On Sustainable Development Path of China Commercial Space

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Abstract

China's commercial space companies have been nourished these years from 2014. But some people say most of them would die within 5 years when they used up all the money in the first round. But that's just the beginning. China space needs them to survive and go on a sustainable development path then they can be a strong strength in China space and have their own position on the world space field.

In this paper, I analyzed the American commercial space from 5 angles, policy, funding, infrastructure, innovation, and private funding. Then I compared the differences among new space in China, Europe, Russia, Japan, and India. The focus is on the comparison between China and American new space for I want to discover the wise methods adopted by the USA, the strong power in the world space. From doing it and combining the actual characteristics of China commercial space, I get down on exploring the path of Chinese commercial space sustainable development path. To develop a commercial space industry is never a simple thing, so I try to recommend the strategies in the short term and long term for developing new space path.

Finally, I make the conclusion. we should do a lot in completing the whole supply chain of this industry and do more in promoting the product performance and satellite application. At the same time establish the new civil-military integration mechanism and talents logistic mechanism.

Keywords: China commercial space, sustainable, development, mechanism

Acknowledgment

For the completion of this thesis, I wrote it firstly for my 7-year-old daughter. I have studied in France for the whole 14 months without her by my side. But I believe all my efforts worth it for a good example for my daughter. I really want her to know girls can be tough and can also be brave to pursue their dreams. I am grateful for my families who are always supporting me. Of course, I thank my country, my company to give me this chance to study here to enrich myself more and for all the friends who are from various walks of industries. They helped me a lot in collecting the first-hand information and gave me precious suggestions. And they even told me their true space career experiences in the interviews with me. I have really appreciated it.

Thank you, IAS and TBS, you really opened my eyes in European and world aerospace world.

All the best to all of you!

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1. Introduction

On February 7, 2018, SpaceX successfully launched the world's most powerful super rocket, called Falcon Heavy. In the mission, two boosters returned successfully, and a Tesla Roadster was launched into space and headed for Mars. Up to now, the Heavy Falcon rocket is the most capable rocket in the world, and it is very economical because it can be reused. It can send 63.8 tons loads to low earth orbit, which is equivalent to a Boeing 737. It meant that immigrating to outer space became possible. It can be said that the launch of heavy rockets has successfully opened a new era in commercial space.

When we look back on its history, we found that the commercial space is based in America. In the beginning, space remained a firmly government-controlled and -directed endeavor well after the capstone Apollo moon landing in 1969. The term "alt.space" was first used in the early 1980s to describe companies that were at last beginning to make serious efforts to reach outer space without needing or relying on the cooperation of NASA or other governmental agencies. These efforts were catalyzed by a historic shift in U.S. policy favoring private space activity, culminating in the landmark Commercial Space Launch Act of 1984. [1][2]

The seeds of today's New Space were brought to fruition by the collapse of the former Soviet Union in 1991 and the releasing of that former superpower's iconic, state-owned, and otherwise mature and proven space assets, technologies, capabilities, and services into the world's private markets. This set off today's competitive, industry-wide, virtuous cycle of "faster, better, cheaper". Near the end of the 1990s, favored by strong public policy, and spurred on by the foundational success of these post-Soviet U.S.-Russian private space ventures, there was a dramatic increase in companies engaging in this process, leading to common usage of the phrase "new space companies." [3] "New Space" (most prominently), "entrepreneurial space," and "commercial space" are now the most commonly used terms, [5] though "alt. space" was still seen occasionally as late as 2011.

Things changed further in the early 2000s as Elon Musk formed SpaceX with significantly more private capital while he articulated a strong and consistent vision of the "colonization of space, beginning with Mars." Since then, the development of commercial space was accelerated. It is expressed by the increase of new entrants, new type of funding, a new business model, etc. it is unlimited in the U.S., but in Europe, China, Japan everywhere.

Chinese commercial space started late because its special Planned Economy and National system. Although China space has already made the great progress in decades. They established the entire industry chain from the components to system assembly. They developed sorts of spacecraft, including manned spacecraft, telecommunication satellite, observation satellite, deep space exploration, and space station. Nevertheless, due to the historical reason, Chinese space remain the traditional government-directed

features. The limitation of a national system will be the constraints of the space market. with the space economy expanding fast, it is not enough only relying on the national mission to support the space activities in the long term. The government-oriented system will reduce the enthusiasm of space companies for innovation. The oligopoly market will be formed. Therefore, the commercial space is necessary to be driven. The new space could allocate the society resource efficiently, including private funding, human resource, etc. Furthermore, it could stimulate the intense competition in the market, drive the enthusiasm of new entrants and set the open innovation atmosphere within an industry.

This paper will discuss the development direction and route of China commercial space by comparing with the world's commercial space, especially America space. This paper will be divided into four parts. Firstly, we will introduce some concepts which will be used in this paper. Secondly, I will compare the current situation of world' commercial space, especially, America, Europe. Thirdly, I will describe the current situation of Chinese commercial space and point out the disadvantages. In the last section, I will propose some recommendations.

2. Concept review

2.1.New space

I use the term "New Space" – sometimes referred to as alt. space, emerging space, space 2.0, and entrepreneurial space – to refer to the increasing presence of nontraditional space actors, such as entrepreneurs, enthusiasts, and hybrid public-private organizations, in the utilization, exploration, and commercialization of outer space. According to the above concept, compared with traditional space in China, commercial space highlights market competition, profitability, and commercialized market behavior. [6]

The new space covers five major domains, including launch vehicles, satellites, manned spaceflight, deep space exploration, and space stations. Among them, the commercial activities surrounding the launch vehicle mainly include rocket R&D, launch, process measurement and control, and launch insurance. Satellite-related business activities are mainly concentrated on satellite applications, including remote sensing, telecommunications, navigation, and science. Manned space includes low-Earth orbit manned and cargo transportation services, as well as space tourism. The deep space exploration and the commercial development of the space station are at the early stage of exploration. The current commercial activities toward deep space exploration include space mining and the manufacture of star detectors which has allowed private companies to participate in the commercial business. The dream of "space city" will become true.

