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CHINA AEROSPACE  
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# Chinese Spaceplane Programs



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November 2021

Printed in the United States of America  
by the China Aerospace Studies Institute  
ISBN 9798763459043

To request additional copies, please direct inquiries to  
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Cover art is “China’s mysterious aerospace aircraft will fly for the first time in 3 years,  
perhaps exceed the performance of the U.S. X-37B” [中国神秘空天飞机将在3年内首  
飞 性能或超美国X-37B], Sina Military News, 12 May 2017, <http://mil.news.sina.com.cn/jssd/2017-05-12/doc-ifyfeius7838004.shtml>.

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# Table of Contents

<b>Acronyms</b> .....	<b>1</b>
<b>Introduction</b> .....	<b>2</b>
U.S.-China Competition in the Space Domain .....	2
Definitions of Spaceplanes .....	2
Why Develop Spaceplane Technology? .....	3
<b>Section 1: Military and Civilian Applications of Spaceplanes for China</b> .....	<b>4</b>
Significance of Space Domain to China from Economic and Security Perspectives .....	4
Civilian and Military Applications of Spaceplanes .....	5
Place of Spaceplanes in China’s Plans for the Space Domain .....	8
<b>Section 2: Ongoing Spaceplane Projects</b> .....	<b>9</b>
Shenlong .....	9
Aotian No. 1.....	13
Tengyun .....	14
CALT Vertical Takeoff Horizontal Landing Reusable Spaceplane .....	16
Tianxing .....	17
Qinglong .....	19
iSpace Spaceplane.....	19
CALT Rail-Launched HTHL Passenger Spaceplane .....	20
<b>Section 3: China’s Progress in Relevant Technologies</b> .....	<b>21</b>
Technologies being Developed to Support Spaceplanes .....	21
Combined Cycle Engines .....	21
Heat-resistant, Durable, Lightweight Materials.....	21
Autonomous Navigation .....	22
<b>Section 4: Competing Space Launch Technologies</b> .....	<b>23</b>
<b>Conclusion</b> .....	<b>25</b>
<b>Endnotes</b> .....	<b>27</b>
<b>Image Sources</b> .....	<b>36</b>

# Acronyms

AVIC	Aviation Industry Corporation of China
BDS	Beidou Navigation Satellite System
BRI	Belt and Road Initiative
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CALT	China Academy of Launch Vertical Technology
CAS	China Academy of Sciences
CASC	China Aerospace Science and Technology Corporation
CASIC	China Aerospace Science and Industry Corporation
CAST	China Academy of Space Technology
CCTV	China Central Television
CMSI	China Maritime Studies Institute
CNSA	China National Space Administration
GPS	Global Positioning System
HTHL	Horizontal Takeoff, Horizontal Landing
ISR	Intelligence, Surveillance and Reconnaissance
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
PLA	People's Liberation Army
PLASFF	PLA Strategy Support Force
PNT	Positioning, Navigation and Timing
PRC	People's Republic of China
RBCC	Rocket-Based Combined Cycle
RLV	Reusable Launch Vehicle
SASAC	State-owned Assets Supervision and Administration Commission
SAST	Shanghai Academy of Spaceflight Technology
SDA	Space Domain Awareness
SSA	Space Situational Awareness
TBCC	Turbine-Based Combined Cycle
TRCC	Turbo Rocket Combined Cycle
TSTO	Two-Stage-To-Orbit
UAV	Unmanned Aerial Vehicle
VTHL	Vertical Takeoff, Horizontal Landing
VTVL	Vertical Takeoff, Vertical Landing

# Introduction

## U.S.-China Competition in the Space Domain

The unclassified summary of the U.S. Defense Space Strategy in June 2020 noted that “China and Russia have analyzed U.S. dependencies on space and have developed doctrine, organizations, and capabilities specifically designed to contest or deny the U.S. access to and operations in the domain. Concurrently, their use of space is expanding significantly. Both countries consider space access and denial as critical components of their national and military strategies.”<sup>1</sup>

China, the focus of this report, has been fielding greater and greater numbers of satellites with communications, navigation and Intelligence, Surveillance, and Reconnaissance (ISR) functions. China now ranks second in the world in number of satellites in orbit and overall spending on spacecraft development.<sup>2</sup> It has made strides in increasing its space domain awareness (SDA)<sup>i</sup> and its ground-based and on-orbit counter-space capabilities, such as anti-satellite missiles and orbital craft that can be used offensively.<sup>3</sup> Some of the space competition also takes place in the economic realm, as China seeks to become the world’s space launcher,<sup>4</sup> provide space-based navigation and internet,<sup>5</sup> and offer other services that increase its global influence.

Spaceplanes are one area in which China seeks to mimic or compete with U.S. technology. Inspired by the U.S. Space Shuttle and more recently by the Boeing X-37B orbital test vehicle, China has several ongoing projects to develop reusable launch vehicles capable of flight in both air and space. While the space industry in China is dominated by state-owned megacorporations, in recent years private companies have begun to enter the spaceplane market. This report will examine each of China’s known spaceplane projects, offer context about China’s overall space plans and ambitions, and provide an analysis of the applications and relative advantages of spaceplane technology.

## Definitions of Spaceplanes

The term “spaceplane” can encompass a variety of different vehicles, but in its broadest sense, refers to a reusable vehicle with characteristics of both an airplane and a spacecraft, capable of flying both in the atmosphere and in space.<sup>6</sup> The most famous example of a spaceplane is the Space Shuttle program, which used rockets to vertically launch a winged orbiter that would maneuver in orbit and return to Earth like an aircraft.<sup>7</sup> The Space Shuttle’s modern successor is Boeing’s X-37B, an unmanned rocket-launched “Orbital Test Vehicle” of the U.S. Air Force. While the official purpose of the X-37B is to test reusable spacecraft technology and conduct scientific experiments in space, its secretive long-duration missions have sparked speculation in Chinese media and other sources about its true military purpose, ranging from reconnaissance<sup>8</sup> to deployment of nuclear warheads.<sup>9</sup> The X-37B is considered an inspiration for several of China’s own spaceplane projects.

The term “spaceplane” is typically associated with the orbiters themselves but can also refer to the entire multi-stage configuration, including the launch vehicle (though the launch vehicle portion may not be reusable). It also applies to vehicles such as Virgin Galactic’s SpaceShipTwo, which is launched by an airplane “mothership” rather than a rocket and only reaches suborbital altitudes. Some tourism-oriented spaceplanes take this form.<sup>10</sup> Single-stage spaceplanes have been conceived but not developed.

While this report will generally use the English term “spaceplane” to refer to all vehicles of the aforementioned

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i Formerly referred to as Space Situational Awareness (SSA).

descriptions, Chinese sources sometimes differentiate between two types of spaceplanes. The literal Chinese translation of “space plane” [太空飞机] refers to Vertical Takeoff Horizontal Landing (VTHL) vehicles that are launched like rockets (or attached to rockets) and land horizontally on runways like airplanes. The X-37B belongs to this category. The term “aerospace plane” [空天飞机] refers to reusable Horizontal Takeoff Horizontal Landing (HTHL) vehicles that take off and land on runways horizontally, like conventional aircraft. An “aerospace plane” may consist of one or more stages and is typically described as using a combined cycle engine that incorporates multiple sources of propulsion such as turbojets, ramjets, and rocket engines.<sup>11</sup> China is developing both kinds of vehicles and both kinds will be covered in this study. “Transatmospheric vehicle” [跨大气层飞行器] is a more general term used to describe Chinese reusable spaceplane projects, encompassing any vehicle that can fly both in the atmosphere and in space.

China’s most high-profile spaceplane project is the Tengyun [腾云], a two-stage horizontal-launch reusable aerospace plane with combined engine technology, which is primarily being developed by the China Aerospace Science and Industry Corporation (CASIC). The plane is set for completion in 2030 and is officially intended for space tourism. Another major project is Shenlong [神龙], an air-launched robotic spaceplane believed to be developed by a subsidiary of the Aviation Industry Corporation of China (AVIC) together with the China Aerospace Science and Technology Corporation (CASC) for military purposes. Since 2016, China has seen an explosion of spaceplane development as both large state-owned enterprises as well as smaller private startups have announced a variety of spaceplane projects.

### **Why Develop Spaceplane Technology?**

Spaceplanes have two main advantages over other types of space vehicles. First, they have the potential to reduce the costs of space missions. While rockets used in satellite launches or other missions must be replaced after each launch, spaceplanes can be reused dozens of times with different payloads, eliminating the costs of constructing new launch vehicles. Second, spaceplanes have greater maneuverability in orbit than other types of space vehicles, allowing them to perform a wider variety of missions and carry out multiple tasks while in orbit. These advantages will be discussed in greater detail in the forthcoming section on the civilian and military applications of spaceplanes.

