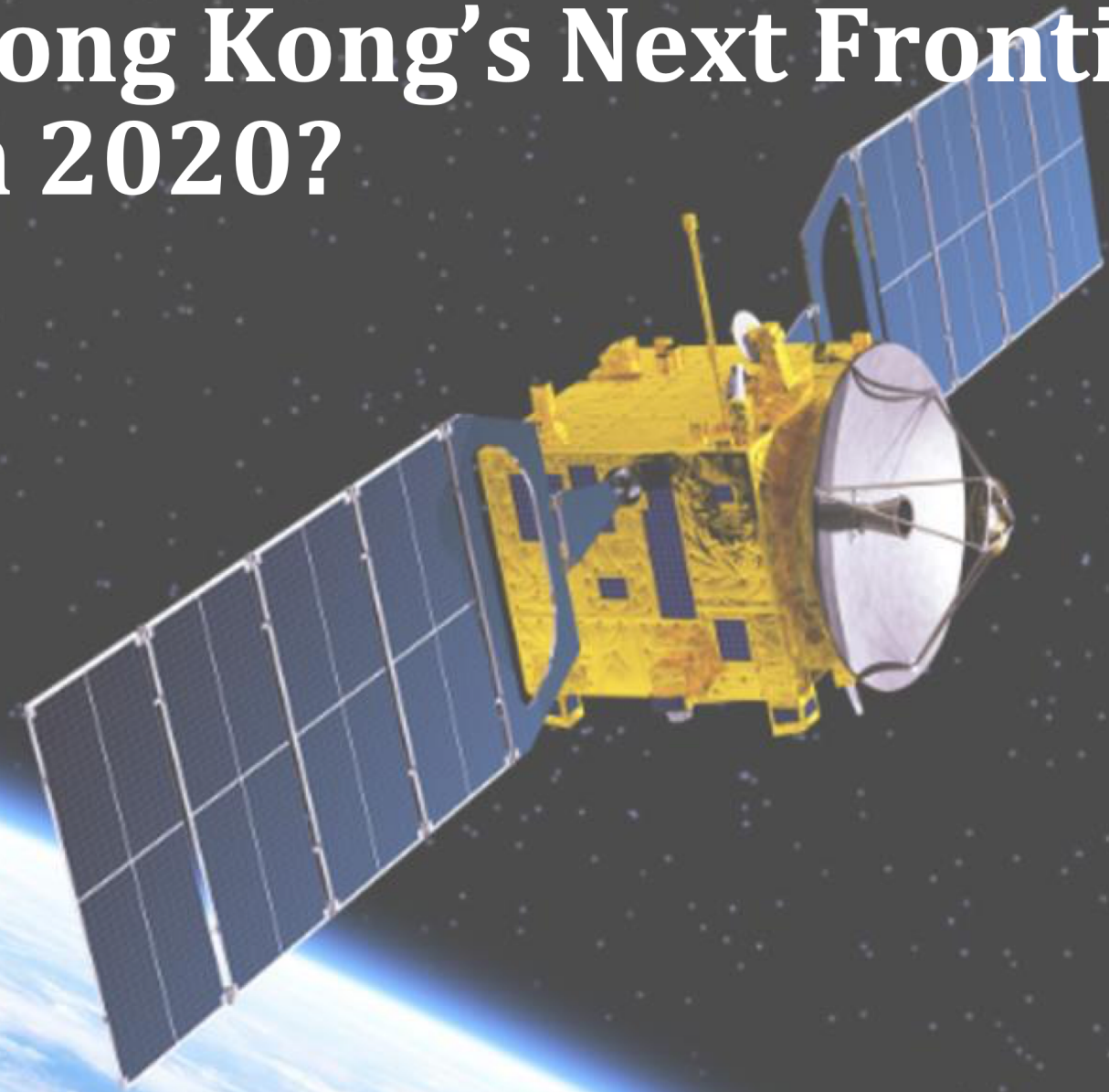


Investing in Outer Space – Hong Kong's Next Frontier in 2020?



September 2019

Benjamin Ho and Dr. Stephen Cheung
SinoAlpha Ventures



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I. Executive Summary

This whitepaper has been written for investors and associates of SinoAlpha Ventures, new to the discussion of investing in outer space. Space provides unprecedented new business opportunities for Hong Kong and is one sector that has been neglected, forgotten, and misunderstood. The paradigm of exploration is changing. Smaller, smarter, and more efficient systems are being developed that could do as well as large, expensive, and heavy systems in the past. Science fiction has become a reality, fuelled by advances in computing, materials, and nanotechnology. **Why not Hong Kong?**

In this paper we have found that there is a solid business case for introducing this new sector in Hong Kong starting 2020. New job creations, new research (such as in food safety, communication, and light materials), new education program for youngsters (such as in CubeSats), and new supply chains are the opportunities. This is investment for Hong Kong because it gives our youth, hope; while for our start-ups, many new scalar opportunities. In fact, if Hong Kong can get a CubeSat off the ground by the end of 2020, we will be able to demonstrate to the world that Hong Kong still has the can-do spirit in abundance.

The paper has been compiled from a select pool of interviewees, open papers, and secondary research. Along the way, more questions have been raised than answered, we believe. This paper is only the beginning of a new journey and should readers like this paper, we may explore deeper and broader subjects, exploring answers to this question: what can a tiny city like Hong Kong possess and contribute to the global Space value chain that has become the new game? How can investors participate? Likewise,

- *Where are the investment opportunities? Risks?*
- *How can this Space Industry be further developed here? What indeed is the role of Hong Kong, Greater Bay, China, the US, and other countries? How can Hong Kong play a part in this industry? Where and how should we begin in Hong Kong?*
- *Where is Hong Kong's equivalent of NASA? What is required is a new government department to spearhead such initiatives across multiple stakeholders?*
- *How by investing in NewSpace can we build on Hong Kong's unique strengths?*
- *Can Hong Kong build small satellites, e.g., CubeSats and an educational program on how to design, build, fly, and reuse CubeSats?*
- *How has Hong Kong fallen so far behind, when places like Nepal has CubeSats put together by high school students?*
- *What are the possible next steps in 2020?*

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This paper would not have been possible, without the insights shared with us. We want to thank especially researchers at SinoAlpha, including Alvin Chan and Miki Wong, and interviewees for guiding us on this short journey that started this summer:

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- Mr. Scott Wong, Space Enthusiast in Greater Bay
- Mr. Peter Yan, CEO of Cyberport
- Ir. Peter Yeung, Head of ICT, Smart City, and Green Tech, HKSTP

Anyone in this field who would like to share their views with us, please write to Ben Ho, benho@gliandco.com to arrange a special interview. Failing that, please write to Corina at rc@gliandco.com. The analyses and projections, rightly or wrongly, belong with SinoAlpha Ventures. **This is a document for internal circulation among its investors only, not for general dissemination.** Please seek permission before doing so.

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About SinoAlpha Ventures and G. Li & Company Limited

SinoAlpha Ventures is a wholly-owned and private investment vehicle of G. Li & Company Limited. G. Li & Company is a premier management consultancy firm with specialties in governance, innovation, and transformation.

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II. Introduction

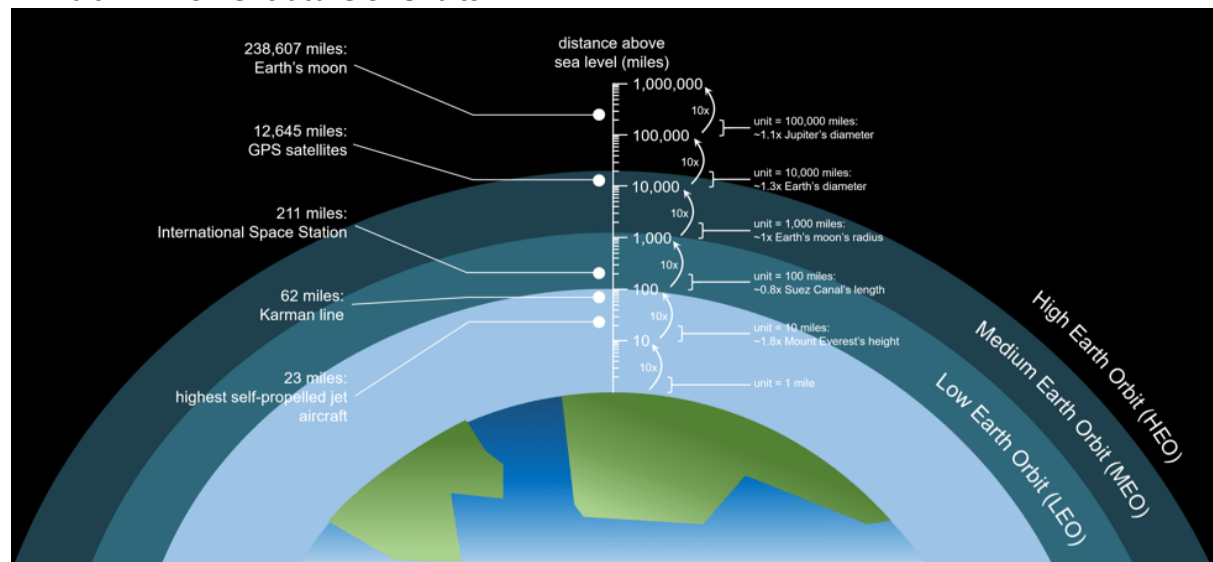
What is outer space or Space?

When we are walking on the streets or flying on a plane, we are moving through Space. Space embraces and surrounds us. It is the void we don't notice. So, what is Space then? Is it a physical entity? One can also assume that the mountains surrounding us, the fish in the vast oceans, the distant stars, and even us human beings all exist in some form of Space. While this fascinating debate has lasted for centuries through various mathematicians, physicists, and even religious experts, we are once again, attempting to open up this dialogue, but for Hong Kong. The Space we are talking about for this paper is outer space.

Outer space (or Space from now on) is that place where hardly anyone would go. Space requires the phenomenal combination of science, mathematics, and communications to comprehend.

For our discussion here, Space is over the Karman Line beyond 100km above sea level. The line has technical and jurisdictional significance. It is the nominal altitude dividing aeronautics from astronautics. For this paper, the Karman line is where the Low Earth Orbit (LEO) begins and goes up to 2,000km. The LEOs offer the most opportunities to startups, universities, and developing countries. (Note: Theodore von Karman was an expert in aerodynamics and was the collaborator and mentor of Qian Xue-Sen (錢學森), father of Chinese rocketry.)