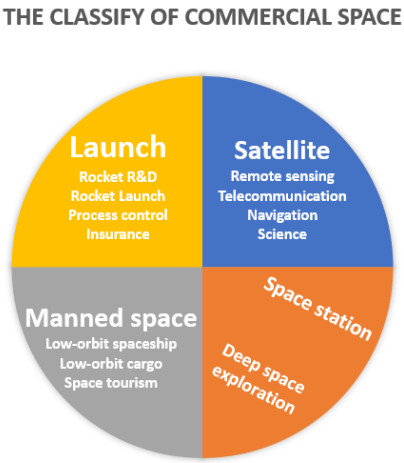

Figure 1 The classify of commercial space

2.2.The industry chain

The satellite industry is a major component of the commercial space economy.

As commercial manned, deep space exploration, and space stations are still in their infancy, the overall economy is small. Compared with them, the satellite industry accounts for a large proportion of the space economy. The satellite industry chain can be divided into four parts: satellite manufacturing, launch, ground equipment manufacturing, and application and operation services.

Table 1The industry chain

The system-level	The subsystem
Satellite manufacturing	· Payload manufacturing · Platform manufacturing
Launch	
Ground equipment manufacturing	· Internet equipment: receiving and control equipment, VSAT · Consumer equipment: TV, broadband, wireless, GNSS
Application and operation services	· Remote sensing services · Flight management · Mobile service · Satellite fixed service · Consumer service

According to the 2017 Satellite Industry Status Report, the total revenue of the global space industry in 2016 was 339.1 billion US dollars with year-on-year growth of 1%. [7]

The total revenue of the satellite industry was US$260.5 billion, accounting for 77% of the total revenue of the space industry with year-on-year growth of 2%, of which the satellite manufacturing industry revenue was $13.9 billion. It decreases 13% year-on-year, mainly due to working satellite is coming to an end of the life. They need to be updated. [7]

The launch service is 5.5 billion US dollars. The ground equipment manufacturing revenue is 113.4 billion US dollars, with year-on-year growth of 7%, mainly contributed by satellite navigation equipment and network equipment. The operating services industry revenue of 127.7 billion US dollars remains the main driving force of the entire satellite industry. [7]

From the perspective of the industrial chain, the revenue from satellite operation services exceeds that of manufacturing and development. It indicates that the development of the satellite industry has completed the transition from upstream to downstream.

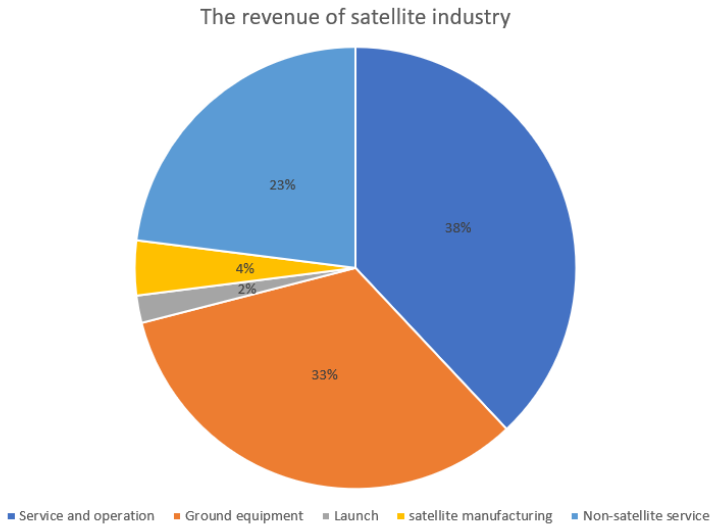

Figure 2 The revenue of satellite industry

2.3. Funding

Until a few years ago, most of the space activities were funded and managed by governments around the world, with the most prominent ones being the US and Russian governments. However, as we have seen over the past few years, there has been a steady rise of private space companies that are independent of governments, which have been undertaking a lot of space exploration and investment activities. These companies have helped to eliminate the monopoly that has existed in the space industry for several decades, as well as intensify the exploration of space after budget cuts that are currently facing government-funded space agencies.

Except for the government budget, the private funding in space mainly come from venture capital firms, angel investor, banks, corporations. According to Bryce startup report 2017[8], Over the 17-year period, the investors distribute to the five channels. Venture capital firms represent the largest number of investors in new space companies, followed by angel investors. These two investor groups comprise about 70 percent of the investors in start-up space ventures. Private equity firms, corporations, and banks (debt financing) make up the remaining 30 percent.

