The combination of wary investors with the need for large investment creates a brutal environment which limits the growth of small and innovative companies in the private space industry.

Yet another hurdle the space industry faces is the health and stability of passengers in space. It is undeniable that, “the human body did not evolve to live in space. And how that alien environment

changes the body is not a simple problem, nor is it easily solved” (Chang). Some health problems, like brittle bone, have been mostly overcome or mitigated, but many are still perplexing. As safety of its customers must be one of the top priorities for a business, the space industry must try to understand and overcome this problem to bring substantial customers and revenue.

A further significant challenge for the space industry is the amount of deadly space debris constantly in orbit. These remains of previous ventures are a threat to the expensive equipment and humans who will be in orbit. “After years of space [activities]...the vast area known as low earth orbit space [has become] crowded with active satellites as well as millions of pieces of debris from dead satellites, spent rocket boosters and stray hardware pieces. Traveling at speeds upwards of 15,000 mph, these derbies threaten...commercial satellites [and more]” (Lockheed Martin News). To make matters worse, unless this problem is solved, it will compound, as debris will hit other debris and split into smaller pieces, “the chain-reaction will only continue to compound: every time a collision occurs, more debris is created and the risk of future collisions rises even more” (Lockheed Martin News). This is not just a threat, but is already a reality, “in February 2009, an operating Iridium satellite unexpectedly collided with a dead Russian Cosmos satellite 500 miles above Siberia. Both satellites were destroyed, resulting in thousands of pieces of new debris” (Lockheed Martin News). Just as a tourist would not go into an active war-zone, so too will passengers be wary and companies stalled unless the problem of space debris is mitigated or solved.

But, perhaps the greatest obstacle the private space industry faces is the risk of human life. Because humans are not made to live in space, and the technology is extremely powerful, there is a constant risk of life and limb involved in space activity. Although NewSpace companies seek to make their products as safe as possible, because they need to make a profit, they must use new, untested methods, and therefore they must take risks. A New York Times author remarked, “The common thread between these new space initiatives is that they all are looking for ways to sharply cut the cost of spaceflight. Without that, analysts say, there is no realistic prospect of making spaceflights both routine and affordable in the future” (Mouawad). However, when trying to sharply cut costs, there is risk and as

such there is the potential for, and the reality of failure. The reality of the risk which the private commercial space industry must undertake was brought to light in October of 2014 when, during a test-flight, Virgin Galactic's SpaceShipTwo crashed, killing the pilot and destroying the ship. Additionally, only a few days apart an Orbital Sciences rocket exploded while lifting off. These events brought a lot of negative media attention to NewSpace and caused many to say the technology and businesses of NewSpace are currently too risky and should not be continued (Mouawad). Many potential passengers of Virgin Galactic withdrew or became much more cautious due in full to the crash (Mouawad).

However, these hurdles will not end the private space industry, rather solutions will be generated by innovation, and progress will continue, scathed but not stopped. To the question of how NewSpace can continue to grow in the face of extensive risk, Mr. Wong replied, "risk shouldn't lead to slowing down in technology. There are two reasons to keep going. For some of the companies that reason is money, but for others it is a passion for space and for increasing the sphere of human knowledge, and there is sacrifice involved in there" (Wong, Interview). Those involved in NewSpace know that risk is inherent to their products, yet they move on, for they know there is advancement to happen progress to make and great leaps to be taken. Just as those involved in private space, Teddy Roosevelt understood that it is "far better to dare mighty things, to win glorious triumphs, even though checkered by failure, than to rank with those poor spirits who neither enjoy much nor suffer much, because they live in that grey twilight that knows neither victory nor defeat". If there is no risk and no chance, there can be no progress, nor advancement. With every rocket left smoldering on the launch pad, the space industry learns more, and prevents that mistake from happening the next time, thus refining and ultimately purifying the industry's process. In fact, the private commercial space industry has already, though it has had a brief time to learn, refined its process incredibly. "Out of twenty-three worldwide commercial launches in 2014, only one was a failure, the Orbital ATK launch of the Antares rocket" (FAA). Clearly while risk is present, it is being overcome, and serves not just as an obstacle for the space industry but as a driving force which motivates better procedures and technology.

