

The Business of Space

Newly emerging private space industry has significant opportunities & risks

MarketLine Theme Report

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1. Executive Summary

In recent years, moves by NASA to privatize aspects of its operations has sparked a new interest in space travel and new space opportunities for many businesses. The most clear of those opportunities has come from the private rocket industry as they snapped up NASA and commercial contracts to deliver equipment such as satellites into space. As NASA continues to commercialize its assets and refocus, it is becoming increasingly clear that there are many challenges and obstacles for companies that want to move into the new Space sector. The most important of all of them, from a business perspective, is the economic case. Many new emerging industries simply don't make sense at the moment as private businesses and that is causing a number of hold-ups in the development of a new space industry.

1.1. Cleaning up space is edging closer to commercial viability

Space debris is a serious long-term threat to the usability of space. When travelling at several miles per second even small flecks of paint will make bullet sized holes in satellites, potentially causing the impacted craft to cease functioning, orbiting Earth devoid of control and therefore capable of causing massively larger collisions with other satellites. Avoiding dystopian scenarios by cleaning up space of debris is now attracting far more attention. The number of objects has ballooned in the past decade, helping to bring about commercial solutions to the problem. Yet, these could easily be insufficient unless the future marketplace is helped along by governments agreeing to new rules.

1.2. NASA is outsourcing to save costs but grandee missions will remain preserve of space agency

For decades the National Aeronautics and Space Administration (NASA) enjoyed sole access to space from the United States. Since 2006, however, the agency has been working with private companies, the progress of which has advanced to the point whereby rocket and spacecraft design and manufacture are being outsourced to private providers. Under pressure to cut costs, NASA is integrating private enterprise into long-term future plans. Yet despite the excitement regarding commercial enterprises winning access to space, some notes of caution are worthwhile. Grandee missions, however, will remain the preserve of the government agency. Flamboyant billionaires cannot muster, and could not justify, the budgets required.

1.3. Age of space tourism is finally dawning as rival companies approach commercial operations

For a while it looked as though the much vaunted age of space tourism would be limited to business billionaires buying rides aboard aging Russian space rockets. After numerous failures and lengthy delays, the formative stages of what may turn into a lucrative industry are now seemingly tantalizingly close to reality. Some companies are looking beyond sub-orbital flights lasting only a few minutes; SpaceX are proclaiming to be preparing for a trip around the Moon in 2023. Lengthy trips into space are edging closer: serious progress towards the creation of private space station has been made and NASA are seeking private buyers of access to the International Space Station. Much is changing very quickly in the still nascent space tourism industry, inciting hope for human exploration.

1.4. Space industries of the future are developing, but still limited by economics

Through the emergence of the private space industry a number of opportunities have started arisen that wouldn't have possible otherwise. Cheaper rocket equipment, reusable rockets and cheaper flight prices are just some of the advantages to have come from private enterprise becoming involved in the space industry. Estimates vary but some sources believe the space industry to currently be worth \$330bn to \$350bn in 2019, by 2040 many expect this figure to be well over a trillion dollars through the spawning of new space based industries. Many are more science fiction at this stage, but others are entirely plausible over the coming decades. The main problem for many of the projects that hope to get off the ground in the coming years is that they do not have a proven business model. Some are worse still, in that they actively don't make any economic sense and so embarking on some of these projects, from a profit and loss basis are impossible.

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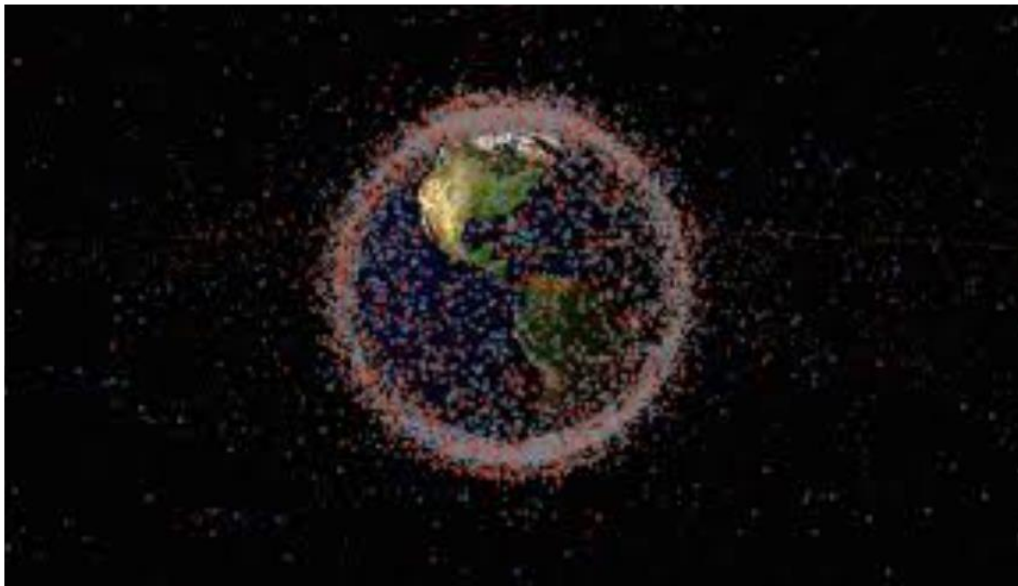
2. Cleaning up space is edging closer to commercial viability

Space debris is a serious long-term threat to the usability of space. When travelling at several miles per second even small flecks of paint will make bullet sized holes in satellites, potentially causing the impacted craft to cease functioning, orbiting Earth devoid of control and therefore capable of causing massively larger collisions with other satellites. Avoiding dystopian scenarios by cleaning up space of debris is now attracting far more attention. The number of objects has ballooned in the past decade, helping to bring about commercial solutions to the problem. Yet, these could easily be insufficient unless the future marketplace is helped along by governments agreeing to new rules.

2.1. Now testing in space is taking place, a commercially viable future looms

A key problem behind the cleanup of space lies in who, or what, will pay for it. Much of the material orbiting Earth uncontrollably was present before the debris concern was granted serious attention, meaning there is no one legally liable for the potential damage caused by a defunct satellite. Yet with the danger of key satellites responsible for essential infrastructure, weather forecasting and operating military hardware rising rapidly, solutions to the problem of space junk are now moving closer to being commercially viable. Even though testing in space of a net capturing system and harpoon setup only recently began, that tests have occurred at all suggests the pace towards an off-the-shelf solution to removing large pieces of discarded rockets and satellites beyond human control is speeding up.

