Strategic Options for Chinese Space Science and Technology

A Translation and Analysis of the 2013 Report from the Chinese Academy of Sciences

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November 2013
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Commentary and Analysis

In April 2013 the Chinese Academy of Science (CAS) published *Vision 2020: The Emerging Trends in Science & Technology and China’s Strategic Options*. The report, which contains recommendations for the near-term development of Chinese science and technology, is a product of a policy planning exercise with a longer term focus called *Innovation 2050: Science, Technology and China’s Future*.

CAS assigned a group of more than 200 experts to review 12 different fields of scientific and technical endeavor for the *Vision 2020* report, including space science and technology. The information and recommendations these experts provide in the CAS report are intended to guide the science and technology policies of Chinese government departments, research organizations, universities, and commercial enterprises for the next decade.

UCS translated the section of the *Vision 2020* report devoted to Chinese space science and technology to give non-Chinese-language-reading observers access to an important internal assessment of China’s plans for space-related research and development. The translation is presented in the second part of this report. The language of the CAS report articulates the views of China’s leading space professionals on the role of space science and technology in the country’s ongoing social, economic, and political development.

**Shifts in Chinese Perspectives on Space**

*Vision 2020* upholds three objectives for national science and technology policy China established in the mid-1980s. The first is to keep abreast of developments in international science and technology that might lead to important breakthroughs. The second is to identify which potential breakthroughs could help solve urgent problems in China’s socioeconomic development and its national security situation. The final objective is to suggest areas where Chinese science and technology policies should be strengthened.

Although the objectives remain the same, the outlook for Chinese science and technology is more positive than it was thirty years ago. In the mid-1980s China’s leading scientists were concerned about falling behind in a rapidly developing international scientific and technical competition led by the United States. The *Vision 2020* report identifies the United States as the global leader, but today China’s scientific and technological community is looking forward to discovering areas where it can compete with the United States in scientific and technical innovation.

The *Vision 2020* report suggests space science and space technology play less prominent roles in this more confident Chinese outlook on the future of national science and technology policy. Moreover, the national security implications of space science and technology take a back seat in the report to apparently serious Chinese concerns about global warming, a pronounced interest in Earth observation, and high expectations for the increased economic returns from China’s space-related investments. Space debris, space environmental awareness, and the emergence of global norms for behavior in space emerge as new issues for Chinese space science and technology policy-makers. Human spaceflight remains politically important, but there are indications the program may eventually be forced to compete with other Chinese space priorities on economic, scientific, and technical grounds.

**Historical Context**

Debates about the relationships between science, technology, public policy, and national development occur in most countries, but they are pronounced in the history of contemporary China. Since China’s defeat in the First Opium War (1839-1842) successive
generations of Chinese intellectuals, reformers, and revolutionaries tied the survival of Chinese civilization to their ability to understand science and apply technology. Effective self-government free from foreign interference was their top priority. Scientific and technological development was focused on military defense.

This ethos played a decisive role in the Chinese Communist Party (CCP) leadership’s early decision to develop nuclear weapons and the missiles to deliver them. The CCP also sought to gain a quick foothold in space by committing to develop and launch a satellite at the same time. The Chinese Academy of Science played a central role in the satellite program, which from the beginning was infused with a broader, non-military vision of the role of space technology in China’s national development, largely because of the vision of Zhao Jiuzhang, the geophysicist who directed it. That vision was compromised by the chaos of the Cultural Revolution (1966-76), which cost Zhao his life, and the launch of China’s first satellite was transformed into a political exercise.

China’s effort to establish a comprehensive presence in space with satellite constellations for communication, navigation, Earth observation, and space exploration began in earnest in the mid-1980s after the chaos of the Cultural Revolution subsided. Chinese security concerns were mitigated through a rapprochement with the United States that afforded China access to U.S. scientific and technological expertise. Commercial and educational exchanges rescued a small, fragile, and aging Chinese scientific and technical infrastructure in urgent need of repair and rebuilding.

While these exchanges were deemed necessary, China’s longstanding quest for scientific and technical self-sufficiency continued. Senior scientists and engineers remained concerned that borrowing from abroad would always leave China a step behind. When U.S. President Ronald Reagan, who championed the exchanges with China, announced his Strategic Defense Initiative, China responded with Project 863—a massive investment in indigenous scientific and technology development that provided significant new funding for space technology.

The insecurities of the older generation of Chinese space professionals engendered a predominantly political and highly nationalistic orientation to space. The larger and more cosmopolitan generation of Chinese space professionals they created in the 1980s now seems poised to take China’s space program in a new direction. Project 863 was created to ensure that China did not fall too far behind in an imagined global scientific and technological contest for supremacy led by the United States. The Vision 2020 report narrows the language of competition to the quest for new scientific knowledge and technical innovation, and repurposes Chinese space technology for economic and environmental goals. Instead of focusing exclusively on competition and national benefit, the new CAS report also looks for opportunities where China might be recognized for its contributions to international efforts to further space science and improve the human condition. The CAS scientists and engineers working today in the space science center that bears Zhao Jiuzhang’s name are finally assembling the comprehensive suite of Chinese space capabilities the late Chinese geophysicist first envisioned in the 1950s.

A Focus on Earth Observation, Global Warming, and Sustainable Development

In The Physics of Space Security, which was recently republished in translation by China’s National Defense Industry Press, authors David Wright, Lisbeth Gronlund and Laura Grego highlight the military limitations of space-based weapons and the military vulnerabilities of satellites and note that space technology is uniquely well suited to the following tasks:

- Large-scale environmental monitoring of, for example, atmospheric behavior, climate change, and deforestation
- Large-scale weather monitoring for weather forecasting
- Astronomy
- Global communication, broadcast, and data transfer
- Highly accurate navigation and position determination
- Reconnaissance on a global or large-scale basis
- Detection on a global basis of missile launches, to provide early warning of attacks and information about the missile testing programs of nations.

The goals for China’s space programs discussed in Vision 2020 match up well with this list. Unlike the language surrounding Project 863, this new set of guidelines for the future development and application of Chinese space technology defines the principal national security benefit of space technology as the provision of a greater real-time awareness of the changes occurring
in China’s environment. Rather than defining China’s strategic interests in terms of keeping up with Reagan’s “Star Wars” program, Vision 2020 refocuses those interests on the problem of keeping up with the dramatic changes occurring in China’s environment and their impacts on the sustainability of national development. The report notes:

For example, over the past few years, industrially developed regions in the east have been experiencing large areas of blanket haze in the spring and summer, leading to such problems as airplane delays, routine collisions in high speed transportation, and increases in respiratory illnesses among residents. Urbanization reaching 56 percent has led to imbalances between regional populations and environmental resources. Against the background of global warming, there are problems with the marked effect suffered by critical traditional agricultural product yields in critical regions of China and the suitability of changing planting patterns. Migrations of harmful insects have broken through to larger boundaries of latitude and elevation. There are problems in predicting and preventing both agricultural disasters as well as communicable diseases between humans and animals. And there are other problems such as the situational analysis and prediction of extreme weather incidents impacting food security and the problem of scientifically and accurately responding to China’s commitment to realize a 40-45 percent decrease in carbon dioxide emissions by 2020.