# Section 1: Military and Civilian Applications of Spaceplanes for China

## Significance of Space Domain to China from Economic and Security Perspectives

### Economic Significance and ‘Prestige’ of Space Domain

Officially, Beijing claims that its development of space technology is strictly for peaceful purposes. In reality, military and strategic considerations clearly play a role in China’s space programs; however, the economic and other non-military drivers of China’s space ambitions are important and cannot be overlooked.

A December 2016 white paper detailing China’s plan to become a “space great power” [航天强国] lists peaceful and open development among the core principles for the development of the space industry and expresses opposition to the “weaponization of outer space.” The stated purpose of developing the space industry is to “explore outer space and expand understanding of the earth and the universe; use outer space peacefully, promote human civilization and social progress, and benefit all mankind; meet the needs of economic construction, scientific and technological development, national security and social progress; improve the people’s scientific and cultural level [全民科学文化素质]; safeguard national rights and interests [国家权益], and enhance the nation’s overall power.” Spaceplanes are mentioned indirectly; the document calls for China to “carry out technical research on low-cost carrier rockets, new upper stages, and reusable transportation systems to and from Earth” as one of the main tasks for the next five years (2016-2020).<sup>12</sup>

The white paper shows the significance of space to China’s non-military goals and priorities. To some extent, China’s space programs are likely driven by a genuine desire to pursue basic scientific research and space exploration. China is also interested in the development of space technologies that can offer tangible economic and societal benefits to the country. One of the People’s Republic of China’s (PRC) most significant space industry projects is the Beidou [北斗] Navigation Satellite System (BDS), a 35-satellite constellation completed in June 2020 which provides Earth observation and navigation services similar to (and in competition with) the United States’ Global Positioning System (GPS).<sup>13</sup> BDS has been used in fields including transportation, forestry, meteorology, disaster relief, and others.<sup>14</sup> Domestically, it is expected to support products and services worth an estimated \$156 billion by 2025; internationally, Beidou services and related products have been exported to around 120 countries and served over 100 million users.<sup>15</sup>

Space is also one dimension of the Belt and Road Initiative (BRI), China’s highly ambitious strategy to build a world-spanning trade and infrastructure network centered on China. More specifically, one of the BRI’s constituent projects is the Belt and Road Space Information Corridor [空间信息走廊], which aims to provide information services to Belt and Road participant countries through a shared network of communication, remote sensing, and navigation satellites (including the Beidou system).<sup>16</sup> Besides developing its own satellites and associated technology as part of the Space Information Corridor, China also sells satellite technology and launch services to other countries, such as Argentina and Nigeria.<sup>17</sup> In the future, spaceplanes and other reusable spacecraft may play a role in providing cheap and reliable launch and satellite maintenance services.

Aside from the economic rewards of China’s space projects, Beijing sees the space industry as a path to greater international prestige and power. Major milestone achievements such as landing a rover on Mars have already won China international recognition,<sup>18</sup> not to mention boosting nationalism at home. China also hopes to be able to shape future international norms and institutions related to space. The BRI is emblematic of Beijing’s desire to shape the international order according to its interests (or at least avoid dependence on Western-dominated



institutions) by building economic ties and political influence with developing nations. This desire extends to space as well, regarding both civil and military rules and norms. For example, China has not supported NASA's Artemis Accords, an international proposal of principles to govern lunar resource extraction,<sup>19</sup> and has joined with Russia to propose an international ban on space-based and anti-space weapons.<sup>20</sup> China's attempt to influence the rules of space are not necessarily wholly due to a genuine commitment to its stated principles; in fact, China has long been developing space weapons despite its proposal to ban them. (Some U.S. experts have even suggested that spaceplanes may offer China a way to circumvent international regulations on anti-satellite weapons, because spaceplanes are ground-based.)<sup>21</sup>

### **Military Significance of Space Domain**

Summarizing the significance of space to future warfare, the 2020 edition of *The Science of Military Strategy* stated, "In the systemic confrontation of future wars, the battlefield will collapse once the space information protection is lost, and the war system will also be paralyzed."<sup>22</sup> In recent years China has progressed significantly, fielding a wide range of space launch vehicles and multiple constellations of Positioning, Navigation, and Timing (PNT), remote sensing and early warning satellites with one of the fastest launch tempos of any country. At the same time, it has worked to vastly improve its supporting infrastructure for space operations, expanded its space domain awareness, and added multiple new anti-satellite capabilities. This matches the more prominent role that space will play in People's Liberation Army (PLA) concepts of military operations. The latest edition of the *Science of Military Strategy* published by the National Defense University suggests that the PLA's operational guidance [作战指导] is shifting to be even more explicitly joint and coordinated across domains (described as multi-domain integrated joint operations [多域一体化联合作战]), including space.<sup>23</sup>

## **Civilian and Military Applications of Spaceplanes**

### **Civilian Applications**

All of China's known spaceplane projects, with the exceptions of the Shenlong and Aotian-1, are publicly stated to be for civilian use.

Perhaps the most well-publicized civilian application of spaceplanes is space tourism, popularized by Western companies such as Blue Origin and Virgin Galactic. Spaceplanes under development by China include some that will be capable of bringing passengers to suborbital flight (about 100 kilometers above the ground), allowing them to experience weightlessness for a short time before descending back to Earth. Other spaceplane projects will be able to rise to orbital altitudes (around 400 kilometers), allowing for longer experiences in "zero gravity" and even transportation to space stations.<sup>24</sup> In this application, spaceplanes have an advantage over rockets in that they provide smoother flying experiences for passengers.<sup>25</sup>

Space tourism is an extreme luxury service that will likely remain unaffordable to most consumers for many years, with ticket prices in the tens or hundreds of thousands of dollars.<sup>26</sup> Nevertheless, the global space tourism market is expected to be valued at \$1.7 billion by 2027, and in China it is projected to reach \$401.6 million by 2027 with a compound annual growth rate (CAGR) of 19.7% from 2020-2027.<sup>27</sup>

Spaceplanes may also offer high-speed travel between destinations on Earth. Several Chinese spaceplane projects claim to ultimately allow passengers to reach any location on Earth within an hour.<sup>28</sup> HTHL spaceplanes can take off and land at ordinary airports, making their potential future use by civilians even more plausible.

Finally, Chinese spaceplanes share many of the functions and applications of the United States' Space Shuttle<sup>29</sup> and similar rocket-launched vehicles. All spaceplanes can be used to carry out technological verification missions and scientific experiments. Spaceplanes that can maintain flight in orbit can also be used to deploy or service satellites and, if they are large enough, transport astronauts.

## Military Applications

China's military-oriented spaceplanes are unsurprisingly highly secretive, and Chinese official sources rarely discuss the military applications of this technology publicly. In fact, as noted earlier, China's public position is that all development of space technology is for peaceful purposes. However, many civilian applications of spaceplanes described above can be useful for military purposes, including rapid transportation, satellite deployment, and verification of military or dual-use technology.

In addition, there has been some semi-authoritative discussion in Chinese sources about military applications of spaceplanes. In 2002, China Academy of Sciences' (CAS) Academician Zhuang Fenggan [庄逢甘], a renowned aerospace industry expert, gave an interview to Beijing Youth Daily in which he explicitly acknowledged that the development of aerospace aircraft is related to the military. According to Zhuang, China seeks to develop aerospace planes that can fly freely between the atmosphere and outer space. These spaceplanes would be "the world's best air and space combat weapons platform" and would carry out dual-use missions. Zhuang identified key technologies China had to master to develop a spaceplane that would serve China's needs, notably including "high stealth technology" and "precision strike" technology.<sup>30</sup>

Course materials on space operations published in 2013 by the Chinese Academy of Military Sciences described a "Space Flight Combat Force" [空间飞行战斗部队] that would employ space-based technologies including "space shuttles" [航天飞机] and "aerospace planes" [空天飞机] to "perform various space operations and related support tasks." The same section of the text notes the role this force could play in reconnaissance, offensive, and support roles. Offensive operations are described as targeting enemy spacecraft with lasers, particle beams, microwaves, or aerosols, while support roles include transatmospheric transportation, inspection, maintenance, refueling, testing, and development of space weapons systems.<sup>31</sup> The flexibility of spaceplanes offers certain advantages in all of these roles.<sup>ii</sup> More theoretical discussions involve the use of spaceplanes and other spacecraft in "Ground—Space—Ground-type attacks" [“地—天—地”式突击] involving directed energy and kinetic energy attacks on ground targets from space.<sup>32</sup>