Exhibit 2.1: Nomenclature of Orbits



Source: Harvard University

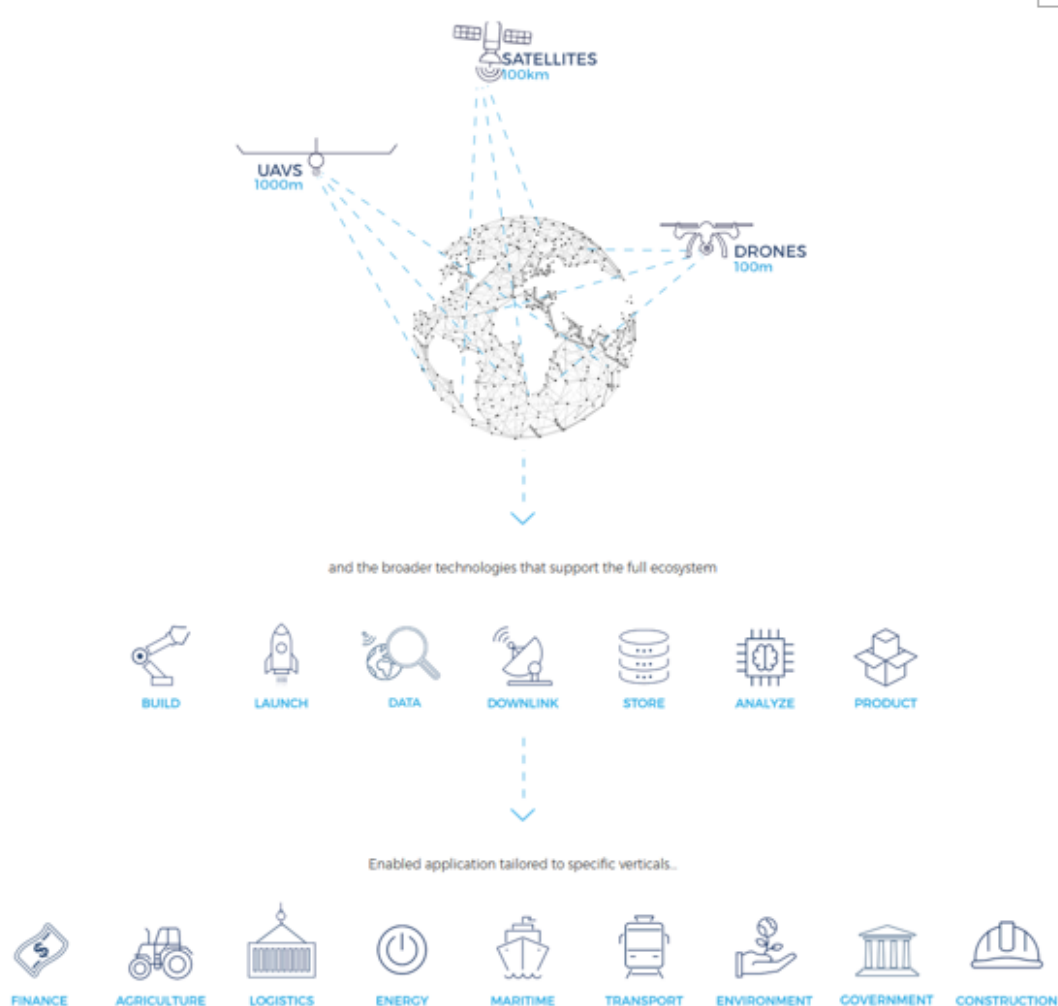
III. Context

The Space economy

The Space economy can be divided into upstream and downstream business activities. Upstream activities would be the business of making and launching spacecraft (including satellites), which for all practical purposes, would be outside the capability currently in Hong Kong. Downstream activities are revenue-generating businesses that are attributable to the business in Space, which inevitably this paper would be principally about. Downstream examples include navigation (GPS and BeiDou), satellite TV, voice, and data communications. Less obvious activities include meteorology and geology, and even insurance (yes, there is a whole sector dedicated to this specialty).

An enlightening view is in Exhibit 3.1 published by a British venture capital firm Seraphim Capital that is actively investing in NewSpace. Drones and UAVs have taken up different altitudes creating different values for new and existing industries. NewSpace has brought innovations to the field of satellites and space ventures. A new category of satellites has created new values for Earthly applications (see below).

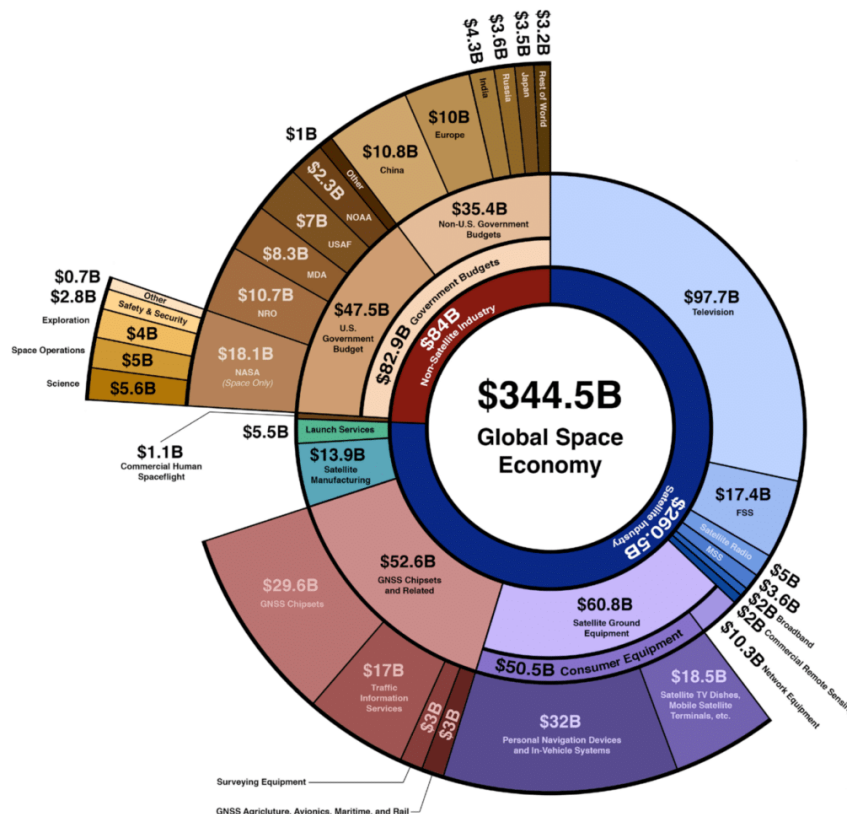
Exhibit 3.1 NewSpace and Impact to Innovation



Source: Seraphim Capital

One estimate puts the global Space economy in 2018 at USD 344.5 billion, according to Bryce Space and Technology in the US. As vast as this may be, this is, however, the traditional view in a world where small and medium-sized businesses are not allowed to thread. **In Hong Kong, we were unable to piece together the potential contribution to the economy given an absence of meaningful data, at the time of the writing of this report.**

Exhibit 3.2: The global Space economy encompasses a vast number of industries



Source: Bryce Space and Technology, 2018

New Space (NewSpace)

New Space (NewSpace from now on) represents a new, growing industry that was only made possible by the convergence of governments deregulating what used to be tightly controlled access. Significant technological advancements in multiple industries including ICT, robotics, AI, navigation, new materials, and many new technologies have encouraged innovative designs and have improved the fabrication manufacture of rockets and spacecraft.

In other words, NewSpace is the democratization, decentralization, and liberation of Space projects by allowing startups and private corporations to gain access to Space. Small and medium-sized enterprises (SMEs) can now play in this Space, and this is supplying beyond

just the US or China markets. Democratization means broad access by parties that previously lacked resources and capabilities to reach outer Space.

NewSpace is currently projected to be a global multi-trillion-dollar business by the 2040s, which is just two decades away. More interestingly, we noticed that it has already passed its infancy stage. Firms in countries large and small outside Hong Kong, developed and developing, have plans to participate. A quick search on the internet has identified a broad range of activities, currently dominated with mostly from the US, however. But China's entry has been rapid.

Exhibit 3.3: NewSpace – who are the major players in the US and China

Players	Activities
Armadillo Aerospace (USA)	Space tourism, commercial spaceflight
Bigelow Aerospace (USA)	Space tourism, Space stations manufacturing
Blue Origin (USA)	Aerospace manufacturer, commercial spaceflight
Deep Space Industries (USA)	Commercial spaceflight, deep Space exploration
Landspace (China)	Launch and ground services
Masten Space Systems (USA)	Rockets manufacturing, robotic spaceflights
One Space (China)	Launch and ground services
OneWeb (UK)	Internet satellite, global communications
Orbital Sciences (USA)	Small/medium Space rocket systems
Planetary Resources (USA)	Asteroid mining, Space resources
Sierra Nevada Corporation (USA)	Space engineering, microsatellites, transportation
Spacety (China)	Satellites and subsystems
SpaceX (USA)	Reusable rockets, commercial spaceflight
Virgin Galactic (USA)	Commercial spaceflight
XCOR Aerospace (USA)	Private spaceflight, rocket engine development

Source: SinoAlpha Ventures Analysis, 2019

IV. Investing in Space

Why invest in Space and what kind of investment opportunities are there?

Investing in Space can be no different than investing in any other industry. Now that Space commerce activity has continued to mature and expand, there are more and more companies related to Space that we can invest in. The biggest separation from investing in Space from other industries is that Space currently is not well defined for Hong Kong investors. Few are seeing the potential and recent shift in technology and applications that are favoring this new sector. Over time, however, we should see more defining boundaries made real by the industry players. For example, apparels that can be worn in Space may give rise to a new category called “Space apparel.”

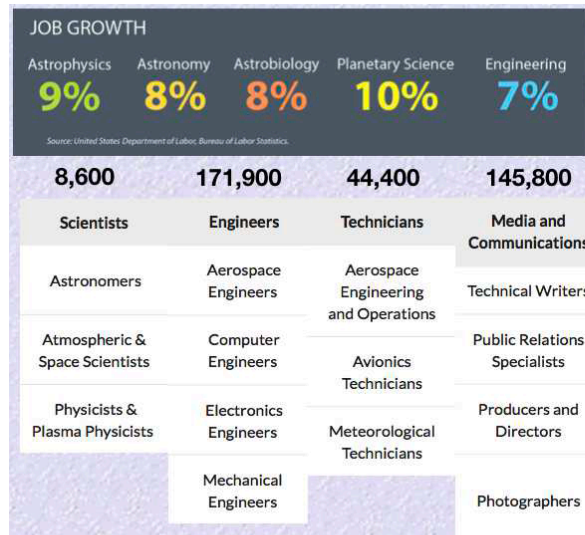
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Investments into traditional Space-related companies continued to surge, hitting a new record high last year to over USD3.2 billion with no signs of any deceleration as noted earlier. Interestingly, the total investment did not come with a single deal larger than USD1 billion. The largest deal was a USD750 million investment into billionaire Jeff Bezos’ Blue Origin. This implies a much more diversified investment environment during last year. According to Bryce Space and Technology, investments from venture capitals, which accounted for 62% of total start-up Space investments grew 22% from a year ago to USD2 billion, a strong positive sign for the industry as these are players that are looking for exponential financial return versus those entities that invest for various strategic reasons. The high growth in venture capital investments in the Space sector is indicative that many believe the business propositions of these startups. But where are these start-ups?

Also, new companies founded by billionaires have grown quite large as measured by the additional money they raised from other investors and by the number of employees. SpaceX, Blue Origin, Virgin Galactic, and Bigelow are examples. These companies are large and have demonstrated their target capabilities to secure contracts from governments (primarily the US and Europe). For instance, governments let commercial firms undertake crewed and cargo missions to the International Space Station (ISS).

In the meantime, a few governments have proclaimed ambitious plans such as the lunar missions by China, the lunar and Mars missions by the US, and similar ones by India. As an alternative to the US model, the European Space Agency (ESA) has done a good deal in building their network of suppliers and partners. The private sector has increased its shares in these missions. Therefore, what used to be internal government projects has become contracts to qualified/competent companies. As such, this trend has allowed governments to participate in space activities and grooming a domestic industry along the way.

Furthermore, Space programs do create jobs and spillover effects benefit many industries such as ICT, materials, medical devices are well known. In the US commercial Space sector alone, just over 200,000 people were employed in the commercial Space sector in 2016, according to the Bureau of Labor Statistics. These workers are employed given their top-of-the-field expertise, allowing the US to remain as the global leader in science and technology.

Exhibit 4.1: Job outlook in the US through 2024

Source: Bureau of Labor Statistics (US)

When small satellites are discussed later in this paper, we will argue that a broader and mission-led participation by startups and universities have contributed to making their current ecosystem very dynamic in those countries. Inevitably for Hong Kong, the local universities, Cyberport, HKSTP, ASTRI, the Airport Authority, and even the Hong Kong Productivity Council, we believe, have to be aligned and working together to bring this about.

Investing in Hong Kong's youth

Investing in Space is a lofty mission for any government. Distractors and realists will attack any investment in Space for Hong Kong as a gamble, and they would be correct in 1969 or even in 1997. Today that is no longer certain. Scientists in 1969 would not have predicted the many applications and commercial benefits their work in Space would bring. Students then were inspired to pursue a career in engineering and science because they saw Apollo 11 and Star Trek and believed they would be creating the next frontiers.

According to an article entitled *Shooting for the Moon* in Nature Magazine (2009)¹,

"A 2009 survey found that 50 percent of the internationally renowned scientists who published in the prestigious journal Nature during the previous three years had been inspired by Apollo to become scientists; 89 percent of the respondents also agreed that human spaceflight inspires younger generations to study science."

¹ <https://www.nature.com/news/2009/090715/full/460314a.html>

Space inspires. Space is indeed the next frontier for many youths. In Space, science comes together, and the amount of integrated science knowledge and application would push the boundaries of any teenager.