CAS informs the Chinese leadership that while China is thoroughly integrated into a rapidly changing global economic and environmental system on which it now depends, “China still does not possess the ability to independently and quickly acquire high-resolution satellite remote-sensing data globally or for focal point regions.” The report argues that remediating this situation is “essential to safeguarding national strategic interests” and should be a primary focus of Chinese investments in space over the next decade.

Space Debris, the Space Environment and Codes of Conduct

The Vision 2020 report confronts the problem of space debris. Unfortunately, it does not call attention to the debris risks associated with the type of anti-satellite testing China conducted in 2007. Nevertheless, the CAS report does make clear that the Chinese space community is keenly aware that debris poses a serious risk to the long-term sustainable human use of space. Moreover, CAS warns that unless “effective measures” are adopted China will not be able to fulfill obligations it has made to the United Nations and other international organizations regarding the mitigation of Chinese created space debris. The report calls for a “significant strengthening” of “research and the construction of related fundamental infrastructure” enabling China to increase its capability to both monitor the space environment and establish early warning for potential impacts.

In addition to space debris, the harsh conditions of the space environment are also a threat to spacecraft. CAS informs the Chinese leadership:

At present, in the area of space debris and environment surveillance and early warning, China has already made certain advances, but there is still a distinct disparity when compared with developed countries. In the area of space debris, China’s research foundation is still relatively frail, and its abilities to independently observe and acquire space debris data are still insufficient, making it difficult to satisfy the requirements for space debris early warning. In the area of the space environment the independent observation required for China in environmental forecasting is still relatively weak, especially the foundation for a space-based survey. Currently there still is no space-based solar imagery surveillance. The quantity and orbital distribution of Earth space environment surveillance satellites are both extremely limited, making it impossible to satisfy the requirements for space environment forecasting.

CAS calls for a concerted effort to close the gap with developed countries in “space situational awareness,” which is also an emerging priority in U.S. space policy and planning. The report includes a number of specific recommendations including increased investment in the second phase of China’s Eastern Hemisphere Space Environment Ground-Based Integrated Monitoring Meridian Chain, also known as the Meridian Project.

The CAS report also contains a brief but potentially revealing comment on China’s position on international efforts to restrain national behavior in space. The report notes, “under the impetus of Europe, the United States is also gradually coming to accept a proposal to establish international norms for space behavior, and future space activities will gradually be constrained by
international standards.” China’s diplomatic efforts have been focused on an international treaty aimed at preventing an arms race in outer space and the Chinese Foreign Ministry sees the emergence of the European Code of Conduct as an unacceptable half-measure that could weaken international support for a binding treaty. But the Chinese Academy of Science, which historically plays a more direct and influential role over the development and implementation of Chinese space policy, seems to be suggesting to the Chinese leadership that if the U.S. is moving towards acceptance of some limitations on its freedom of action in space because of the European initiative, China should prepare to accept the same constraints.

Reform and Reorganization

China’s human spaceflight program and its robotic deep space exploration program, which includes the lunar program, receive the lion’s share of both the domestic and international media coverage of Chinese activities in space. But the CAS report suggests that without reforms in Chinese national space policy and administration, neither program should be expected to make significant contributions to the primary objective of China’s national investment in space science and technology, i.e., the pursuit of new scientific knowledge and technical capabilities that serve overall national development. This is not because the programs are unsuccessful, but because they are not organized and administered effectively. CAS applauds the achievements of China largest and most expensive space programs:

Yet, behind this phenomenon of prosperity there is still a lack of coordination in systems and mechanisms. For example, the essence of human spaceflight and deep space survey programs is the human exploration of space, with the goal of scientific discovery and scientific research, thereby motivating technological development. The managing organs executing these two programs, however, are not the same ministry, and these two organs do not have the function of developing science. This then has unavoidably made it so that these two programs have an intense emphasis on the project mission and technological breakthrough. After project missions are satisfactorily completed, the goal of future sustainable development is lost.

The report indicates that China’s applied satellite programs also suffer from a similar lack of effective organization and administration:

In the area of space applications, China has launched a large quantity of application satellites, but because of separation between ministries, there is a lack of unified planning and coordination, data sharing rates are extremely low, and the phenomenon of redundant acquisition of the same or similar data is commonplace, creating low-level redundancy.

CAS argues that Chinese space policy should be placed back under the control of a single special committee and that an “actual national space ministry” should run all space activities and programs. The Chinese National Space Agency does not have the budget, the personnel, or the political authority to play that role. If enacted, the reforms CAS recommends in the Vision 2020 report would put all military, commercial, and scientific satellite programs under a unified administrative organ that reports directly to the central political authorities. Such a development could radically transform China’s current approach to national space policy, including making it more transparent and accountable to the expectations of the international space community.
Space Science and Technology: Discovering the Basic Laws of the Universe, Harnessing the Strategic Resources of Space

Outer space is humankind's fourth frontier, after land, sea, and air. Beginning in 1957, with the first successful launch of a human-made satellite into Earth’s orbit, numerous scientific discoveries combined to reveal an entirely new image of the universe. Over time, this image revolutionized the way that people understand nature and themselves, thereby leading to profound changes in humanity’s modes of production and way of life. Today, an increasing number of countries recognize that space technology not only serves to expand the realm of human understanding. It also has practical applications capable of transforming entire nations. The field of space technology is characteristically forward-looking, but what makes it irreplaceable is how it blends its progressive outlook with a unique set of priorities based on the importance of innovation and technological integration. Of all the fields of human inquiry that focus on the merging of technology and science, the field of space technology is the most powerful source of support for a country’s economic and social development.

Development of Space Science and Technology in the Next 10 Years: New Trends and Characteristics

Space science and technology is a field in which science and technology are closely interwoven. Currently, the primary focus of humankind's space exploration is the moon, Mars, and asteroids. We are striving to probe ever deeper and more remote corners of the universe, continuing to explore its origin and evolution, to understand the nature of dark matter and dark energy, and to unveil the mechanisms behind solar flares. The main body of the International Space Station (ISS) has been completed and is expected to produce a steady flow of new scientific knowledge and benefits. At the same time that Earth observation satellites have been covering the physical parameters of each layer of the planet, they have also been monitoring the effects of human activity on the Earth, especially that resulting in global greenhouse emissions, so as to respond to climate change and to the need to satisfy requirements for the long-term survival and development of the human species. Trends and characteristics in space technology development over the next 5 to 10 years also include better monitoring of the space environment, improved early-warning systems for space debris, the establishment of an internationally recognized space code of conduct, and the transition towards the marketization and commercialization of space technology.