Various Western experts as well as unofficial Chinese media have offered speculation and analysis of the military applications of China's spaceplane projects as well as the X-37B, which is seen as the American counterpart to or inspiration for some of the Chinese projects. For example, a 2008 article republished on CCTV's website<sup>33</sup> and other Chinese media<sup>34</sup> noted the potential of aerospace planes as platforms for space weapons and anti-strategic missiles, saying they had greater autonomy and flexibility in deployment than less mobile space-based assets. It also said that spaceplanes could be used as air-to-air combat platforms, shooting to destroy other spacecraft more quickly than can be achieved with ground-based missiles. This application of spaceplanes is an alternative to developing kinetic or directed energy weapons based in orbit. Aerospace planes could also attack ground targets more stealthily and suddenly than conventional military aircraft and have the further advantage of consuming no fuel while in orbit and very little fuel while performing attitude adjustments, suggesting they could

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ii The categories of likely space missions for the PLA include Space Deterrence [空间威慑], Space Blockades [空间封锁作战], Space Strike Operations [空间突击作战], Defensive Space Operations [空间防御作战] and Space Information Support Operations [空间信息支援作战]. See: Dean Cheng, "Space and Chinese National Security: China's Continuing Great Leap Upward," in Joel Wuthnow, Arthur S. Ding, Phillip C. Saunders, Andrew Scobell, Andrew N.D. Yang, eds. *The PLA Beyond Borders: Chinese Military Operations in Regional and Global Context*, [https://ndupress.ndu.edu/Portals/68/Documents/Books/beyond-borders/990-059-NDU-PLA\\_Beyond\\_Borders\\_sp\\_jm14.pdf](https://ndupress.ndu.edu/Portals/68/Documents/Books/beyond-borders/990-059-NDU-PLA_Beyond_Borders_sp_jm14.pdf). 324-327 and Jiang Lianju [姜连举] Wang Liwen [王立文], eds. *Lectures on Space Operations* [空间作战学教程], Beijing: Academy of Military Sciences Press [军事科学出版社], 2013. pp. 126-154.

engage in military operations for very long periods of time without landing. None of China's spaceplane projects at the time (and probably to this day) possessed most of the capabilities described in the article. It is possible that projects like Shenlong were mainly for technical verification to assist the ongoing development of more useful future military aerospace craft.

According to Dr. Andrew Erickson, Professor at the U.S. Naval War College's China Maritime Studies Institute (CMSI), larger versions of the Shenlong could use on-board sensors, deployed microsattellites, and other systems to expand China's Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) capabilities in space. Spaceplanes with rapid on-orbit maneuverability could survey different areas and potentially evade enemy tracking and anti-satellite systems. They could also potentially act as anti-satellite platforms themselves. Finally, spaceplanes have advantages over conventional rocket launch systems in that they are reusable and versatile, allowing for some cost savings in missions such as reconnaissance and satellite launches.<sup>35</sup>

Chen Guangwen [陈光文], a Chinese commentator on military affairs, wrote in 2017 that "obviously, China is [...] actively developing aerospace aircraft that can perform long-term combat missions in space." Some Chinese experts have speculated that Boeing's X-37B space shuttle was an "advanced space fighter or space combat spacecraft" that could launch missiles from orbit above a target, shortening attack time to the point that the enemy missile defense system would not have time to react. According to Chen, China's Shenlong "is probably no exception" and may even be used by China's PLA Strategic Support Force (PLASSF).<sup>36</sup>

It should be reiterated that the military applications of China's existing spaceplane projects are not confirmed by official sources and that there are some differing opinions on the subject. For example, a 2014 article from Tencent's military column "Jiang Wu Tang" [讲武堂] argued that aside from technology verification missions, neither the X-37B nor China's own Shenlong [神龙] and Aotian-1 [傲天一号] spaceplanes had significant military value because they lacked "wide-range orbital maneuvering capability" [大范围变轨机动能力].<sup>37</sup> However, in July and August 2021, China tested a maneuverable aerospace vehicle that circled the earth in low-earth-orbit before advancing toward a target on Earth. Financial Times reported this to be a nuclear-capable hypersonic missile, but Chinese officials claimed it was a test of a reusable spacecraft. Insufficient details are available to determine if the craft was a maneuverable hypersonic glide vehicles or represented a new advancement in spaceplane technology.<sup>38</sup>

## Place of Spaceplanes in China’s Plans for the Space Domain

The public agendas for the development of China’s space industry are set mainly by governing bodies like the China National Space Administration (CNSA) and major industry players like the state-owned CASC and CASIC. In 2018, CNSA Spokesperson and Systems Engineering Department Director Li Guoping [李国平] described an overarching three-phase plan for space development with major milestones in 2020, 2030, and 2050.<sup>39</sup> It is summarized in the following table:<sup>40</sup>

Milestones for Chinese Space Programs	
2020	<p>“Make major breakthroughs in key points and enter the ranks of Great Space Powers” [重点突破, 进入航天强国行列]</p> <ul style="list-style-type: none"> <li>• Complete Beidou GNSS</li> <li>• Launch China’s Mars mission (Tianwen-1)</li> <li>• Complete the “China High-Resolution Earth Observation System”</li> <li>• Lunar sample return mission (Chang’e 5)</li> <li>• Begin construction of a long-term space station (completion expected 2022)</li> </ul>
~2030	<p>“Make comprehensive improvements, join the front rank of global Great Space Powers” [整体跃升, 跻身世界航天强国的前列]</p> <ul style="list-style-type: none"> <li>• Complete first flight of heavy launch vehicle (expected 2028)</li> <li>• Establish orbital service and maintenance system</li> <li>• Autonomous orbital refueling</li> <li>• Automated maintenance of spacecraft in orbit</li> <li>• Automated space debris removal</li> <li>• Establish the “Space-Earth Integrated Information Network”</li> <li>• Complete national civil space infrastructure (2025)</li> <li>• Crewed lunar landing</li> </ul>
2050	<p>“Take the lead, Comprehensively Become a Great Space Power” [超越引领, 全面建成航天强国]</p> <ul style="list-style-type: none"> <li>• Crewed mission to Mars</li> <li>• Establish long-term base on the Moon</li> <li>• Deep space exploration, including visiting the edge of the solar system</li> <li>• Creation of low-cost, reusable spacecraft transportation system</li> </ul>

Spaceplane development does not appear prominently in this overarching plan until the final 2050 milestone, which includes the creation of a “low-cost, reusable spacecraft transportation system.” It is worth noting that other than spaceplanes, reusable rockets would also fall under this description.

Below the level of national policy, China’s spaceplane development is driven by the plans of its major aerospace companies like CASC and CASIC. In November 2017, CASC unveiled a Space Transport Road Map outlining its (and more generally, China’s) goals for spacecraft development in five-year increments. By 2020, the plan said China should have first-class rockets that provide diversified commercial launch services to the world; by 2025, China should develop a reusable suborbital vehicle that can enable suborbital space tourism; by 2030, China’s first heavy-duty launch vehicle should make its first flight and by 2035 become fully reusable; by 2040, China’s “next generation of launch vehicles” should be put into use and space transportation systems should have achieved multiple long-duration interplanetary round trips; by 2045, China should be a leading space power, capable of “large-scale human-machine collaborative exploration of space.”<sup>41</sup> The plan overlaps with the broader CNSA plan (for example, the development of a heavy launch vehicle by 2030) but seems to be more ambitious in its time estimate for the development of reusable space transportation.

CASIC has put forward its own space vehicle development plans, most recently unveiled at a conference in October 2020. CASIC’s plans include improving and enhancing the frequency of commercial rocket launch services, finishing the construction of its 80-satellite Xingyun [行云] constellation, and completing its two-stage Tengyun spaceplane by 2025.<sup>42</sup>

The following section provides an overview of known spaceplane projects, public tests, and milestones, likely intended uses, and timelines.