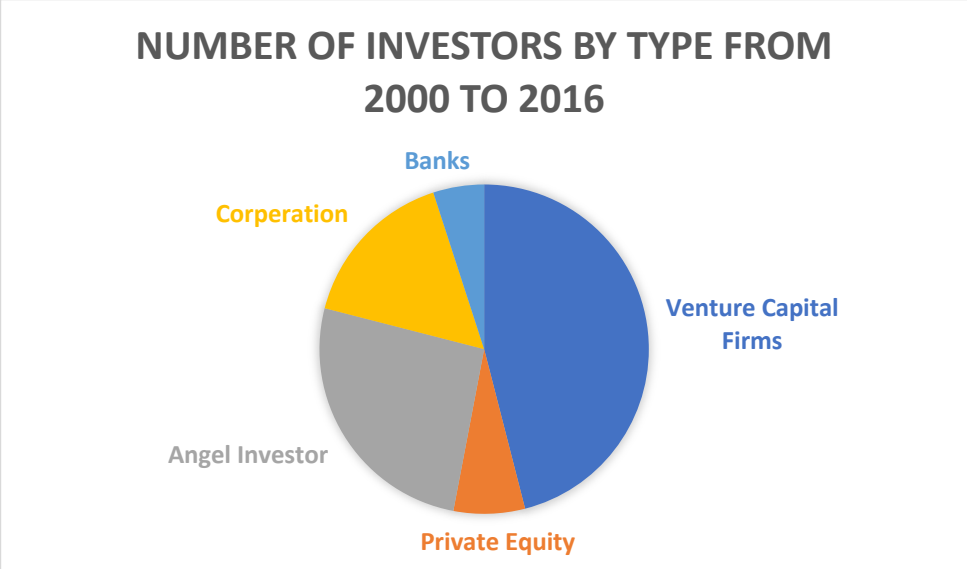

Figure 3 The number of investors by type from 2000 to 2016

As we can see that the venture capital was the most important funding in new space. Why are these firms invest in an industry that has been viewed by most venture capitalists to be risky and slow in yielding returns in the past? Below are some of the top reasons why venture capital firms are racing to invest in the space industry:

- *The promise of high returns*

Profit is the main motivation for venture capital firms when they are searching for businesses to invest. The high-end technology that is developed by space companies can provide very lucrative returns, these technologies could be used in other fields. Thus, attracting several capital venture firms.

The space industry also offers a promise of high returns from ventures such as space tourism and natural resources that can be found in space. In fact, some space companies have already been established with a sole purpose of mining rich resources found in the space once the activity becomes viable. Other space businesses are also currently developing technology such as spacecraft that will be used in space tourism. And while these activities might not be currently viable, they will be a huge gold mine for investors once they are successful.

- *Increase in the number of space businesses*

Another reason why venture capital firms are entering into the space industry is the increase in the number of businesses that operate in the space industry. According to New Space Global, a company that tracks and provides information about space businesses, there are about 1,000 space businesses that are currently involved in space activities, a significant increase from just 100 companies in 2011.

The company also predicts that the number of these companies will continue to increase in the process of commercializing the space intensifies. This development has helped to show venture capital firms and other investors that the space industry is a viable investment opportunity, thus diminishing the long-held view that it is risky – after all these companies are generating huge profits from their activities.

- *The prestige that comes with investing in the space industry*

When space exploration started, there was a huge space race between countries, as nations – mainly the USA and Russia – competed with each other in the exploration of the final frontier. The competition to explore the outer space reduced over time, but it has been revived in the past few years, and this time around it is being led by companies. In what is being termed as "space race 2.0", companies all over the world are competing to make huge milestones in the exploration and commercialization of the space, and just like with the original space race, prestige is a huge motivation.

Venture capital firms have also not been left behind in this new space race, and several investors are venturing into the space industry with the hopes that they will be associated with prestigious space projects such as space tourism or sending humans to Mars. This has helped to create a huge boom in the space industry, thus encouraging more investment in space. [9]

3. The current situation of the space industry

Commercial space has become the core dominant position of the global space economy. the US Space Foundation divides the space economy into two parts: the government space budget and the commercial market revenue. The government budget includes civil space budgets and military space budgets, while commercial market revenues are divided into commercial infrastructure and logistic, commercial space products, and services.

Table 2 The revenue of the commercial market

Commercial infrastructure and logistic	**Commercial space products and services**
Commercial satellite manufacturing	Broadcast live
Launching	Audio broadcast
Ground station and equipment	Fixed satellite service

Space insurance	Mobile satellite service
IR&D activities	Earth observation
Sub-orbit commercial flight	

In the past 10 years, the global space industry has maintained a steady forward trend. The government's space budget and commercial market revenue have maintained a ratio of 1:3. The main position of commercial space in the development of the world's space industry has become more prominent. According to the Space Report 2016 [10], the total global space economic revenue in 2015 was approximately US$322.94 billion, of which the government's space budget was US$76.52 billion, accounting for approximately 24%; the commercial market revenue was approximately US$246.42 billion, accounting for the total space economy 76% of the value.

3.1.Commercial space in America

When I look back on its history, I found that the commercial space is based in America. And the development of commercial space is a long-term process. The development of American space for more than 70 years has not only formed a complete industrial chain for commercial and space development but also cultivated a talent and technology reserve for commercial and space development.

In this process, the United States has carried out numerous space programs in various fields such as launch vehicles, satellites, manned spaceflight, space shuttles, deep space exploration, etc., which has greatly promoted the advancement and development of space technology, and has formed the situation in which private enterprises compete with each other. The complete industrial chain has been also established during this period. At the same time, the development of American space not only accumulated technology preparing for the development of commercial space but also provided a complete brain reserve for the development of commercial space. I summarized some reasons why America commercial space could lead the world.

3.1.1. Policy

- *Continuously improved legal policies provide behavior rules and legal policy support for commercial spaceflight.*

In order to support the development of commercial launches, the US government has formulated and promulgated a series of related laws, regulations, and policies since the 1970s, providing guidelines for the commercialization of rocket launching, satellite manufacturing, and satellite applications. Especially in the past 20 years, perfect policies and regulations have spawned a large number of commercial space companies. SpaceX, Blue Origin, OneWeb, and other companies have gained development opportunities.