It is so out there, so long term, that the HKSAR government can only be seen to be investing in extending the career possibilities for our children, and their children.

But where is Hong Kong's current Policy on Space Commercialization? Instead of just being a connector for the GBA², can Hong Kong become the "Space" hub for GBA? More importantly, why haven't we seen more foreign companies investing in Hong Kong?

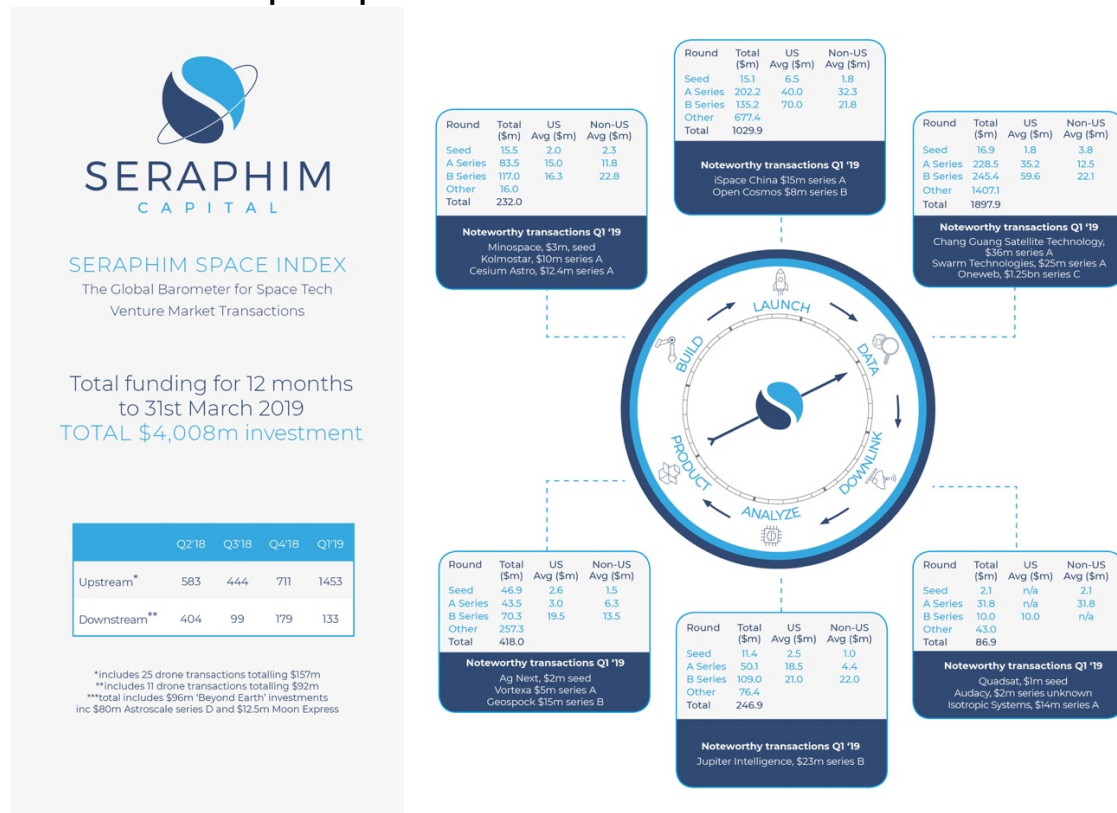
Investing in start-ups

Another notable trend is the number of non-US investors. While US start-ups continue to dominate the start-up sector in Space, taking up around 80% of all investment last year, almost half of the investor base and start-ups in the previous three years are based outside the US. 2018 was for the first time where the number of non-US investors investing in start-up Space companies nearly matched their US counterparts. While there is no projected data for 2019 and beyond, there or in Hong Kong, the trend is still clear that more investors from outside the US and the dollar amount into Space start-ups is still growing.

In the UK, the VC firm called Seraphim Capital, a well-known player investing exclusively in the Space industry suggested that the total investment in uniquely Space around the world has now been well over USD 4 billion for just one year (the period between March 2018 and March 2019.) Investments have been made in six areas – build, launch, data, downlink, analysis, and product; with a large amount going to launches and data generation and analysis.

² Greater Bay Area.

Exhibit 4.2: VC Seraphim Space Index



Source: Seraphim.

In Asia, the pace has picked up considerably. According to the VC firm Fresco based in Asia, two CubeSat firms -- Planet and Spire -- together share over two thirds of the launches for CubeSats globally. CubeSats for research without cost constraints is much easier than conventional research, and many universities have done this. The challenge for Asia, particularly Hong Kong, is the lack of a platform for Space which would undoubtedly foster innovation. Currently, with a fragmented market globally, lack of specialized capital, limited access to relevant data, and a disconnected Space community, the challenge is enormous for any firms in Hong Kong to explore this new industry.

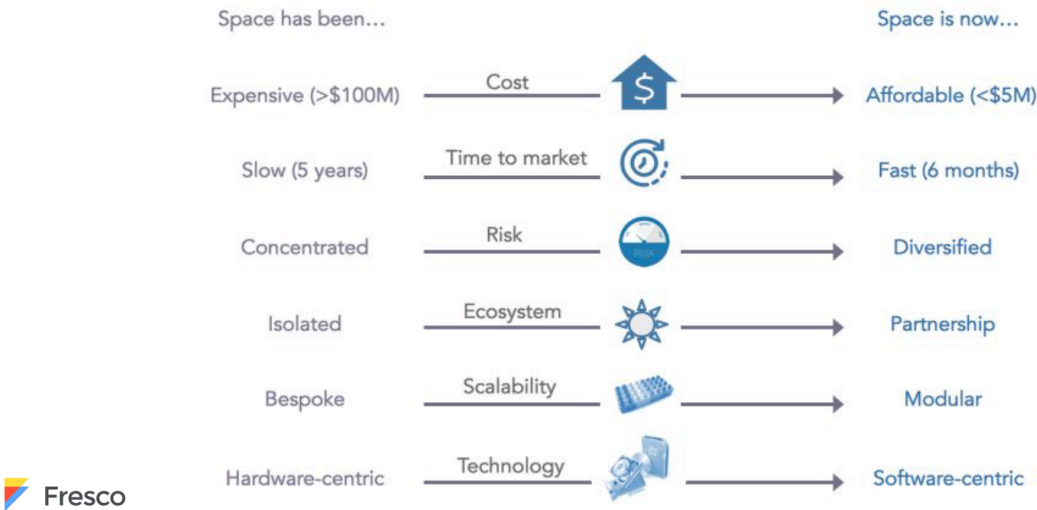
DataSat opportunities have become much richer, but many challenges remain. Dysconnectivity, lack of private sector and government investment, and the lack of a platform are some of the key challenges. Interestingly, the following diagram illustrates how Space has changed fundamentally to something that is much more affordable, doable, and viable for a small city like Hong Kong.

But can Hong Kong government truly provide the tipping point? Perhaps only if it knows how and when to leverage this new Space economy.

Exhibit 4.3 Examples of DataSat Opportunities

Space is Different Now

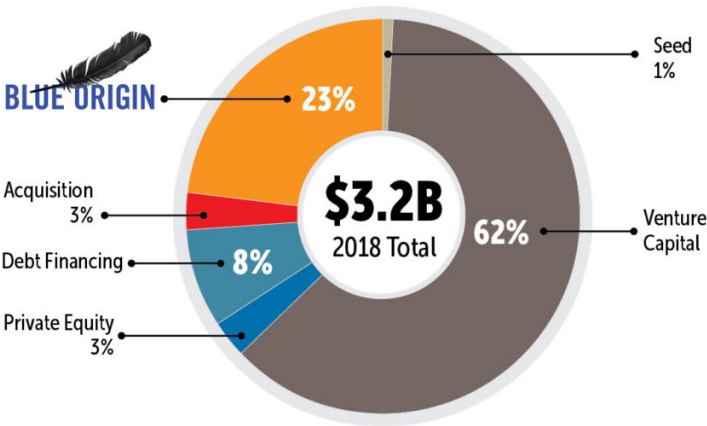
New space creates new data opportunities



Source: Fresco

Exhibit 4.4: Venture capital funds, in general, are increasing their contribution in start-up Space investments

Blue Origin comprised over 20 percent of all investment in start-up space companies in 2018.



Source: Bryce Space and Technology

- **Against**

On the surface and many distractors, they expect that space programs are expensive and risky as it is often difficult for governments to justify such large paychecks when it comes down to funding. (This is, however, no longer true.) With varying levels of success since

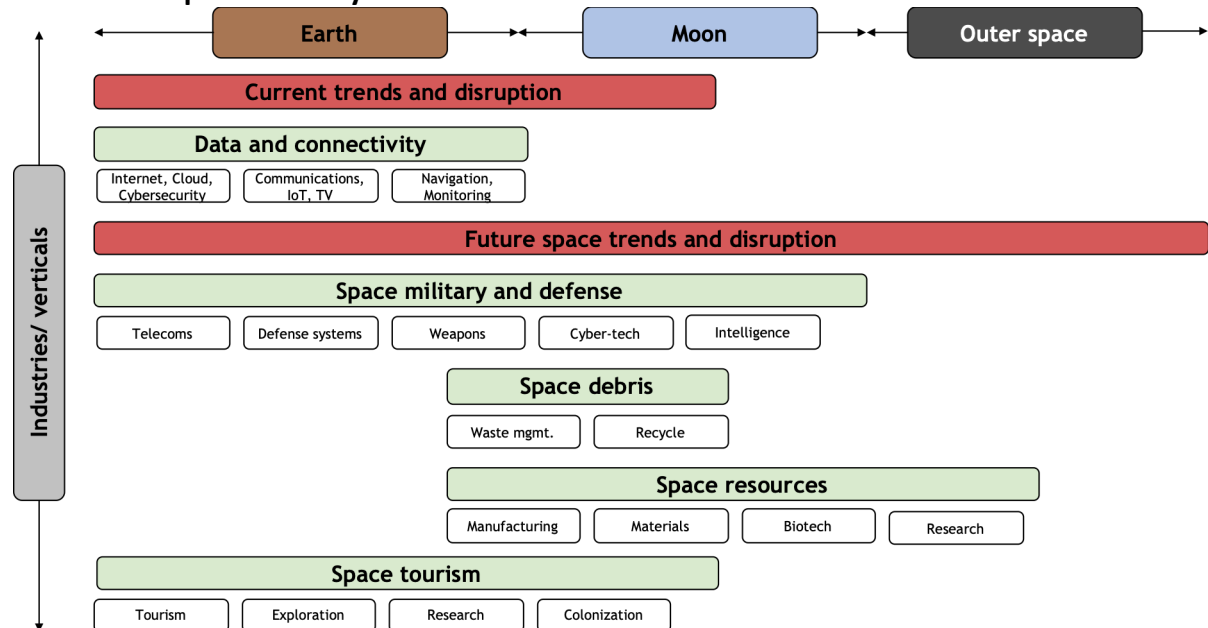
their commencement from the late 1950's it still costs a hefty range between USD4,000 and USD10,000 per kilogram to put anything up into LEO. Investment returns are difficult to calculate and justify while the risk-reward has significantly improved after years of technological breakthroughs. Hence, some believe the high barriers to entry is mainly due to governments tight control (For the HKSAR government, it was more an oversight than a purposeful neglect.) The amount of investments used in Space has always been subject to scrutiny by citizens and politicians, as funding could definitely be used instead for the current social and economic problems on the ground.

...but without making risky investments, how are humans able to understand the true value of Space investments?...

Looking ahead, Space as an investment theme will continue to impact multiple verticals beyond just aerospace and defense. The next section below breaks down the potential industries that could be disrupted or created with Space commercialization. Morgan Stanley Research currently estimates the global Space industry to generate revenues north of USD1.1 Trillion in 2040, up from the current level of USD350 Billion, with the near-term significant contribution derived from satellite and internet bandwidth demand. Broadband data via satellite could represent up to 50% of the projected USD1.1 Trillion market. As more satellites are launched, the unit cost for data will be driven down, just as demand for data skyrockets. As we enter into the 5G era, industrial use cases require substantial incremental demand for big data.