Figure 1: Map of satellites in orbit around Earth



Source: Popular Science

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A consortium of private businesses and academic groups working under the University of Surrey created the RemoveDEBRIS satellite that was tested in space. Both tests were successful. In one a net was propelled towards a sizable object, wrapping around it before plunging out of orbit and burning up in the atmosphere. Another involved the firing of a harpoon towards a

fixed target attached to a carbon fiber boom and secured by a tether. So strong was the impact that the boom broke. Demonstrating the current state of technological knowhow in the conditions in which they would operate ranks as a key moment in what is likely to emerge as a private space cleaning industry.

Even though much excitement was aroused, the involvement of supranational bodies and governments remains pivotal. The 100kg RemoveDEBRIS satellite was partially funded by the European Commission and utilized expertise funded by governments. For the time being this assistance is vital owing to the lack of customers. Such customers will likely materialize due to the pressure being exerted for interested parties – governments, space organizations and private companies – to become legally responsible for disposing of aging orbiting satellites and those to which control has been lost. Given the growth of the private space industry in the form of rockets and most recently the outsourcing of space craft design by NASA, a viable commercial market could soon emerge. Products utilized would likely be predicated on the sort to have been tested by the University of Surrey.

The involvement of Airbus and other technologically sophisticated companies hints at future progress being rapid. Harpooning large pieces of debris and entire satellites has long been discussed as a possible means by which objects could be removed from orbit, but without leading expertise such ideas remain on the drawing board. Provided the conditions required for a private marketplace emerge as many expect them to, the presence of firms such as Airbus will provide the necessary momentum to take the ideas contained within the RemoveDEBRIS satellite and produce them on a scale to enable cost reductions. Forcing costs down could become vital if international laws and regulations fail to develop in a way in which owners of satellites are responsible for disposal.

2.2. e.Deorbit problems exposes difficulties in creating marketplace for cleaning of space

Some of the technology utilized on the RemoveDEBRIS satellite was originally intended for a different project, the failure of which and subsequent redirection reveals fundamental issues relating to the development of a private space cleanup industry. e.Deorbit was conceived by the European Space Agency to remove a failed and uncontrolled satellite called Envisat which fell silent in 2012. That target was selected because it remains one of the largest and most dangerous pieces of debris in orbit; calculations predict that left alone it will eventually plunge into the atmosphere after over 150 years more spent circulating the planet. During that time the degree of damage it is possible the satellite could cause is substantial due to its large size and dangerous orbit route. Yet a tentative launch year of 2023 was stymied by a failure to garner enough support for a one-off mission, causing attentions to be turned towards developing tools which any satellite or large piece of debris could be removed from harm's way.

Figure 2: Artist's rendition of the deployed EnviSat spacecraft



Source: European Space Agency

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The problems in garnering enough interest to take down a single object, however dangerous, is a leading example of why creating a private space cleaning industry will depend on governments creating the market to begin with. Having decided a harpoon or net would not perform the task (at least at that point in the development of those tools) the ESA determined a robotic arm would be the preferred choice. Costing an estimated EUR300m, the budget would have required agreement from the ESA ministerial council and at a gathering of member states. Obstacles faced by the project caused the changing of philosophy regarding creating a means to remove objects from orbit. Luisa Innocenti, head of the ESA Clean Space initiative, said the agency had found raising money for a single-case mission was unfeasible. Given the stated importance of removing Envisat from orbit, if the resources from the European Space Industry cannot be mustered then it is highly unlikely that for the time being they can be gathered for any other one-off mission.

Being unable to bring down Envisat not through technological shortcomings but through lack of money means the opportunity to push technology forward has been lost. At the very least the successful removal of Envisat would have proven it was possible to capture and dispose of a large and uncontrolled object. Although the price would have been high due to being the first such instance, such a demonstration may have brought about a rapid growth in attention from private enterprise in developing new space debris clearing technology. So high is the number of tumbling objects orbiting irregularly, and therefore must be removed, motivation to fund several missions is needed and could have emerged from a successful removal from orbit of Envisat.

2.3. Scale of space debris problem is worsening, creating a greater need for commercial solutions

The number of trackable objects orbiting the Earth has increased radically over the past few years, especially after the Chinese government launched a missile at one of its own satellites. Though most likely a demonstration of technological expertise directed towards the United States, the consequence for satellites currently in orbit are potentially extremely dangerous. Nobu Okada, founder and CEO of the Japan-based company Astroscale, said at present rates space will be unusable in a few decades. As early as 2011 NASA scientists warned the space junk problem was at a tipping point; since then the problem has worsened considerably. Although a major satellite collision has yet to occur, the chances of a collision are increasing at speed. Worse still, according to scientists, removing one deceased satellite from space will not prevent one

impact; rather to prevent one collision around 50 satellites would need to be made to slow down to force them into burning up in the upper atmosphere.

Figure 3: Nobu Okada



Source: SpaceNews

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Growth in private satellite launches does not bode well for reducing the chances of two satellites hitting one another, spraying large chunks of debris across the path of satellites in low-earth orbit. When China destroyed a satellite with a missile fired into space, the explosion resulted in 150,000 centimeter or larger sized pieces to be ejected, any one of which could result in a catastrophic satellite collision. As the number of pieces that could cause extensive damage increases, so too will the pressure from private industry, governments and space agencies alike to create a means of governing the disposal of satellites and removal of trackable objects. Because so much of the growth in satellites of late has come via private companies such as SpaceX, the requirement these companies to be responsible for satellites will likely prove affective partially because of the high number of launches to have taken place of late. Over 15,000 satellites are planned to be launched into low-earth orbit by private companies between the next five to 10 years, many of which are penciled in to provide global internet services. Resultantly the potential for disaster is likely to rise considerably, creating a pressing need for an affordable means of sweeping up debris in space.

Bank of America Merrill Lynch estimates by 2045 the value of the private space industry will be \$2.7tn. This figure includes manufacture and use of infrastructure to space-enabled applications such as satellite phones and weather services. As the number of objects that could cause a satellite to stop working increases, heightening the consequences of satellites crashing into one another, the predicted growth will fall into doubt. Such is the growth in scale that leading private space companies are now reaching, the need for the operations of companies dependent on space being a safe environment for space craft and satellites is quickly strengthening.