Table 3 The policy issued by the American government [7]

Domains	Release time	Policy	Objective
Commercial launch	1984	*Commercial Space Launch Act*	Encourage and promote private enterprises to participate in commercial space launch activities
	1998	*Commercial Space Act*	
	2010	*US National Space Policy*	
Telecommunication	1962	*Communications Satellite Act*	Encourage the development of commercial satellite communication industry
	1996	*Telecommunications Act*	
	2000	*Orbital Act*	
Navigation	1996	*Global Positioning System Policy*	Policy guidance and implementation guidance for activities such as satellite navigation system construction and application
	2004	*US space-based positioning, navigation and timing policy*	
Remote sensing	1984	*Land Remote Sensing Commercialization Act*	Relaxing the government's control over high-resolution satellite remote sensing data Allowing private companies to get involved in the development of high-resolution commercial remote sensing satellites.
	1992	*Land Remote Sensing Policy Act*	
	1994	*Commercial remote sensing policy*	
Manned space	2006, 2010	*National space policy*	Encourage private enterprises to participate in the competition for manned space and cargo transportation
	2013	*National space transportation policy*	
	2017	*NASA Transition Authorization Act*	
Deep space exploration	2015	*Commercial Space Launch Competition Act*	Encourage innovation and reduce the cost of future near-Earth orbit and deep space exploration missions

From the beginning of the National Communications Satellite Law in 1962 and the Encouraging Private Space Competitiveness and Entrepreneurship Law promulgated in 2015, the booming development of American commercial space today is the result of more than half a century of continuous development. Therefore, the development of commercial space is a process step by step. A large amount of new entrants has sprung up during this period. I take some famous companies as the example.

Table 4 The leading commercial space companies in America

Domains	**Company**	**Founded time**	**Main business**	**Main product**
Launch	Space X	2002	Commercial satellite launch	Falcon 9, Heavy falcon
	Orbital ATK	2015	Small and medium space launch vehicle and commercial Propulsion system	Pegasus, Minotaur, Antares rocket
Satellite manufacturing	Orbital ATK	2015	Development of small and medium-sized satellites	Star 2, telecommunication, earth observation satellite
Remote sensing images	Digital Globe	1992	Provide high-resolution commercial image data And advanced geospatial solutions	Worldview series, GBDX data platform,
	Planet Labs	2010	Earth observation imaging	Dove constellation
Data service	Orbital Insight	2013	Obtaining sum by analyzing satellite images Sales data, combined with artificial intelligence algorithms Provide data analysis services for enterprises	Building a large-scale data and analysis Analytical platform for geospatial data
	Spire Global	2012	Collecting weather for government and commercial customers data	Deploy a meteorological satellite network
Space tourism	Blue Origin	2000	Commercial space flight	New Shepard
	Virgin Galactic	2004	Suborbital flight	Spaceship Two

	XCOR Space	1999	Suborbital space travel	Lynx Mark I and Mark II
Manned and cargo	Space X	2002	International Space Station cargo replenishment or manned	Dragon
	Orbital ATK	2015	Provision of replenishment services for the International Space Station	"Cygnus" spacecraft
Deep space exploration	Planetary Resources	2010	Space exploration and space resource development, Hope to achieve automated asteroid mining	Arkyd-100

3.1.2. Funding

- *Government buys space services to support the development of commercial space companies.*

In support of the development of commercial space companies, the US government has developed a series of funding programs to support commercial space launch and transportation, including Commercial Orbital Transportation Services (COTS), Commercial Resupply Services (CRS), Commercial Crew Development (CCDev), and Commercial Crew integrated Capability (CCiCAP), Certified Product Contract (CPC), Commercial Crew Transportation Capability (CCtCap), etc. Taking CCDev and CCtCap as the examples. [11]

- *Commercial Crew Development Round 1 (CCDev1)*

As NASA retired the space shuttle, the ability of private industry to take on the task of providing routine access to space was of vital importance. In 2010, NASA invested a total of nearly $50 million of the American Recovery and Reinvestment Act (ARRA) funds for CCDev1 to stimulate efforts within the private sector to aid in the development and demonstration of safe, reliable and cost-effective crew transportation capabilities. It included the development and maturation systems and subsystems, such as a spacecraft, launch vehicle, launch abort systems, environmental control, and life support system, launch vehicle emergency detection systems and more.

- Blue Origin - $3.7 million
- Boeing - $18 million
- Paragon Space Development Corporation - $1.4 million
- Sierra Nevada Corporation - $20 million
- United Launch Alliance - $6.7 million

- *Commercial Crew Development Round 2 (CCDev2)*

CCDev2 kicked off in April 2011 when NASA awarded a total of nearly $270 million to four companies to aid in further development and demonstration of safe, reliable and cost-effective transportation capabilities. The agency also signed unfunded Space Act Agreements to establish a framework of collaboration with additional space companies. As part of those agreements, NASA reviewed and provided expert feedback on overall concepts and designs, systems requirements, launch vehicle compatibility, testing and integration plans, and operational and facilities plans.

- Blue Origin - $22 million
- Boeing - $92.3 million
- Sierra Nevada Corporation - $80 million
- SpaceX - $75 million

- *Commercial Crew Integrated Capability (CCiCap)*

CCiCap continued the development of three fully integrated systems in August 2012. The Space Act Agreements called for industry partners to develop crew transportation capabilities and to perform tests to verify, validate and mature integrated designs.

- Boeing - $460 million
- Sierra Nevada Corporation - $212.5 million
- SpaceX - $440 million

The table 5 will clearly show which American space companies benefit from the government funding.