The problem of space debris, just as the other problems NewSpace faces is being addressed. Currently under development is the Space Fence, which will help mitigate and evade the potential dangers of space debris, “Space Fence will move space situational awareness from being reactive to predictive...Space Fence will make 1.5 million observations a day to detect, track, measure and catalog items as small as a baseball – an estimated 200,000 objects. It’s a ten-fold increase in the objects being tracked” (Lockheed Martin News). While this will not be a cut-and-dry solution to space debris it will help greatly and will enable private commercial companies to have a sense of security with their products. As for the hindrance of passengers’ health, progress is constantly being made, both by the private industry and by governmental agencies. In fact, one of the main purposes for the ISS is to understand and study the conditions of humans in space. Various experiments and investigations of health and stability of astronauts are constantly underway at the ISS (Chang). Thus, it is clear that the work and effort to overcome this problem and each problem the space industry faces is underway, and so, while it may at times seem NewSpace will fail, it will eventually overcome its problems.

Although there are not currently enormous direct benefits from the private commercial space industry, there are various societal betterments and successes due to the space industry. While outer space may seem incredibly far away, it is closer than it seems. And while we may not realize it, most of us use space every single day. In fact General William Shelton, the commander of the U.S. Air Force Space Command remarked, “we are so dependent on space these days that we plug into it like a utility” (Lockheed Martin News). In a single morning, it is certainly plausible for you to ‘plug in’ to space in various fashions. Perhaps you wake up, check the weather, drive over to the ATM to withdraw cash, and then proceed to drive to work. A normal morning by most standards, yet what you may not realize is that you utilized space four times in your morning actions. Among other services, space enables weather forecasting, live television broadcasting, GPS guidance, and accurate and legitimate ATM withdrawal. In fact, satellites are currently a 300 Billion USD industry (Christensen, Interview), and besides providing useful everyday services, help militaries and peacekeeping agencies worldwide gain monitoring and imaging capabilities which are vital for intelligence.

Furthermore, though it is not massive, there is already profit being generated from the private commercial space industry. Along with the 300 Billion USD generated from satellite companies, commercial launches are generating revenue: “estimated revenues from the 23 commercial launch events in 2014 amounted to approximately \$2.36 billion. These revenues are nearly a half billion dollars higher than in 2013” (FAA). While it is hardly a speck when compared to the overall economy of the world, progress is progress, and it cannot be ignored that these liftoff companies are already generating revenue. Additionally, Space Adventures Ltd. has successfully launched and returned seven tourists from space. However all the launches were conducted as if the passengers were astronauts, thus requiring very large prices, as well as extensive preparation and training.

Additionally, several new technologies have come as spin-offs or direct descendants of space technology. A report by the International Space Exploration Coordination Group noted:

The wider list of technological benefits [from space] encompasses improved solar panels, implantable heart monitors, light-based anticancer therapy, cordless tools, lightweight high-temperature alloys used in jet engine turbines, cameras found in today's cell phones, compact water purification systems, global search and rescue systems and biomedical technologies. Additionally, scratch-free lenses and mobility devices for paralyzed individuals have come about from technology originally developed for use in space (ISECG).

With such evidence, it can hardly be debated that space has not made an impact on our technology, many in ways which, were it not for space, would never have come about.

Moreover, space allows advanced warning for natural disasters, disease, and more on a global level. During the 68th United Nations Assembly on space, many country's representatives noted the positive benefits of space, “the representative of Iran pointed out that his country was disaster-prone and benefited from [space based] disaster management [programs]” (68th UN Assembly). The benefits noted however went well beyond disaster monitoring capabilities, “as a small island developing state, Tonga, said its representative, was particularly susceptible to the impact of climate change and natural disasters. It was especially grateful for the assistance it had received...[in] environmental monitoring, natural

resource management, disaster risk reduction and climate change” (68th UN Assembly). Other countries echoed this gratitude for space technology, “highlighting the beneficial aspects of outer space technology, the representative of Nigeria said that...a collaboration between Algeria, South Africa, Kenya and Nigeria...was aimed at providing easy access to satellite data for use in disaster management, food security, public health, infrastructure, land use and water resource management” (68th UN Assembly). Clearly space has already made an impact on our daily life and the way we operate. From your smartphone and television to the farms of Africa, all the way at the shores of Tonga, the benefits of space are already evident.