2.4. Private companies are attracting funding in race to make space cleanup viable

Tokyo-based Astroscale has won a combined \$130m in funding and set up a base in the United States, where company CEO Nobu Okada believes the most important regulatory developments will occur. Even without rule changes, the business Okada is developing may still thrive. His idea – to fix a small plate with a ferromagnetic coating to the exterior of a satellite before

launching, enabling a Astroscale machine to fix onto it using a robotic arm equipped with a magnetic tip to push a satellite out of its orbit and towards the atmosphere – has much going for it, but for the time being it relies upon makers of satellites taking action voluntarily. So far the cost has yet to be determined. Given the expense of launching a satellite (which is estimated to start at \$50m and can reach \$400m), even though costs are expected to fall substantially in the next few years, it is still asking a lot for companies launching satellites to provide the money to launch another satellite to ditch the first.

Figure 4: Astroscale



Source: Astroscale

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Despite this, the company is attracting attention and meaningful funding. The company hopes to work with governments and businesses to build the planned retrieval system; Astroscale entered a technical cooperation with the European Space Agency, agreeing to exchange data and expertise relating to space debris. Cooperation with supranational bodies will be important to growing private enterprise in this area: under the agreement the ESA will provide collision assessments for the Astroscale satellite, valuable information that unavailable outside of such organizations. So far progress towards a demonstration has been significant if delayed. Originally penciled in to launch in 2019 but now delayed until 2020, the End-of-Life Service by Astroscale (ELSA) is intended to be the first demonstration of technology for debris docking and removal. Operated from the National In-orbit Servicing Control Centre Facility in Harwell, UK, in the demonstration the 'Servicer' satellite will capture a 'Client' satellite weighing 16kg. Additionally, the company is working on technology that would enable large pieces of debris, not just whole satellites, to be disposed of, though when such ideas can be tested in space remains to be seen.

2.4.1. Government involvement incited by fear of 'Kessler' effect will help develop companies

The Kessler effect was originally proposed by NASA scientist Donald Kessler in 1978. Kessler described the mathematics behind a self-sustaining collision of space debris in low-earth-orbit, eventually making space all but unusable for LEO satellites. Such is the extent of modern-day reliance on satellites, for governments Kessler presents a very serious problem regarding national security and economic health. Consequently, the likes of Astroscale are seeking out these governments to offer support. Okada is betting that governments would prefer to work with private companies rather than fund what would likely be an expensive program from scratch, and certainly better than ignoring the problem altogether.

Collisions to have already taken place demonstrate the seriousness with which the problem of space debris is being met. In 2009 the US launched Iridium33 satellite collided with the Russian built Kosmos-2251. Even though this crash has so far not caused additional incidents, the scattered debris remains and could yet strike other satellites, causing them to fail. To what extent governments will assist with private companies will depend a lot on international cooperation and this poses a serious threat to companies developing means of taking satellites out of orbit. At present unconventional weapons are banned in space by international treaty, but that does not mean governments will be unconcerned by the prospect of satellites being launched capable of destroying other military grade satellites. Much work has to occur before the cleanup of space on the scale envisioned by Okada and others can take place.

2.4.2. Changes to insurance would help develop space cleanup industry

Creating a physical presence in the United States could be an important step, not only for Astroscale but for the collective might of the nascent space cleanup industry too. New rules concerning what companies must do in the event of a satellite failing or after it has served its usefulness would help matters. As of October 2018 only 5% of satellites in low-earth-orbit were insured. However, progress has been rapid, and roughly half of all GEO satellites do have insurance. According to Nick Allain, spokesman for Spire, a company that operates dozens of cubesats that collect weather and ship-tracking data, in 2013 insurance was not sold at a price point that was viable, but since then the situation has changed somewhat and now insurance is sold on a launch-by-launch basis. As insurance becomes more commonplace, so insurers could offer services regarding the removal of a nonfunctioning satellite.

Figure 5: Artist's impression of a cubesat



Source: European Space Agency

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Whether that will then take cover beyond the reach of companies launching satellites remains to be seen, but such a development would be a welcome boon to companies such as Astroscale. The introduction of international rules determining that satellites must be insured against failure in space and that cover for the removal of satellites from orbit be compulsory would create the market Astroscale and others require. Though unlikely to happen soon, additional agreements between governments to remove unusable satellites launched years or decades ago is needed. For the developing marketplace a cohesive international ruleset is vital. At present taking preventative measures to ensure future satellites can operate in a safer environment does not have a lucrative business case backing it, but if the costs of not insuring against having to purchase the services of Astroscale or any other similar company are high enough then the business case emerges. Even though the initial cost of insuring a satellite against having to be artificially removed from orbit would be high, a commonly accepted ruleset determining such insurance be purchased would provide enormous economies of scale, bringing down the price.

3. NASA is outsourcing to save costs but grandee missions will remain preserve of space agency

For decades the National Aeronautics and Space Administration (NASA) enjoyed sole access to space from the United States. Since 2006, however, the agency has been working with private companies, the progress of which has advanced to the point whereby rocket and spacecraft design and manufacture are being outsourced to private providers. Under pressure to cut costs, NASA is integrating private enterprise into long-term future plans. Yet despite the excitement regarding commercial enterprises winning access to space, some notes of caution are worthwhile. Grandee missions, will remain the preserve of the government agency. Flamboyant billionaires cannot muster, and could not justify, the budgets required.

3.1. Political pressure to cut costs has driven development of private sector

Though fans of space entrepreneurs trumpet the creation of successful private space rocket companies as a revolution, in truth the emergence of SpaceX, Blue Origin and others has been fostered by political pressure on NASA budgets. Opening contracts to the private sector provided such companies with a market that could extend beyond purely commercial satellite launches. The policy change has been critical to the rapid rise of commercial enterprise from bit-part players to drivers of innovation and increasingly the desired option from interested parties. Had it not occurred then the degree of sophistication of product offering now possible from the likes of Musk and the Jess Bezos created Blue Origin would likely have been a great deal less.