Table 5 The funding condition of America space

Company	CCDev1	CCDev2	CCiCap	CPC	CCtCap	Total
Alliant Techsystems		×				
Blue Origin	×	×				$25.6 million
Boeing	×	×	×	×	×	$4.82 billion
Excalibur Almaz Inc.		×				
Paragon Space Development Corp.	×					$1.4 million

Sierra Nevada Corporation	×	×	×			$363.1 million
SpaceX		×	×	×	×	$3.144 billion
United Launch Alliance	×	×				$6.7 million

3.1.3. Infrastructure

- *NASA's infrastructure and expertise are valuable resources for emerging space companies.*

NASA's infrastructure and expertise are valuable resources for emerging space companies. The agency's investments in facilities and capabilities began with the acquisition of research centers managed by the National Advisory Committee for Aeronautics established in 1915 and Army missile expertise acquired shortly after NASA was established. As the agency's priorities and missions evolve, the retirement of the Space Shuttle means that valuable infrastructure and experience can now be made available to the emerging space industry. These assets, otherwise latent, provide emerging space companies with capabilities they could otherwise not afford. The benefit to NASA is that it can leverage advancements made by these companies to help execute and assist agency programs. The benefit to the American taxpayer is that high-value resources are continually reused, rather than abandoned or removed. Use of these publicly funded assets means that the U.S. space industrial base can remain vigorous and competitive. [12]

- Ames Research Center (ARC) provides support in wind tunnel testing, risk analysis, test beds for human space flight, and thermal protection system (TPS) testing and analysis. ARC used its expertise and facilities to help SpaceX develop the PICA-X ablative material used on the company's Dragon capsule. The Center has been working with Paragon to evaluate the company's TPS being designed for a mission sponsored by the Inspiration Mars Foundation. ARC has also provided support to Blue Origin, Boeing, and SNC.
- Johnson Space Center (JSC) is supporting companies like Blue Origin, Boeing, SNC, and SpaceX in the development of commercial crew and cargo with engineering support and testing. For example, JSC supported SNC in the technical development of, and operations support for, the Dream Chaser Space System.
- Glenn Research Center's (GRC) unique Plum Brook facilities feature the world's largest space environment simulation chamber; the world's only test facility capable of handling rocket engine firings; a cryogenic test

facility; and a hypersonic wind tunnel. These facilities have been used for tests by many emerging and traditional space companies including SNC and SpaceX.

3.1.4. Innovation

In order to reduce costs and shorten the development cycle, commercial space companies attach great importance to technological innovation, new technology applications, and innovations in management models.

Taking rockets and Earth observation as an example, commercial space companies attach great importance to technological innovation and application of new technologies:

- Space X is working on manufacturing a new spacecraft, the BFR vehicle, designed for its mission to Mars. This vehicle would be nine meters across, bigger than the Apollo Saturn V rocket, and the largest spacecraft ever built. SpaceX is also exploring (Placeholder1) the possibility of using the BFR for suborbital travel between cities on Earth. It is estimated that with the BFR most long-distance flights would take less (Placeholder2) (Placeholder3)an hour. [13]
- Rocket Lab developed the Electron which is a two-stage orbital expendable launch vehicle. Both stages use the innovative Rutherford rocket engine, the first electric-pump-fed engine to power an orbital rocket.[4] There are nine Rutherford engines on the first stage and one vacuum-optimized version on the second stage. https://en.wikipedia.org/wiki/Electron_(rocket)
- ARCA Space Corporation is announcing the Haas 2CA, an innovative orbital launcher capable of placing itself, along with its payload, entirely into low Earth orbit without using multiple stages like current space vehicles. This kind of vehicle is known as being Single Stage to Orbit (SSTO). The Haas 2CA, named after Austrian-Romanian medieval rocket pioneer Conrad Haas (1509-1579), uses a linear aerospike engine that is around 30% more fuel efficient than the current rocket engines. [14]
- SpaceX's business model places a strong emphasis on the reusability of its vehicles to make its launches more financially and environmentally sustainable. Most rockets have hitherto been discarded at sea. This year, SpaceX became the first company to reuse rockets commercially. It safely launched, landed, and re-launched its Falcon 9 spacecraft over a dozen times. [13]
- Planet Labs, Inc. is an American private Earth-imaging company. In order to access the distribution channel, it extends their value chain to offer end-to-end data solutions to customers. The offerings include customizable, subscription-based monitoring data and cloud-based APIs. [15]

3.1.5. Private funding

- *Private funding is the driving force of the booming US commercial space. It stimulates the innovation and competition*

As I discussed in Chapter 2, Participation by individuals is characteristic of how space exploration in the United States began. It was private capital from successful entrepreneurs that contributed to the construction of America's first ground-based astronomical observatories during the early part of the 19th century. Shortly after the dawn of the 20th century, investments from philanthropists like Daniel Guggenheim, the dedication of inventors like Robert Goddard, and research conducted by amateur rocket societies combined to advance the development of American spaceflight technology. Individual Americans investing in and advancing the exploration of space is not a new phenomenon.

NASA was a major boost to American space efforts when it was established in 1958, tapping this current of innovation and merging substantial expertise and funding in a way that placed men on the Moon and a research installation in Earth orbit. Today, teams big and small, from the government to garages, continue to pursue the challenge of spaceflight, leveraging a legacy that is almost as old as the nation itself.