## Section 2: Ongoing Spaceplane Projects

### Shenlong

Shenlong [神龙]<sup>iii</sup> (“divine dragon”) is China’s oldest known spaceplane project still in development, dating back to at least 2000. Designs presented in 2000 showed a delta-winged spaceplane with one vertical stabilizer and with three high-expansion engines. Based on those models, the craft was estimated to be 12 meters long with a wingspan of 8 meters and a mass of 12 tons.<sup>43</sup>

In December 2007, the first known photograph of a Shenlong craft surfaced on Chinese military websites, showing what appeared to be a small space shuttle suspended underneath a Xian H-6 bomber. Although government authorities did not confirm the authenticity of the photograph or the existence of the project, the Chinese characters “shen long” [神龙] could be seen on the side of the shuttle’s fuselage, suggesting it was the spaceplane. The craft appears to be a small transatmospheric vehicle [跨大气层飞行器] with one rocket nozzle in the back and black heat shielding on the bottom, resembling a miniature version of Boeing’s X-37B spaceplane.<sup>44</sup> According to analysis of the photograph by aeronautics expert Mark Wade of Encyclopedia Astronautica, the Shenlong model in the photograph is an unmanned aerodynamic test vehicle with an estimated mass of around 4,500 kg, a length of about 6.5 meters, and a diameter of about 0.8 meters.<sup>45</sup> This is notably much smaller than the dimensions estimated from the models in 2000, and with only one rocket engine and no visible stabilizer.



*The only known photo of the Shenlong suspended from an H-6 bomber (next to a close-up on the spaceplane itself).*

Shortly after the leak of the photograph, images showing an H-6 bomber with a Shenlong model suspended from it via a “trapeze” and a computer-generated aerodynamic model of the Shenlong from Chinese Central Television Channel 7’s long-running military program, *Military Report* [军事报道] appeared on internet forums.<sup>46</sup> Unlike the leaked photograph, both models show the Shenlong craft with a large vertical stabilizer.

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iii As a side note, the use of the character “Shen” [神] may indicate the Shenlong is a national science project at the same level as the Shenzhou [神舟] manned spacecraft, the Shenwei [神威] high-powered computer, and the Shenguang [神光] high-powered laser.



Two images from undated CCTV-7 broadcasts showing aerodynamic models of the Shenlong spaceplane suspended and air-launched from an H-6 bomber.

Analysts such as Richard Fisher have suggested that the lack of stabilizer on the model in the leaked photograph indicates that that particular spaceplane may not have been intended to be launched into space, but rather was a prototype intended to test aerodynamic compatibility with the H-6 aircraft. Fisher also assessed from the images that the Shenlong was not large enough to carry a substantial payload, crew, or passengers, nor to sustain flight in low-Earth orbit (LEO) if launched from an H-6 bomber. However, it could likely perform short flights in LEO as needed for technology testing missions, suggesting the spaceplane is intended as a technology demonstrator.<sup>47</sup>

Mark Wade also noted that the small, unmanned Shenlong from the photograph could be a scaled-down mockup for a manned spaceplane concept but was more likely a full-scale model of a robotic spaceplane or a boost-glide bomber system.<sup>48</sup>

More recently, some Chinese media seemed to confirm more details about the Shenlong. According to a 2016 article in *China Daily*, the Shenlong is a reusable aerospace plane similar to the X-37B, which is carried to suborbital altitudes by an H-6 bomber aircraft and then air-launched into orbit. It is reportedly able to change its orbit at high speed and able to travel to any destination on Earth within an hour. The article also says the Shenlong can be a powerful anti-access strategic weapon.<sup>49</sup>

In January 2016, U.S. media reported that Chinese military affairs commentator Song Zhongping [宋忠平]<sup>50</sup> had told a Hong Kong newspaper that the PLASSF would be equipped with the Shenlong spaceplane. Song reportedly said that “the unmanned Shenlong is being developed as space weapons launch platform, as well as for surveillance, intelligence, and early-warning missions” which columnist Bill Gertz noted as the first time an individual associated with China’s military had directly connected the Shenlong to space warfare applications. The article also included a claim that the Shenlong would be deployed for both civilian and military missions and serve as a test bed for the development of larger, manned spaceplanes.<sup>51</sup>

Several days later, China’s Global Times responded to Gertz’s article, publishing a rebuttal that was also featured in Xinhua<sup>52</sup> and on the website of the China Academy of Space Technology (CAST).<sup>53</sup> In the article, Song claimed his intended meaning had been exaggerated. Song said the Shenlong was “just a verification platform for testing the reentry glide return technology of a winged aircraft” rather than a piece of equipment that could be used to equip troops immediately. An unnamed military expert was cited as saying the current Shenlong was too small to have practical military uses. Even if the spaceplane were scaled up to the size of the U.S. X-37B, the expert said it would still have limited military potential due to several technical and practical challenges.<sup>54</sup> While

the expert's comments are plausible, it is also possible he was deliberately downplaying the Shenlong's military applications.

## Development

Speculation on Chinese internet forums suggested that the early design stages of the Shenlong took place between 2000 and 2004, and that the photo leaked in 2007 may have been taken in late 2005. Internet posts from around the time of the photo leak claimed the Shenlong was part of China's 863 Program, which was started in 1986 to promote high-tech dual-use research and development. More specifically, various posters online claimed the spaceplane was designated with the program number "863-706" and that some of its design and testing was carried out by the 611 Design Institute, part of the AVIC subsidiary Chengdu Aircraft Industry Group.<sup>55</sup> None of this information has been verified by official Chinese government sources but the claims have been repeated in Chinese media.<sup>56</sup>

On 11 December 2007, the same day the Shenlong photograph leaked, the Hong Kong-based state-run newspaper *Wen Wei Po* [文汇报] published an article on China's plans to develop aerospace planes. Citing CAS Academician Zhuang Fenggan, the paper reported that China planned to develop and test a reusable transatmospheric aerospace plane sometime during the 11<sup>th</sup> Five Year Plan (2006-2010) and that the Xi'an Yanliang Strength Testing Base [西安阎良强度试验基地] would be involved in this testing. The Yanliang base at the time was affiliated with AVIC I,<sup>57</sup> one of two offshoots of AVIC that resulted when the state-owned company split in two in 1999 (AVIC I and AVIC II were later re-integrated into a single company in November 2008).<sup>58</sup> While neither Zhuang nor the *Wen Wei Po* article mentioned the Shenlong by name, it is noteworthy that AVIC I was responsible for military aircraft development and included the Chengdu Aircraft Industry Group, the same company alleged to be involved in designing the Shenlong spaceplane.<sup>59</sup>

In 2010, an article from the journal of the defense contracting giant China Ordnance Industry Group's (also known as Norinco) 201<sup>st</sup> Research Institute assessed that the Shenlong was still in the airdrop testing phase, far behind the development status of the X-37B.<sup>60</sup>

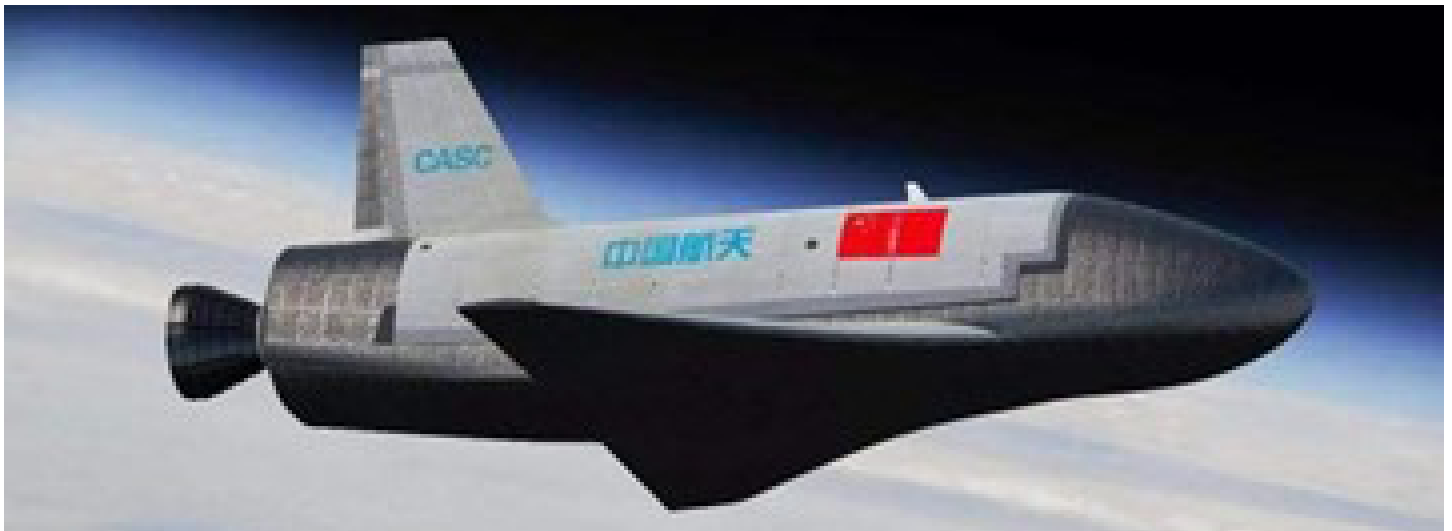
The only confirmed flight test of the Shenlong took place in early 2011. On 8 January 2011, Shaanxi province TV news reported on a successful suborbital test flight of a Chinese "transatmospheric vehicle" and broadcast an image. Later in June 2012, Hubei province media confirmed that this vehicle was the Shenlong spaceplane.<sup>61</sup> Another 2012 report also stated that the Shenlong "suborbital bomber" [次轨轰炸机] project had had breakthroughs in four key technologies in just over two years, completing the thrust engine needed for the aerospace plane to operate.<sup>62</sup>