Figure 6: Space Shuttle



Source: NASA

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Central to why space travel was so expensive for NASA to undertake was that the Space Shuttle was exceptionally versatile: the craft could fix space telescopes, carry eight people and modules for the International Space Station into orbit. Justifying the expense of developing a replacement was always tough to justify, and a fatal breakup of the Shuttle on re-entry cemented the view of those in Congress arguing for NASA to be smarter with how money was being spent. In practice that

meant the space agency was being pressured to help develop offerings from private companies, and then buy them. Budget cuts meant the Constellation program, the replacement to the Shuttle, was cancelled, leaving NASA to depend on aging Russian rocket designs to carry astronauts to the ISS – hardly a publically acceptable position for the government funded organization to put up with for long. The case for cutting back NASA in-house development had therefor become compelling. Emboldened by emerging gaps in the market, the number of companies now competing for contracts from NASA that previously would have been fulfilled inside the space agency ranks is expanding, driving the trend towards a model that more closely resembles that which the government utilizes for defense procurement. Even when a SpaceX rocket exploded, replacing dependence on Russian technology with a rocket developed in the United States was sufficiently alluring to cause Senator John McCain to declare that the “mishap in no way diminishes the urgency of ridding ourselves of the Russian RD-180 rocket engine”.

So far the cost advantages offered by privately developed rockets suggest the direction of travel away from bespoke NASA created rockets and towards commercial rockets, is likely to speed up. A research paper written by Edgar Zapata at the Kennedy Space Center, the cost advantages of using SpaceX and Orbital ATK cost the space agency two or three times less than if the Space Shuttle was still in operation. Although an unfair comparison – the Space Shuttle was a highly versatile machine, whereas the private sector offerings are highly focused products – the point remains: costs still fall when private sector options are preferred regardless of which products are compared. The study also examined the NASA Orion Multi-Purpose Crew Vehicle (Orion MPCV) – designed to carry a crew of four to destinations beyond low Earth orbit (LEO) – against the costs expected from the SpaceX designed Dragon capsule (developed from the unmanned version) and Boeing are creating the CST-100 Starliner to take astronauts to the ISS and back. Competing against the private sector to shuttle astronauts to and from low Earth orbit will be tough for NASA, but the long-term goal of the Orion craft – to reach the Moon and then Mars – means the design must cope with added burdens that the private sector offerings will not attain for a long time to come. Nevertheless, the NASA report states the projected cost of a Dragon is \$2.2bn; the Starliner is currently estimated to cost \$3.27bn. Both well below the cost of Orion. Each flight Orion makes will cost \$1bn, which is troubling for NASA: Dragon comes in at \$308m per trip; Starliner at \$418m.

Figure 7: Orion MPCV



Source: NASA

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Yet the competition against NASA has not been entirely without help. NASA invested \$140m into the development of the SpaceX designed Falcon 9 rocket, and the company along with the likes of Orbital ATK have access to NASA test data from the Orion project, thus enabling private operators to advance smoothly through development stages that would conventionally have been much more expensive to complete. Central to why the space agency has been so accommodating to helping companies it is in direct competition with is to placate those in Congress who NASA needs to keep happy to

maintain the annual \$21bn budget. That this has so far resulted in cost reductions and expanded the pool of options available for space travel and associated industries. During 2016 NASA went so far as to seek private sector help to bring down the costs of Orion to a more competitive level.

3.2. Private sector involvement is now extending to spacecraft as NASA returns to the Moon

Historically the involvement of private companies in space travel has been limited to designing and building the next generation of rockets. The market has been primed for this for a while. The Space Shuttle was built using 1970s technology, and its retirement helped open the way for new entrants to capture the custom of NASA regarding LEO trips. Now that is changing. Private enterprise has been invited to design and build spacecraft for journeys to the Moon according to NASA specifications. NASA administrator Jim Bridenstine announced nine US companies would compete in delivering experiments to the lunar surface. Under pressure to recapture the public imagination, and with a Mars trip unfeasible even for the vast budgets available to the space agency, getting missions to the Lunar surface underway as quickly as is sensible means opening up contracts to private companies is an attractive strategy. Since China successfully landed a probe on the dark side of the Moon an important motivation to fund space exploration is being boosted: national pride.

Nine companies were selected for contracts to supply spacecraft to NASA. Though a combined value of \$2.6bn may not appear much in regards to the mega-budgets commonly associated with space exploration, growth could be substantial: in 2016 alone SpaceX, Sierra Nevada Corp and Orbital ATK combined received \$14bn worth of resupply contracts. Many companies invited to bid are young with big ambitions, but Lockheed Martin Space is also present, signaling the interest of major businesses in associated industries. Limited resources should engender competition, helping to rapidly develop the industry. Mergers and acquisitions are highly likely given the fragmented and specialized nature of leading companies currently present. Right now the contracted companies will be limited to small launch vehicles and robotic rovers, but that still represents a major advancement in what the private sector can offer NASA by way of commissioned services. Succeed and the scope of contracts put out for tender by the space agency will widen significantly. However, space exploration remains a high risk business.

Figure 8: Jim Bridenstine



Source: Science Friday

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If privately built rovers make it to the Lunar surface and then fail to function as intended, the enthusiasm for diversifying supply would dampen quickly. The stated desire for more affordable and frequent Moon visits means the number of opportunities for companies to design and build spacecraft will increase over the coming decade. However, most of the companies picked by NASA have never flown spacecraft of the complexity needed to travel beyond low Earth orbit. Only recently has the private sector reached this point, however. One company to be working with NASA, TeamIndus, was created to compete for the Google Lunar XPrize, a competition to send a robot to the Moon for which the prize was \$30m. Yet Google was forced to cancel it owing to none of the teams being even close to completing the challenge by the set deadline. Now, however, those companies have developed to the point at which NASA feels confident to buy their services.

Leading names in the private rocket industry are not intent on missing out either. Behind closed doors both SpaceX and Blue Origin are believed to be working with NASA on the Moon project. The space agency has long been working with defense company Lockheed Martin on the Orion Multipurpose Crew Vehicle and is involved with Boeing elsewhere. Smaller players could end up challenging the now established companies working in space, diversifying the product range and enhancing competition. For now NASA is benefiting from private enterprise having reached the point at which the endeavors of the US in space can be led by non-government organizations, and that suggests the private space business will expand swiftly. However, there is one problem: there remains only one viable customer. Outside of space tourism beyond LEO, which at present is only one Japanese billionaire for a flight that remains at best four years away, NASA is the only buyer. And that means the potential scale of the space industry beyond satellites will not behave like a normal market would and is solely dependent on government funding via space agencies. Once the initial enthusiasm wears, the present scalability of private space travel outside of low Earth orbit could become a very serious problem.