RESEARCH IN SPACE SCIENCE HOLDS MAJOR BREAKTHROUGHS

EVIDENCE OF THE POSSIBILITY OF LIFE OCCURRING OR LIFE SURVIVING OUTSIDE OF THE EARTH SYSTEM

Currently, research into Mars has already discovered proof of the existence of a large quantity of underground water, as well as other indicators of the possible existence of life. The American Mars probe Odyssey has already detected direct evidence of shallow ice within one meter underground. Water is the source of life, and no forms of life of which we are currently aware can exist without water. Liquid water is an important marker indicating the existence of life. Surface telescopes and the European Space Agency’s (ESA) Mars Express have both detected methane in Mars’ atmosphere, and scientists deduce there are localized methane
gas sources or sinks on Mars. Ninety percent of the methane in Earth’s atmosphere comes from biological activities and the question of whether or not underground microorganisms produce the methane in Mars’ atmosphere awaits further research and exploration. The American Mars lander Phoenix discovered perchlorate at the landing site, and perchlorate is an important chemical compound used by microorganisms for metabolism. Scientists deduce that the landing site may be a zone suitable for the existence of life. In August of 2012, the American Mars lander Curiosity successfully landed on the surface of Mars, which was the most complete Mars scientific laboratory that humankind has ever launched into the sky. The two planned flights of the European Space Agency’s (ESA) life on Mars exploratory mission (ExoMars) are scheduled for 2016 and 2018. The probe will land on Mars, and begin deeper explorations into the existence of life on Mars.

In terms of Europa exploration, after analyzing data from the Galileo probe, American scientists have recently confirmed that hidden under the surface ice layer of Europa is a large quantity of relatively warm salt-containing liquid water. The cycling between ice and water makes possible the transmission of energy and nutrients between the surface of the celestial body and the hidden water. New evidence also indicates that a large, shallow lake of water exists under the surface of Europa, which also makes this satellite very possibly suitable for the existence of life.

It can be predicted that the discovery of life or proof of the existence of life outside of Earth’s system would be an important breakthrough in humankind’s understanding of the objective world and of ourselves, and would greatly expand humankind’s knowledge of life’s phenomena and patterns.

**EXPLORATION OF ONE BLACK—TWO DARK—THREE ORIGINS HAS PRODUCED A LARGE NUMBER OF SCIENTIFIC DISCOVERIES, AND MAY TRIGGER A NEW REVOLUTION IN PHYSICS.**

Since the 16th century, astronomical research has led to six leaps in humankind’s understanding of the universe, including: the establishment of heliocentric theory, the solar system is not the center of the universe, the galaxy is not the entirety of the universe, the universe is expanding, the universe originated in the big bang, and the universe’s expansion is accelerating.

We now realize that the universe contains only two types of oddities—black holes and the big bang.

One black refers to black holes, one of the universe’s oddities. A large amount of astronomical observation indicates that within the universe, black holes of a mass several times greater than the Sun are scattered throughout the galaxy, and in the center of almost every galaxy exists a black hole of huge mass. However, the secrets of the black hole are far from being understood, and future research will produce important breakthroughs in the areas of the black hole’s form and evolutionary mechanism, the influence of the black hole’s feedback on the surrounding environment and the formation and evolution of the universe’s structure, the space-time structure and patterns of matter movement near the black hole, and a final test of the general theory of relativity, etc.

Two dark refers to dark matter and dark energy. Astronomical observation indicates that of the total matter and energy of the universe, 23 percent is dark matter which does not emit light but has gravitational effects, 73 percent is dark energy which has negative pressure, and only 4 percent is normal matter which can be explained by the current Standard Model of physics. Dark matter and dark energy are known as the two new black clouds shrouding 21st century physics, and challenge gravitational theory and the Standard Model of physics. In 2011, the Nobel Prize in physics was awarded for successes in astronomical observational research, namely the discovery of accelerating expansion in the universe and the demonstration of the existence of dark energy.

However, at the present moment we still know almost nothing about the characteristics of dark matter and the nature of dark energy. Dark matter and dark energy played a decisive role in the history of the universe's evolution, and will also determine the universe's future and destiny. Research into these areas may very well bring about a new revolution in physics.

Three origins refer to the universe's origin in the big bang, the origin of each celestial body and structure within the universe, and the origin of life. The big bang is the other oddity of the universe, and we currently cannot yet understand how the universe was created; we don't know whether or not there is only one universe now, or whether there was only one universe in the past. The origin of each celestial body and structure within the universe, as well as the origin of life, are important questions that still perplex humankind to this day. In the future, research will address such scientific questions as the formation of large-mass stars, the formation of star clusters, the initial conditions for the formation of stars, the purpose and evolution of stars' surrounding discs, whether or not life originated on a celestial body outside of the solar system and how life evolved.

Therefore it can be said that one black, two dark constitutes the skeleton of the universe, and three origins constitutes the flesh of the universe. Exploration surrounding these scientific topics has the potential for numerous scientific discoveries, and may trigger a new revolution in physics.
RESEARCH INTO THE MECHANISM OF SOLAR ERUPTIONS, AND THE CHAIN REACTIONS TRIGGERED BY SOLAR MATTER IN INTERPLANETARY AND EARTH SPACE WILL PROVIDE SCIENTIFIC SUPPORT FOR HUMANKIND'S LONG-TERM DEVELOPMENT

The Sun is the closest star to us and is also an energy source necessary for the life of humankind and the Earth. The effect of the Sun's activities on the Earth's space environment, on global changes, on the basic conditions of the Earth's surface and air, and on humankind, is increasingly attracting the attention of the world. In recent years, this field of study has made a series of important achievements. In terms of the origin of solar winds, first the three-dimensional structure of the polar region's coronal holes and open magnetic fields was reconstructed, which determined the formation height of the solar wind's initial outflow. Furthermore, from this was extrapolated a new three-dimensional image of the solar wind's origin. In the heliospheric space, Voyager 2 was used to detect data and numerical models, and carried out direct, on-the-spot observation of the terminal shock waves on the edge of the solar wind. This is the first time in human history that information was sent back from the edge of the solar system. In terms of magnetic field reconnection, the European Space Agency's Cluster Project was used, for the first time directly observing proof of magnetic zero in the Earth's magnetotail. Furthermore, satellite observational research of intact three-dimensional magnetic reconnection geometric structures was completed. At the same time, based on the magnetic field data detected by Europe's Mars Express, the phenomenon of magnetic field reconnection was discovered in the induced magnetosphere of Venus for the first time.

