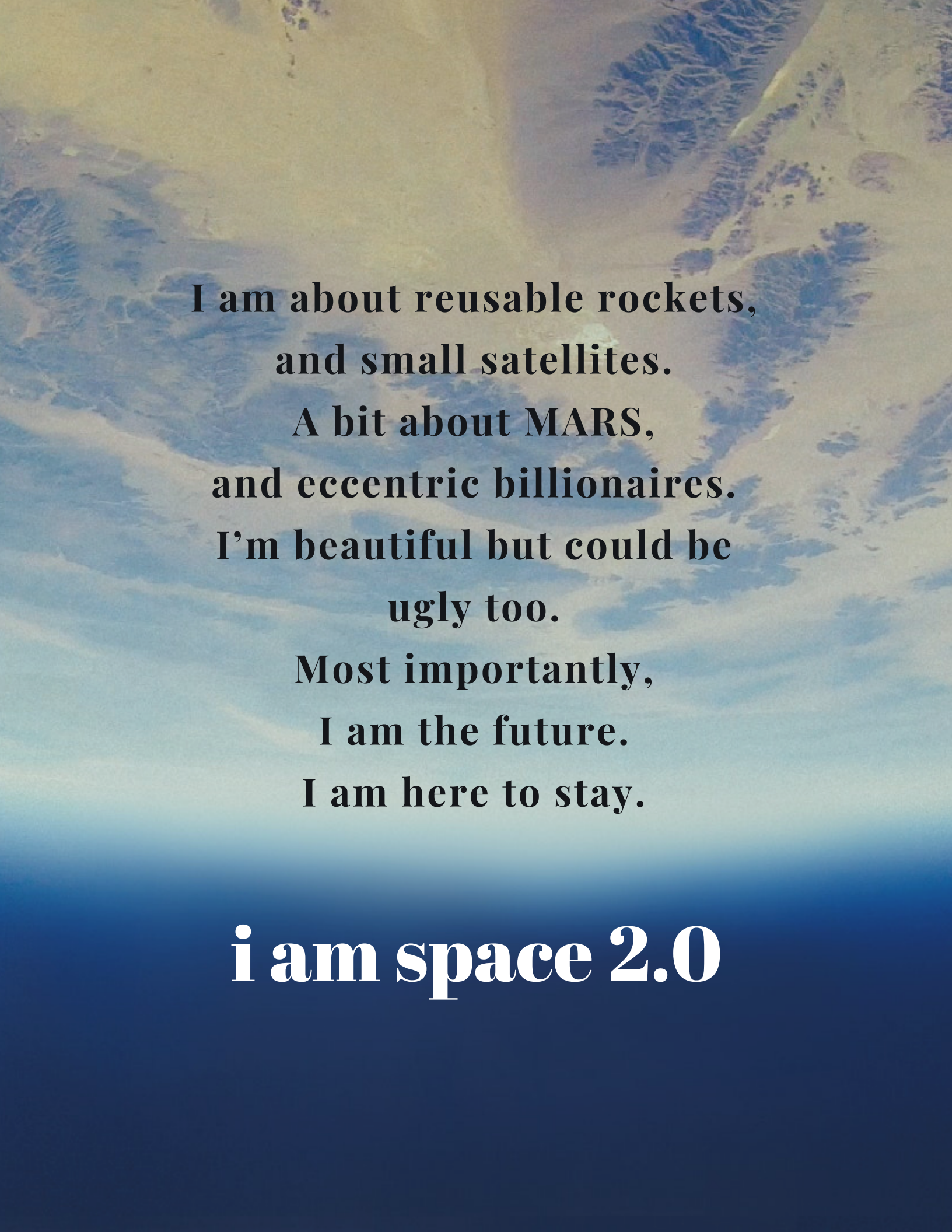
JANUARY 2019

RESEARCH

KIS CAPITAL PARTNERS

THE RISE OF COMMERCIAL SPACE INDUSTRY

Can the technological changes taking place in the space industry hold the potential to transform the way we live on Earth?


I am about reusable rockets,
and small satellites.
A bit about MARS,
and eccentric billionaires.
I’m beautiful but could be
ugly too.
Most importantly,
I am the future.
I am here to stay.
i am space 2.0

in this paper

WELCOME TO SPACE 2.0

THE NEW RACE FOR SPACEFLIGHT SUPREMACY

THE STORY

During May of 1961, US President John F. Kennedy declared:
"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth"

To many people, at that time, of course, this was just science fiction... But fiction turned to reality in July 1969, when Neil Armstrong notified Houston, "Houston, Tranquillity Base here. The Eagle has landed." Millions of people around the world followed Armstrong on camera, as he descended down a ladder and uttered the historic words, "That's one small step for man, one giant leap for mankind."

Today, almost 50 years on, millions look at this sector with new found interest – of promise of much more than the moon.

Today is about reusable rockets, insanely quick flights across the planet, and of course, living on mars!