3.3. NASA outsourcing slows when limits of technological capacity are pushed outward

Fundamental to the argument of outsourcing NASA to private companies is the risk of bankruptcy and competition drives down costs and propels innovation. For much of the time this is true, and of late has enabled the space agency to do more with less, placating critics of large government funded agencies. Yet the pushing of what is technically possible does not have a business case behind it, just as was the case in the Space Race. Although NASA is first seeking to return to the Moon, the long-term aim of not just the agency but the likes of both Musk and Bezos are to go to Mars. Yet there is no business case for such an undertaking at present. Consequently, the further limits of human exploration in space will remain under the sole control of government backed organizations. Here lies the extent of full private sector involvement with NASA.

Figure 9: Artists impression of manned Mars landing



Source: ExtremeTech

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History suggests that is not about to change, either. It has taken five decades for the required advancements in space travel to arrive at the point where commercial viability of a Moon trip is taken seriously. Even with big budgets a potential shot at taking humans to Mars is at best the thick end of two decades away, meaning the point at which Elon Musk could take his company there on a paid for trip is could very well be at least a human life time away. That, of course, does not exclude SpaceX or Blue Origin from any involvement, but the focus of those companies lies elsewhere, suggesting the extent of involvement in a Mars mission would not be at the same level as it is for the planned Moon journeys. Such missions are horrifically expensive because new technology must not only be developed but often invented as well. Doing so means pursuing many research and development routes, something which is very much harder to do in the private sphere. Dennis Tito attempted to initiate a private effort called the 'Inspiration Mars' that chose 2018 as a year to perform a fly-by around Mars but the project never made serious progress towards that goal. (Tito originally wanted to fund the project until 2014 and then find investors from there on and secure funds through media rights sales. Money, however, failed to materialize before cancellation occurred.)

The point at which NASA will step back from Mars trips, as the organization currently is with Moon missions, is when the business case becomes unviable. It may take much more than tourism to bring this about. Sci-fi fans have long been familiar with the concept of space mining; such developments would likely be required to justify the spending needed for companies to operate at the level NASA might be at within the next two decades. Troublingly, even the most informed observers can only be vague about what will happen regarding going beyond the Moon and into the planets. Regardless of what happens, the extreme limits of what is possible shall continue to be dominated by government funding.

4. Age of space tourism is finally dawning as rival companies approach commercial operations

For a while it looked as though the much vaunted age of space tourism would be limited to business billionaires buying rides aboard aging Russian space rockets. After numerous failures and lengthy delays, the formative stages of what may turn into a lucrative industry are now seemingly tantalizingly close to reality. Some companies are looking beyond sub-orbital flights lasting only a few minutes; SpaceX is proclaiming to be preparing for a trip around the Moon in 2023. Lengthy trips into space are edging closer: serious progress towards the creation of a private space station has been made and NASA are seeking private buyers of access to the International Space Station. Much is changing very quickly in the still nascent space tourism industry, inciting hope for human exploration.

4.1. Governments are becoming more involved in creation of space tourism

Despite proclamations from space entrepreneurs that the coming of space tourism is a private sector effort, governments are playing a key role in the development of space tourism. Under pressure to reduce costs and to maximize usefulness from assets that are beginning to age, NASA is offering trips into space available only to the world's superrich. The government funded space agency is opening up the International Space Station (ISS) to private travelers and companies alike. Costing \$59m before the addition of a nightly fee of \$35,000, tourists will soon be able to buy a stay of up to 30 days. Although revenues from this service will be minimal compared to the multi-billion-dollar budget NASA enjoys, heaping pressure on that budget means the organization is keen on maximizing the value of assets by offering them to the private sector for a high fee.

Figure 10: International Space Station



Source: Space.com

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The entry of NASA to space tourism came as a surprise but is backed by sound reasoning. Opening up the ISS to space tourists means the agency can compete against the loftiest ambitions of Blue Origin and SpaceX, a company which recently announced the intention to offer a flight around the moon and back to Earth. Yet the space agency is going for a very different market than the likes of Virgin Galactic. Vast price tags charged by NASA dwarf those of proposed operators, most of which range between \$200,000 and \$250,000 for a trip lasting just a few minutes. To fill the space tourist slots will be tough owing to the tiny number of people armed with the required resources, whereas private operators offering short flights can tap a much larger pool.

Consequently, the opportunities for private enterprise to buy access to the ISS could easily end up being the most lucrative revenue stream, placing the long-term prospects of multiple week long stays aboard the space station as an infrequent event. Moreover, the agency would likely prefer being associated with technically advanced companies operating in business areas which would benefit from space travel. Media attention being lavished on an exceptionally wealthy person would put the agency logo on the front-pages of newspapers around the world, but during an era where brand perception in the US has become politically important regarding long-term funding from the government, the gains beyond receipt of a lump sum appear limited. However, given the International Space Station is now 20 years old, NASA is under pressure to maximize revenues while opportunities to do so remain open. Whether the allure of space travel will be cheapened by NASA – plans are to allow companies to buy trips into space purely for profit, including flying objects into space and returning them to Earth for the sake of providing novelty value – remains to be seen.

Governments are also becoming involved in the creation of spaceports, helping improve the business case for private operators. The UK Space Agency is creating regulations to allow sub-orbital flights. Creating the administrative structure to allow such a facility is important due the time lag between creating rules and regulations and a private space operator moving in. It is reported the UK government is working with the US on establishing safeguards, essential if disastrous accidents are to be avoided. After creating the National Space Council, the UK Space Agency pledged £7.85m (\$9.4m) to help Virgin Orbit – a private satellite launching company – establish a base at Spaceport Cornwall. Establishing such bases will be important for the growth of space tourism because the industry requires facilities to grow sufficiently quickly to bring down costs. Doing so is essential for long-term sustainability. The pool of people able to afford the journey and willing to spend the money to do so is very small; increasing the size of that group is most important to keep money flowing into space tourism on a long-term basis.