The Space value chain and the industries it affects

Exhibit 4.5: Space industry value chain



Source: SinoAlpha Ventures Analysis, 2019

What Hong Kong industries stand to benefit and why? What is the potential?

We believe a myriad of industries would benefit in both Hong Kong and mainland China. In fact, any businesses that goes to serve a distant market, providing quality and certifiable stand-alone and minimum servicing for a harsh environment like outer Space to a desert along the One Belt One Road (OBOR) can immediately see the potential in this market. Any foreign businesses outside Hong Kong that has a particular need for sourcing quality products for Space parts in Hong Kong, paid through virtual banks, delivered remotely or produced locally through 3D printing, verified their quality through Hong Kong's international certification systems with transaction conducted in English or any foreign languages that can handled by AI, and wrapped around with the appropriate type of insurance and refund, can be done through Hong Kong. Countries that have been encouraging development in their space sector should look for Hong Kong and the GBA as an alternate provider of Space supplies. The overlapping factors are too timely to ignore.

Off the top, at the minimum, the following in Hong Kong would be enhanced:

- 3-D printing³
- Apparels (high tech fabric that doesn't need washing)
- Communication (satellite)⁴
- Consumer
 - Space tourism
 - Consumer goods (apparels, tricorder, etc.)
 - Movies and entertainment (weightlessness, computer graphics, etc).
- Defense and Coast Guards
 - Monitoring and compliance related
 - Smuggling
 - Rescue and first responder
- Ecological and geographical
 - Weather forecasting
 - Early warning and disaster management
 - Land development and monitoring
 - Building surveying and Smart Building designs
- Educational
 - University research
 - New syllabuses
- Financials
 - Space Insurance
 - Venture capital for the Space Industry
 - Virtual banking

³ The business opportunity of the Space Industry is difficult to predict. One start-up, called Made in Space, leverages on 3D printing of parts in Space that can make emergency replacement parts. The logic is that over 70% of the ISS can be made out of plastic. This company has already placed a 3D printer on the ISS. *"Made In Space is the Space-based manufacturing company. We specialize in leveraging the unique properties of the Space environment to develop solutions to commercial, industrial, research and defence challenges. We see a future where life and work in Space are commonplace."*

⁴ The most obvious applications of small satellites in LEOs are in communications. The data acquisition part does not consume much power. The transmitting part consumes a lot of power, depending on data complexity. No doubt, a cell phone has plenty of computing and storage power but the chips are also power hogs. Will be worse for 5G because of the computation complexity. Eventually, power consumption can go down when 5G chips are fabricated by the latest IC fab capability.

- Logistics and e-commerce (supplying parts and replacement made in Shenzhen to overseas buyers)
- Medical testing and emergency supplying of medical equipment
- Micro-motors (or going into miniaturization)
- Navigation
- Pharmaceuticals
- Program Management⁵
- Professional sector and support services for the SMEs
- Telecommunications
 - Bandwidth
 - Data transfer and communications
 - Cloud storage
 - Cybersecurity
 - Navigation
 - Telemetry
- Remote sensing (measuring distances and geolocation)
- Rockets⁶
- Super light materials (since payload is a huge fixed costs)
- Solar Cells
- Space Food⁷
- Space Travel⁸

Using NASA and its efforts throughout the years as an example, proprietary information such as the construction to biological experiments conducted in relation to Space have led to spinoffs that have been and will continue to improve life on Earth. Space provides a strong feeder to start-ups. In Hong Kong where our start-ups are fairly narrowly focused, an investment in NewSpace potentially can open up so much more industries and help diversify our ecosystem.

⁵ This comprises a team of techno-program managers contracted by agencies to run satellite projects. The manager has to be fluent about all sorts of requirements and work with other service providers (such as launch services) on seamless delivery. Currently, CubeSats by universities have “home-grown” program managers. As small satellites serve more business missions, a third party program manager may be viable.

⁶ Up and down the ecosystem, the “sexiest” is the design and fabrication of rockets. SpaceX big rockets cost tens of millions to make and they also charge customers about 30% of that cost as fees to deliver payloads—the dollar value is still much cheaper than other competitors because of reusability. Small rockets probably cost a few million USD. Fuels are, surprisingly, not expensive.

⁷ The World Economic Forum in August 2019 reported that NASA has figured out ways to make food out of thin air. A company in Finland called Solar Foods is about to bring a new protein powder called Solein, made out of CO₂, water, and electricity. <https://www.weforum.org/agenda/2019/08/nasas-idea-for-making-food-from-thin-air-just-became-a-reality-it-could-feed-billions/>

⁸ This is actually substantial revenue-generating. There are generally two branches. **Near Space orbits:** Virgin Galactic develops a small space plane to be launched by a bigger plane high in altitude. This is called Horizontal Launching. The space plane flies for a few hours (several round the world trips) at, say 50km altitude, enough to vow its passengers without the extensive training to be astronauts. I can see Sir Richard Branson or another Richard wanting to do the same seeing China, Russia, Asia Minor. **ISS or TienGong-3:** Once companies like Blue Origin (Jeff Bezos) and Bigelow successfully build hospitable suites that are attached to or launched from the ISS, things will take off fast. Again, it depends on whether TienGong-3 will follow suit.

V. Where and How to Begin?

In the US, they began with the establishment of NASA, with self-promoters like Werner von Braun, and with challengers like the Russian Sputnik. Above all, the US had John Kennedy. But that was in 1969 and Apollo 11 which landed the first man on the moon.

Today, part of the US Congress's plans was that the innovative new technologies being created to explore Space should also be applied on Earth, benefitting the greater public and stimulating the economy on many fronts. Although technology transfer was not the forefront of NASA's Space program, it remains a significant contributor over the years as partnerships with the private sector help move its technologies into industrial production, offices, markets, and consumer goods. The benefits from these NASA-private partnerships have trickled throughout the global economy, forming new industries, creating new jobs, and improving the overall quality of life to people.

Although just barely touching the tip of the iceberg, the employment of Space has already created new markets and given life to many SMEs. This sector has helped save lives through early natural disaster warnings and weather forecasting, expedited search and rescue operations, improved the efficiency and sustainability of agricultural and natural resource management, advanced medical science, accelerated the global proliferation of financial operations through better broadband and other communications technologies.

Recently a Chinese newspaper issued in mid-August 2019 cited how the private sector in China has quickly jumped onto the Space Industry by participating in the making and launching of rockets. More than 100 new SMEs had been established to take advantage of the new industry, compared with just zero a few years back. A private firm in Beijing with slightly over a three-year history had successfully launched a rocket (SQX-IYI) and put two satellites into orbit on 25th July.

So, why not Hong Kong? Can Hong Kong's SMEs play a role?

SMEs participation in the Space Industry

Since this will become a new sector for Hong Kong, to entice SMEs to play, the HKSAR government would probably need to drive this with a "PUSH" strategy, that is, similar to what the US government has done.

The government would identify the mission-critical areas that are needed for this smart city. But PUSH requires the funding side to have more than just screening capability of funding applications. The funding side should prepare a roadmap type of guidance to push for better efficiency and effectiveness systematically. This can be developed by a committee (with no conflict of interest) with front line knowledge of the field. Instead of, or in addition to, a committee, the government should have technocrats who know the field. The technocrats could be developed within the civil servants ranks in the departments they are employed in. They would form the innovation team that includes funding an Small Business Innovation Research (SBIR) type program from each department. These programs brings local suppliers closer to the government, which is either the first user or can refer to the resulting innovation to commercial users. Education and environment are cases in point.

For HKSAR, that would be the types of materials and supplies needed by the Central Chinese government in the launching to the placement of satellites into orbit.⁹ The HKSAR would identify and would purchase items thus created or sourced by the local firms. Conversely, the HKSAR government, probably under guidance from ASTRI, Cyberport, or the Hong Kong Science and Technology Park (HKSTP), could ask SMEs to solve Hong Kong's pressing problems using the context of Space. These problems could be about ways in contributing to our solving of our aging population, food scarcity and waste treatment, smart city, smart buildings, and any subject that needs experimentation, validation, and distant delivery. Once the SMEs can deliver the goods per specifications, the HKSAR would be their first customer.

SBIR, known as America's Seed Fund and is one of the largest sources of early-stage capital for technology commercialization in the US, encourages such mission-guided research for American SMEs. For example, SBIR has invested over USD1 billion in health and life sciences companies that are creating innovative technologies that would align with the National Institute of Health's mission to save lives and improve health. A key objective has been to translate promising technologies to the private sector and extend innovation to reach consumer markets.¹⁰ The products thus developed would be brought by the sponsored government entities. The government as a customer can pre-select, say three to five proposals and see which of the proposals could deliver. It is a paradigm shift from the current way of HKSAR government subsidy to SMEs and it forces different agencies and government departments to have a dedicated group to look at what they need and follow industry trends. This form of business model has been applied in the UK, EU, and in mainland China. But unfortunately, not yet in Hong Kong.

In Singapore, things are even more creative in enriching the ecosystem. The government there has set up new Centres of Innovation (COIs) for aquaculture and energy sectors. Each COI was set up in partnership with polytechnics and research institutes. Each COI provide support for companies looking to deploy specific technologies, supplying anything from laboratory facilities to consultancy and training courses. New Professional Conversion Programs are also being offered for professionals looking to make a career move into blockchain, embedded software, and pre-fabrication.

International collaboration and the role of Hong Kong

Current research onboard the International Space Station (ISS) continues to break significant ground as NASA and its partners are actively conducting new tests and experiments on this orbiting research laboratory. We understand China was not a invited member to the ISS. Some research outcomes can be expected, such as a better understanding of the long-term effects for the human body living in Space, and the physiological benefits and information that can be transferred back to Earth. Inevitably, any activity involving outer Space requires

⁹ We understand the HKSAR Government has been generally following a PULL strategy in funding SMEs innovation efforts. That is, it is up to the SMEs to come up with the idea then petition the Government for subsidy, along a range of available and dedicated funds. The government does not guide the SMEs or promote a particular product, but approves the funding based on administrative competence of the SMEs.

¹⁰ See <https://sbir.nih.gov/>

international collaboration. Because China was not invited to play in the first ISS, she has made a promise that China's version of the ISS would involve as many other countries as possible. Inevitably, this sounds like an opportunity for Hong Kong to assist in rounding up the various international players.

How can Hong Kong not build on our strengths, which is engendering international cooperation?

The continued advancement of remote medical procedures that allow Space astronauts to stay healthy can also as well provide needed medical support and expertise to people in remote regions around the world. Furthermore, the knowledge and development of sustainable living, such as water recycling and energy conservation, needed in the orbiting laboratories of the ISS can be transferred on Earth as we learn to treat our planet to be more sustainable. There are also many other lesser-known outcomes and indirect fields of studies by exploring outer space.

Above all of these benefits, one of the most profound effects is the strong spirit of international collaboration. Being the largest and more technically advanced spacecraft ever built, ISS is a global partnership between many nations. In addition to station assembly, the international partner agencies (NASA, the Canadian Space Agency, the European Space Agency, the Japan Aerospace Exploration Agency, and the Russian Federal Space Agency) train and launch crews provide ground support for the orbiting research facility. The extraordinary level of international commitment and partnership in Space is what will help propel us humans in our continued exploration of Space. Like many of the technologies created for and from the ISS, the benefits of this international partnership also come back down to Earth. Given the need for international cooperation, there is indeed a role for Hong Kong.

Singapore, in its efforts to educate the government and industry, established their version of a space agency called the Singapore Space and Technology Association (SSTA)¹¹ in 2007. But *where is the Hong Kong Space Agency? Perhaps the first action is to devise a blueprint for the establishment of this new coordinating agency in Hong Kong?*

What else can bring back the spirit of international cooperation and trade to Hong Kong then Hong Kong can be a part of Space?

¹¹ <https://www.space.org.sg/>

VI. Current Disruption in Space

Reusable rocket is one of the most important technological breakthroughs in NewSpace. It brings down the launch cost substantially. So far, only SpaceX and Blue Origin have demonstrated this capability with large rockets. Large rockets are used to launch regular satellites to different orbits as well as deliver crew and cargos to the ISS. The launch fees are where big money is.