The potential and procurable benefits of the private commercial space industry are gargantuan and very widespread across nearly all of global society. Firstly, there will be massive economic benefits. As previously noted, the private commercial space industry already generates several billion USD of revenue. This will not just continue to grow, but will burgeon into a major industry, providing large revenue streams to the global economy. There are already growth indicators, including 2014 being the highest number of licenced orbital launches since 2004, 71% more than in 2013. Eleven of the twenty-three US launches [in 2014] were commercial, five more than in 2013” (FAA). More intriguing however, are the projections and predictions by experts in the field, such as estimates on private space travel cited by Dr. Collins, an expert in the space industry, “Cost estimates by the Japanese Rocket Society,...and others...indicate that once space travel grows to 1 million passengers/year, prices could fall to 5000 Euros for sub-orbital flights, and 20,000 Euros for orbital flights. The latter is equivalent to some 200 Euros/kg or about 1% of launch costs today...We can estimate that if suborbital passenger travel had started in 1950, orbital travel could have grown to perhaps several million passengers/year by 2000” (Collins). If private passenger travel in space could potentially have grown to several million passengers per year from 1950-2000, with the new technological capabilities and techniques of today, the timetable of 50 years could only be shrunk. Moreover, this acknowledgment of the economic potentials of the private space industry is not limited to just a few overly optimistic dreamers, but is a widely avowed as the future reality by many experts. For example, the Futron Corporation examined

American interest in space travel in 2002. They forecasted that “by 2021, over 15,000 [suborbital] passengers could be flying annually, representing revenues in excess of US \$700 million” (Futron). In fact, steady revenue and economic prosperity via passenger flights almost began this past year. Virgin Galactic, prior to the crash of October 2014, had planned to begin launching passengers into space in the coming year, 2015. In fact, Virgin Galactic already has a queue of soon-to-be customers, “about 700 people had reserved seats on Virgin Galactic, with tickets costing \$250,000 each” (Mouawad). Even with a safety concerns swirling, Virgin Galactic alone, has raised 175 million USD, without having ever taken a passenger into space. This shows the public willingness to purchase private spaceflight, and the undeniable fact that private space is no longer a dream, rather it is a wrinkled reality, needing but a little ironing. Clearly there is public desire and economic demand for private space services. The experts agree, the businesses believe, and the awaiting customers know, the only path which private commercial space can go is up, up and away.

The growth in private commercial space will not only result in economic benefits, but will also vastly improve employment. Mr. Wong remarked, “I think it will be good for the economy, as it will create jobs. Though the jobs will be supplemental to the jobs here on earth, so they won’t be in direct competition. Space is interesting because it provides a very unique approach and something that is not done here on earth so both industries can grow at the same time because they provide a different set of services that are complementary to each other” (Wong, Interview). Obviously as a company grows, it will hire more employees, and if an entire industry grows, it will take into it many, many workers. With the private space industry, the employment effects will be especially incredible because of the very wide scope of professions and careers within the space industry. Mr. Wong observed, “The space industry is not just engineers or scientists, they’re looking for lawyers, for doctors, they are looking for people who are interested in media, people who are interested in public relations, there is *so* many jobs that can get you into the space sector, even now. And with the growth of the space industry, it will only become easier” (Wong, Interview). Just as the airline industry is not just pilots, but includes flight attendants, travel agents, ground supervisors, technicians, mechanics, public relations, air tower control workers,

media representatives, and even journalists for magazines, the space industry will take in a conglomerate of professionals. But just how many might the space industry employ? It is impossible to place number on just how sizeable the private space industry might be, but currently 1.85% of the entire worldwide labor force is employed in aviation and related tourism (ATAG, The World Bank), and the space industry could potentially be as large if not larger as it offers a similar service but in a different location. As unemployment becomes an increasingly pressing issue for the world, fostering an entirely new industry, that of private space, would not only be beneficial, but would perhaps be the solution which the world craves.