4.2. Low-earth orbit space flight companies are getting very close to commercial operations

Since its inception during 2004, Virgin Galactic has been seemingly only a few years away from taking paying passengers into sub-orbital space flight at a cost of up to \$250,000 per journey. 15 years on, the inaugural flight has yet to take place. Beset by problems developing the rocket engine to the required level and a fatal accident in testing have repeatedly pushed the anticipated launch date back. Now, however, expectations are the company are readying for launch after it was announced flights would no longer take place at the testing facility in Mojave, California, and takeoff from the Spaceport America site, a short distance from Los Cruces in New Mexico, the firm will use for commercial flights. Yet in the time since entrepreneur and head of Virgin Group, Richard Branson, has been joined by rivals, most notably the Jeff Bezos founded Blue Origin and the Elon Musk created SpaceX, both of which have taken a very different approach to than that pursued by the Burt Rutan designed craft. Competition between the mothership model built by Virgin Galactic – in which the spacecraft is slung below a jet aircraft and taken up to the high atmosphere before being released and the rocket engine ignited – and the ground launch option taken by Blue Origin and SpaceX should bring about speedy innovation, helping to reduce costs and increase the potential size of the space tourism market.

Figure 11: Virgin Galactic



Source: Virgin Galactic

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According to Virgin Galactic early demand is healthy. The company claims to have sold more than 700 tickets to date. Six passengers will be aboard each flight, meaning the company has sold enough to cater for easily over 100 flights. If journeys to the lower reaches of space do begin in 2019 then Virgin requires them to be successful to build additional demand to that which has accrued since the project was announced in 2004. Branson will need to start commercial flights soon if his company is to gain the early media attention. Rivals are edging closer to starting commercial services too. Blue Origin has flown into space 10 times (as of January 2019) and still hopes to fly passengers in 2019. The company has also achieved much higher trajectories than Virgin has, extending stays in space from six minutes to 10 minutes – a small but probably commercially significant improvement – and reaching 346,000 feet in altitude.

Blue Origin remains cool on the prospect of launching services in 2019, though. According to an official representative “We will move through our New Shepard flight test program step by step and fly humans only when we are ready.” This view points to delays and problems being anticipated. Space travel has traditionally been dangerous and accidents will likely be fatal, potentially destroying the business and causing funding to evaporate. 2019 would not be the first year that many interested observers predicted services to space would begin; the finish line has been sighted repeatedly only to then disappear.

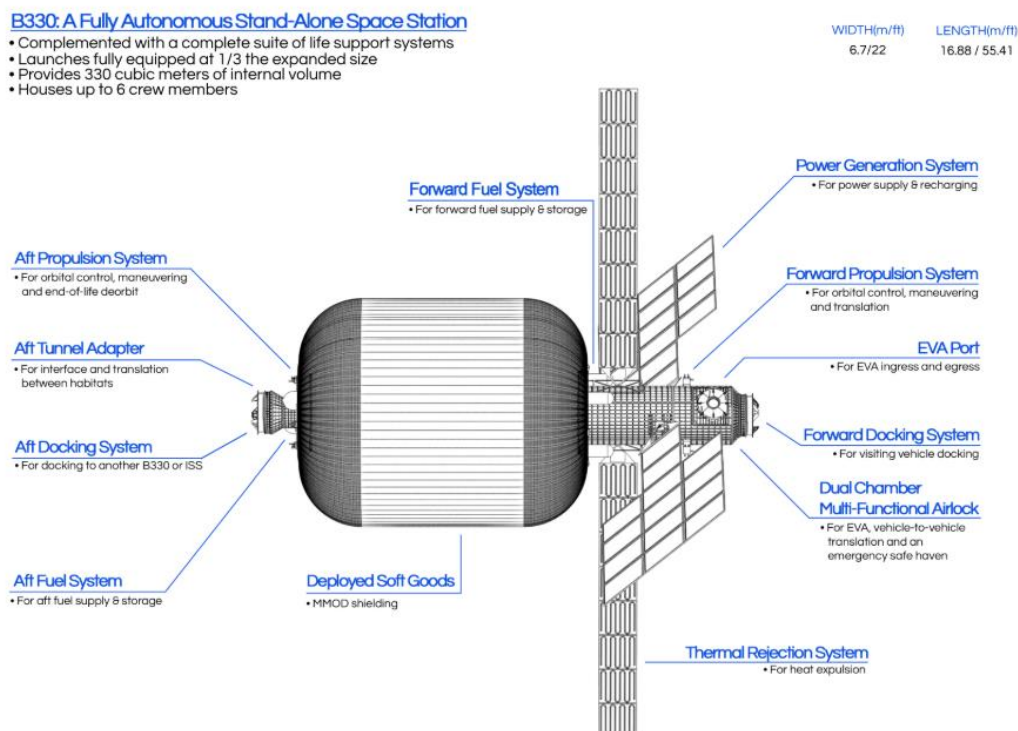
4.2.1. Need for a perfect safety record and long-term funding means more delays could yet occur

Funding is a key reason why those to have already paid over \$200,000 for a seat could find themselves waiting longer. Even though Virgin claims to have sold more than 700 seats, the revenue from that is thought to be around \$80m – a small amount compared to the investment needed on a long-term basis. Virgin Galactic has since announced the company will go public and hopes to raise \$800m from a sale of 49% of the firm. For Virgin Group this is nothing unusual. Richard Branson has frequently sold large shares in his companies and holds no shares in several firms that operate the Virgin brand under license. Securing funding from a special-purpose acquisition company, and keeping them onboard on a long-term basis, will depend on having an impeccable safety record. Whereas the early airline industry was able to survive disasters, in the modern world failures for space companies will be much more public and would attract worldwide attention. Recovering from a fatal accident involving paying passengers would likely be very much harder than the early airline companies found it.

4.3. Creation of space tourist space station is drawing closer as technology develops

Privately funded space travel has long been sought after. Held back by the exceedingly large budgets required that put leaving the Earth beyond the reach of all but a few governments, space travel is now coming down in cost, opening access to non-government organizations. Technological developments suggest the price of building a space station are falling rapidly, enabling wealthy individuals to buy a ride for a fraction of the cost charged to the world's first space tourist, Dennis Tito. US based Bigelow Aerospace has been behind much of the cost reduction in construction of space station modules. By creating modules that can be inflated in space, the cost of taking them into orbit and the complexity of operations to join them to an existing structure has been reduced. Moreover, the company has already proven the technology works. During 2016 NASA attached the Bigelow Expandable Activity Module (BEAM) to the International Space Station, helping to secure an extension to the contract for a further three years. (The ideas behind the inflatable modules were originally developed by NASA in a project titled Transhab, but it was canned due to ISS cost overruns. Bigelow then purchased the patents in 2000, leading to the Genesis program which launched in 2006.) So far the module has worked as intended and further modules could soon be used for human habitation. Made out of Vectran, a material twice as resistant to impact as Kevlar, Bigelow claims the inflatable modules are stronger than the rigid variants the company hopes to replace.