The people laying the foundation, of a future dependent on space, promise it will improve life on Earth. But the future they describe is packed with wonder and controversy in equal measure—and although few have noticed, it's coming to pass right now (1).

living a multi-planetary life

FAST FORWARD TO YEAR 2080

The cost of a trip to Mars is about $200,000. Since some of your friends have already moved to Mars and loving it there, you have also decided to take a chance. With a hundred other people, you board SpaceX's Interplanetary Transport System. There are a thousand other spaceships, along with yours, ready to take-off. It's a five-star cruise like experience and you don't even realise when you reach Mars (2).

This is just a small part of Elon Musk's vision – you might actually be living on Mars another 50-100 years from now. And, he is not the only one vying to send you to Mars - NASA, United Arab Emirates and Mars One have similar plans. (2) (3)

Many people look at this interest in Mars as 'sudden' and 'eccentricities of billionaires'. It is neither. We've always been driven to explore the unknown and discover new worlds.

Of course, curiosity alone is not enough. It has to be accompanied with technological advances and economic models which incentivise governments and private enterprise to take it seriously. Such advancement has come in the form of reusable rockets and small satellites. Just like in the past (see Appendix A), where space exploration opened up possibilities that were not thought of at the time, today these two developments have given us the possibility to colonise Mars.

There is little doubt that these developments are the most important since the industrial revolution and are going to create some of the greatest investment opportunities of our lives. But before we get too excited about these path-breaking developments and look into what the future holds, lets trace our steps to the events that allowed private enterprise to dip its toes into the space pool.

why space, now?

A SHIFT THAT HAS RENEWED INTEREST IN SPACE

Space exploration, by no means, is a cheap endeavour. Add to this, the uncertainty of procuring useful technology and the dangers in space. For the private sector, this concoction was poison.

It is no surprise then, that traditionally the most dominant role in this sector has been played by national governments. The exception to-date has been the satellite telecommunications industry. Also, the private sector has, in a limited way, been also involved in the provision of launches for private and government satellites. **Essentially, the role of the private sector was limited to servicing national space programs** (4).

If we were to characterise the space economy until today in a few words, it would be - big government programs, a few big contractors, little competition, no growth and lately, little innovation.

However, all this is set to change and the sector has caught the fancy of private enterprise over the last decade or so due to a confluence of factors. Chief among these factors are: a) budget cuts for NASA since the global financial crises; b) falling costs of entering the industry; and c) lucrative government contracts providing much needed impetus for private players.
To give a perspective, while NASA spent around $44 billion in 2015 dollars at the height of the space race, it has received less than half of that amount, around $18 billion for its annual budget in recent years (5). With crew & cargo transportation and maintenance costing a lot, **NASA has been able to spend only 7% of its Low-Earth Orbit and Space Flight Operations budget on research** (6). This has forced NASA to shut down many of its programs. For instance, the Space Shuttle program, which used to carry astronauts and important cargo to the International Space Station, was discontinued in 2011 (7).

To fill this void, NASA has increasingly turned to the services of the private sector. In place of the Space Shuttle program, NASA has formed Commercial Resupply Services contracts with private companies like SpaceX, Orbital ATK (now part of Northrop Grumman) and Sierra Nevada Corporation (8). **These contracts cost only around $191 million per mission vs. $450 million per mission cost of the Space Shuttle** (9) (10).

so, what is changing?

THE PRICE OF ADMISSION

According to Jeff Bezos, he was able to start Amazon with little resources because most of the heavy lifting in the development of infrastructure had already been done. The internet was up and running, the postal service was alive and well, and the payment systems had developed for online retail to be a reality. This infrastructure, according to him, allowed 'dorm-room entrepreneurship' to flourish in the internet age.

The same cannot be said of the space industry at the moment because the "price of admission is really high". You literally need hundreds of millions of dollars to do anything interesting in space. Blue Origin (Jeff Bezos' space venture) wants to **reduce this price of admission by focusing on reusability.** He wants to build the infrastructure on top of which a new wave of entrepreneurs with creative ideas can build their businesses.

The advent of small satellites and reusable rockets is acting as the watershed moment for the next generation of space entrepreneurs.

Satellites have revolutionized many aspects of our lives as they have the ability to see large areas of Earth at one time. **This allows them to collect more data, more quickly, than instruments on the ground.**
For instance, before satellites, it was difficult to cover a vast area as TV signals didn't go very far and were often blocked by mountains or tall buildings. Further, TV signals don't follow the Earth's curve as they travel in a straight line and would simply go off into space (11). Similarly, faraway places were inaccessible by phone because it was hard to set up telephone wires over long distances or underwater.