Another disruption is the size of the satellites and the ecosystem around this. Today, even Nepal and Singapore have educational programs for their high school children on building these new smaller satellites called CubeSats. These education programs are available from the US, based on our preliminary investigation.

Can Hong Kong play a part?

Reduced launch costs also allow the launch of medium-sized satellites (several hundred kgs) to the LEOs by the hundreds and thousands as constellations. These satellite networks “hug” the Earth making global Internet services a much-coveted “goose that lays the golden eggs.” Reportedly, China and India today can launch a CubeSats at a cost of US\$ 40,000 to US\$ 80,000 depending on manpower.

The array of many small satellites has also created another set of disruption. Potentially, perhaps the launching of small satellites, or CubeSats, given our perfect equatorial position and vast surrounding water coverage, would provide the magic launchpad for Hong Kong.

The disruption in satellites

CubeSats began as a collaborative effort in 1999 between Jordi Puig-Suari, a professor at California Polytechnic State University (Cal Poly), and Bob Twiggs, a professor at Stanford University’s Space Systems Development Laboratory (SSDL). The original goal of the project was to provide affordable access to Space for the university science community, and it has successfully done so. (Perhaps the ongoing collaboration in Space between the Hong Kong Polytechnics and our own University of Hong Kong echoes this spark that took place in the US.)

It is recognized that the small, standardized platform of the CubeSat can help reduce the costs of technical developments and scientific investigations. This lowers the barriers to entry while greatly increasing the accessibility to Space, leading to an exponential growth in the popularity of CubeSats since their inception.

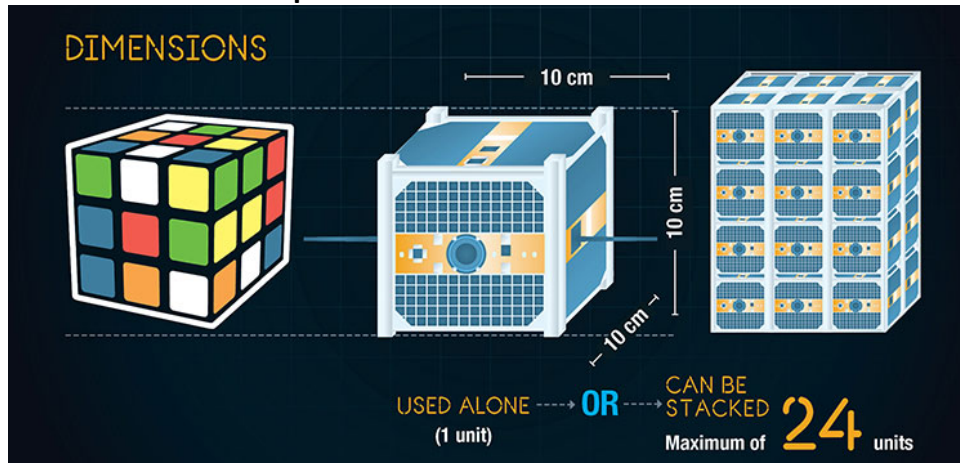
- Innovation
- Research capabilities
- Small missions
- The aim for cost reduction

Are CubeSats the answer to low-cost Space advancements?

What is a CubeSat, and can Hong Kong build it?

A CubeSat is a squared-shape miniature satellite - 10x10x10cm – slightly larger than the size of a Rubik's cube weighing at just 1kg. A CubeSat can be used alone (1 unit) or in groups of multiple units (maximum 24 units) to suit the needs of a specific mission.

Exhibit 6.1: CubeSat specifications



Source: Canadian Space Agency

CubeSats are miniature satellites that have been used exclusively in low Earth orbit (LEO) already for the last 15 years and are only becoming used for interplanetary missions. From the start, they were most commonly used for LEO applications such as remote sensing and communications. New use cases that started last year involved the deployment of CubeSats in missions to Mars, while more are being considered for the Moon and Jupiter exploration missions.

The main cubic structure is made of aluminum and serves to hold the key components along with others such as cameras, sensors and scientific payloads. Just like any satellite, CubeSats are custom built to the specific requirements of their missions but have at least three standardized things:

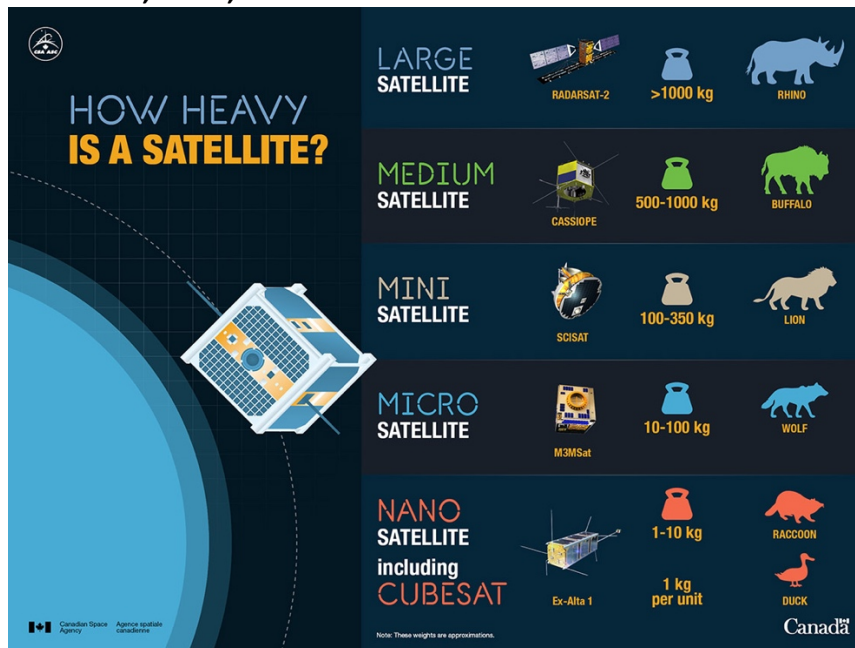
- 1) Antenna and radio communication system – which sends and receives information to and from Earth
- 2) Power source – usually battery operated with solar panel as support
- 3) Computer – to execute instructions to ensure the proper function of the satellite

To CubeSat users, a 1U satellite looks like a cube with solar panels and communication antennas deployed after launched to orbit. A flight package must fit inside this 1U or multi-units. Several single units can be loaded into a launcher (P-Pod), which is then mounted inside a large rocket as secondary passengers. The pod will launch the CubeSats when the rocket reaches designated orbits.

But CubeSat is not the only small satellites in the market. Smallsats keep getting smaller. Stanford and Cornell have just demonstrated chipsets (stamp size satellite that is an IC with printed antennas). Balloons have been used as satellites, for relaying information that doesn't need to be repeated.

The downside of CubeSats and other formats is also due to their limited form factor. They are only expected to be in orbit for several weeks and usually lose altitude due to small drags. They lack both altitude control to keep them in orbit and power to operate multiple sub-systems as large satellites do. That is why satellites to be deployed for global Internet services are medium-size (several hundred kgs). They are NOT CubeSats however.

Exhibit 6.2 Size, Mass, and Nickname



CubeSat can offer a large variety of applicable missions, here we breakdown CubeSat missions into four major categories we see as key for future investments:

- 1) **Technology demonstration** – the harsh environment of being in a natural vacuum offers the ultimate testbed. Furthermore, the environment helps test new instruments and materials in order to validate their readiness to be integrated into a more complex Space mission.

Example use case – A CubeSat was used to study the performance of a new thermal imaging camera, allowing it to carry out under the rigorous environment in Space to evaluate the overall quality of the images and the reliability of the instrument.

- 2) **Scientific experiments** – to carry out small scientific experiments for research purposes.

Example use case – The collection of information on the magnetic field and radiation to better understand and predict weather patterns such as earthquake detection.

- 3) **Educational projects** – Provide students with a unique hands-on experience in developing Space mission from design, to launch and operations.

Example use case – tracking signals of endangered wildlife through the collection of radio signals emitted from collar bands.

- 4) **Commercial** – Provide telecommunication services, earth observation and navigation.

Example use case – CubeSat equipped with cameras that capture live high-resolution images of Earth for clients in the agricultural, city-planning or business intelligence field.

CubeSats tend to hitch rides into Space using extra payload Space available on rockets being launched. They are usually packed into a container, in which they are activated and ejected into Space at certain distance milestones. Furthermore, they can be deployed from the International Space Station through a different technique.

Similar to satellites, CubeSats can now either go alone or in a constellation network. This is an innovative solution looking for commercial problems. A startup Made In Space, based in Mountain View, California take advantage of 3D printing technology to drive down the costs of CubeSats and different spare parts used in the International Space Station.

Given the popularity of CubeSats, one can quickly see the possibility of compiling parts from Shenzhen, as Shenzhen is the hardware capital of China, if not the world.

Perhaps on a lesser scale, why can't Hong Kong develop an education program similar to Junior Achievements for secondary school and university students and ask the students to source such parts?

Education Programs Using CubeSat

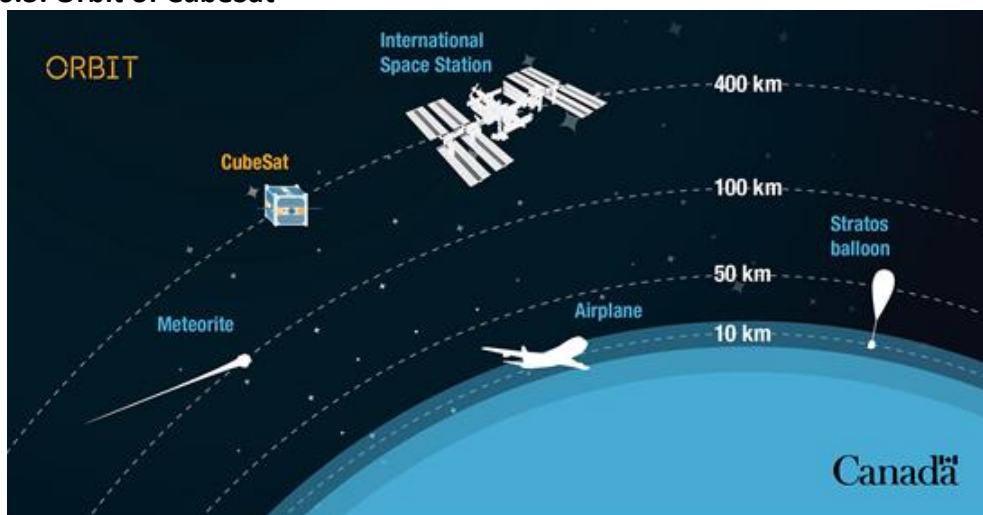
Using CubeSat as a vehicle to teach children about space engineering has been going on around the world for decades. Nepal, Singapore, and India have programs for their high school students. Apparently, this is not popular in Hong Kong, for various reasons which we have yet to identify. ***Where is Hong Kong's CubeSat program?***

We believe there is tremendous mileage in creating and establishing such programs in Hong Kong. Hong Kong government potentially can promote Space using a hands-on MakerBay-like program. To do this, the schools will form student teams to assemble then launch small

satellites. The teams and experimentations will be based in Hong Kong but not limited to just students in Hong Kong in future years¹².

The benefits of knowledge transfer from practitioners to students through similar apprentice programs are well documented in the US and Germany. Space projects are where new technologies such as artificial intelligence, Big Data, and quantum communications are deployed for sciences and services for the benefits back on Earth. Exposure to this world will open the mindset and unlimited opportunities for our students. At a higher level, the lowest measure of success is a new source of human talents aspiring to be taikonauts, scientists, and entrepreneurs from Hong Kong and the highest is putting Hong Kong back in the center of the new world, or literally, extending Hong Kong's connectivity to 400 km above the earth.

Exhibit 6.3: Orbit of CubeSat



Source: Canadian Space Agency

CubeSats can be built at a much quicker pace, often within two years but more importantly, the cost reduction is achieved from two fundamental ways – 1) lightweight, reducing fuel consumption and, 2) rocket-share with large satellites by piggybacking on their payloads to get to Space. The technological costs associated with CubeSats are also significantly lowered due to the simple and standardized parts used and are also readily available off-the-shelf. This also provides plenty of opportunities not only for Space enthusiasts but also research studies up to the university level in Hong Kong. Although CubeSats were initially developed to support low-cost access to Space for university research, but today they are being used in both commercial and research projects and many companies are manufacturing CubeSats and components. CubeSats are no longer restricted to aerospace companies. Universities and even high schools can develop them. The World is Not Enough (WINE) is a new generation of CubeSats funded through SBIR that take advantage to explore Space.