Figure 12: Bigelow Aerospace B330 Space station



Source: Bigelow Aerospace

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The relationship with NASA is very important because it has so far proved the concept of inflatable space modules is not only viable but the cost reductions are sufficiently large to raise the prospect of creating the first privately funded space station. Better still, the reality of a private space station for tourists and commercial entities alike has key commercial advantages over previous government backed projects.

Equipped with a volume equivalent to one-third of the ISS, the B330 can house six people, just like the ISS, but without the need for multiple launches and complex procedures to join them together. A one-launch space station would drastically cut costs, bringing the price tag to within the reaches of private buyers. Creating a space station the same size as the ISS would only require three launches, the cost of which has come down considerably since the International Space Station project was originally launched. Consequently, the potential for space tourism taking place over a period of days and weeks, instead of just a few minutes attainable from sub-orbital flights, has improved somewhat.

If the Bigelow project succeeds, and the company can attract enough wealthy people who desire to travel into space to be sustainable on a long-term basis, the business model of the future space tourist industry would be transformed. Early pioneers such as Virgin Galactic and Blue Origin could become bit-part players in the game they helped to create. Though being at what can laughingly be referred to as the 'budget' end of the space tourism industry could very well still be lucrative, the major revenues would come from long-term stays. During 2017 Bigelow Aerospace reached an agreement with rocket and orbiting spacecraft company United Launch Vehicle. By the end of 2022 the two partners hope to have launched a B330 module into low lunar orbit to serve as a lunar depot. Hopes are the space station would serve as an anchorage for lunar business development. This raises the prospect of the very wealthiest space tourists buying a trip to orbit the moon in what would be a substantial development on the plans for a single journey around the moon announced by Elon Musk and penciled in (for now) for 2023. Potential costs remain unknown. But as what the super-wealthy can afford to do reaches ever further into space, so what will be possible on a budget of just a few thousand dollars by 2040 advances.

Notes of caution should be issued, however. During the development of commercial sub-orbital space companies, dates set for the first flights to take place were continuously pushed back despite good initial success in testing which caused Richard Branson to declare his company would start services in 2009 – a decade later and the first paid for flight has yet to occur. The same could easily happen with space station tourism. Initial testing has proven successful, but much needs to happen before the super-rich can book a week-long stay in zero gravity.

4.4. Space tourism is now extending to the Moon but pushing extremes incites viability doubts for now

Not known for sticking to target dates, the effervescent Elon Musk declared in early 2019 that his SpaceX rocket company would take Japanese billionaire Yusaku Maezawa on a paid for trip around the Moon and back to Earth in 2023. The retail magnate claims he wants to take artists with him but so far has not decided whom he wants to bring. (The availability of those he has in mind remains undetermined). Just as was the case with Dennis Tito, the number of people able to contemplate such a trip is tiny, but that such advances are being contemplated signals the speed at which the anticipated space tourism industry is predicted to develop at. Despite this, the launch date is optimistic and could easily be pushed back; due to the experimental nature of space travel, unexpected delays are a likely possibility and the January 2019 announcement was the fourth such Moon related mission Musk has made so far.

Figure 13: Yusaku Maezawa



Source: BBC

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Exciting though a privately funded trip around the Moon is, the business case for the journey being anything other than a one-off for many years to come appears strong. Musk stated that the price paid by Maezawa would have a material impact on the multi-billion dollar development costs of the Big Falcon Rocket (BFR) that will be utilized. If accurate, the claim points to the price dwarfing the \$58m a flight to the ISS will reportedly cost. Even for the super-rich keen enough on space to pay tens of millions of dollars, following in the path of Maezawa would appear to be out of reach, placing Moon tourism a while away yet even for the world's billionaires. How much Bigelow Aerospace can change that outlook via the B330 space module can only be estimated vaguely for now.

5. Space industries of the future are developing, but still limited by economics

Through the emergence of the private space industry a number of opportunities have started arisen that wouldn't have been possible otherwise. Cheaper rocket equipment, reusable rockets and cheaper flight prices are just some of the advantages to have come from private enterprise becoming involved in the space industry. Estimates vary but some sources believe the space industry to currently be worth \$330bn to \$350bn, by 2040 many expect this figure to be well over a trillion dollars through the spawning of new space based industries. Many of these are more science fiction at this stage, but others are entirely plausible over the coming decades. The main problem for many of the projects that hope to get off the ground in the coming years is that they do not have a proven business model. Some are worse still, in that they actively don't make any economic sense and so embarking on some of these projects, from a commercial profit and loss basis are impossible.

5.1. Private rocket companies need reliable space industries to supply

Multiple organizations, both private and state owned, are now in the game of producing reliable rockets that deliver pay loads into space. From Space X, Blue Origin, Boeing and Lockheed Martin through to Roscosmos, ESA, NASA and CNSA they all want to make access to space easier. However at present these organizations are mostly reliant on satellite contracts, some government funded scientific endeavors and ISS resupplies, but little more. There is a great deal of talk about the potential industries that could spring up should costs come down, but very little has actually happened so far to encourage them. The primary reason for this is that beyond tourism, there are very few economic reasons that would draw companies into space. Should a government organization decide it was going to fund a moon or mars base then all number of industries could spring up around it providing energy equipment, terraforming, food, space stations, space mining, transport logistics and construction to name but a few. But with no initial impetus it is very difficult to see many space industries ever getting off the ground for simple economic reasons. However, NASA is beginning to move into a facilitating role happy to support ambitious missions and letting companies take over the equipment supply. China too is pushing for its own space stations and sending out Moon missions, so the environment where new ambitious space industries might emerge is beginning to form but still some way away in all likelihood.