On 4 September 2020, China launched a Long March 2F rocket from the Jiuquan Satellite Launch Center which contained a "reusable experimental spacecraft."<sup>63</sup> On 6 September, Xinhua reported that the spacecraft had conducted a successful orbital flight and reusable technology verification mission, circling the Earth for two days and returning to the landing site.<sup>64</sup> Satellite imagery revealed that the craft landed at an airbase with a long runway in the Gobi Desert, near the Lop Nur nuclear test site.<sup>65</sup> Official media reporting on this vehicle launch contained very little detail and no images or video, but it is generally believed the reusable spacecraft was a spaceplane. Various unofficial media sources have speculated that the vehicle was a version of the Shenlong,<sup>66</sup> with at least one Chinese source specifically referring to it as the "Shenlong-1" [神龙一号]. The source included an artistic rendering of the "Shenlong-1" in orbit with solar panels deployed.<sup>67</sup> However, it is possible that the spacecraft being tested was something else, such as the Aotian-1 or the second stage of the Tengyun.

Although Chengdu Aircraft Industry Group (and by extension, AVIC) appears to be the main designer and tester of the Shenlong, various sources have pointed to possible involvement of CASC and the Chinese Academy of Launch Vehicle Technology (CALT), a CASC subsidiary also known as the CASC First Academy, in the project's development. Western observers such as Andrew Erickson have drawn a connection between the Shenlong and Reusable Launch Vehicle (RLV) designs presented by CALT.<sup>68</sup> Renderings of the spaceplane sometimes show it marked with the CASC logo; however, this information cannot be verified in authoritative sources.



*Depiction of a Shenlong spaceplane in orbit with solar panels deployed.*



*Depiction of the Shenlong spaceplane in orbit, featuring a CASC logo.*



## Aotian No. 1

Aotian No. 1 [遨天一号] is a reusable transatmospheric orbiter that completed a successful test flight on 22 September 2013.<sup>69</sup> The successful test was initially announced by the CALT Research and Development Center's official Weibo account, but the post was deleted shortly afterward. According to the post, Aotian No. 1 was likely launched from an Ilyushin Il-76 transport aircraft. The purpose of the test was likely to test the vehicle's high-speed autonomous approach and landing capabilities.<sup>70</sup> This suggests the vehicle may be designed to be unmanned or optionally manned. Some sources have speculated that the spacecraft resembles the Dream Chaser, a pilot-optional multi-mission spaceplane developed by the Sierra Nevada Corporation for the transport of cargo and astronauts to low-Earth orbit destinations.<sup>71</sup> CALT appears to be the primary developer of the Aotian aerospace plane.

Little information about Aotian-1 is available from authoritative sources beyond the announcement about the September 2013 flight test, but an article on the Chinese military news website Xilu [西陆] highlighted two other news items involving an unnamed aircraft which it speculated was the Aotian-1. In November 2013, Xi'an's Northwestern Polytechnical University [西北工业大学] announced on its website that its School of Automation had participated in the development of an electric brake control system for the high-speed autonomous approach and landing of an unmanned aerial vehicle (UAV) developed by CALT. On 26 January 2014, the website of Fujian Province's State-owned Assets Supervision and Administration Commission (SASAC) published an article that a company based in Zhangzhou, Fujian Province, had assisted with a recent high-speed autonomous approach and landing test for a major CALT vehicle project. According to Xilu, the high-speed autonomous approach and landing test confirmed the subject was an aerospace vehicle, while the timing and the involvement of CALT suggested it was likely the Aotian-1.<sup>72</sup> It is also possible that these tests were actually for the Shenlong project, which is believed to be connected with the Aotian-1 spacecraft;<sup>73</sup> Chinese journalist Chen Guangwen [陈光文] has described the Aotian as a miniature or technical trial version of the Shenlong.<sup>74</sup>

## Tengyun

Tengyun [腾云] is a spaceplane project being developed by CASIC. It is one of five “Yun” [云] (“Cloud”) aerospace projects<sup>iv</sup> that CASIC officially launched in 2016.<sup>75</sup> The CASIC “Cloud” website describes Tengyun as a two-stage-to-orbit (TSTO) aerospace vehicle that can take off horizontally from an airport and accelerate into the atmosphere. At a certain altitude, the two stages separate, and the first stage returns to land horizontally at the airport, while the second continues into low-Earth orbit to complete its mission. The second stage can also return to Earth and land horizontally upon completing its task.<sup>76</sup>



*Still image from animation of the Tengyun spaceplane landing on a runway.*

Tengyun’s first stage, the “parent” aircraft used to launch the orbital vehicle, is an unmanned hypersonic drone that will be capable of ascending to an altitude of 30 or 40 kilometers while transporting the smaller second stage mounted on top of it.<sup>77</sup> The first stage will reportedly be over 80 meters in length and weigh over 140 tons, while the second stage will be around 20 meters long. Both are expected to be reusable up to 100 times, considerably more than any of the Space Shuttles.<sup>78</sup> The parent aircraft features a turbo rocket combined cycle (TRCC) engine, which integrates jet engines, ramjets, and rocket engines into its mode-shifting propulsion system. Tengyun’s ramjets can reportedly reach Mach 4.5 and it has been estimated that future ramjets could reach Mach 7-10.<sup>79</sup> Tengyun’s developers say they have achieved or plan to achieve technological breakthroughs in the creation of this combined engine as well as other key technologies, such as airframe/propulsion integration.<sup>80</sup>



*Unofficial depiction of the Tengyun’s second stage orbiter deploying a satellite.*

The second stage of the Tengyun, which outwardly resembles the U.S. Space Shuttle, uses a liquid-fuel rocket engine for propulsion. Besides transporting crew, passengers, or cargo, it will reportedly be able to deploy small satellites and conduct various technology verification missions.<sup>81</sup>

<sup>iv</sup> The other four projects include the high-altitude long-endurance UAV Feiyun [飞云], the stratospheric airship Kuaiyun [快云], and satellite constellations Xingyun [行云] and Hongyun [虹云].

According to the CASIC Cloud website, the Tengyun spaceplane will be able to carry both people and cargo and is primarily geared toward commercial operations. When carrying people, it could be used for space tourism or transportation of astronauts. It could also launch satellites, deliver cargo to space stations, carry out space emergency rescue missions, and perform other functions.<sup>82</sup> It is hoped that the spaceplane can reduce the cost of civilian space travel as well as the cost of launching satellites.

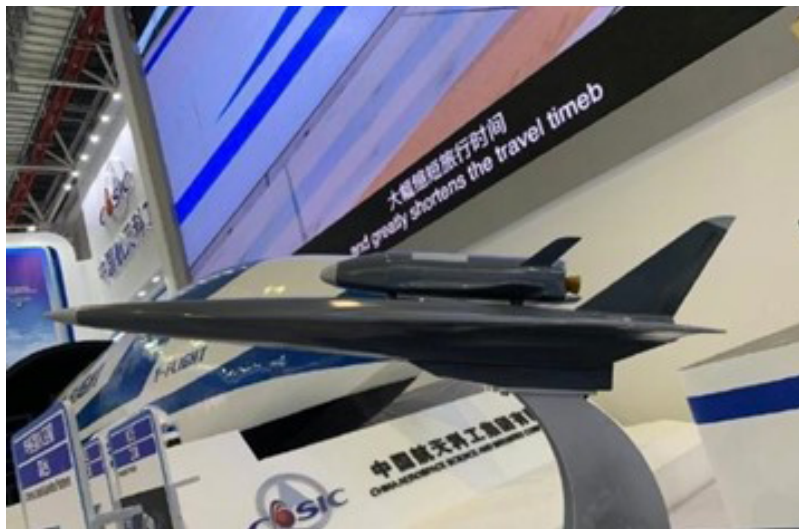
Despite the public emphasis on commercial applications, Tengyun also has several potential military applications including deploying military satellites, carrying weapon payloads, or performing maneuvers to attack other satellites. The Tengyun’s second stage might also return to Earth at speeds above Mach 20, allowing it to be used as a hypersonic weapon to strike any target on Earth within an hour.<sup>83</sup>