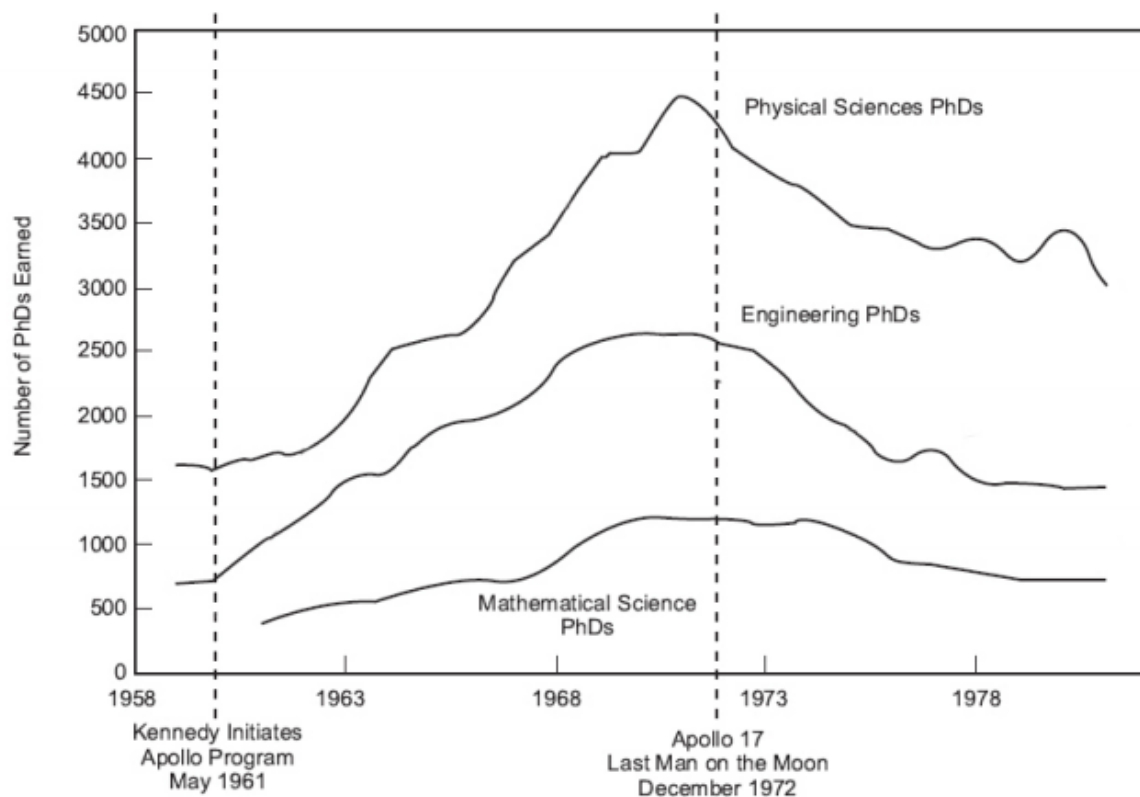
Besides global economic and employment increases, the private space industry will also bring new innovations and technologies. Even from the meager amount of space activity we as a species have conducted, there have been many innovations and technological advancements, the ISECG noted, “From the early days of spaceflight, it became apparent that space exploration was an efficient driver for basic science and technology. The new challenges called for new approaches. The cost of launches drove designers to make spacecraft computers lighter, smaller and with the highest performance and dependability. Solar cells, batteries and fuel cells were driven by space needs and benefitted many sectors on Earth” (ISECG). Just as the small amount of space activity already in action has made various technological advances, so too will continued space activity result in continued innovations with implications here on earth. While we cannot pin-point exactly where we will make discoveries, we know they will come. “Though the precise nature of future benefits from space exploration is unpredictable, current trends suggest that significant benefits may be generated in areas such as new materials, health and medicine, transportation, and computer technology” (ISECG). Many of the technologies will come as spin-off products, or products originally designed for a separate purpose but then adapted into another field. These spin-offs, because they come from an entirely different approach bring what normal research never can,

“People often ask; If you like spin-off products, why not just invest in those technologies straightaway, instead of waiting for them to happen as spin-offs? The answer: it just doesn't work

that way. Let's say you're a thermodynamicist, the world's expert on heat, and I ask you to build me a better oven. You might invent a convection oven, or an oven that's more insulated or that permits easier access to its contents. But no matter how much money I give you, you will not invent a microwave oven. Because that came from another place. It came from investments in communications, in radar. The microwave oven is traceable to the war effort, not to a thermodynamicist" (Tyson).