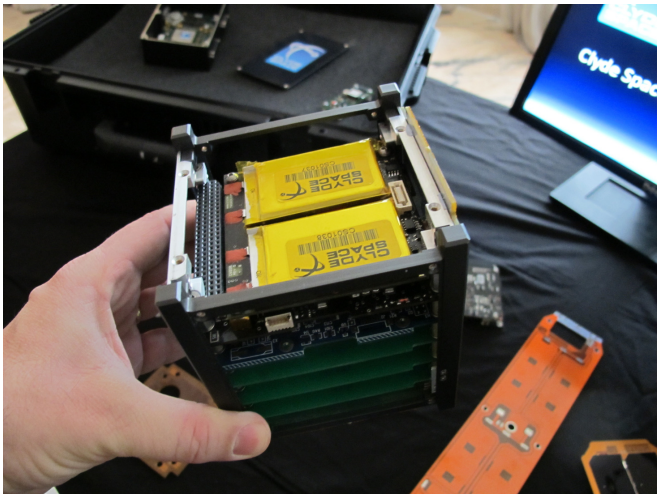
With satellites, TV signals and phone calls can be sent up to a satellite which can then send them back down to different places on Earth. These advantages led to the rise of companies like **DISH Network Corporation (NASDAQ: DISH), Iridium Communication (NASDAQ: IRDM) & Inmarsat (LON: ISAT) which started using satellites to provide television and voice & data communication services respectively** (12). However, because these satellites are huge and cost hundreds of millions of dollars to launch into orbit, satellite communication has remained a niche segment until now. This is changing with the advent of the CubeSat.

then: traditional satellites

big, slow

EXPENSIVE

now: cubesats



"What's the problem? Satellites are big, expensive and they're slow", is how Will Marshall, founder of private company Planet, described satellites back in 2014 which according to him, were the biggest impediments to innovation in Space (13).

To give you a perspective, a traditional satellite can weigh 3 tons and can be 6 meters tall and 4 meters wide taking up the entire payload space of a rocket, meaning that only one satellite can be launched per rocket. **The total cost to build and launch such a satellite into Earth's orbit can be hundreds of millions of dollars** (14).

It is this problem that Marshall, along with Robbie Schingler and physicist Chris Boshuizen set out to solve (15).

And solve they did by developing a version of a CubeSat (also known as a NanoSat) that could fit the latest high-resolution cameras and sensors and **weighed less than 5 kilograms.**

when small means

BIG BUSINESS

CubeSats are based on the standard CubeSat unit, namely a cube-shaped structure measuring 10x10x10 centimetres, known as 1U and consist of mostly off-the-shelf components (16). This has meant that depending on the specification, a CubeSat can be **built and placed into orbit for less than a million dollars.** Not only have costs reduced but the time it takes to build and launch a satellite has shrunk substantially. For instance, in the case of a large satellite, it can take anywhere between 5 to 15 years from the need being identified to the satellite being placed into orbit. **CubeSats, however, usually take less than 8 months for the same process** (17).

Launch costs have also reduced on a per satellite basis since multiple satellites can now be carried in a single rocket. For instance, in February 2017, the Indian space agency, ISRO, launched **104 satellites on a single rocket into low earth orbit, shattering the previous record of 37 satellites** (18).

To give a perspective of the rapid developments in the sector, Euroconsult (an international research firm specializing in the satellite sector) had forecast back in 2009 that 1,220 satellites will be built for launch over the decade 2010-2019 or 122 satellites a year on average. **In 2017 alone, 450 satellites were launched.** (19) (20)

Satellites of course have utility only if they are in space. But how do you get a satellite into Earth's orbit? Here is where the rocket comes into the picture. These vehicles helped launch, among other things (like cargo, space probes), satellites beyond the Earth's atmosphere.

Space rockets are 'rockets with stages', namely, payload system, guidance system and propulsion system. Until recently, none of these sections could be reused which meant that **for every launch, a new rocket had to be built.** This is the major reason why cost of rockets has remained very high.

LAUNCH COSTS

THEN

$450 MILLION

NOW

$90 MILLION

then: traditional rockets

now: reusable rockets

USE AND THROW… NOT ANYMORE

Traditionally, launch services had been a **virtual monopoly of United Launch Alliance – a joint venture between Boeing Co (NYSE: BA) and Lockheed Martin Corporation (NYSE: LMT),** especially in the area of launching critical Military payloads (21). Coupled with the fact that rockets could only be used once, it is no wonder that the **launch cost alone could be as much as $450 million** (22).

Taking air travel as an example, if airlines had to build a new plane for each flight, **the price of a one-way ticket could be as much as $500,000** (23).

On the other hand, if rockets could somehow be reused, there can be a drastic reduction in launch costs. This is precisely what some private players like Space X, Blue Origin and Rocket Labs are trying to achieve.

In 2018, out of the 14 rockets that SpaceX attempted to land, it was able to successfully do so for 12 of them. According to SpaceX, the modifications to its Block 5 Falcon 9 rockets would enable these rockets to "fly 10 times or more before needing light refurbishments."