¹² Experience in the US show that early CubeSat period, over 60% approved projects were proposed and undertaken by students of all backgrounds. Now, networks of thousands of small satellites are either in the works or have already been launched for commercial applications—first and foremost of which is in global data communications.

However, the scope of CubeSat experiments has various limitations due to the reduced capacity to carry scientific instruments as they cannot carry large payloads in them. The mission duration is also shortened to an average operational period of three months to a year as their reduced cost also mean they are generally designed to last for a shorter period of time before the cessation of operations. Usually, CubeSats that stay within the LEO burn up in the atmosphere upon re-entry, leaving no trace of debris. Another major downside risk CubeSats face is that its electronics are smaller and therefore subject to radiation deterioration. Sometimes smartphones are deployed in CubeSats since it is quite powerful in terms of weight to performance ratio. ***In fact, programming on Smartphones for CubeSats potentially can become a new sub-industry that can be established in Hong Kong.***

Over the years, CubeSats have rapidly expanded beyond educational purposes and created its own niche within government entities, various industries aiming to diversify their business scope from leveraging Space technology and academia, all having the aim to expand their technological capacity. Governments elsewhere, for example, are now providing a platform for low-cost technology development and scientific research. This helps enable the acceleration of flight-qualified technology as well, generating innovative public-private partnerships (PPP) between government entities and the private sector. It also provides improved opportunities to develop the expertise and skills required for future careers in the Space sector. PPP is one of the government initiatives that is well endorsed by the HKSAR government, and here we have given PPP real ammunition for developing real business cases.

Three cases of CubeSat initiatives from Universities that are worth citing include:

- 1) **University of Michigan** – commenced initiative in 2007 and was made possible by the Student Space System Fabrication Laboratory (S3FL) together with the CubeSat initiative offered through California Polytechnic State University. The primary objective was to provide students with the knowledge of a design-build-test-fly (DBTF) environment in order to train the potential future Space industry workforce. The initiative would provide students the ability to learn the engineering design process in a real-world environment with actual applications. The ultimate goal is for existing students to complete the mission, refine it for newer projects and reverse engineer syllabus, identifying whether it could be a plausible course for future students.
- 2) **University of New Brunswick** – Partnership between the University of New Brunswick, Université de Moncton and New Brunswick Community College with plans to launch their CubeSat from the ISS in 2021. The mission objective is to provide new insights into the behavior of Earth's ionosphere, capturing data of various Space weather patterns as these events can significantly interfere with communication systems and electrical grids. Three cameras will be on-board the CubeSat studying the distribution of oxygen atoms, aurora and airglow events all for earth science and meteorological applications. Results of the experiment would be used to advance the student understanding of the technology, construction, and operation of satellites.

- 3) **University of Virginia (UVA)** – Formed a collaborative project called the Virginia Space Grant Consortium that includes UVA, Old Dominion University, Virginia Tech and Hampton University. The project designed, developed, and instrumented three CubeSats to obtain measurements of the properties of the Earth’s atmospheric density, drag and debris orbiting the Earth. The project was also sponsored by NASA, and they have delivered the CubeSats to SpaceX for launching.

Since 2015, NASA has funded and begun launching CubeSat pairs that could communicate with each other without commands from the ground. This is technology demonstration towards constellations of tens and hundreds of nano satellites orbiting around Earth in some planned manner. This is a natural path similar to drones flying in swarms.

We believe that Hong Kong can become a new breeding ground of CubeSat innovation and development by leveraging on multiple university research platforms as well as government entities such as The Hong Kong Science Park, Cyberport or even the Airport Authority. The Hong Kong Polytechnics University, City Polytechnics University, University of Hong Kong, the Chinese University of Hong Kong, and the University of Science and Technology should be in great position to leverage similar initiatives.

Perhaps what is needed is a new government department to spearhead such initiatives across multiple stakeholders?

VII. Can Hong Kong Act as Another Gateway for China?

A discussion about developing the Space industry in Hong Kong that does not include China is a pointless discussion. The dragon that breathes is China. The Space on top of Hong Kong is controlled by China. No serious discussion about Space matters in Hong Kong can be sanctioned unless it has been blessed by the HKSAR Chief Executive¹³. This level of centralized control reflects the level of openness and transparency on the matter of Space, pre-2019.

But that is the past...

One Country, Two Systems

Going forward, we believe that a stronger case can be made for the discussion to be decentralized and where the One Country Two Systems can be clearly articulated. Hong Kong has a key role to play in opening up the market of Space. The Hong Kong government, therefore, needs to petition Beijing to grant the territory certain airspace rights above Hong Kong, which technically belongs to China.

Indeed, much more in-depth research, discussions, and dialogues are needed, and potentially, leading to the development of a policy position for both the Central Chinese and the HKSAR governments.

China – operating at an accelerated pace just like any other new industry

To outsiders, China's Space industry was a completely closed-off government-controlled endeavour. While western satellites were launched by Chinese rockets with compensation, there was no sign that the government intended to open the sector up to entrepreneurial firms (both domestic or foreign entities). China was excluded from the ISS project for political reasons. However, China's own version of the ISS – the Tian-Gong (天宫) and the first launches of modules have been successful. But the laboratory is still not ready for human occupation and operation today. Together with rockets for different uses, China is still on the learning curve with many "first demonstrations".

The Space industry in China began to gain traction and generated a lot of heat in recent years, especially after the nation opened up its industry to private investment and rolled out new policies on Space commercialization. This led to a massive influx of the number of Chinese startups with the support of venture capital funds and giant corporations all wanting to front-run the potential investment opportunities of a relatively new developing industry.¹⁴

According to our recent investigation, China moved to steadfastly allow domestic private sector to participate in the Space business. After decades of rapid economic development, China's private business sector has accumulated enough technological know-how, research talent, and financial strength to enter the Space business, according to mainland Space

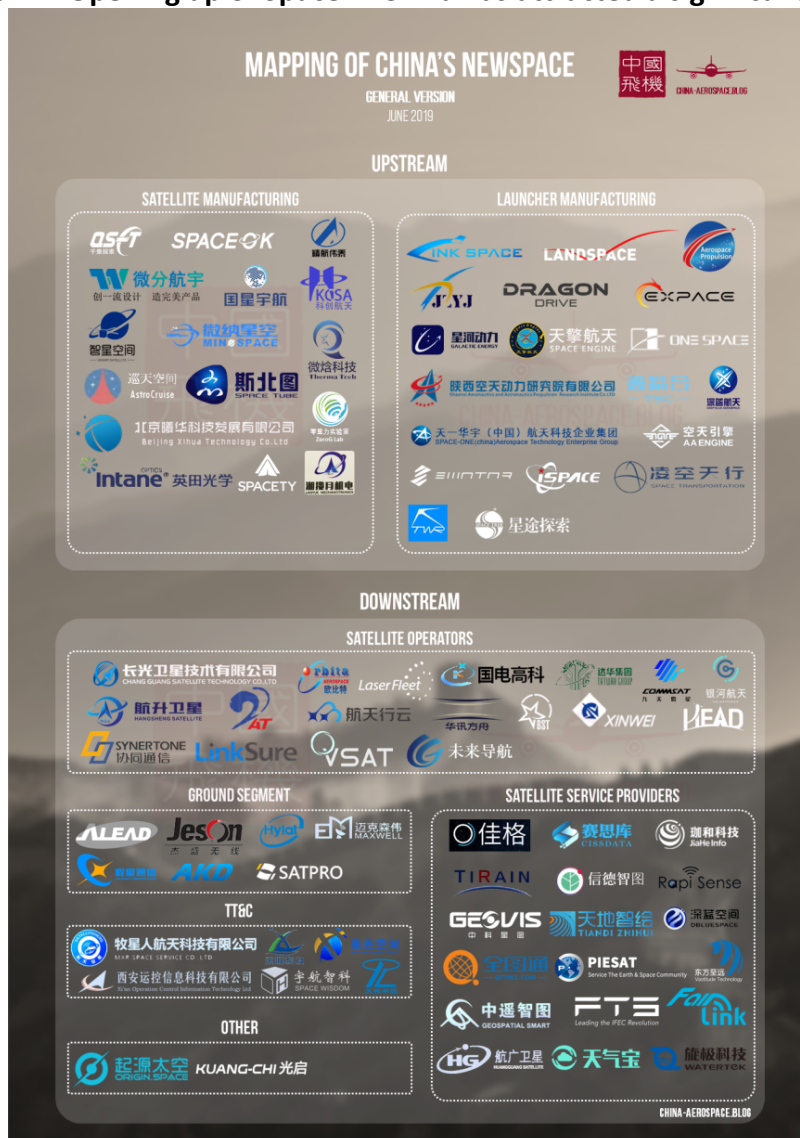
¹³ https://www.ofca.gov.hk/filemanager/ofca/common/Industry/telecom/outer_Space/gn32016_guideline.pdf

¹⁴ It would be a good research as our next project to dive deeply into one of these companies.

experts. Some were already important suppliers to the military. For Hong Kong to remain relevant and contributory to such efforts, we believe It is an opportune time for the private business sector in mainland China to begin connecting with their counterparts in Hong Kong. How to do this is worth exploring.

There are three possible verticals for Hong Kong, according to Professor Joseph Michalski of the Faculty of Knowledge Exchange at HKU. The first is research and education, and he believes this will further raise the bar for our universities and applied laboratories. Research that requires a context of weightlessness is an obvious choice. The second is commercial and he believes this opportunity is unprecedented for Hong Kong. The third is military, and he believes Hong Kong does not need to be involved. The commercial sector in Space has involved sharing of IP and the US and China have been cooperating very closely on a number of fronts. ***Perhaps Cyberport and the HKSTP in their efforts to extend into One Belt One Road (OBOR) can leverage this new ecosystem and start connecting the dots for a new commercial sector?***

Exhibit 7.1: Opening up of Space in China has attracted a significant amount of startups



Source: China-Aerospace blog

China versus the world

The Futon Space Competitiveness Index in Exhibit 7.2 ranks nations in their overall competitiveness in space industries. Although the US continues to lead, the gap with others has narrowed substantially.

Exhibit 7.2 Relative competitiveness of nations in Space

RELATIVE COMPETITIVENESS CHANGES BY COUNTRY, SCI 2013 TO SCI 2014

	Argentina	Australia	Brazil	Canada	China	Europe	India	Iran	Israel	Japan	Russia	South Africa	South Korea	Ukraine	USA	Average Change
Argentina	0.00		-0.30													
Australia		0.00										-1.02				-0.92
Brazil			0.00											-0.38		
Canada				0.00							-2.31					+0.66
China					0.00				-1.01							
Europe						0.00									+1.53	
India							0.00						-1.07			
Iran		+0.35						0.00								
Israel									0.00							
Japan					+0.14					0.00						
Russia						+3.05					0.00					+2.98
South Africa	+0.92											0.00				
South Korea										+1.84			0.00			
Ukraine						-0.95								0.00		
USA				-1.39											0.00	

Source: <http://spaceref.biz/commercial-space/futron-releases-2014-space-competitiveness-index.html>

Citing the above website for the 2014 Report,

“.....of the 15 countries analysed, only the United States has shown seven straight years of competitiveness declines. By contrast, China, Japan, Russia, and India have improved their own space competitiveness by 35%, 44%, 20%, and 16%, respectively, over their own relative starting points from when Futon's benchmarking process began in 2008.”

China's regulatory framework

Incredible results in the Space sector has put China on the forefront of having one of the most relevant and influential Space sectors. This has all been achieved through significant steps from a technological standpoint. However, what seems to be lagging is an adequate regulatory and open framework applicable to Chinese Space activities, which still seems to be at its infancy stage. Other major contributors to Space such as the USA, Russia and the EU already have comprehensive legislation regulating domestic Space activities. What this means is that potentially Hong Kong can still play a role to influence such national policy as the policy is being developed.

Can we?