In the next 5 to 10 years, humankind will conduct multiband, around-the-clock, high resolution, and high precision observations of the Sun. In particular, unmanned vehicles will be able to withstand intense heat, for the first time allowing close observation of the Sun, and mechanics of the Sun's activities will be revealed. Research on the relationship between the Sun and the Earth increasingly emphasizes the holistic linking processes in the Sun-Earth system, and observation system for integrated space-based and Earth-based elements are improving daily. The processes of space weather will be examined on both the macro and micro levels, with a special emphasis on the entire course and basic physical processes of the formation, release, transmission, transformation, and dissipation of large-scale turbulent energy from space weather incidents. Understanding the impact of solar electromagnetic radiation and high-energy particles on changes in global weather, namely the routes and mechanisms by which this takes place, and launching quantified evaluation thereof, will become an important frontier in the research of natural factors in global change. The chain reaction processes of solar movement—interplanetary space turbulence between planets—Earth space storms—Earth global change—human activities will become a primary focus in Sun-Earth relations research. Since it is closely related to human survival and development, future discoveries and breakthroughs in this area will provide scientific support for humanity's long-term, sustainable development.

ESTABLISHMENT OF THE INTERNATIONAL SPACE STATION WILL CONTINUOUSLY GENERATE NEW SCIENTIFIC KNOWLEDGE AND BENEFITS

In November 2011, construction on the main body of the International Space Station was completed, and it entered an era of comprehensive use. During the course of the construction of the International Space Station, 1,309 research personnel from 63 countries already launched 1,251 space science and application research projects, leading to major scientific achievements in such areas as the measurement of the thermal physical characteristics of materials, the three-dimensional organizational structure of cells, the crystalline growth of proteins, gene expression disparities in microgravity, and microbiological pathogenicity.

The International Space Station has already entered an all-new scientific research and application stage. In 2011, the number of life science and physical science research projects held at the International Space Station grew over one hundred percent. In 2012, United States funding for scientific research on the International Space Station increased nearly 50 percent. Such capabilities as an uninterrupted microgravity environment, an external vacuum radiation environment and stable materials replenishment, six astronauts operating in orbit for long periods of time, and 110kW of power have made the International Space Station a unique space science and technology lab. The effective payload of the International Space Station represents the most advanced space science and technology levels in the world today. The 29 internal experiment cabinets provide highly integrated laboratories for research on human anatomical science, life sciences, fluid physical science, combustion science, space materials science, and Earth observation. An external truss supports astronomical, space physics, and space technology test loads. In 2011, led by Nobel recipient Samuel Chao Chung Ting, the Alpha Magnetic Spectrometer (AMS-02), construction of which took 17 years, was installed on the International Space Station. Its weight is nearly 7.5 tons and is used in surveying cosmic rays and seeking out dark matter and antimatter and understanding the origins of the universe. In 10 months of work it has already observed 13 billion incidents.
The main countries and organizations participating in the International Space Station are all intensely arranging more science and application research while researching and developing more high-level science application payloads to send to the International Space Station. The European Space Agency is currently researching and developing container-less processing experiment cabinets and plasma physics experiment cabinets, and plans to send the Atomic Clock Ensemble in Space (ACES) to the International Space Station in 2015. In addition, it has also deployed the Atmosphere-Space Interactions Monitor (ASIM), which is a climate change-monitoring platform that surveys atmospheric electrical discharge. Research and development for the Japan Aerospace Exploration Agency's (JAXA) electrostatic suspension furnace experiment cabinet is already nearing completion and it is anticipated that its Calorimetric Electron Telescope (CALET) will be sent to the International Space Station in 2013 to survey wide energy spectrum electricity and gamma rays, with the goal of surveying dark matter. The Japan Aerospace Exploration Agency is currently also in the process of pushing a plan for diffracted Earth atmospheric Cherenkov beam survey of very high-energy cosmic rays. The International Space Station will continue operating until at least 2020. It is anticipated that thousands of scientific experiments, scientific observations, space applications, and technology tests will be held there, making it the largest-scale space research activity in the history of humanity and possibly leading to a series of major research achievements.

THE CORE OF EARTH OBSERVATION IS DIRECTED TOWARD THE IMPACT OF HUMAN ACTIVITIES ON THE EARTH, AND IS DEVOTED TO RESOLVING THE MOST URGENT GLOBAL PROBLEMS

The International Council for Science put forth its 10-year plan and declaration on Future Earth in London in 2012. This plan proposes the use of innovations in science and technology to build a Future Earth global research platform to help resolve the challenges of the world's three most urgent problems. These three most urgent problems are, respectively, how to satisfy water and energy requirements while experiencing high-speed growth in the human population; how to prevent natural and manmade disasters; and how to more accurately measure greenhouse gas emissions at the national level and realize the verification of national emissions-reduction goals and international emissions-reduction promises.

To deal with the globe's most urgent problems, the international community across the board has come to realize that it is necessary to strengthen scientific research on global systems, improve integrated systems of Earth observation and prediction, utilize comprehensive space information to provide support for decision-making, build platforms for managing networks, improve the level of global-scale observation resources and data information resources sharing, deal with and ameliorate the negative changes currently taking place in the global system, and guarantee human survival and development.

In order to monitor the impact and changes generated by the land-atmosphere-ocean natural state and human factors on the Earth, since the 1990s the United States' Earth Observation System (EOS), Global Earth Observation System of Systems (GEOSS), and Global Monitoring for Environment and Security (GMES) plans, the European Space Agency's Environmental Observation Satellite (ENVISAT) plan, and Japan's Advanced Earth Observing Satellite (ADEOS) plan have been sequentially proposed and implemented, building a space-air-land three-dimensional technological and application system for coordinating observation of changes in the global system. Of unprecedented global scope and over a sustained time period of more than 10 years, these plans have provided information about long-term changes in global atmospheric physical elements and chemical composition, ocean surface dynamic physics and biomass, biological and physical situations on the Earth's land surface, global magnetic fields and mass distribution, and cryospheric changes. They have also accurately observed the solar radiation around the globe and changes therein. While systematically observing the natural changes in the globe's various spheres, global observation systems have also observed on a global scale a sustained increase in the density of greenhouse gases such as carbon dioxide caused by human activities at the local and global levels involving the combustion of large quantities of fossil fuels, which results in excessive carbon dioxide emissions, as well as increases in other pollutants and aerosols. Humans have also greatly changed the Earth's surface albedo and Earth surface greenhouse gas emissions through soil usage. The United States' National Aeronautics and Space Administration and the European Space Agency have successively established and put into operation such network data assimilation and sharing systems as the North America Land Data Assimilation System (NLDAS), the Global Land Data Assimilation System (GLDAS), and the European Land Data Assimilation System (ELDAS). They have shared over 80 global change information products and multiple models, and at the same time interactively loaded models and data products. This series of observation achievements played a positive role in achieving consensus about the need to slow down and deal with global changes during United Nations Conventions on Climate Change (UNCCC) such as those held at Copenhagen in 2009, Cancun in 2010, and Durban
in 2011, as well as in United Nations Climate Change Talks, and have played a supporting role as various countries devised regional sustainable development strategies for 2020.