### **Development**

The Tengyun spaceplane and the other “Cloud” projects were officially announced in 2016. On 19 October 2020 at the 6<sup>th</sup> China International Commercial Space Summit, CASIC announced a major breakthrough in the development of the Tengyun’s combined cycle engine, a core technology for the project. The spacecraft successfully completed an ignition test of its combined engine and performed two test flights of the “aerospace plane” portion (i.e., the second stage), which was launched by a Long March rocket.<sup>84</sup>

In April 2018, the South China Morning Post reported that the CAS Institute of Mechanics was building a factory in Hefei, Anhui Province for the commercial production of hypersonic engines, including scramjets.<sup>85</sup> Scramjets built in this factory are likely to become part of combined cycle engines for reusable hypersonic aircraft, including the first stage of the Tengyun.<sup>86</sup>

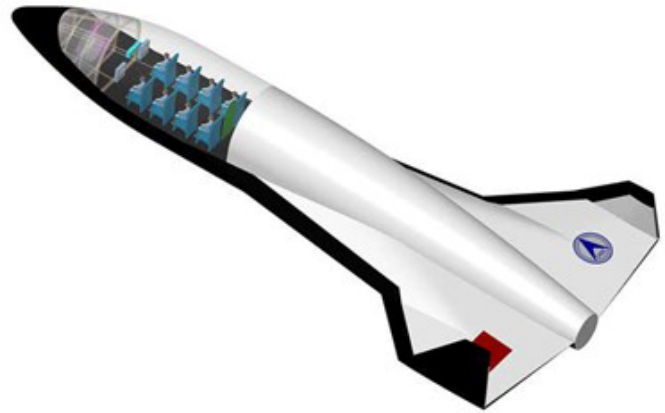
According to CASIC’s development timeline released in October 2020, the corporation intends to complete research and carry out a technology verification flight test of the Tengyun in 2025. By 2030, the spaceplane project should be complete and begin commercial operation in orbit.<sup>87</sup>



*Physical model of the Tengyun as seen at a CASIC exhibition.*

## CALT Vertical Takeoff Horizontal Landing Reusable Spaceplane

In October 2016 at the International Astronautical Conference in Guadalajara, Mexico, representatives from CALT announced that they had designed a one-stage reusable spaceplane for space tourism. The spaceplane, whose name was not made public, would take off vertically like a rocket and land autonomously on a runway like an airplane. The vehicle would use a rocket engine fueled by liquid methane and oxygen to take off and climb into the atmosphere, reach its predetermined altitude through inertia after burning through the propellants, and finally return to Earth in an unpowered gliding maneuver.<sup>88</sup>



*Concept art of CALT's planned VTHL single-stage spaceplane.*

CALT designed two versions of the plane at different scales. The smaller version weighs 10 tons, has a wingspan of six meters, and is designed to carry up to five passengers to an altitude of 100 kilometers at a maximum speed of Mach 6. Passengers would experience weightlessness for about two minutes before descending back to Earth. The larger version of the spaceplane weighs 100 tons and has a wingspan of 12 meters. It is designed to carry 20 passengers to an altitude of 130 kilometers at up to Mach 8, allowing them to experience up to four minutes of weightlessness.<sup>89</sup> If the project is successful, this larger version of the CALT spaceplane would be the world's largest spaceplane. It would also be large enough to launch small satellites with the help of a small rocket that could serve as an attachable second stage.<sup>90</sup>

At the time, design team leader Han Pengxin [韩鹏鑫] said that each spaceplane would be able to carry out up to 50 flights. He also estimated that test flights could take place over the next several years, with real launches occurring as early as 2020. The spaceplane would ultimately be put into use by 2030.<sup>91</sup> At the time of writing (August 2021), this timeline does not appear to have been realized as planned.

Some reporting on the spaceplane announcement in October 2016 also noted that two months earlier on 31 July 2016, CASC (CALT's parent corporation) announced that it was developing a combined-power aerospace vehicle for space tourism, which would integrate turbine engines, ramjets, and rocket engines. It was intended that the aircraft would take off using the turbine engines (like an ordinary airplane), then use the ramjet upon reaching a certain speed, and finally use the rocket engine to boost to orbit from the upper atmosphere.<sup>92</sup> While the spaceplane mentioned in this earlier announcement was also not named, it was implied by the reporting to be the same one announced in the Guadalajara conference. However, it is also possible that this announcement was in reference to the Tengyun spaceplane, which is known to use combined engine technology.

On 16 July 2021, CASC announced that it had successfully carried out the first suborbital flight mission of a reusable spaceplane. The spaceplane was launched from Jiuquan Satellite Launch Center and landed at the Alxa Right Banner Airport [阿拉善右旗机场] in Inner Mongolia,<sup>93</sup> nearly 137 miles away. Official reporting did not reveal the name of the spacecraft or any additional identifying details, but it has been speculated based on the developer, the timing, and the nature of the test that this may have been a version of the same commercial spacecraft CALT announced in 2016.<sup>94W</sup>

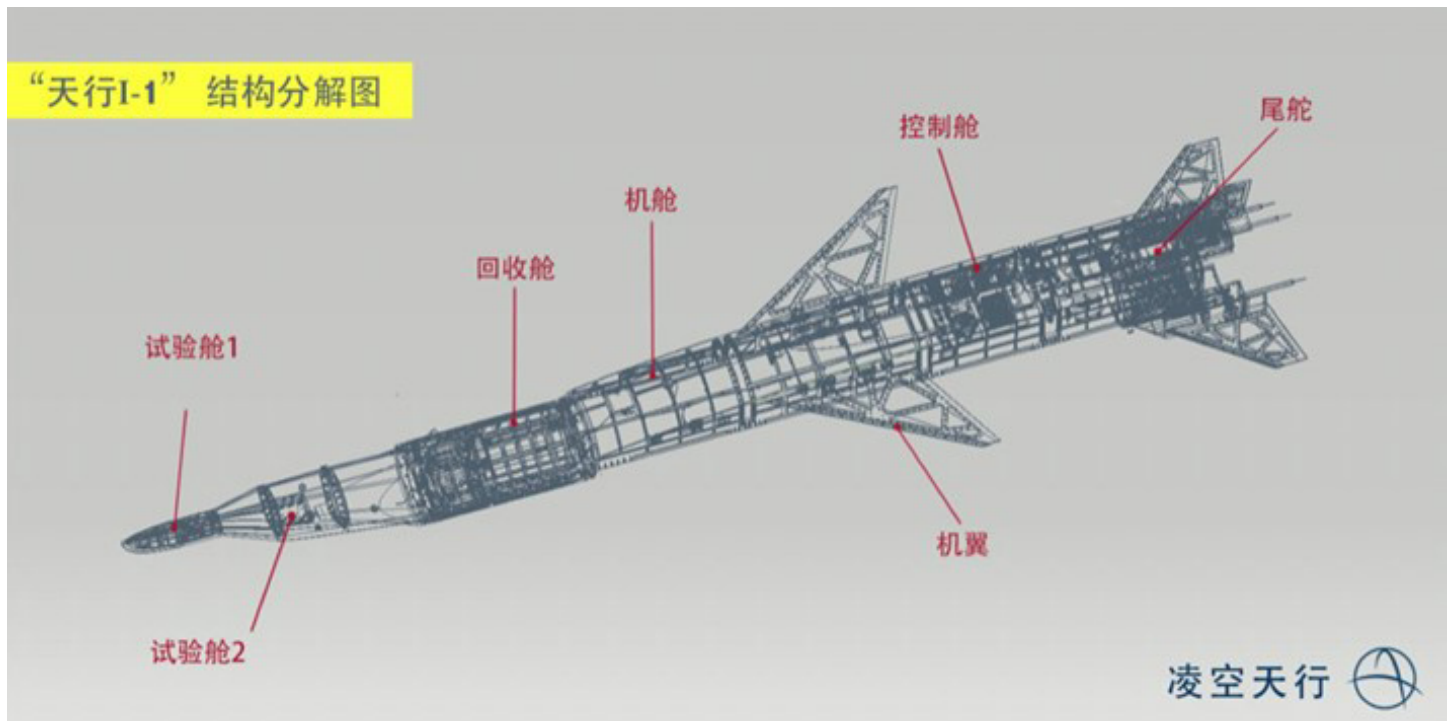
## Tianxing

Tianxing [天行] is a family of reusable spacecraft resembling winged rockets under development by the Beijing-based private startup Space Transportation [凌空天行], which was founded in 2018. In 2019 the company successfully performed two suborbital flight tests of its first reusable rocket, the Tianxing-1.<sup>95</sup> The rocket launches vertically and can maintain horizontal flight in the upper atmosphere using its fin-like wings, before gliding back down to Earth horizontally.<sup>96</sup>