It is because of advancements like these that SpaceX believes that it may be able to lower the price of a launch to as little as $700,000 in the future. That means in 10 years' time, private companies may be able to stage 214 launches for the price of a single NASA launch today (24).

Apart from reusability, greater competition for launches has meant that **costs have already come down by a factor of more than 4x.** For instance, in March 2017, SpaceX won a contract to launch a US satellite at an all-in cost of $93.5 million, well below the ~$400 million charged by ULA (25).

And with the advent of small satellites which do not require very heavy payloads, launch costs are expected to fall further. Many companies, including Rocket Lab, Virgin Galactic and Vector Space Systems are building small launch vehicles to cater to the growing market for launching small satellites alone. For instance, Rocket Lab recently completed its first ever mission for NASA launching 13 small satellites all for a total launch cost of $5 million . The table below highlights the different payload capacities and price points amongst these companies (26) (27).

Company	Rocket	Capacity	Price
Rocket Lab	Electron	150 kg	$4.9 M
Virgin Galactic	LauncherOne	400 kg	$10.0 M
Vector Space	Vector H	100 kg	$3.0 M

Reducing costs of doing business in space is opening up possibilities that hitherto were the realm of science fiction.

SINCE YEAR 2000

$14B

INVESTED

70%

HAS COME IN THE LAST 5 YEARS ALONE

ALL SET TO TAKE-OFF

87

venture capital firms

invested in space start-ups in 2017

180

since year 2000

angel- and venture-backed space companies

a new space economy BECKONS

TRENDS

There was a time when space sector was mainly comprised of launches and satellites. Not anymore.

The new frontier in rocketry and small satellites has reduced the cost of accessing space and opened up very attractive possibilities - more than those provided by satellite internet. It will therefore be no surprise if space becomes a place where every company conducts at least a portion of its business.

Moreover, in the coming years, the space program is expected to increase our knowledge of solar energy power, cryogenics, environment, and many more areas that impact us every day. This will lead to increase in demand for space applications and various bodies have forecasted significant growth in commercialization of the industry.

This has led to a spate of activity and the sector has attracted ~$14 billion in equity financing since the year 2000. Over 70% of that has come in the last 5 years alone (28). Today, the global space economy is worth an estimated $348 billion and close to 50 nations have government space budgets.

It is thus an opportune time to have a look at some sectors that might be the first to take advantage of this new economic sphere, and some of the trends that stand out.

communication

A NICE LINE REQUIRED

It would be hard to remember but back in the 1990s, there was intense competition between telecom companies as to the best technology to provide mobile communication services – satellite phones vs. cellular phones (that used land-based towers). As we all now know, it was won by the cellular companies. However, what is relatively unknown is that **cellular companies did not win because they had superior technology, coverage or service, but because the high costs of satellite phones (both equipment and service fees) were a deterrent to mass adoption** (29). Even today, typical rates for voice calls from a satellite phone cost anywhere between $0.80 to $1.50 per minute (30).

This equation might soon change as new low-cost, high bandwidth satellite connections threaten to undermine traditional telecom business models (31). For instance, Australian listed **Sky and Space Global Ltd. (ASX: SAS), is planning to build a commercial telecommunication network** and provide coverage to millions of people living in a band around the equator – stretching from Darwin to Hong Kong (32).

Similarly, the economics of satellite broadband connections have improved with the invention of the CubeSat (33). As per Internet World Stats, only 55% of the world's population has access to the internet (34). **That means that around 3.5 billion people lack such access.** Looking to this unmet demand and falling costs of launching satellites, several companies including **ViaSat (NASDAQ: VSAT), SpaceX, OneWeb and Telesat are in the process of developing broadband networks by launching constellations of small satellites into low-Earth orbit.** OneWeb plans to launch 900 satellites into orbit by 2027. Similarly, SpaceX received approval for launching more than 7,500 satellites to build its broadband network (35).

To give you a perspective of the sheer numbers involved, if things go to plan, these new firms will launch more satellites over the next decade than have ever been launched in the history of space exploration (36).

satellite imagery

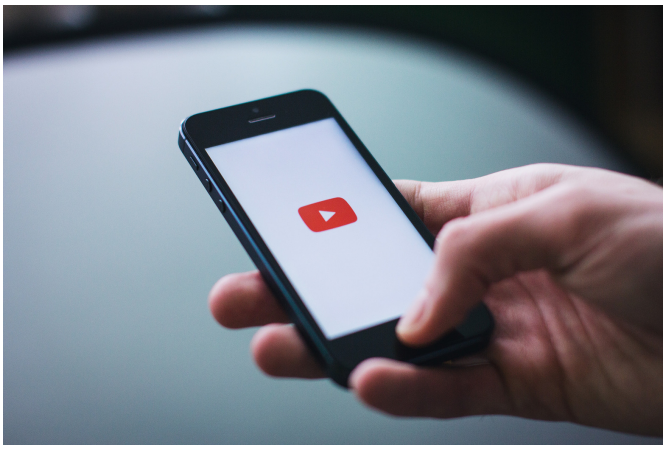
INDEXING THE PLANET

If Planet's first mission was to launch a bunch of CubeSats with high definition cameras into space and create a database of images of every corner of the Earth each day, its new mission is to combine space technology with artificial intelligence to create a **"database of all the sizeable objects on the planet."**

Imagine being able to count the number of planes at an airport or ships on a port on any given day and being able to compare it to history. Marshall gives an analogy – Google indexed what's on the internet and made it searchable, Planet wants to index the Earth and make it searchable (37).