China has only passed two low-level administrative regulations that address the launching and registration of Space objects. China acted in haste when authorities decided it had to

significantly bridge the technological gap with the US and the then Soviet Union, legal developments took a back seat or probably was not even on their agenda. As the technological difference has narrowed significantly over the years, now should be the time China should focus on expanding its minimal Space regulatory structure in order to better adapt to its future expansion.

What legal specialty would Hong Kong need to develop? Perhaps Hong Kong, through its international network, can proactively help China connect and catch up to the rest of the world through a new role as a bridge in the matter of Space. Hong Kong has always been a bridge for China and the world, on all other matters ... except Space.

Exhibit 7.3: Space law and regulations in China

Space-related laws:	Description:
Measures for the Administration of Registration of Objects Launched into Outer Space (2001)	- To ensure the implementation of the requirements set in 1975 Registration Convention, which demands states parties to register Space objects in a national register as well as to transfer relevant information to the UN Secretary-General for inclusion in an international registry.
Interim Measures on the Administration of Licensing the Project of Launching Civil Space (2002)	- To set forth the legal regime for the licensing of launches of civil, non-military objects into outer space. - Applications to be submitted to the State Administration for Science, Technology and Industry for National Defense (SASTIND) nine months prior to launch. - The measure provides a good foundation to comply with the requirements of Articles VI of the Outer Space Treaty and to administer the launch of civil Space objects. - Two major drawbacks – 1) whether the measure extends beyond the launch itself and covers activities already occurring in outer Space post-launch and, 2) issue of liability does not extend to private entities making it difficult for Chinese authorities to ask for compensation when necessary.
Interim Instrument of Space Debris Mitigation and Management (2010)	- Enable the domestic implementation of a series of international technical standards and recommended practices aimed at reducing the pollution of the Space environment. - Space debris refers to all man-made objects in Earth orbit or re-entering the atmosphere that are non-functional. - The regulation is managed by the SASTIND and requires operators to comply with a series of technical standards.
Treaties signed:	
Outer Space Treaty (1967)	- Treaty that formed the basis of international Space law and was opened for signature in the US, UK and former Soviet Union. - By 2019, 109 countries are now parties to the treaty, with another 23 having signed but yet to ratify. - Prohibits the placing of nuclear weapons in Space, limits the use of the moon and all other celestial bodies to peaceful purposes only. - Establishes that Space shall be free for exploration and use by all nations.
Rescue and Return Agreement (1968)	- Elaborating on elements from the Outer Space Treaty (Articles 5 & 8), member states shall take all possible steps to rescue and assist astronauts in distress and promptly return them to the launching state.

	- Upon request, the states should provide assistance to launching states in recovering Space objects that return to Earth outside the territory of launch.
Liability Convention (1972)	- Elaborating on Article 7 of the Outer Space Treaty, the convention provides that a launching state shall be absolutely liable to pay compensation for damage caused by its Space objects on Earth, to aircraft and damage due to its faults in Space. - Have clear procedures for the settlement of claims.
Registration Convention (1976)	- Ratified by 69 states, the convention requires states to communicate with the UN with details about the orbit of each Space object.

Source: Oxford Research, Britannica, UN Office for Outer Space Affairs

Chinese officials have begun to stress the importance of having a more comprehensive regulatory framework that can suit the stage of its domestic Space program as a failure to do so could undermine future growth and investment opportunities. Over the past decade, China has continued to complement its existing Space-related regulatory framework with a series of white papers on its Space activities issued every five years by the State Council. Naturally, for Hong Kong to do anything in this realm, we would need the blessing of the State Council. ***Is this possible?***

The five-year working white papers typically cover a broad scope that ranges from domestic Space exploration to international cooperation. These papers provide an overview of the progress made in previous years, along with future policy and strategic goals of the Chinese Space program going forward. It is important to note that these white papers are only there as a reference as they are not legally binding. Perhaps Hong Kong should take a stab on drafting this white paper next time?

But despite that, the papers are significant because they represent the sheer size of the Chinese Space program and their active role in the international field. The importance of China's State Council's white papers includes:

- 1) Raising transparency over the nature and implementation of the domestic Space program, creating a more acceptable and reliable partner for international cooperation projects,
- 2) Provide international players of China's position in undertaking and respecting international obligations towards the use of Space,
- 3) Show awareness of a set of regulatory frameworks for Space.

Or, perhaps Hong Kong can start drafting our version of this white paper and add our thoughts to their paper? In any case, developing a strategic blueprint would appear to be the next step for the HKSAR Government.

A few factors should also be taken into consideration when forming new legislation in China's (and Hong Kong's) upcoming Space race include:

- 1) **The size of the pie is still growing** at extraordinary rates as China's capabilities expand into all subsegments within the Space industry. As the industry continues to grow, adequate policies need to be implemented for better and more efficient administration.
- 2) **China's position in the global Space value chain** would only improve through bilateral agreements with foreign entities. A stronger regulatory framework would significantly improve the governing of such arrangements across the many nations.
- 3) **The proliferation of its domestic private Space players** may constitute legal bottlenecks for the government. As China's Space industry begins to open up further, with partners with foreign entities taking a bigger role in the future, stronger legislation should be put in place. Hong Kong's unique position may now be an advantage.
- 4) **Partnership and business opportunities of foreign entities** engaging in Space in China will continue to be a trend as China's importance in the global Space value chain rises. But for this to happen, China will have to put in place a strong regulatory environment to attract and encourage more foreign entities in engaging in activities in China. This would include an environment that promotes Space investments, legal protection of foreign entities to operate domestically, intellectual property rights protection, and various other legal issues. Again, the very stuff that has defined and strengthen Hong Kong. **Why not?**

As we mentioned earlier, China's regulatory framework on Space still lags behind most competing nations in the Space race. Its regulations still lack substance and complexity for it to expand much further.

Perhaps this is a new area that Hong Kong can proactively work with mainland authorities and begin to build stronger mutual links and trust?

It would appear that Hong Kong, given its experience, exposure, and inclination to be at the forefront of international discussion, has a particular interest, and obligations to step up.

China's BeiDou system and how far we have come

BeiDou Navigation Satellite System (BDS) is a Chinese project that commenced in 2000, with the goal of providing a Global Positioning System (GPS) similar to that from the US GPS. The systems are shared as public resources, with a principal of "BDS is developed by China and dedicated to the world." China will work with all other countries, regions and international organizations to promote global satellite navigation development.

A three-step strategy of development was formed:

- 1) By end 2000, China completed the construction of BDS-1 and provided services to the whole country;
- 2) By end 2012, construction of the BDS-2 was completed and began to provide services to the Asia-Pacific region;

- 3) By end 2018, a total of 19 satellites had been launched to complete a preliminary system for global services. It is planned to comprehensively complete the BDS-3 deployment with the launching of 30 satellites by 2020.

On 25th June 2019, the 46th BDS satellite was successfully launched on board a Long March 3B rocket from Xichang Satellite Launch Center. This was the 21st constellation satellite and the second inclined Geostationary (IGSO) satellite added to the BDS-3 constellation. This will join the 20 previously launched BDS-3 satellites to enhance coverage and performance further.

China started developing Beidou in the 1990s and will spend an estimated US\$8.98 billion to US\$10.6 billion on it by 2020, according to a 2017 analysis by the US-China Economic and Security Review Commission. The system was named after the Chinese word for the Big Dipper star pattern and is at the core of an industry that will generate more than Rmb400 billion (USD79 billion) of revenue by 2020, according to a forecast by the China Satellite Navigation Office.

An important difference between BeiDou and GPS is that the former is a two-channel system. According to industry experts, linking BeiDou with 5G when it becomes fully available can change the game significantly.

Given Hong Kong's love for mobility and smartphone, shouldn't Hong Kong find a niche between 5G and BeiDou?

[Hong Kong – has already been contributing to the global Space race](#)

Pockets of excellence have been developed in Hong Kong, albeit independently.

According to Dr. Pablo Saz Parkinson and Director Quentin Parker of the Laboratory for Space Research (LSR) from the University of Hong Kong (HKU), LSR announced its plan to immediately establish a new LSR at HKU-Zhejiang Institute of Research Innovation (HKU-ZIRI) in the Lin'an district of Hangzhou, Zhejiang province. With a strategic investment of HKD10 million, the laboratory is designed to help put Space and Planetary Sciences and related activities squarely on the map at HKU and for Zhejiang.

Moreover, new "Space" partnership was established on 31 Jan 2018 in Shenzhen. The collaboration includes the School of Astronomy and Space Science of Nanjing University, the Beijing Institute of Space Mechanics and Electricity, Satelliteherd, and Beijing Origin Space Ltd. HKU-LSR is working on the construction, assembly, and testing of the "HKU No.1 satellite". This is an X-ray astronomy telescope with a focused primary scientific goal to search for dark matter in massive neighboring galaxy clusters. This will also be the first soft X-ray satellite in the world that uses the "Lobster-Eye" technology.

LSR continues to broaden their reach, from signing an MoU to become a full member of the SAST-led Joint Innovation Centre for Space Science (JICSS), HKU-LSR will be joining 17 top mainland universities with the aim of leading all major Chinese-led space science satellite missions in the near future. They are also looking at further commercial opportunities for HKU and the LSR brand as they plan to open another facility in Dongguan. They aim to

receive a major grant from HKU for an AI-GBA (Greater-Bay area) project that includes a commercial remote sensing project.

Professor Yung Kai-Leung and his colleagues from the Hong Kong Polytechnic University helped design and construct a robotic mount for the Chang'E 4 spacecraft. This also included the mission-critical camera that captured the world's first landing on the far side of the moon by the Chang'E 4 spacecraft. Prof. Yung is no stranger to Space research. He and his team have built equipment for Space agencies in Russia and the European Union, but it must be especially gratifying to be able to conduct research for his own country, and all in the comfort of his own lab.

Wu Wei-ren, Chief Scientist of the lunar program, recently revealed that scientists from NASA had requested to use Chang'E 4's relay satellite to help them plan an American mission to the far side of the moon. It is not clear what came from the American's request made several years ago. In today's hostile environment between China and the US, such requests would be unthinkable.

Where is Hong Kong with such discussion? We were not able to identify, unfortunately.

According to Dr. Parkinson who teaches Astrophysics at HKU, it is clear that the central Chinese government sees Space commercialization as one of critical importance and this imperative is trickling down to Hong Kong. Given Hong Kong's status as a global metropolis, its strong international links, and its location in the Greater Bay Area, Hong Kong is ideally located to capitalize on the growth of China in the area of Space science. As the top university in Hong Kong and the only one with major research strengths in the field, HKU should take the lead in training the next generation of Space scientists. The establishment of LSR in 2016 already puts a strong claim toward this goal. An aim is to have a Masters of Space Engineering in collaboration with Zhejiang ready for enrollment as early as 2020.

From these examples, we see Hong Kong is well-positioned to help China with its scientific endeavors. As China is being put under greater scrutiny by many Western countries when it comes to science and technology, Hong Kong may find itself in another opportune moment in history. Doors on collaboration are being closed for China, but Hong Kong, they have remained ajar for some time now. We seem to have a loose toehold, although we seem to have remained nonchalant about the whole matter. Perhaps this is an over-statement.

Without proper marketing, communication, and promotion by the HKSAR government, how else should citizens think?

Improper communication can have a disastrous effect, even things are not true. Recently, many ethnic Chinese scientists, though American citizens, have fallen under suspicion of espionage, because of race and with people whom they associate themselves, which naturally would be Chinese speaking scientists.

All these signals and phenomena have put Hong Kong in a unique position once again, not only to help research on the mainland but to serve as a bridge for the scientific communities in China and overseas. We see this as a timely opportunity that should not be missed. ***Do you?***

VIII. What are the Emergent Risks with the Commercialization of Space?

As a nascent industry, the business prospect of Space commercialization depends partly (but a large extent nevertheless) on government support in budgets and partly on how much and how fast existing industries see LEO flights as mutually beneficial. In the foreseeable future, the industry will be a hybrid market (shared by both government and private sectors). The prospect for start-ups to exit financially is more on the M&A side rather than IPO. Some start-ups will fail; a few will have to merge. The industry will expand and consolidate through boom and bust rapid cycles. Since most missions still run in sums exceeding millions of dollars, large corporations are better equipped to build facilities and employ skilled labor. Therefore, large companies have a higher probability of success, taking innovations to Space missions, but this is not a guarantee.