Currently, an important frontier in international Earth observation systems is the development of global greenhouse gas satellite surveillance systems, the launch of research into Earth system carbon cycles, and at the same time, through the construction of a satellite-surface observation network for atmospheric greenhouse gas density distribution and change assimilation, systematically support a detection system to check the emissions-reductions of each country as they deal with climate change. Of these, greenhouse gas surveillance; cloud and aerosol surveillance; global precipitation surveillance; and ocean, ice, and snow change surveillance will still continue to be the crucial pillar supporting climate change research and forecasting.

HUMANS’ RELIANCE ON SPACE IS RISING, AND THE DEMAND FOR SURVEILLANCE AND EARLY WARNING OF SPACE DEBRIS AND THE SPACE ENVIRONMENT IS BECOMING INCREASINGLY PRONOUNCED

In the wake of global economic and social development, humankind’s degree of reliance on space is continually increasing. Navigation, communications, television broadcast systems, weather forecasts and disaster surveying all rely on space systems consisting of human-made satellites. To guarantee the safety of space activities, the demands of the world's aerospace powers for information on space debris and the space environment are becoming increasingly pronounced. If a chain of collisions were ever to occur between orbital satellites and space debris, it would become impossible to enter space, and space systems would experience total paralysis. At the same time, the threat posed to space systems by solar eruptions could also generate temporary paralysis or even the permanent loss of space systems.

Over the past few years, countries and regions such as the United States, Russia, and Europe have been improving their surveillance and forecasting capabilities for space debris and the space environment, and have created an enormous surveillance and forecasting system. This has also given rise to the following developmental trends: the conduct of continuous observation and catalogue management of space debris (at present, the quantity of space targets currently on record already exceeds ten thousand, but the actual quantity is far greater than this); the formation of integrated space-Earth observations systems for surveying the space environment as well as the gradual formation of an origin-process-result cause-and-effect chain of surveillance; guaranteeing that service systems are gradually improved as the users being served gradually expand to include all space systems users; under the impetus of Europe, the United States is also gradually coming to accept a proposal to establish international norms for space behavior, and future space activities will gradually be constrained by international standards.

SPACE TECHNOLOGY WILL FURTHER REALIZE COMMERCIALIZATION AND MARKETIZATION

As opposed to the period of the Cold War, space technology is in the process of heading from unfathomable sophistication to civilian use, commercialization and marketization. The development of the American Space-X company has already shown that commercial enterprises can also complete high-precision, sophisticated tasks such as manned space flight, and furthermore can greatly lower costs. High-precision, sophisticated satellite technology is also gradually heading towards commercialization, and costs are being lowered through modularization and standardization. This is especially true of the micro- and nano-satellite technologies which have rapidly developed over the past few years, and which have allowed the functions of a large satellite to be separated and carried out by multiple microsatellites of low cost, reliable quality, and high redundancy.

Major Space Science and Technology Requirements Necessary for Building an Innovative Nation

As an extremely cutting-edge, innovative, challenging, and leading scientific and technological field, space science and technology will play an increasingly important role as the nation's innovation drive develops.

MAKING BREAKTHROUGHS AND IMPROVING HUMANITY’S ABILITY TO UNDERSTAND THE OBJECTIVE MATERIAL WORLD

The scientific revolution has had an extremely large impact on the course of human development. The history of contemporary science has already clearly shown that a large quantity of scientific discoveries and important advancements have come from the exploration of the universe and outer space, such as the United States' Hubble Space Telescope's (HST), which has played a key role in the discovery of dark energy, and the United States' Kepler Space Telescope, which has fundamentally altered the pattern of
research on planets external to the solar system. Research has shown that the nature of the Earth, which we rely upon for survival, is incredibly sensitive to the nature of the universe, the forms of the basic laws of physics, and the values of the basic parameters of physics. This implies that there are close, but not yet fully understood, connections between the source and evolution of the universe, the basic laws of physics, and the formation and evolution of life. If a breakthrough is made in any one domain, it would provide new inputs and boundary conditions for the other domains, and could trigger a series of breakthroughs, or even lead to a new scientific revolution, profoundly altering humanity's understanding of the objective material world and advancing the development of human civilization.

Scientific discovery has only firsts, no seconds. As one of the world's ancient civilizations, China has historically played a decisive role in the observation and exploration of the cosmos. In recent times, however, the Chinese people as a whole have yet to make substantial contributions to space science knowledge or discovery; this includes humankind’s six major leaps in understanding the universe, and also the numerous and revolutionary scientific discoveries made since human-made satellites took to the skies. As a world power with a rapidly-developing economy and growing international influence, China's degree of contribution to space science knowledge is disproportionate to her status as a great power, and does not conform to China's goal of building an innovative nation.

Making predictions based on current development, during the 21st century the field of space science will give rise to revolutionary breakthroughs in physics, astronomy, the life sciences, and Earth science. In this new round of scientific exploration, China should seize the opportunity to strive for major scientific discoveries and breakthroughs in basic theoretical research, and through this put to work the Chinese people’s important role in the exploration of the cosmos and in improving humankind’s ability to understand the objective material world.

**LEADING AND MOTIVATING CHINA'S PATH BREAKING DEVELOPMENT OF RELATED HIGH TECHNOLOGY**

Space science satellite projects involve many new demands, new ways of thinking, new designs, and new manufacturing methods, and as such are an important source of innovation. They play a clear role in leading and motivating development within aerospace technology and related high technology. Space science satellites differ greatly from application satellites. In terms of orbital design, even if science satellites are operating within Earth space, the majority still require specialized orbital design far exceeding that of conventional application satellites, such as large elliptical orbits, low perigee orbits, frozen orbits, and formation flying orbits, etc. Due to the impetus of deep space exploration projects, the use of planetary gravity-assisted flight technology has already become commonplace. In the past few years, new orbital design theories have also appeared, such as the Interplanetary Superhighway (IPS) theory. In terms of interplanetary propulsion technology, solar sail propulsion technology and nuclear propulsion technology have already been developed. In the area of satellite structure and thermal control, there has already been a breakthrough in the concept of relative independence between platform and payload for space science satellites. An integrated platform and payload design concept has been created, and the configuration of a large quantity of science satellites has already changed drastically. In the area of effective payload technology, scientific observation and exploration need to obtain data that exceeds that of predecessors in the areas of detection windows, ultrahigh space resolution, ultrahigh sensitivity, and ultrahigh time-space criteria. As a result, it is necessary to realize new design and technology innovations. Therefore, each space science satellite project is both non-redundant and not for production, and involves many new lines of thinking and new designs; they play a clear and comprehensive role in leading and motivating the development of aerospace technology and related high technology.