Just as the example given, spin-off products can, and do, because of their unique perspective and approach, solve problems and provide solutions which never would have been found otherwise.

Furthermore, the private space industry will cause educational benefits, specifically and increased interest in STEM. Because of the uniqueness of space, and its application of advanced STEM technology, it causes intrigue and interest in advanced STEM education. An incredible example of how space activity is an astounding driver for STEM education is the boom of advanced STEM degrees which occurred during the Space Race of the 1960's (ISECG):



As shown in the graph above, it is undeniable that space inspires education, especially advanced STEM degrees. The height of space activity directly mirrored the height of advanced STEM degrees which are very important. Buzz Aldrin, an strong advocate for STEM education wrote, “STEM is a field in which we should encourage and promote because it: appeals to all ages, inspires creativity, develops curiosity and critical thinking, is interdisciplinary, appeals to both genders and promotes equality, provides international and cross-cultural cooperation, and strives for a common, thriving future” (Aldrin). Not only did the Space Race, a the time of greatest space activity, inspire PhD’s, but it impacted and inspired an entire generation of STEM professionals who even today help improve and shape our world, “A 2009 survey found that 50% of the internationally renowned scientists who published in the prestigious journal *Nature* during the previous three years had been inspired by Apollo to become scientists” (ISECG). It is unarguable that we need scientists and experts in STEM, because now there is, and forever there will be a need to find new solutions and solve the world’s ever pressing problems with the sciences.

Besides measurable impacts, the private commercial space industry will also have many intangible benefits on the world, such as increased environmental appreciation, cultural fulfillment, and a higher standard of work. The ISECG recognized, “[the expansion into and exploration of space] also results in various intangible impacts due to the social and philosophical dimensions that address the nature and meaning of human life. Intangible benefits include the enriching of culture, the inspiration of citizens, and the building of mutual understanding” (ISECG). One unequivocal example of how space activity has impacted the culture on earth is seen in the impacts of *Earthrise*, the first picture of Earth as a whole, taken by Apollo 8 as they orbited the moon on December 24, 1968. This photograph, as it was the first time humanity saw the planet as a whole in the midst of the vastness of space, brought about a new cultural perspective. Neil deGrasse Tyson, had the following to say on this moving photograph,

We went to the moon, and we discovered earth...How [did the photo and new perspective] affect culture? I got a list: 1970, the comprehensive clean air act is passed, Earth day is birthed March 1970, the environmental protection agency was founded in 1970, Doctors without Borders was

founded in 1971...DDT gets banned in 1972, Clean Water Act 1971, 1972 Endangered species act, the catalytic converter gets put in in 1973, Unleaded gas, 1973. We're still at war in Vietnam, there is still campus unrest, yet we found the time to start thinking about earth. That is space operating on our culture and you cannot even put a price on that (*We Stopped Dreaming*).

Such powerful evidence cannot be mere coincidence. This photograph and its ensuing viewpoint changed our cultural perspective and made us see the fragility and delicacy of our planet. In such a manner will future travel and commerce in space too act. Moreover, the flourishing of the private commercial space industry will result in other intangible benefits including increased precision, and a higher standard of work. Since space systems require extreme accuracy, "Anyone who want to build spacecraft...or who even wants to supply bolts and screws to the space industry must work on a higher level of precision than [ever before]...That standard has influenced our entire industrial base, and therefore our economy" (Griffin). Through these examples, it is clear that the space industry will not only bring benefits measurable by quarterly reports, but will profoundly affect our culture.