5.2. Commercial Space stations are likely, but the right business case needs to emerge

A number of companies have been looking to create options for opening commercial space stations that orbit the earth. Bigelow Aerospace is an example of one of the organizations that have been pushing to raise funds to launch a commercial space station for a number of decades. However, until that is a reality, Bigelow has been building modules for the ISS. Bigelow along with SpaceX has launched expandable BEAM units which are now a fixed asset of the ISS. However in 2019, the environment is getting more favorable. NASA is rapidly allowing more and more private companies access to its technology and its contracts. The singular problem for companies like Bigelow, is that they already fundamentally have the technology to build a commercial space station and private rocket companies are fully capable of delivering it to space, but there is no real use case at present for a commercial space station. Bigelow has funded a multimillion dollar research project in the words of CEO, Robert Bigelow to find out "what the hell a commercial market really looks like," Commercial space stations could be the basis for a number of private enterprises from tourism to scientific exploration, but until they are in place and travel to these stations is significantly reduced in cost it is hard to predict just what might emerge. Without partners on board though it requires an enormous leap of faith for companies like Bigelow.

Figure 14: Bigelow module attached to ISS



Source: NASA

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5.2.1. NASA allows commercial access to the ISS, part of a defunding plan

An unknown factor in the mix at present is NASA and the commercialization of the ISS. The US government announced that it wants the ISS defunded by 2025 and to be effectively fully commercialized. Part of this coincides with NASA's changing agenda towards deep space exploration, rather than low-earth orbit projects in the hope that NASA stepping to one side will allow the space for other organizations to enter the market. As a result, in June 2019 the organization announced that it was allowing tourists and business ventures access to the ISS. NASA stated: "NASA is opening the International Space Station for commercial business so U.S. industry innovation and ingenuity can accelerate a thriving commercial economy in low-Earth orbit." The aim for a number of years has been for private industry to take over the costs of running the ISS so that NASA can move onto other projects with less of the ISS cost on its balance sheet. ISS costs NASA around \$3bn per year or \$1.37m per day, excluding the project and development costs that would increase this figure to \$7.2bn per day. The aim is to reduce these colossal fixed costs, by allowing commercial enterprise to take over either via running the station or through generating income from tourists or other commercial projects.

5.3. Space Mining is a completely implausible suggestion at present and may be decades away, if at all

In 2017, excitement was brewing over the possibility that mining asteroids could soon be a reality and that it could provide all the resources the planet would ever need. A Goldman Sachs report speculated that asteroid mining was actually cheaper and more plausible than popularly believed. US senator Ted Cruz stated that the world's first trillionaire would come from space industries. Billionaires involved in the space industry began proclaiming that in future all heavy industry could take place in space, fueled by the enormous resources found in asteroids. The resources of asteroids are bountiful, that much is true, there are over 16,000 near earth asteroids and they contain vast amount of rare earth materials such as platinum nickel and gold. Deep Space Industries and Planetary Resources were two start-ups that aimed to focus on this new industry and make asteroid mining possible. Initially, they had some success both with angel investors and technology development.

However, investor funding began to dry up and Planetary Resources (PR) and Deep Space Industries (DSI) were eventually acquired for their assets with little prospect of their original goals remaining. Fundamentally, the boards of both companies contained those obsessed with the romanticism of a Space Mining industry and pragmatists that were trying to build a business model. Ultimately the conclusion was that at least within the next decade, there would not be any customers for mining. Material mined from an asteroid would not be able to be brought to earth because of the enormous cost of doing so and that means a moon base would be needed to process and use the material and that prospect is still many years away. Both PR and DSI did have useful technologies such as DSI's water propulsion system, and PR's hyperspectral sensors, which could have been licensed for use on earth in the short term to keep the companies active, but they both failed to do this. Asteroid mining makes economic sense once there is a substantial human presence in space working on all manner of other industries that require raw resources, until that is the case asteroid mining is not plausible as an industry.

Figure 15: Planetary Resources long term mission

Metals

Planetary Resources' long-term plans include mining asteroids for structural and precious metals. Structural metals will be harvested and used as construction materials in space. Sourcing these materials from beyond Earth's gravitational influence enables the construction of low-cost structures that are not limited by size. Precious metals will be used for in-space manufacturing of high-end electronics, laboratory equipment and spacecraft components.



Source: Planetary Resources

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5.4. Robotics for space settlements and engineering projects do have a future

An industry that could eventually be very profitable for both the space industry and for applications on earth, could be that of robotics. A major cost factor on the ISS is the need for manned crews of multiple people. Rockets with human cargo have

to receive NASA approval to do so, and require many more safety features in driving up the cost. Robotics that could back up crews or even replace them in some circumstances would be enormously useful to future space industries. This has been shown through NASA's creation and development of the Valkyrie robot program. Initially designed as a potential environmental disaster robot, many now suspect the Valkyrie of being the first of a number of advanced robots that could be put to use on grand space projects such as Mars or moon missions. Robotics is particularly well suited to this type of task and potentially better able to survive the extreme conditions on other planets or in Space than a human crew. Whether robotics could ever effectively replace human crew is debatable, but if significant missions in space are authorized such as the Mars mission, robotics will be essential in order for this to happen. There are also multiple use cases for robotic technologies on earth too meaning the economic case for this tech is more feasible.

Figure 16: NASA's Valkyrie Robot



Source: NASA

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5.5. Mars or moon base absolutely essential to kick start commercial space industry

Fundamentally, analysts of the private space industry are struggling to make sense of the underlying economic case behind many start-ups that want to do business in space. Angel investors have pulled the plug on many businesses that were exciting but had no customers to sell their product to. The opportunities for business in space will require further public political will and public money in order to get many new industries going. For instance, a multi-billion dollar investment from NASA in a mission to Mars or the creation of an off-earth base or colony, would spawn multiple new business opportunities

for a wide range of companies. However without this injection of cash and emphasis, businesses would not be able to do this alone and therefore many of predictions in recent years about asteroid mining or terraforming, will not be possible. Companies looking for opportunities in the space industry should focus on the plausible. The satellite industry is growing moderately well and connected to this is the eventual opportunity to provide services such as space clean up once serious funding becomes available. Further opportunities will be available from NASA's commercialization of the ISS through backing up maintenance, logistics, tourism and supplies. Companies should focus on these plausible business cases and monitor the development of projects from government space industries to plan their next steps.

6. Appendix

6.1. Sources

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6.2. Further reading

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7. Ask the analyst

We hope that the data and analysis in this case study will help you make informed and imaginative business decisions. If you have any questions or further requirements, MarketLine's research team may be able to help you. The MarketLine Research team can be contacted at ReachUs@MarketLine.com.

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