Innovations in space science and technology also play an extremely powerful leading and motivational role in the development of related high technology and industry, and can promote development by leaps and bounds. Taking the United States Apollo program as an example, many 20th century Apollo program technologies have already been successfully transferred to other domains, greatly advancing the development of related high technology in other science and technology domains, as well as changing the daily lives of the people. For example, the CT scan imaging technology that we commonly use today has its origins in the Apollo Program and laptop computers are also a product of computer miniaturization originally proposed for the Apollo spacecraft. Global positioning and navigation technology, which is already part of daily life, also has its origins in the accomplishments of astronomical research. Some of the biological and pharmacological experiments currently being implemented on the International Space Station are already approaching application, and it is hoped that marketization will be realized in the near future. The results of space materials science research is hoped to provide high quality materials that are difficult to obtain on the Earth's surface, while the transfer of its technological achievements to the Earth may greatly advance processing and manufacturing
methods for Earth surface materials. Around 1990, American scientists conducted a special examination of the contributions made by the United States' National Aeronautics and Space Administration (NASA) to the national economy, and they concluded that for every U.S. dollar invested in NASA's space projects, 14 U.S. dollars in economic stimulative effects were generated in the United States' national economy. The 2002 Strategic Aerospace Review for the 21st Century published by the European Commission pointed out that Europe's space activities played a crucial strategic role in the area of guaranteeing Europe's security and economic prosperity. They were called the engine of wealth, driver of innovation, garden of new materials, new manufacturing methods, and new technologies, and the pillar for maintaining global competitiveness, thus giving high praise to the important strategic role held by space science and technology in Europe.

On China’s journey to build an innovative country, following in the footsteps of advanced foreign technology will no longer be able to satisfy China's demands for sustainable development. Therefore, vigorously developing space science and technology, leading and motivating rapid development in related high technology domains in China, and extending gains into other science and technology domains and industries is an important requirement for China's development strategy of building an innovative country in the new age as well as a major strategic requirement for increasing the country's science and technology strength and overall competitiveness.

DEALING WITH THE MAIN ISSUES FACED DURING DEVELOPMENT, SAFEGUARDING NATIONAL STRATEGIC INTERESTS

At the same time that China is promoting innovation to drive development, accelerating industrial modernization, urbanization, and the establishment of modernized agriculture, it is also facing new issues and new challenges in the course of development. For example, over the past few years, industrially developed regions in the east have been experiencing large areas of blanket haze in the spring and summer, leading to such problems as airplane delays, routine collisions in high speed transportation, and increases in respiratory illnesses among residents. Urbanization reaching 56 percent has led to imbalances between regional populations and environmental resources. Against the background of global warming, there are problems with the marked effect suffered by critical traditional agricultural product yields in critical regions of China and the suitability of changing planting patterns. Large area migrations of harmful insects have broken through boundaries of latitude and elevation. There are problems in predicting and preventing agricultural disasters as well as communicable diseases between humans and animals. And there are other problems such as the situational analysis and prediction of extreme weather incidents impacting food security and the problem of scientifically and accurately responding to China's commitment to realize a 40-45 percent decrease in carbon dioxide emissions by 2020.

At the same time, accompanying the strategy of heading out China has already carried out investment and cooperation with over 170 countries and regions, gradually becoming a global great power, with national strategic interests also continually expanding. At present, China still does not possess the ability to independently and quickly acquire high-resolution satellite remote-sensing data globally or for focal-point regions. This has become a shortcoming for the country in mastering information about global developmental and strategic environments essential to safeguarding national strategic interests. Dealing with the main issues faced during development, safeguarding national interests, and realizing the ability to expand space information support to wherever national strategic interests extend have imposed urgent demands on space science and technology. Strongly developing space science and technology will provide an important bolster and support services for national macro-level decision making and strategic development.

BOLSTERING THE LONG-TERM SUSTAINABLE DEVELOPMENT OF SPACE ACTIVITIES

Since the first manmade Earth satellite took to the skies in 1957, humans have launched approximately 8,000 spacecraft, and there are nearly currently 3,000 operating in orbit. The space waste left behind during the course of human activities in space becomes space debris. Space debris primarily originates from inoperable spacecraft, rocket bodies which no longer work, items cast off by satellite launches or during satellite work (camera lens covers, packaging, empty fuel tanks, effective load fairings, separated apparatuses, and spin apparatuses, etc.), fragments created from space item explosions or collisions, material (such as paint, etc.) which has fallen off the surfaces of spacecraft, material (such as coolant, etc.) which has leaked, and solid granules ejected during solid fuel rocket operation, etc. The daily degradation of the spacecraft operating environment has already seriously impacted the safety of human activities in space. For example, one of the possible reasons for the space shuttle Columbia accident was an encounter with space debris. How to reduce and deal with space debris has already become an issue receiving international attention.
The facts of human aerospace activities over the past few years show that the security, performance, and operating life of the various spacecraft operating in the outer space environment are without exception impacted and constrained by the space environment, especially disastrous space weather incidents. These kinds of impacts and constraints could cause spacecraft to experience malfunctions and abnormalities, leading to a decrease in system performance and, when serious, leading to complete system breakdown. According to statistics, the proportion of satellite malfunctions and abnormalities caused by space environment factors is nearly 40 percent. Dramatic changes in the Earth's space environment caused by solar activity can also lower the quality of satellite communications, navigation and positioning, and even completely cut off signals, constituting a serious threat to safety for the health and lives of astronauts. Following the arrival of the peak year of activity for solar cycle 24, the disastrous impact dramatic solar activity flares (solar super flares) have on human production and infrastructure has also been gaining an increasingly high degree of attention.

If effective measures are not adopted to solve the aforementioned issues, the long-term sustainable development of human activity in space will be severely impacted. The daily lives of the people and economic and social development will also be affected, and there will be no way to meet obligations to United Nations and other relevant international organizations to reduce space debris and realize commitments made to the global community.

Therefore, it is necessary to greatly strengthen research on space debris and the construction of related infrastructure, and to improve space environment surveillance and early warning capabilities.