Space Transportation also jointly developed the Jiageng-1 [嘉庚一号] test carrier rocket with Xiamen University based on the Tianxing-1. This rocket completed a successful flight test and landing in April 2019, which was the first test flight of the Tianxing-1 platform. The Jiageng-1 is 8.7 meters long with a wingspan of 4.5 meters and a mass of 3,700 kilograms at takeoff. It can fly up to 4,300 km/h (2,672 mph) and reach suborbital altitudes. It also features an in-cabin low-frequency communication system designed by a Xiamen University team and carried a payload of various technology verification devices during its first launch.<sup>97</sup>



*A photograph of the Jiageng-1 technology demonstrator.*



*A diagram of the Tianxing-1 reusable launch vehicle.*

The Tianxing-2 is currently under development; in November 2020 Space Transportation performed ground tests of its Lingkong-1 [凌空一号] engine, which will be the main engine of the Tianxing-2. The tests also verified the reliability of the vehicle's pyrotechnics system, servo system, gas rudder system, separation system, structural system, and thermal protection system. The Tianxing-2 is intended to be a modular carrier platform for carrying out flight tests over Mach 10. Although an article about this engine test describes the Tianxing-2 as a multistage carrier rocket,<sup>98</sup> an earlier source from April 2019 claimed it would be an upgraded version of the Tianxing-1 single-stage test platform, with improved capabilities and lower cost.<sup>v</sup> The same April 2019 source was among the very few that referenced a Tianxing-3 and Tianxing-4. Tianxing-3 is meant to be a reusable carrier rocket based on the Tianxing-2, which carries and then detaches a second stage space vehicle which in turn proceeds to carry payloads (such as small satellites) into orbit. Tianxing-4 is a planned suborbital spaceplane that can be used for space tourism or for rapid transportation of passengers or goods around the world.<sup>99</sup>

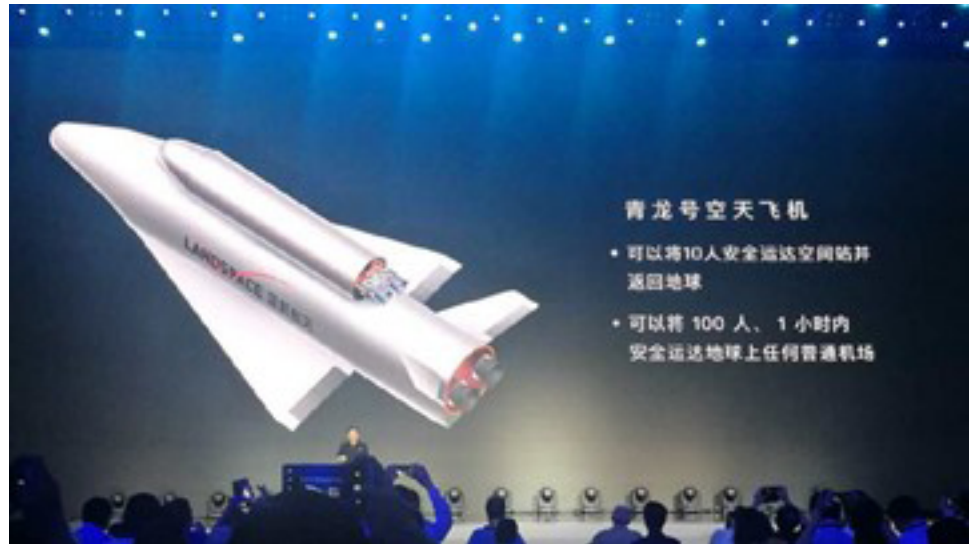


*Concept art of four reusable launch vehicles in the Tianxing family.*

<sup>v</sup> It is unclear whether the disparity reflects a change in the intended design of the Tianxing-2 since 2019 or a mistake in one of the sources.

## Qinglong

The Qinglong (lit. “Green Dragon”) Aerospaceplane [青龙号空天飞机] is a spaceplane project announced in 2018 by the Chinese company LandSpace [蓝箭]. The Beijing-based company claims the plane will be able to safely transport 10 people to the space station and back to Earth or transport up to 100 people to any location on Earth within an hour. An image of the spaceplane concept shown at LandSpace’s 2018 presentation depicts a two-stage vehicle consisting of a small rocket mounted atop a delta-winged spaceplane, suggesting an HTHL design.<sup>100</sup> Qinglong does not appear to have been publicized outside the 2018 presentation: even the LandSpace website itself does not contain any mention of it.



Concept art of the Qinglong spaceplane from a 2018 LandSpace presentation.

## iSpace Spaceplane

iSpace [星际荣耀], whose name is also translated as “Interstellar Glory,” is a Beijing-based private spaceflight startup established in 2016. The company is focused on commercial satellite launches,<sup>101</sup> a service provided by its Hyperbola [双曲线] series of rockets, and is known for being the first private Chinese company to reach orbit. iSpace also claims to be the first Chinese private company to release a “suborbital concept vehicle” [亚轨道概念飞行器] for space tourism, though this vehicle appears to be in conceptual stage. While no further information about this vehicle can be found online, an image on the company website appears to show a single-stage delta-wing spaceplane with a narrow, elongated body and a single rocket engine. The concept may suggest a VTHL spaceplane, though this is not certain.



Concept art showing the side and top views of the planned iSpace spaceplane.

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## CALT Rail-Launched HTHL Passenger Spaceplane

At China's National Space Day event in April 2021, CALT presented a video entitled "One Hour Global Arrival in the Space Transportation System" which showcased two different concepts of hypersonic point-to-point transportation. One of the concept vehicles was a single-stage HTHL spaceplane that is shown being launched from a high-speed electromagnetic rail and then using a hybrid rocket engine to accelerate from Mach 2 to Mach 15. After reaching suborbital altitudes, the vehicle then descends to its destination on Earth, landing horizontally on a runway like a conventional aircraft. The video claims this technology will allow passengers to travel to any destination on Earth in less than an hour.<sup>102</sup> It is not clear whether the spaceplane in the video is just a concept at this time or whether CALT is currently in the process of developing such a vehicle.



A screenshot from a CALT presentation showing a rail launched HTHL spaceplane.



## Section 3: China's Progress in Relevant Technologies

### Technologies being Developed to Support Spaceplanes

CASC engineer Zhang Yong claimed in 2016 that China would master all relevant spaceplane technologies within 3-5 years.<sup>103</sup> This is not a trivial task, as spaceplanes require a range of complex technologies from high-temperature resistant materials to entire systems. Slower progress in any of these could have a major effect on the timelines for the programs examined in Section 2. While it is difficult to count the different technologies that must be developed to produce functional spaceplanes, several can be identified as particularly critical. The following section provides an overview of China's progress in developing key technologies needed for spaceplanes.

### Combined Cycle Engines

Because spaceplanes must be able to fly both in the atmosphere and in space, they require multiple integrated propulsion systems. This is particularly true of HTHL spaceplanes such as the Tengyun, which use turbo engines to take off like an airplane, ramjets to reach suborbital altitudes at hypersonic speeds, and finally, rocket boosters to enter orbit.<sup>104</sup> China has made considerable progress on combined cycle engine technologies over the past five years. CASIC, Tengyun's main developer, announced in October 2020 that it had made a breakthrough in the spaceplane's TRCC engine and completed an ignition test.<sup>105</sup> Other types of hypersonic combined cycle engines under development include turbine-based combined cycle (TBCC) and rocket-based combined cycle (RBCC) engines.<sup>106</sup> A TBCC engine that integrates a turbine with a scramjet engine was successfully tested by the AVIC subsidiary Chengdu Aircraft Research and Design Institute in January 2019.<sup>107</sup> In April 2018, the China Academy of Sciences' Institute of Mechanics announced it would construct a factory in Hefei, Anhui province, for the mass production of various types of hypersonic aerospace engines.<sup>108,vi</sup>

### Heat-resistant, Durable, Lightweight Materials

Like other types of space vehicles that are meant to be recoverable (such as space capsules), spaceplanes must be made with materials that are lightweight, heat-resistant, and durable enough to maintain the vehicle's structural integrity for multiple flights and landings. China has a strong materials science research base, whose total volume of papers exceeds that of the United States and whose funding from the government has quadrupled since 2008, making it the second-highest recipient of state funding in China among all scientific disciplines.<sup>109</sup> In 2020, research on heat-resistant materials for reusable spacecraft was named by the China Space Conference as one of the top focus areas of the astronomical domain.<sup>110</sup> Some of China's recent accomplishments in aerospace materials include a new ceramic-aluminum alloy that reduces the weight of aircraft while being 30 percent stronger than traditional aluminum alloys<sup>111</sup> and many applications of additive manufacturing (3D printing) to the production of spacecraft components, including carbon-based ceramic thermal shielding.<sup>112</sup>

While information about the particular materials used for each of China's spaceplanes is not publicly available, China's successful flight test and landing of an orbital spaceplane in September 2020, as well as its repeated success in recovering crewed space capsules, suggests that its efforts to develop heat-resistant, lightweight spacecraft materials have met with a certain amount of success.