- Robert Bigelow, a hotel entrepreneur and founder of Bigelow Space, has spent $250M, and pledged over $500M, on the development of inflatable habitation modules for living and working in space.7 In 2013, Bigelow Space was awarded a contract by NASA to install a small inflatable technology demonstration module on ISS in 2015.
- Microsoft co-founder Paul Allen invested about $26M in the development of Scaled Composites' SpaceShip One, the demonstration vehicle that won the $10M Ansari X PRIZE in 2004. This vehicle served as the basis for the development of SpaceShipTwo, a much more capable vehicle announced to begin operations in 2014. Sir Richard Branson, the founder of Virgin Group, invested $100M in Virgin Galactic to provide suborbital flights for private individuals using a fleet of SpaceShipTwo vehicles.8 By 2013, about 625 people had reserved tickets at a price of $200,000-$250,000.
- Amazon CEO Jeff Bezos established Blue Origin in 2000, a venture dedicated to providing low-cost suborbital and orbital transportation services, using his own fortune. In 2013, his team successfully test fired the company's BE-3 engine, the most powerful liquid hydrogen-liquid oxygen rocket engine developed in the U.S. since the introduction of Pratt & Whitney Rocketdyne's (now Aerojet Rocketdyne) RS-68 a decade ago.
- SpaceX, founded by entrepreneur Elon Musk, has invested about $500 million to build vehicles to access LEO and beyond.9 He hired Thomas Mueller, an engineer who was designing and building rocket engines in

his garage, to manage the development of the Falcon 9 launch vehicle. In 2012, SpaceX became the first company to provide commercial cargo services to the ISS.

In a nutshell, America stands today at the opening of a second Space Age. The American space agency NASA is proud of developing the capabilities that allowing American entrepreneurs together to explore the space industry. These initiatives—both at NASA and in the private sector— are expanding the nation's opportunities for exploration and for the economic development of the solar system.

3.2.Commercial space in Europe

Europe company focus on the development of space integration and actively catches up: In general, the legal system of European commercial space, the innovation capability of the private enterprise, and the international competitiveness are obviously weaker than the United States. In order to expand the efficient allocation of space resources in the world, Europe actively seeks international cooperation, and emphasizes the development of space integration, promotes the construction of the two major projects of the Saga Galileo Navigating Satellite System and the Copernican Earth Observation and the new generation of launch vehicles. France has shifted its research to satellites, focusing on a new generation of high-resolution optical Earth observation, high-low-orbit advanced telecommunication satellites, etc.

In addition, in order to accelerate the start-ups' growth and innovation, some private funding was established.

Table 6 Space Funds and Accelerators in Europe

Organization	Type	Level	Funding	Selected Portfolio
Seraphim Space Fund	VC	Series A	The £50m fund backed by leading space companies and ESA. Invests in both downstream (software), and upstream (hardware) 'New Space', along with space applicable technologies such as drones, IoT, AI, robotics and nanomaterials. New $250 million global funds being raised too.	
ESA BIC	Incubator	Seed	2-year program to help start-up businesses that apply space technology to non-space industrial, scientific and commercial fields in 19+ locations.	
Stardust Accelerator / Ventures	Accelerator / VC	Seed / Series A	Ventures are new $200 million debut fund to invest in early-stage space startups over the next three years. $3 million to $5 million for Series A stage deals, reserving	DSI, Phase Four, EnduroSat, EarthCube, Accion, Ursa Space, Astro

			capital for larger follow-on rounds as well.	Digital, Audacity
Airbus Bizlab	Accelerator	Seed	Six-month tailored acceleration programme. 3 locations - Toulouse (France), Hamburg (Germany) and Bangalore (India).	
EBAN Space	VC	Seed, Series A	Promote and advance Europe's ecosystem for entrepreneurship, innovation, and investment in the space sector.	
SpaceStarters	Crowdfunding	Seed	Crowd investing platform for space-based innovations.	
Moonshot	Accelerator / Incubator	Pre-seed		
UK Space Tech Angels	Angel	Pre-seed	Provide to its investors an inside access into the space industry. The initiative between LBA and Seraphim Capital.	
Space3ac	Accelerator	Pre-seed	6-week program for space industry startups in the downstream sector in Poland.	
NewSpace NYC	Incubator	Pre-seed		

3.3.Commercial space in Russia

Russia is struggling in the commercial launch market and is striving to break through the dilemma: Russia is a traditional space power. In the largest field of space communications and satellite platforms and space equipment manufacturing, Russia has been subject to the development of microelectronics. The main market share is contributed by the rocket launch service, but with the rise of a series of cost-effective rocket launch service providers such as SpaceX, Russia's single market competitiveness has gradually declined. Last year, Russia plans to set up a unified commercial launch service operator, intending to implement flexible marketing policies for different customers to defend its space launch market share.

3.4.Commercial space in Japan

Japan attaches great importance to seeking new technologies: Since the 21st century, Japan has actively participated in commercial space, continuously promoting space policy reforms. In 2015, the Japanese domestic rocket H-2A was first implemented and successfully completed commercial space launch, but the cost is not dominant. Japan is actively seeking technology to further reduce costs and enhance its international competitiveness.

3.5.Commercial space in India

India is advancing in the commercial launch market: India first entered the commercial launch market in 2007, sending one Italian satellite into space. Since then, in order to reduce the cost of launching, they have been working hard to develop a multi-star technology, which will be completed in February 2017. Successfully launch the 1 arrow with 104 stars, breaking a record of the number of human single-shot satellites. Relying on low-cost launch advantages, India is currently ranked first in the global commercial space service outsourcing field.

3.6.Commercial space in China

Compared with the development of commercial space in the United States, in addition to the state-owned commercial space companies, such as Science and Technology Rocket Company, Changguang Satellite Company, other private commercial space companies are in the initial stage of development. Especially don't have the ability to launch to the precise orbit. There are few micro-nano satellites that can be independently developed and operated, most of them are CubeSat.

Table 7 China commercial space companies [16]

Company	Position
Kegong Rocket	Launch vehicle R&D
Changzheng Rocket	Launch vehicle R&D
Yiling space	Launch vehicle R&D
Lanjian space	Launch vehicle R&D
Like space	Launch vehicle R&D
I-space	Launch vehicle R&D
Changguang Sat.	Satellite D&A (design and application)
Xingyun	Satellite D&A
Hongyun	Satellite D&A
Zhuhai Orbita Control	Satellite D&A
Spaceok	Satellite D&A
NineSky	Satellite D&A
Spacety	Satellite D&A

What's the most important thing is that China does not have a complete commercial space industry chain, and they lack experienced space engineers.