Other companies such as **DigitalGlobe (now part of MacDonald, Dettwiler and Associates Ltd.), Descartes Labs, Vinsight and Spaceknow** are all using satellite imagery to provide useful data to various industries. For instance, Descartes Labs uses chlorophyll density images, taken by satellites, to predict agricultural output.

According to its CEO Mark Johnson, the **Descartes' algorithms' prediction of corn output was off by just 2.5% for the last 10 years** (38). Vinsight, a California-based start-up, which focuses on grapes and almonds, estimates that **farmers can get a yield prediction that is three to four times more accurate** (39).



[Click on the image yo listen to Will Marshall of Planet give a TED Talk on how satellite imagery will transform the Earth]

Database of all the sizeable objects on the planet.

space tourism

TO MOON AND BEYOND

It is only in the last few years that space tourism has caught the public's attention with billionaires like Elon Musk, Jeff Bezos and Sir Richard Branson all vying to send people into space for leisure travel. However, what is relatively unknown is that sending tourists into space is not a new concept. Virginia-based private company, **Space Adventures, Ltd. was the first space travel agency in the world,** arranging the travel of a private citizen to the ISS on board the Russian Soyuz spacecraft in April 2001.

From 2001 to 2009, Space Adventures had arranged all eight of the flights to space completed by private citizens to date. As far as the costs are concerned, **it is estimated that it cost anywhere between $20M - $25M per person for such travels** (40).
By 2007, space tourism was thought to be one of the earliest markets that would emerge for commercial spaceflight (41).

TO THE MOON AND BACK

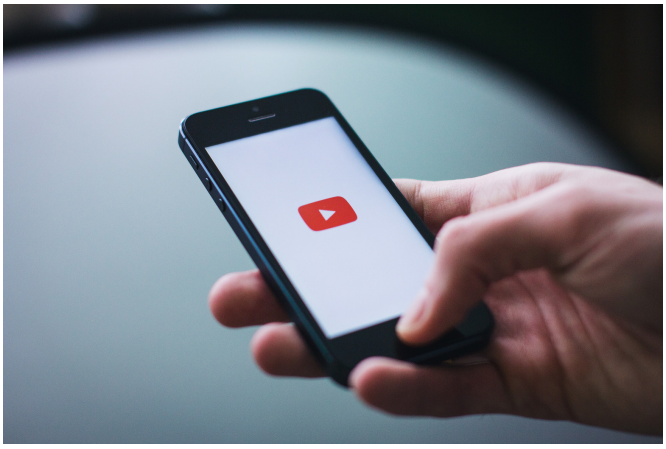
Elon Musk wants to take the concept of space tourism a step further... well many steps further. **He wants to take tourists on a ride around the Moon.** And Japanese billionaire and online fashion tycoon Yusaku Maezawa is his first customer. Although the price for the trip is undisclosed, some speculate that the trip is **likely to cost upwards of $175 million per seat** (42).

The mission is planned for 2023, and Mr. Maezawa is likely to become the first human on a lunar journey since 1972. The only impediment, it is reliant on a rocket that hasn't been built yet. SpaceX's CEO, Elon Musk autions, "It's not 100% certain we can bring this to flight." (43)

Ride around the Moon in $175 million

NEW YORK TO SHANGHAI... IN LESS THAN AN HOUR

SpaceX also wants to use this "to-be-built" rocket for point-to-point Earth travel in direct competition with traditional airlines. SpaceX's vision is to use a boat to take passengers out to a floating launch site. The rocket's ability to leave the Earth's atmosphere would allow it to travel at speeds much faster than traditional airlines, drastically reducing the time it would take reach anywhere across the globe.
In fact, SpaceX believes that a flight from **New York to Shanghai would take less than an hour** vs. a 15-hour flight currently, and **would cost somewhere between an economy and business class air ticket** (44).
But are such prices really possible? Well, SpaceX's logic is simple. **In the time that it takes for a long-haul aircraft to complete 1 flight, the rocket will be able to complete a dozen flights making it economically affordable for a large section of the population.**



[Click on the image to listen to Gwynne Shotwell's TED Interview on SpaceX's Plan to Fly You Across the Globe in 30 minutes]

TO THE EDGE OF SPACE

With SpaceX's moon trip costing astronomical sums, owner of Virgin Galactic, Sir Richard Branson is working on something more affordable. **For a price tag of about $250,000** (45), Virgin Galactic's space plane, VSS Unity, will carry two pilots and six passengers into space to experience a few minutes of weightlessness.
According to the company, around 800 passengers have already signed up for the experience (46).