The Country Needs to Strengthen the Strategic Layout of Focus Points in Space Science and Technology

Over the past 5 years, China has successfully launched the Chang E 1 and Chang E 2 satellites; has very successfully carried out manned aerospace rendezvous and docking tests; the Special Space Science Strategic Pioneering Science and Technology Projects have started a new chapter in China's space science development; and various types of application satellites, exemplified by the Beidou navigation satellite, have successfully been operating in orbit. China's space science and technology has been developing rapidly, and earned a high degree of attention from international space circles. Currently, China is making the journey from being a major power in space to being a strong power in space. Heading towards the year 2020, not only do we need to master the new trends and characteristics of development in the field of space science and technology but, more importantly, we must also make full use of its important supporting role in the country's socioeconomic development and national security. Through reasonable innovations in system mechanisms and prompt assignment of strategic focal points, we can greatly improve our capacity to innovate in space science and technology, and thus provide powerful scientific and technological support for seizing the strategic high ground in space development.

CONTINUAL SUPPORT FOR A SERIES OF SPACE SCIENCE SATELLITE PROJECTS

Space science is an important source of major scientific breakthroughs and technological innovation. As of today, over 80 percent of the contributions humankind has made in the field of space have come from the space programs implemented by the United States and Russia, with the remainder coming from Europe, Japan, etc. There are almost no contributions from China. Compared to the strong aerospace powers, China's space science and exploration program is just getting started. As a world power with a rising economy, we should make appropriate contributions to world scientific development at the same time as our economy is rapidly developing, especially in the field of space science, which involves basic issues of human development and has the potential for major scientific breakthroughs. Through developing space science, we can not only make contributions to the development and advancement of world civilization, but also promote the development of fields such as technology, economy, and national defense within China, and infuse a steady flow of vitality into China's building of an innovative country.

Within the country at present, under the framework of the Special Space Science Strategic Pioneering Science and Technology Projects, the Chinese Academy of Sciences is in the process of organizing engineering development for the “Twelfth Five-Year Plan” space science satellite mission. The intention is to launch space science satellites to directly acquire firsthand survey data and make major discoveries or breakthroughs in this cutting-edge scientific domain. However, we must recognize that the timeframe for a space science mission, from the concept proposal, engineering research, and launch into space, to the achievement of scientific results, is often years or even decades. We have to establish a complete chain, from the original proposal of the scientific ideas and strategic planning to the production of scientific results, and only with sustained and stable support for
As such, after making a start with the Special Space Science Strategic Pioneering Science and Technology Projects, it is suggested that China establish a long-term space science satellite series program with stable support, incorporate it into the country's conventional science and technology program system and, through sustained support for space science satellite missions, consistently achieve advanced world-level scientific results, gather and stabilize a team of strongly innovative persons talented in high technology, lead and motivate high technology development, and promote comprehensive increases in the country's scientific and technological strength.

PREVIEW OF THE ARRANGEMENT OF CHINA'S SPACE STATION SPACE SCIENCE AND APPLICATION RESEARCH

China will launch the core module for a space station and two experiment modules around 2020, complete the assembly and construction of a 60-ton level near-Earth orbit space station, and operate it for 8 to 10 years. It will possess the ability to support 17 tons of effective space payloads.

The major benefits of the space station will be concentrated and embodied in the areas of space science and application. At present, China is planning to begin developing research work on space science, technology, and applications. China's space station is vetting proposals on a number of leading-edge space science issues: resolving the main medical issues of long-term piloted spaceflight, exploration of dark matter and dark energy in the formation and evolution of the cosmos, the fine structure constant and comparison of space-to-Earth time-system precision/general theory of relativity experiments, macro-level low-temperature quantum-state cold-atom physics research, research on the form of existence, reactions, and origin and evolution of life in extreme conditions, and research on the relationship between changes in the Sun and the Earth. It will further strive to make major discoveries with international impact and improve China's overall space science levels. It also proposes a series of technological innovation projects striving to make major breakthroughs in technology, including large, multifunction space active optics and cold optics systems, quantum adjustment and control and photo-communication, X-ray pulse satellite navigation, and terahertz communications.

The use of China's space station will become China's largest-scale piloted space science and application plan, and a strategic project for China to promote leading-edge space science exploration and inspire future space application technology development. This is an enormous challenge pregnant with opportunity. The next five years is a crucial stage that will determine the space science and application missions of China's space station that requires an increased investment in space station space science and application missions, strengthening research on relevant space science research and arrangements for advanced payloads, continuous innovative scientific thinking, new concepts, and new methods to make China's space station the most important space laboratory in the later international space station age. This will also propel the important domain of Chinese space science into the world's leading ranks and motivate future Chinese development in the area of new, high-level space technology. Progressive strengthening of the space science arrangements for the space station is recommended.

ESTABLISHING A SYSTEM FOR SURVEYING GLOBAL CHANGES RELATED TO HUMAN ACTIVITY

At present, new rounds of Earth-observation programs are continually being proposed at the international level. At the same time, however, because of a sustained downturn in the world economy, the continuation and expansion of Earth-observation systems by various principal countries is facing difficulties. China has already arranged pre-2020 service satellite and special project satellite programs, including those for weather, oceans, environment, resources, and mapping. Faced with the challenge of global changes, it needs to arrange a Chinese global-change science satellite plan. Greenhouse gas survey systems are mainly comprised of high-precision polar-orbit ultra-high resolution optical spectrum detection satellites, surface verification systems, and model assimilation systems. The emphasis should be on making breakthroughs in non-polar-orbit space platforms (including the space station or non-polar-orbit satellites) ultra-high optical spectrum detection technology, and solving the cloud and aerosol satellite quantified detection that goes along with this. In addition, at the same time as one is developing first generation remote-sensing satellite technology, at present it is also necessary to lead the way in conducting research on satellite active remote-sensing technology, realizing space carbon dioxide laser radar remote sensing, etc., placing China in the world's front ranks in the area of supporting climate change research and checks for dealing with emissions reductions.
Based on the Earth satellite observation technology and expertise we currently possess, we should, using Lagrangian points 1 and 2 as a foundation for an Earth observation satellite constellation, develop continuous radiation and imagery observation, which will allow complete information on continuing change to be obtained for Earth system research. It is hoped this will produce breakthroughs that will bring new understandings of the processes of Earth systems.