Furthermore, increased space activity will result in improved global peace and reduced international strife. Space, due to its challenges and the resulting need for international cooperation, helps unite the world in global endeavors. The ISS is one, if not the single best example of how working together with unified purpose and resources, many countries can set aside disputations and accomplish more than any one country could do alone. The ISS stands as an example to diplomats, politicians, activists, and citizens worldwide of what international collaboration can accomplish. "Cooperation [on the ISS] has expanded over the years, resulting in 68 nations to date that have participated in ISS activities. The ISS partnership demonstrates the functional dimension of international cooperation in space" (ISECG). Even as contentions and various strife have risen between the involved countries down on earth, the ISS orbits, ever standing as an emblem of the greatness which nations can achieve in partnership. Additionally, as there is increasingly more international conflict over resources in resource wars, space provides a solution, "If...it is assumed that the resources of space are economically accessible, this [would] eliminate the need for resource wars...It is also worth noting that the \$1

trillion...committed to wars in the Middle-East in the 21st century is orders of magnitude more than the investment needed to...start the commercial use of space resources” (Collins). When examined from this perspective, it seems obvious that we should focus more of our wealth and efforts on the space industry instead of jousting for the limited resources on our planet. Yet NASA and capital given to private companies remains less than one percent of the total government spending by the US government (*We Stopped Dreaming*). Eventually, we will need to expand our reach to other planetary bodies, or else we will consume nearly everything which is available on earth, and then kill each other over the rest.

In the long run, the expansion of NewSpace and increased human activity in space will become not only beneficial, but will be vital for our survival as a species. It seems to most that the world is becoming ever darker. From newspaper stories about violence and upheaval in distant countries to foresights of our planet’s imminent destruction by global warming, the dominant view today is that the world on a downward spiral to its ultimate destruction. However, this is merely do to the lens in which we examine earth’s difficulties. Those who believe in space however, realize that earth is not hopeless, but rather is in dire need of expansion. Dr. Collins clarifies this perspective through a metaphor:

An interesting explanation of the potential of space travel and its offshoots to revitalise human civilisation is expressed in the idea that "The Earth is not sick: she's pregnant". Although this idea may seem strange at first sight, it is a surprisingly useful analogy for understanding humans' current predicament. According to the "Pregnant Earth" analogy, the darkening prospect before humanity is due to humans' terrestrial civilisation being "pregnant"—and indeed dangerously overdue—with an extra-terrestrial offspring. Once humans' space civilisation is safely born, the current stresses on the mother civilisation will be cured, and the new life may eventually even surpass its parent (Collins).

Through this alternative outlook, one can see earth’s troubles not as indicators of doom, but as a signal that it is time for our species to expand onto other planetary bodies. The stress of more than seven billion humans pounding, drilling, and using our tiny earth, has become too much for the wants of humanity, and unless all greed can be overcome, we, as a species must expand to other planets. When it comes

down to it, “We're either going to be on Earth forever until some extinction event claims us, or we're going to be a multi-planet species, out there exploring the stars, [Elon] Musk said” (Achenbach). Musk, the CEO of Space X, Dr. Collins, and all those who participate or root for NewSpace, understand that the private space industry has grown from being a comic book storyline, to a reality, and will soon become an absolute necessity for humanity.

To conclude, currently we are on the boundary of creating a new industry and opening a new frontier for business, habitation, and more. Ralph J. Cordiner summed it well when he wrote, “The world is extending its boundaries out from the planet into space: a tremendous enlargement of the area in which man will find resources for living. To explore and tame the new space frontier will require a great technological effort” (Cordiner). This great effort will bring many benefits to mankind both those we can and those we cannot predict. Indeed we cannot, any more than the European citizens of 1492, or the businessmen of 1994, foresee just how much our world will be changed by this next great step in the continuing progress of mankind. And just as Europe’s expansion into the New World, Thomas Jefferson’s acquisition of the Midwestern United States, and the aviation, computer, and internet industries all at first seemed risky, unfruitful, and not worth the costs, through perseverance, innovation and unshakeable drive to develop and utilize the new frontier, what was a dream grew into a hope and ultimately became reality, impacting the world for the better. Thus so too will the utilization of space by the private commercial industry be profoundly impactful for all of humanity. Doubtlessly being another giant leap for mankind.

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