Not all are convinced about the utility of this technology though, with Australian Astronaut, Dr. Andy Thomas describing it as "*just a high altitude aeroplane flight and a dangerous one at that.*" (47)
Rather than human spaceflight, Dr.
Thomas believes that Virgin Galactic's technology will have more utility as a spin-off, developing the "*capability to launch satellites, small satellites from under the wing of an aircraft on a small booster.*"

In any case, regular human spaceflight for space tourism purposes is likely to become a reality soon.

800 passengers have already signed up for the experience.

COMMERCIAL SPACE STATIONS, OR SHALL WE SAY, SPACE HOTELS

When humans start flying to space for leisure, a natural extension would be to stay there for a few days just like a holiday, albeit an expensive one! **Private companies, Bigelow Aerospace and Axiom Space are hoping to solve exactly that need.**

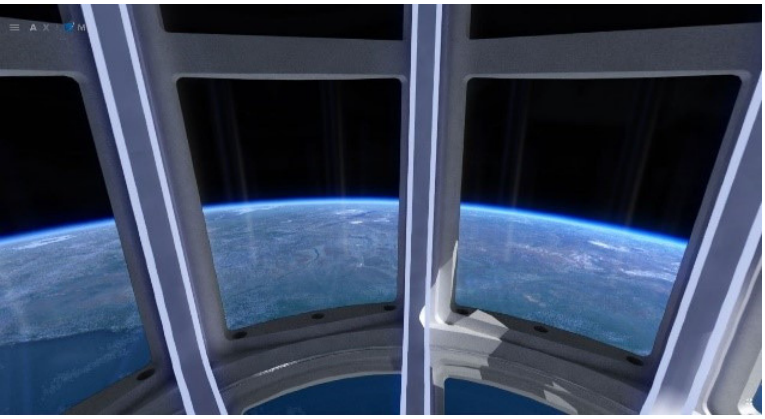
Bigelow Aerospace was founded by a US real estate mogul and specialises in inflatable space habitats, patents for which were licensed from NASA (48). Since then, Bigelow has expanded on the technology and in 2016, docked the Bigelow Expandable Activity Module (BEAM) on the ISS, where it is currently being used as a storage area.

Axiom Space Station will house the largest space-window observatory ever. Will cost $55M for a 10-day stay

By 2021, Bigelow plans to develop and launch two, fully autonomous commercial space stations, called the B330, which will link together to be called the Alpha Station. At 330 cubic metres, the **B330 has 210% more habitable space than the ISS destiny module with only 33% more mass.** They will house amenities such as a toilet, semi-private quarters, exercise equipment, food storage and prep area and a personal hygiene station (49). Initially, Bigelow plans to sell stays to governments who need space time to conduct experiments in orbital laboratories and **a 2-month lease is expected to cost somewhere around $25M excluding launch costs** (50).

Axiom Space also plans to launch a commercial space station which will replace the ISS once it is retired in 2025. Although Axiom Space does not have an expandable module, it makes up for it in design, having been designed by the well-known French designer, Philippe Starck (51). The Axiom Space Station will house the largest window observatory ever constructed for space and a 10-day stay will cost around $55M including launch costs and training (52).

Artistic renderings of views from the observatory window of an Axiom Space Station. Image credit: Axiom Space



mining amongst the stars

THE ACTUAL FINANCIAL AND TECHNOLOGICAL BARRIERS MAY BE FEWER THAN YOU THOUGHT

If we look back in time, we'll see that our desire for more and more resources fuelled our need to explore land and the oceans. Today, inspired by the founding manifesto for asteroid mining by John, S. Lewis' Mining in the Sky (1997) (53), ambitious entrepreneurs have plans to head into space in search of the precious resources that can be found on the moon and thousands of asteroids orbiting relatively close to our planet.

Depending on their type, asteroids can contain anything from carbon to water to precious metals (54). **Some data suggests that a small percentage of asteroids contain relatively high concentration of precious metals such as platinum and gold** (55). And according to a report by Goldman Sachs, the **value of a single platinum-bearing asteroid could be between $25 billion to $50 billion** (56).

The Goldman Sachs report also suggests that asteroid mining is more realistic than many would believe, with costs "*comparable to traditional mines*" and that "*while the psychological barrier to mining asteroids is high, the actual financial and technological barriers are far lower.*"

WHO ARE THE PLAYERS?

A number of companies are currently working to make asteroid mining a reality. Seattle-based **Planetary Resources is one of the largest** and oldest of the lot with **initial investors including the likes of Google co-founder Larry Page and chairman Eric Schmidt.**
Planetary Resources announced its asteroid mining plans in 2012 with the vision of **extracting water ice from near Earth asteroids and selling it as propellant.** And in January 2018, it conducted a test of its Arkyd-6, a CubeSat with the company stating that the test "satisfied all of its mission requirements" (57).