INCREASING SURVEILLANCE AND EARLY WARNING FOR SPACE DEBRIS AND THE SPACE ENVIRONMENT

Internationally, the United States has taken the lead in establishing relatively high-level space-Earth integrated space debris surveillance systems and space environment survey systems. At present, in the area of space debris and environment surveillance and early warning, China has already made certain advances, but there is still a distinct disparity when compared with developed countries. In the area of space debris, China's research foundation is still relatively frail, and its abilities to independently observe and acquire space debris data are still insufficient, making it difficult to satisfy the requirements for space debris early warning. In the area of the space environment the independent observation required for China in environmental forecasting is still relatively weak, especially the foundation for a space-based survey. At present there still is no space-based solar imagery surveillance. The quantity and orbital distribution of Earth space environment surveillance satellites are both extremely limited, making it impossible to satisfy the requirements for space environment forecasting. In the area of space environment early warning technology, China is basically on the same level as developed countries in the areas of forecasting element coverage and forecasting capabilities, but there is a relatively large disparity when it comes to space environment forecasting methods and the accumulation and foundation of model-building research, which also impacts practical forecasting levels.

Therefore, it is necessary to greatly increase the ability to deal with the threat of space debris and space environmental protection capabilities. Work that needs to be urgently done at present includes: (1) Expanding Earth surface surveillance equipment types and quantities as well as increasing independent space debris data acquisition capabilities; supporting advanced protective materials research and development and the building of Earth surface test equipment; improving space debris protection design systems, improving capabilities for carrying out collision risk assessment and protective structure optimization design for China's piloted spacecraft and application satellites as well as possessing the ability to carry out collision early warning for spacecraft launches and operations in orbit. (2) Building a space environment information support system with coordinated space-Earth detection as a foundation, conduct solar activity and interplanetary environment detection, orbital space environment detection, space electromagnetic environment detection, near-space environmental detection, and Earth surface coordination detection, make breakthroughs in such crucial technologies as space-based solar imagery technology, solar storm cause-and-effect chain coupling forecasting technology, advanced space environment detection payload technology merging space environment information, and implement building for the second period of the Eastern Hemisphere Space Environment Ground-Based Integrated Monitoring Meridian Chain (abbreviated Meridian Project). (3) Further increase strengths in sustained and stable Earth surface continuous observation, realize three-dimensional precision observation of the space environment while building and improving Earth surface supplication support systems matched for space-Earth coordination, establish and improve fundamental databases and data sharing platforms for the space environment, and improve environment information precision analysis and prompt forecasting and alarm capabilities.

CONSTRUCTING A NATIONAL SPACE INFORMATION SUPPORT AND SERVICES SYSTEM

Build a five-station network for reception of satellite and Earth surface data and construct a national global space data acquisition system. Accelerate the building of our national global space information support system, provide global development and strategic environment information for the heading out strategy, and provide high-resolution data and information products for research of global and regional issues. Build a five-station network on the foundation of completing the building of a remote sensing satellite and Earth surface reception three-station network, and guarantee that China's space information support capabilities realize a leap from Asia to the world by 2020. This primarily includes building remote sensing satellites and Earth surface reception stations within the Arctic Circle, making breakthroughs in unmanned mission automatic data reception and automatic system processing completion technologies, and realizing the ability to provide data in one hour, the ability to report information on global disasters and major emergency incidents within two hours, and the ability to survey the ecological environment within 24 hours, and realizing high-speed, secure transmission utilizing international common-use networks.
Strengthen space data-intensive scientific research and information services. Give prominence to using mass data methods to examine global and regional problems, focus on conducting research on physical models and mathematical methods for global changes and regional human population and resources rebalancing, carry out research on Earth environment multi-dimensional heterogeneous massive ocean data network calculation technology, mass data environment space data-intensive calculations and knowledge discovery methods, and examine and forecast environmental changes, environmental risks, and environmental trends and patterns (haze formation mechanisms and development patterns and harmful insect migration patterns) on a global scale and for hot point regions, and propose sustainable development and handling schemes. Through 10 years of effort, build a national space information support and services system and provide scientific information support for the country in macro-level decision-making and in resolving global and regional issues.

STRENGTHENING UNIFIED PLANNING AND COORDINATION OF NATIONAL RESEARCH, DEVELOPMENT AND APPLICATION IN THE SPACE DOMAIN

The major international space-faring nations (regions), including the United States, Russia, Europe, and Japan, all consider space strategy on the national (regional) level. For example, every time a new administration takes office in the United States, it reorganizes and releases new space development plans and policies. This is also the case for Russia, where major aerospace programs are personally determined and directed by the highest leaders in the government. This is not only because space science and technology play a powerful stimulating and motivational role for a country's other domains, but also because space science and technology capabilities are a comprehensive symbol of a country's national strength. They play multiple roles, including those that are political, diplomatic, science- and technology-related, and economic. In the early period of aerospace development, that is, the period of the "two bombs and one satellite," China's major programs were also directly determined by special committees in the central government.

After reform and opening up, and especially after entering the 21st century, China's national strength has gradually increased, the pace of space infrastructure construction has quickened, and the number of satellites launched has developed from one every several years during the 1970s and 1980s to multiple satellites every year (21 satellites were launched in 2011). Yet, behind this phenomenon of prosperity there is still a lack of coordination in systems and mechanisms. For example, the essence of human spaceflight and deep space survey programs is the human exploration of space, with the goal of scientific discovery and scientific research, thereby motivating technological development. The managing organs executing these two programs, however, are not the same ministry, and these two organs do not have the function of developing science. This then has unavoidably made it so that these two programs have an intense emphasis on the project mission and technological breakthrough. After project missions are satisfactorily completed, the goal of future sustainable development is lost. At the same time, development in the area of space science satellite programs with the goal of scientific discovery and research is slow. It has been only recently that a special project on space science satellites in the real sense of the word has been formed in China: the Special Space Science Strategic Pioneering Science and Technology Projects. In the area of space applications, China has launched a large quantity of application satellites, but because of separation between ministries, there is a lack of unified planning and coordination, data sharing rates are extremely low, and the phenomenon of redundant acquisition of the same or similar data is commonplace, creating low-level redundancy.

Therefore, it is suggested that the top-level design and resources organization for China's space program be strengthened and reforms be carried out in the area of systems and mechanisms: (1) Refer to the experiences of advanced aerospace countries, strengthen research on space planning and space policies, and provide guiding thinking and principles for top-level design. (2) Restore the leadership of a special committee in the central government over the devising of space policies and planning, determining major aerospace programs, and reforming systems and mechanisms. (3) Study the United States, Europe, and Japan, unify the human space program, deep space survey program, and space science satellite program together for administration, establish an actual national space (aerospace) government ministry, and comprehensively lead, plan, organize and implement work in the aforementioned three domains. (4) Establish application satellite user coordination mechanisms, break down the barriers dividing ministries that own a series of satellites, and through the comprehensive development of data, make use of the achievements of the current program to the greatest extent possible and reduce low-level redundancy. (5) Implement commercialization in such domains as launch and satellite research and development, using the self-regulating role of market mechanisms to lower costs, improve quality, and promote the expansion and transfer of technological capabilities to other domains.