In addition, through the business of the above-mentioned commercial space companies and the disclosed technical solutions, most private commercial companies on the market mainly focus on the overall integration of the system, and few enterprises position them in the industrial development downstream of the industrial chain.

4. Discussion

4.1.The comparison between China and America in Commercial space

Comparing the various aspects of commercial space between China and the United States, the differences between the two are shown in the table. The development features of commercial space between China and the United States is quite different. The rapid development of commercial space in the United States benefits from three factors: firstly, perfect commercial space law and regulations. Second, the vast openness of space infrastructure and the strong funding support. The third is the mature commercial space industry chain and a large number of market-oriented space talents.

Table 8 The comparison of commercial space between China and America

	China	America
Policy and law	Encourage from the top level generally, but not effective in practice (laws do not promote activities)	The acts were formulated and promulgated since 60s last century and continuously improved.
Infrastructure	-Closed to the private partners	-Open for the private partners
Commercial contracts	-Less contract could be provided to private company from government.	-The complete contract and funding system could be provided to the private company.
Market	-Dominated by government-directed missions	-Mixed market -Civilian market, military market, abroad market.
Supply Chain	-Close system -Low commercialization. -Crowded in the system-level players. -Less qualified suppliers.	-Complete commercial supply chain. -Enough suppliers to support the system activities.
Technology innovation	-Closed innovation	-Open innovation
Brain	-Lower mobility. -The brain crowded in the state-owned company	-Higher mobility. -Brain gain could be easier for a new entrant.

Recently, the Chinese government is also formulating and promulgating relevant policies and regulations but compared with the third factor, the Chinese traditional space industry chain and engineer are basically sealed within the system.

Table 9 The Chinese policy toward commercial space

Commercial space policy	Main contents
State Council's guidance on encouraging social investment in the key innovation domain, Jan. 2014	Encourage **private capital** to develop, launch and operate commercial remote sensing satellites
Medium- and long-term planning for national civil space infrastructure, Oct. 2015	Support **private capital** to carry out value-added product development, operation services and industrialization promotion
Opinions on the integration of economic development and national defense development, Mar. 2016	It is clear that "the integration of military and civilians has become a national strategy"
China Space（White paper），2016	Encourage the **private capital** and social forces to participate in space science research and production, space activities such as infrastructure construction, space information services, satellite operations, etc. Developing commercial space
2017 National Defense Science and Technology Bureau Civil-Military Integration Special Action Plan	It has clarified 30 annual work in 6 aspects, which proposed to promote the integration of military technology into regional economic development. and continue to optimize the policy environment in the areas of investment, taxation, and access for attracting **private investment**.

On the road of self-supplement, China Space began with the imitation of the former Soviet P-2 missile. After more than 60 years, from 0 to 1, it has built a complete system of the space industry. Rockets and launch services, satellites and their applications, manned spaceflight, deep space exploration, and other aspects have achieved world-renowned achievements.

In terms of launch vehicles, China has three general design units for launch vehicles. At present, there are nearly 20 in-service series, ranging from low-orbit to high-orbit, from series to bundling, from single-star to multi-star, from the no-man to the manned. In the satellite field, there are 8 satellite manufacturers in total. China developed a series of satellites, including telecommunication broadcasting satellite series, “Fengyun” meteorological satellite series, “Shijian” scientific exploration and technology test satellite series, “Ziyuan” Earth Resources Satellite Series and the “Beidou” navigation satellite series. But as for the technical level and performance of the products, China still has a certain gap with strong players.

In the actual situation, whether it is the launch vehicle development, launch service, or satellite development and manufacturing, China doesnt miss anything or even has surplus capabilities in some aspects. But because of weak industry foundation (historical reason), the performance of products can't be the same level as traditional players in the world.

In a nutshell, I summarized the issues faced by China space by comparing with the strong player.

External issue:

The product lack of competitiveness, and a low degree of marketization.

Internal issue:

The traditional supply chain, technology, human resource are sealed in the national system, lacking mobility.

4.2.To explore the path of Chinese commercial space

The other issues we have to face is the huge national system can't be commercialized quickly. The internal issue is harder to resolve than the external issue. Therefore, I suggested the product and service strategy and System strategy to push the China space's transformation.

4.2.1. Product and service strategy (short-term)

- ***Leverage the technology advantages of incumbents, and improve the performance of the product.***

  - Launch

In recent years, SpaceX Corporation of the United States has significantly reduced the cost of rocket launch services through reused technology and new manufacturing process. At present, its global commercial launch market share has reached more than 30%. Compared with China's Long March series of launch vehicles, Chinese have no competitive advantage. They mainly focus on the domestic launch service market. In addition, in terms of carrying efficiency, engine performance, structural coefficient and other indicators or parameters of the rocket, there is no advantage with similar foreign launch vehicles.

Therefore, in terms of the commercial development of launch vehicles, the focus is on promoting technological innovation and improving rocket performance through commercial development methods, further reducing the price of launch services, enhancing the competitiveness of launch vehicles, and expanding the global launch market share.

  - Satellite manufacturing

Since China launched the first satellite "Dongfanghong-1" in April 1970, the products of China space have covered satellites such as telecommunication, navigation,

meteorology, and remote sensing. However, compared with the advanced level in foreign countries, there remains the big gap between satellite performance. In terms of overall indicators, such as short life and weak power supply. In terms of cost, the cost of achieving the same performance is higher. In terms of manufacturing, such as integration Low, poor manufacturing consistency, etc.