Every investment comes with a certain magnitude of risks. Space is no exception. Despite the potential use cases of Space commercialization, previous failures of large-scale Space companies include Iridium, Teledesic, and TerreStar. The reasons were mainly attributed to the products they were selling. These were large projects initiated by large corporations. Thus, size is not a guarantee for success. Risks can only be curtailed by reducing uncertainties and through experimentation. One role we see of the HKSAR Government is first identify such uncertainties then move towards eliminating them through transparency and research.

Technology risk:

Failure to launch is perhaps the most visible manifestation of technology risks. This is no different from aviation. It previously took decades and millions of flights for commercial aviation to attain its present safety record.

Success rates of all launches (including manned flights) have been between 93% and 96% for each of the decades since the 1970. In the future, individual and constellations of CubeSats and small satellites will be launched as “primary passengers” in increasing traffic volumes.

Spaceflight too involves many complex systems and components, some of which have to endure high g-load and high temperatures. The private sector can now leverage the advances in ICT, 3D printing, nanotechnology, new materials, navigation, and AI.

Financial risk:

The returns on investment (ROI) is probably one of the more important metrics all investors look at before making any decisions. Because of the amount of moving parts in the equation, calculating the returns from Space investments might be even harder. Many companies and industries within the Space value chain have benefited somewhat from Space-related innovation, therefore determining which to include in the calculation can be tricky and extremely subjective. The development of Cat Bond in the insurance industry is one tool that have been used to transfer such risks.

Other risks:

As a part of the next version of this paper, perhaps we or someone better endowed like the HKSAR government or a risk consultancy, should conduct a general risk assessment of this sector. **We would recommend that we categorize various risks we deem important to take note of, before making significant investments into the Space race.**

IX. Conclusion

In just a short period, China has made substantial technological advancements in the Space sector that have enabled it to undertake successful Space missions in both LEO and lunar explorations. Even more so, the narrowing gap in technology has moved far ahead in comparison to the progress of its own legal and regulatory framework. Indeed, so far, China has only enacted two low-level legislation regulating certain aspects of its Space activities. It will no longer be acceptable and sustainable going forward as China's importance in the global Space value chain increases.

How can Hong Kong play an integral part in the development of new legislation, and not just one part?

We stress again that if China does not take the initiative, it will fall further behind. If Hong Kong does not participate, we will be further marginalized. Arguably, failure to modify the present state of affairs might undermine future advancements and be detrimental to financial opportunities in the Space sector. Notably, however, Chinese authorities seem to be aware of the need to upgrade and expand national Space legislation. It remains to be seen the scope and type of such law and the timing of its possible release. ***But how can Hong Kong raise its level of participation and inject some vitality into the discussion?***

We have already seen China's commitment in their Space strategy, as shown in the latest five-year plan white paper in 2016. Perhaps from now till the next paper in 2021, we will see significant changes and a more robust regulatory framework and environment to pull themselves further, ideally, involving Hong Kong as a tipping point.

Is Hong Kong right for NewSpace

Some investment groups in Hong Kong are aware of NewSpace in other parts of the world. The key issue is their investments elsewhere would have NO relevance to Hong Kong as a society and its economic future. To be relevant, we need to be part of, big or small, the NewSpace ecosystem. This ecosystem is changing and most of Hong Kong is NOT even tracking NewSpace. The opportunities for research, education, and commercial is unprecedented for Hong Kong.

Some science and technologies are not "right" for Hong Kong, and they would never gain any momentum beyond academic research. Scientific trends and graduates move on to other professions and opportunities. Since the investment community in Hong Kong is not inclined to be visionary but primarily put money in a pot already cooking, the ecosystem of NewSpace has to be nurtured by entities that are not merely motivated by financial ROI but by higher causes.

For this research team, potential next steps would be to do a deep dive into one of the SMEs in the Space Industry, compile a risk map of this space, and pull together an education program for building CubeSats at the high school and university levels.

X. Appendix

In this section we provide some relevant information including current legislation in Hong Kong and background to a few major foreign players in the Space industry,

- A. Current Space-related regulations in Hong Kong
- B. SpaceX
- C. Blue Origin
- D. Virgin Atlantic
- E. Other US Aeronautical Companies

A. Current Space-related regulations in Hong Kong

Licensing Criteria

In deciding whether an Outer Space Licence should be granted to an applicant, the following matters relate to the Applicant would be relevant (from Office of the Communication Authority (OFCA) website):

1. The Applicant
The applicant for an Outer Space Licence shall normally be a company incorporated in the Hong Kong Special Administration Region (HKSAR) - 2 - under the Companies Ordinance (Cap 622).
2. Financial Capability
The applicant should possess sufficient financial capability in launching and maintaining the operation of the satellite network. The applicant should specify the costs incurred and demonstrate that it has sufficient financial backing, either by its own capital, the capital of its shareholders or loan capital to carry out the activities to be licensed. The applicant should have reasonably sound and detailed business plans with contingency measures to cope with different reasonably foreseeable circumstances.
3. Managerial Strength
The applicant should possess the managerial strength required for the establishment and operation of satellite, including the procurement of satellite, procurement of launch of satellite, arrangement for insurance, coordination and registration of satellite networks in accordance with the regulations of the International Telecommunication Union (ITU), etc.
4. Technical Competence and Experience
The applicant should possess sufficient technical expertise and be experienced in the establishment and operation of satellite networks. Without limiting the generality of such requirement, the applicant should be familiar with the relevant laws of the HKSAR and the obligations of the People's Republic of China under international laws and conventions. In particular, the applicant must be conversant with the prevailing regulations of the ITU and the procedure of the Radio Regulations applicable to satellite services.

5. Nature of Space Activity

The activities to be carried out by the satellite has to comply with the international best practice in preserving the outer Space environment and secure compliance with the international obligations of the People's Republic of China with respect to the carrying out of any activities in outer Space. A brief technical account of the satellite or Space activity, the payload, mission and launch means should be provided.

6. Safety and Damage Considerations

To facilitate the DG Com's consideration on safety issues, the applicant should specify as to whether the Space object will (a) re-enter the atmosphere or be recovered, (b) emit any solid or ionizing or gaseous materials, (c) operate any laser, (d) carry any radioactive or nuclear material or (e) carry any form of animal life.

7. Technical Information for Space Object

The applicant should demonstrate that the technical parameters designed for the Space object shall comply with relevant ITU and international regulations - 3 - during its planned mission.

8. Insurance arrangement

The applicant shall give warranty and undertaking that before the launch of the satellite an insurance policy should be effected covering third party liabilities arising out of the launch of the satellite including the launch phase and first year of the in-orbit operation of the satellite. The insurance policy shall remain valid and enforceable by the Central People's Government of the People's Republic of China and the Government of the HKSAR against the insurer.

9. Status of Frequency Coordination

With respect to the ITU satellite filings based on which the applicant develops its satellite networks, the applicant should demonstrate that the coordination with other relevant satellite networks has progressed satisfactorily to such a stage that it can warrant the issuing of a licence, subject to any appropriate conditions to be attached

10. Implementation Schedule

Where appropriate, the DG Com may require that the satellite network proposed by the applicant be rolled out within a reasonable time-scale. In this situation, the applicant may be required to provide a comprehensive roll out plan taking into consideration contingencies (e.g. launch failure) and demonstrate a strong commitment to adhere to the implementation schedule (e.g. through performance bonds or other forms of assurances if necessary).

11. Compliance with the "Guidelines for De-commissioning of Satellite and Mitigation of Space Debris" issued by OFCA.

The applicant has to demonstrate that it can comply with all the requirements as stipulated in the "Guidelines for De-commissioning of Satellite and Mitigation of Space Debris" (hereafter the "De-commissioning and Mitigation Guidelines"), which can be downloaded from OFCA website.

B. SpaceX

Founded in 2002, SpaceX designs, manufactures and launches advanced rockets and spacecraft and has the vision to revolutionize Space technology, with the ultimate goal of enabling people to live on other planets. As of its latest round of financing, the private company has a valuation of over USD30.5 billion after 22 rounds of funding. SpaceX's Falcon Heavy Rocket is currently the most powerful operational rocket and can lift over twice the payload of the next closest operational vehicle at one-third of the cost. Its major customers are NASA and the US Air Force.

C. Blue Origin

Founded by Jeff Bezos in 2000, the company's mission was to develop private human access aimed at reducing costs, reusing rockets and gaining reliability. NASA has signed contracts with Blue Origin, giving various grants upon milestones.

D. Virgin Galactic

Founded by Richard Branson in 2004, the company offers suborbital spaceflights to Space tourists, suborbital launches for Space science missions and orbital launches of small satellites. On 9th July 2019, Virgin Galactic announced that it will go public via merging with Social Capital Hedosophia (SCH) after a capital injection of USD800 million in exchange for 49% of the company. The combined enterprise value of the firm is estimated to be USD1.5 billion.

E. Other US aerospace companies

The "big three" U.S. aerospace companies are:

- 1) Boeing
- 2) Lockheed Martin
- 3) Northrop Grumman (which acquired Orbital ATK as of June 6, 2018)

In addition, Boeing and Lockheed Martin co-own

- United Launch Alliance (launch services)

Other major U.S. aerospace companies that manufacture spacecraft, instruments and/or launch vehicles and/or provide launch services include:

- Aerojet Rocketdyne (rocket engines)
- Ball Aerospace (spacecraft and instruments)
- Harris (including Excelis, with which it merged) (spacecraft instruments)
- International Launch Services (launch services)
- Maxar Technologies (incorporating Canada's MacDonald Dettwiler Associates or MDA, Space Systems Loral, DigitalGlobe, and Radiant Solutions — satellite manufacturing and services, robotics)
- Raytheon (spacecraft instruments)
- Sierra Nevada (spacecraft)
- SpaceX (Space Exploration Technologies) (launch services and potentially satellite communications)

Major U.S. companies that sell Space-related products or services include:

- Dish Network (satellite television)
- DirecTV (satellite television)
- SiriusXM (satellite radio)
- Iridium (mobile satellite telephone)
- Globalstar (mobile satellite telephone)
- Trimble (GPS consumer equipment)
- Garmin (GPS consumer equipment)

Entrepreneurial companies:

- Astrobotic (robotic lunar landers)
- Axiom Space (commercial Space station)
- Bigelow Aerospace (expandable/inflatable Space stations)
- Blue Origin (personal spaceflight and rocket engines)
- Deep Space Industries (originally asteroid mining, later deep Space propulsion—bought by Bradford Space Group, Jan 2, 2019)
- GeoOptics (radio occultation weather data)
- Moon Express (robotic lunar landers)
- Nanoracks (hardware and services including delivery to ISS of cubesats for deployment)
- Near Space (stratospheric balloons)
- OneWeb (communications satellites)
- Paragon Space Development Corp. (environmental control and life support systems)
- Planet (formerly PlanetLabs) (earth remote sensing, which bought Terra Bella, which was previously Skybox)
- Planetary Resources, Inc. (originally asteroid mining, acquired by blockchain company ConsenSys Oct 31, 2018)
- PlanetIQ (radio-occultation weather data)
- Rocket Lab USA (smallsat launches from New Zealand)
- Space Adventures (personal spaceflight)
- Spire (radio-occultation weather data)
- Stratolaunch (Space transportation)
- Up Aerospace (suborbital launches)
- Vector Space Systems (smallsat launches)
- World View Enterprises (stratospheric balloons)

Major non-US aerospace companies:

- Airbus (formerly EADS — European satellite manufacturing)
- Arianespace (French, launch services)
- Eutelsat (European fixed satellite services)
- Inmarsat (global mobile satellite services, based in the United Kingdom)
- Intelsat (global fixed satellite service, based in Luxembourg)
- Mitsubishi Heavy Industries (Japanese, satellites and in-Space platforms, launch services)
- SES (European fixed satellite services)
- Surrey Satellite Technologies (SSTL — British, small satellite manufacturing)
- Telesat (Canadian fixed satellite services)
- Thales Alenia Space (European satellite manufacturing)
- Virgin Galactic (personal spaceflight, smallsat launches, UK)