Another player, **Deep Space Industries (DSI) aims to introduce a swarm of small, low-cost spacecrafts** that would go out to many near-Earth asteroids at once and harvest small amounts of raw material. These will then be aggregated at a central depot between the Earth and moon.
Other smaller companies like **Aten Engineering, TransAstra Corporation, Asteroid Mining Corporation, etc.** are also hoping to land the big time.

A LONG ROAD AHEAD

Before we get too excited about the prospects of asteroid mining, two recent developments highlight that the road to mining riches is going to be a long and winding one. After going through some **financial difficulties and running into funding problems, Planetary Resources was acquired by ConenSys Inc., a blockchain company** (58).
More recently, **DSI has shifted its focus from mining towards small satellites,** including the production of a propulsion system called Comet that uses water as propellant and has been acquired by Bradford Space, a U.S.-owned company with facilities in the Netherlands and Sweden (59).

There remain a number of important questions regarding the viability of asteroid mining as well. For instance, the composition of asteroids is highly uncertain since **none have been sampled directly** – estimates are based primarily on observation and analyses of meteorites – fragments of asteroids which have fallen to Earth (60).

According to a Harvard professor, it is possible that out of the thousands of near-Earth asteroids, **only a handful of may be economically worthwhile** and practically feasible to mine (61).

Further, there are **legal challenges to overcome.** For instance, space exploration is currently governed by the United Nation's Outer Space Treaty which expressly forbids the "national appropriation by claims of sovereignty, by means of use or occupation or by any other means" of outer space and celestial bodies. This is frequently interpreted to mean that the Treaty denies private property claims in space, although some have argued that mining by non-national entities is permitted (62).
Accordingly, spacefaring nations would need to develop a clear legislative framework in order to provide certainty and incentivise private enterprise to mine asteroids.

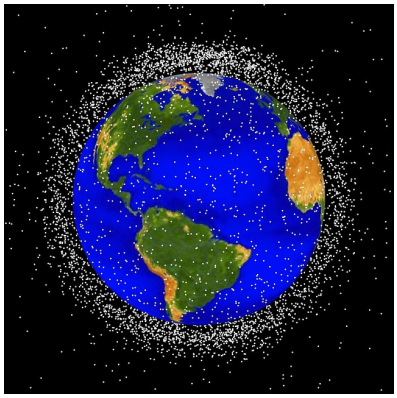
the challenges

SPACE DEBRIS

We hope the preceding paragraphs have made you to think a lot about how satellites and rocket technology has come a long way and is influencing our lives in a multitude of ways. But what happens to a satellite after its useful life is over and how exactly do space agencies 'deal' with 'dead' satellites? They end up becoming what is known as 'space debris' or 'space junk'.

As of 2017, NASA estimates that there were more than 500,000 pieces of space junk that were being tracked as they orbit the Earth (63).
But why is space debris such a big problem? Well, **a 2-inch object in space travelling at 7 kilometres per second has the impact energy of 1.8 kgs of TNT** (64). So, something as small as a penny or fleck of paint, can cause damage to critical systems. Not only do these cause extensive damage, but can also lead to a cascading collision of objects which keeps generating more and more debris. For instance, in 2009, a US commercial Iridium satellite smashed into an inactive Russian communications satellite creating thousands of new pieces of space shrapnel that now threaten other satellites in low Earth orbit (65).

SPACE EXPLORATION HAS ALWAYS BEEN RIDDLED WITH CHALLENGES WHICH HAVE TESTED THE LIMITS OF HUMAN INGENUITY. IT IS NO SURPRISE THEN THAT INCREASED ACTIVITY AND PARTICIPATION OF PRIVATE ENTERPRISE HAS CREATED FRESH CHALLENGES FOR THE SECTOR.



The scene from the movie, Gravity, where a rouge piece of satellite caused catastrophic damage to the space station Sandra Bullock was working on is not out of the realm of possibility.
Over time, these pieces of debris can lead to a situation called the Kessler Syndrome (66), making the Earth's lower orbit impassable with millions of pieces of debris flying around! Therefore, proper management of space debris is critical if we want to avoid being locked out of space (67).
Recognising the threat, space agencies around the world are trying to cooperate with each other to formulate a binding regulatory framework to deal with this issue.

WEAPONISATION OF SPACE

Today, we rely on satellites for many essential functions – whether it is ATM transactions, navigation systems, telephone communication or even power grids (68). **Therefore, if one nation destroys another's critical satellites from earth, it can almost send its target back into the nineteenth century!**

And of course, in such cases, destruction will not just be limited to civilian uses. Armed forces also rely on satellites for intelligence gathering, enemy monitoring as well as in operations of high-precision weaponry. By destroying a military satellite, an enemy nation can almost cripple its target.