The difference in satellite performance is reflected in the performance parameters, more detail is in the system design capabilities, chips, materials, and industrial base. This gap can't be filled in a short term. But the improvement of top satellite performance can be reached in the short term through technology acquisitions. Meanwhile, the satellite, like a launch vehicle, also have a lot of room for cost reduction.

- ***Strengthen the satellite application in the market in order to drive the space players' marketization.***

Taking the telecommunication application as the example [17], China has limited satellite bandwidth resources. According to the annual report data of various companies, Asia-Pacific Satellite and Asia Satellite operate a total of about 14 Gbps of bandwidth, only parts of the resources are provided domestically. Synertone Comm is the Chinese subcontracting operator of Thaicom-4 "IPSTAR" with a total bandwidth of 45 Gbps. Chinese available bandwidth is 12 Gbps. In addition, China Satcom has some satellite bandwidth resources. In contrast, there are seven high-throughput satellites available in Europe, Qualcomm has available 8 satellites in, and they are mainly based on the Ka-band (the bandwidth of the Ka-band satellite can reach more than 100 Gbps). The satellite communication bandwidth resources available in China are significantly lagging behind. Thus, China will work to improve satellite communications capacity in the coming years.

In addition, in terms of earth observation industry, Data processing is always done in-house. The entire chain is sealed in a traditional area from the government funding to government end-user. In contrast, even though the government remains the first user for earth observation from the international perspective, but it has allowed the private company to share the market through providing the service. By fertilized with IT technology, Earth observation technology could be used widely (used for local-based service) and promoted quickly (high revisit). China should also strengthen the added-value service in Earth observation, to drive the satellite application widely.

4.2.2. System strategy (long-term)

Some policies have been promulgated by the government. I observe that most of them allow the private capital to enter the space field. But in terms of the new entrant who is funded by the private capital, the important issues are technology, human resource, and distribution channel.

The key technologies are always sealed in the incumbents (CAST, SAST, CAS). It is treasured for them through accumulated since the 60s. The talented person is also sealed in these state-owned enterprises, sometimes being surplus to requirements. The

distribute channel is also occupied by the state-owned enterprises in order to deter the new entrants.

Therefore, I suggested a System strategy to drive the national system to shift to the market system.

- ***Through top-down guideline, making the off-the-shelf technology and knowledge shift to the civil application.***

The government could set some guideline to help start-ups gain the off-the-shelf technology or knowledge. Firstly, many new entrants are designed to maximize the benefits reaped from commercial off-the-shelf technologies, from reduced manufacturing costs as well as from leaner industrial processes, to attract the low-end customer at the early phase, Secondly, this way could protect the advanced technology remain in the incumbents. They are designed to make benefits by sustaining technology innovation to meet the high-end requirements. Third, some off-the-shelf technologies are not obsolete. they aren't aligned with the direction of the company strategy in a specific period, therefore, to be off the shelf. These technologies maybe arise the new product through shifting to other application. These may be new markets to explore with these ideas, which the established company may be poorly suited to address.

- ***Encourage new entrants entering the more public missions, to form the healthy and strong industry chain***

The government should open the satellite application market for more players. Typically, the structure of space industry is the pyramid, more players should be needed in the downstream of the industry to meet the number of demands and get more revenue. Taking the telecommunication industry as the example, Satellite telecommunications will play a broad role in military, maritime, emergency, power, oil and gas, mining, civil aviation, and other fields. This needs a large number of players to provide the satellite application service. It is said that the Chinese telecommunication market is assessed about 34.3 billion yuan, of which 3.15 billion yuan is for satellites manufacturing.3.6 million yuan is for launch, and 1.4 billion yuan is for the construction of the ground. Finally, the satellite telecommunication service is 24.9 billion yuan. The huge benefit will also attract more new entrants.

The government should encourage the private company participating in the public mission. On one side, some strong private company with advanced civil technology could promote the space supply chain, on the other side, through increasing the competition between the private company and state-owned enterprise, it could reduce the development cost, and stimulate the product innovation.

Establish the perfect social insurance system and talent logistic measures to facilitate the availability and mobility of skilled workers

The most important reason to explain the talents fear to move is uncomplete social insurance system and talent logistic measures. These only can be seen in the state-owned company and universities, even though some private company has a better salary.

Therefore, the government should establish the perfect policy to protect the talents' basic benefit to facilitate the availability and mobility of skilled workers and high level professionals.

Under the high mobility labor market, the trained workers could diffuse the knowledge that they possessed from the fortified towers of internal R&D organization to suppliers, universities, consultants and other third parties etc. With information more widespread, new companies could access useful knowledge that previously they could not. One company could profit from the training and experience of another company by hiring away some of the latter company's workers, or through hiring consultants who used to work at another company. A fluid labor market permitted even start-up firms to pioneer the commercialization of promising new technological opportunities. For private companies, this fluid market created a powerful attraction to exit the larger firm for the opportunity to earn a significant reward. It also created strong reasons for individuals to invest in their own education, to learn as much as they could so that they might increase their value in the auction market for talents.

5. Conclusion

The process and results of the commercial space development in the United States reflect the complete commercial space development system with "national leadership, civil servicing for the military, and military leading civil". The commercial space company and the government have formed positive closed-loop feedback. Commercial space companies are profitable by providing cheap and reliable basic space services to government or commercial customers, while the government supports technology research and development and operations of commercial space companies through providing orders, project cooperation, and financial support.

Under the current environment of military-civilian integration, China commercial space industry should learn from the development experience of American commercial space to resolve the external issue and internal issue. The short-term strategy and long-term strategy are recommended in this paper. Two key points should be emphasized here. The products performances should be raised at a competitive market price. What's more important, from strategic point of view and in longer run, the more matured mechanism of civil-military integration and more smooth flowing talents pool should be established.

<End of dissertation>

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