In January 2007, when China shot down one of its own satellites, the whole world sat up and noticed. Russia and US have had such a capability for more than two decades and with China testing its own missile systems, many started predicting the worst – a space arms race.

The possibility of such an arms race cannot be ruled out especially, considering that there is no comprehensive space-weapons treaty. One simply cannot downplay the challenge weaponisation will be to world peace and the future of mankind. There is also the concern of creation of more debris with each such test or use of missiles in space. For instance, when China tested its anti-satellite missile, its satellite shattered into 800 fragments that were 4 inches wide or larger, and millions of smaller pieces. This huge debris cloud could take a quarter century or more to clear out (69).

THE FUTURE IS OURS TO MOULD

We have always been fascinated by the unknown and continuously strive to push the boundaries of our knowledge. This is one of the reasons why space had captured our imagination and has been a topic of discussion throughout history – from religion to science to art and literature.

However, it is during the space race of the 1960s that the sector caught public fancy. It was marked by intense competition between the Soviet Union and the United States for spaceflight supremacy.

Today of course, the contentious space race is a distant memory. Rather, a new race is taking shape – a race between private businesses led by billionaire entrepreneurs, who have a passion to create a bolder future.

First steps have already been taken - rockets are already being partially reused and cube-satellites have opened up many possibilities including, mining of asteroids. We are at a juncture where science fiction is becoming a reality and this new reality is set to radically change our lives here on Earth.

Of course, the road is rocky. As we discussed in the previous section, there are many challenges that have to be dealt with, be it regulatory, space debris or weaponization of space.

The way we see it, today's space industry is similar to the early days of air travel. The way air travel led to economic, geo-political and social change can serve as a guide for what the space industry might do in the coming decades.

For instance, in the early years of commercial air travel, only the wealthy could afford to fly. However, technological advances and reducing costs enabled widespread usage. Today, aeroplanes are the preferred means of travel for even the masses and are considered 'busses of the sky'. They have disrupted business models of both passenger rail as well as ocean liners and are gaining ground in the freight market, too. **When it comes to travel, it seems that speed conquers distance.** The result is the intricately interconnected world we live in today.

As commercialisation of the space industry picks up speed, it will not only attract new entrepreneurs, but also capitalists willing to back them in realising their vision.

In the end, we can say, that while the finish line of the space race might not be clear, what is clear is that new-age entrepreneurs will continue to push it back.
As an investment theme, space is arguably going to be the most important one in the years to come.

companies in space exploration

SOME OTHER PRIVATE COMPANIES THAT DESERVE TO BE MENTIONED

SPIRE offers data & analytics that deliver insights in remote regions of the world.

ACCION SYSTEMS is pioneering scalable electric propulsion technology to create a new ion engine which will be lighter, more efficient and more powerful than conventional propulsion systems.

ENVIEW is involved in 3D geospatial analytics transforming datasets into insights to protect people and infrastructure.

KEPLER COMMUNICATIONS develops next-generation satellite communication technologies and provides global satellite data backhaul services for wideband and Internet of Things applications. Their long-term goal is to build a network of satellites to provide in-space connectivity.

SKYWATCH provides a digital infrastructure for the distribution of Earth observation data.

URSA SPACE SYSTEMS deliver geospatial intelligence products that using space-based data from radar satellites which work through the and at night.

appendix a

BENEFITS OF SPACE EXPLORATION

The Space Program's research and advancements extend well beyond spaceflight. It's by pushing the boundaries of space research that we've made thousands of unforeseen advances in technology on Earth that we use each and every day. Infact, most people don't even realize how much they rely on space and satellite technology. These include things like GPS systems, weather tracking, many noninvasive medical procedures, electronics and computer miniaturization, and clean-room systems, along with numerous materials and lubricants. And, of course, much of our communication and entertainment passes through satellites.

In fact, every year since the mid-1970s, NASA has published a list of space technologies that have been integrated into everyday items. The tangible benefits span from life-saving medical devices to protective eyewear. To date, NASA has documented nearly 1,800 "spinoff" technologies. Here's a short list :

- Artificial limbs
- Baby formula & Freeze-dried food
- Cell-phone cameras
- Firefighter gear
- MRI and CAT scans
- Memory foam
- Water filters
- UV-blocking sunglasses

Intangible benefits

Apart from above, there are many benefits, to which it will be difficult to assign a value. For example, what is the value of better understanding the universe? Think of finding methane on Mars, or discovering an exoplanet, or constructing the International Space Station to do long-term exploration studies. Each has a cost associated with it, but with each also comes a smidgeon of knowledge we can add to the encyclopedia of the human race . There are also benefits that maybe we cannot anticipate ahead of time. The Search for Extra-terrestrial Intelligence (SETI) is a network that advocates looking for life around the universe, likely because communicating with beings outside of Earth could bring us some benefit. And perhaps there is another space-related discovery just around the corner that will change our lives drastically.

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