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vi For more information about Chinese developments in propulsion systems, see: Peter Wood and Alex Stone, "China's Ballistic Missile Industry," China Aerospace Studies Institute, 10 May 2021, [https://www.bluepathlabs.com/uploads/1/1/9/0/119002711/bluepath\\_labs\\_ballistic\\_missile\\_industry\\_report\\_2021.pdf](https://www.bluepathlabs.com/uploads/1/1/9/0/119002711/bluepath_labs_ballistic_missile_industry_report_2021.pdf).

## Autonomous Navigation

Autonomous navigation is an important area of technological development for spaceplanes. The Shenlong, the first stage of the Tengyun, and some others are uncrewed robotic spacecraft, but even the spaceplanes intended to accommodate crew and passengers may be designed with autonomous functionality.

As with spacecraft materials, the specifications of the guidance and navigation systems used by each of China's spaceplane projects is not publicly known. However, generally speaking, China has made great strides in developing, testing, and implementing autonomous navigation systems for aerospace vehicles over the past decade. Some of the technologies China has developed for autonomous navigation for spaceflight and landing include on-orbit X-ray pulsar navigation,<sup>113</sup> spectral redshift navigation,<sup>114</sup> and infrared vision-based guided landing systems.<sup>115</sup> China has also successfully implemented autonomous navigation technology in various existing spacecraft. For example, in June 2021, the crewed spacecraft Shenzhou-12 successfully carried out China's first autonomous rapid rendezvous and docking with the Tianhe space station module.<sup>116</sup> Robotic craft such as the Tianzhou cargo carrier have also demonstrated autonomous navigation and docking capability.<sup>117</sup> Even more impressively, China was able to land and operate multiple rovers on the moon and one on Mars between 2013 and 2021; both types of missions required autonomous navigation due to the distances involved, which are much greater (though in one less dimension) than any spaceplane would be expected to travel.<sup>118</sup>

## Section 4: Competing Space Launch Technologies

The rapid expansion of the “new space” industry in the past decade, featuring many Chinese companies spun off from or created with the assistance of China’s aerospace giants, has led to the creation of a wide range of space launch vehicles. While this trend is responsible for the development of new spaceplanes, it has also led to the production of other space launch technologies that may compete with or even totally obviate the need for some spaceplane programs.

For example, the “rapid launch” capabilities of the Kuaizhou [快舟] and other rocket systems allow China to carry out space launches much more rapidly and frequently than in the past. The Kuaizhou 1A completed nine successful launch missions between January 2017 to July 2021 and set a record for the shortest interval between launches from the same spaceport (a mere six hours). Plans for the Kuaizhou program include doubling its total number of launches per year by 2023.

Globally, SpaceX’s development of vertical launch and recovery technology has created a new design path for reusable space launch vehicles, and Chinese companies have been quick to follow. China’s leading spacecraft developer CALT is developing the partially reusable Long March 8R (CZ-8R) [长征八号R型], an upgraded version of the expendable CZ-8 which resembles SpaceX’s Falcon 9. By 2025, it is expected that the CZ-8R will be capable of vertical landing and recovery and will include a reusable first stage and booster.<sup>119</sup> CALT also presented a video in 2021 featuring a reusable VTVL (Vertical Takeoff, Vertical Landing) passenger rocket concept greatly resembling SpaceX’s Starship; it is unclear whether this project is just a concept or is actually being developed.<sup>120</sup> The CASC subsidiary Shanghai Academy of Spaceflight Technology (SAST) is also developing the Long March 6X (CZ-6X), a reusable VTVL version of the Long March 6.<sup>121</sup> Among private developers, the space start-up iSpace is developing the vertical-landing Hyperbola-2 [双曲线二号] reusable rocket.<sup>122</sup> Another private firm called LinkSpace [翎客航天] has successfully tested its RLV-T5 reusable VTVL rocket in 2019.<sup>123</sup> Several other private firms are also developing fully or partially reusable rockets.<sup>124</sup>

Rapid-launch and reusable rockets are appealing alternatives to spaceplanes for several reasons. The primary reason is simply that rockets are a much more mature and well-understood technology than spaceplanes: all objects placed into orbit to date have been launched vertically by rockets. By contrast, only two models of orbital spaceplane have even been put into use: the Space Shuttle and the Boeing X-37 (both of which were themselves launched on rockets). As with other reusable spacecraft, creating workable spaceplanes requires developing materials that are durable, heat-resistant, and lightweight enough to make multiple trips to space while safely delivering crew and cargo. Developing HTHL spaceplanes presents the additional difficulty of integrating multiple types of propulsion systems for the various stages of flight. Second, while reusability (and therefore cost savings) is a major selling point of spaceplanes, SpaceX’s successful development of reusable VTVL rockets has inspired a new wave of research into reusable rockets that may negate this particular advantage of spaceplanes. Reusable spaceplanes can also allow launches to happen much more frequently, but both reusable rockets and rapid-launch rockets can enable the same capability. Finally, while spaceplanes have some advantages over rockets when it comes to carrying crew or passengers, most space missions today can be accomplished with unmanned craft.<sup>125</sup>

Nevertheless, the existence of the spaceplane projects described in this report demonstrates that China is still interested in developing spaceplanes concurrently with various advances in rocket technology. There are several possible explanations for this. First, most known Chinese spaceplane projects are officially geared toward civilian space tourism and rapid global transportation; spaceplanes are indeed much better suited than rockets or space capsules for the safe and comfortable transportation of civilian passengers. Space tourism has the potential

to become a lucrative market for China in the near future, while hypersonic transportation will revolutionize international travel if it becomes feasible. The ability of spaceplanes to land at (and in some cases take off from) ordinary airports is a significant advantage for civilian travel applications. Second, orbital spaceplanes have greater on-orbit maneuverability than most other spacecraft, allowing them to perform a wider possible mission set including satellite maintenance, satellite retrieval, stealthy reconnaissance and navigation, and counter-space operations. Third, spaceplanes have significant technological overlap with hypersonic weapons and aircraft and thus may be used for hypersonic technology verification or themselves possess useful offensive strike capabilities.<sup>126</sup> Finally, it is possible China is developing spaceplane technology simply to keep up with the United States, its main geopolitical rival.<sup>127</sup>

It is worth pointing out that although none of China's spaceplane projects have been put into operation at the time of writing, the PRC has also yet to field a working VTVL reusable rocket. Therefore, to the extent that reusable spaceplanes and rockets are rival technologies, the ultimate winner of their competition remains to be seen. China's national plans to develop reusable launch vehicles do not specify what form those vehicles should take. It is fully possible that some of the aforementioned spaceplane projects will not be completed due to technical challenges, insufficient funding or profitability, changing government priorities, or other reasons; the same is true of the various reusable rocket projects. It is also possible that both technologies will ultimately be adopted for different missions; for instance, using rockets for most orbital launches and spaceplanes for civilian transport and suborbital military applications.

## Conclusion

Although China's spaceplane programs play a relatively small role in China's planned space programs, the technology has seen major investment since the Tengyun program was announced in 2016. While spaceplane development has historically been driven by the military and China's state-owned aerospace giants (the two oldest projects featured in this report, the Shenlong and Aotian-1, are both military projects), recent years have seen a greater number of civilian-oriented spaceplane projects developed by smaller private firms.

It must be noted that the lack of detailed information from reliable sources about many of these projects makes it difficult to gauge the status and prospects of particular projects or of the industry as a whole. Military-oriented spaceplane projects such as the Shenlong are unsurprisingly highly secretive and classified. To date, the only clear photo of the Shenlong available online is the one leaked in 2007, which was likely a non-functional prototype model. News of spaceplane launches such as the ones in 2020 and 2021 often do not include the name or identifying details of the spacecraft being tested, leaving it up to speculation. Information for most of the non-military projects is sparse as well. For a given spaceplane project, it is unclear whether the absence of up-to-date information is because the project is still in very early stages, has been impeded by technological or financial hurdles, has failed, or been canceled, was folded into another project, was superseded by other priorities, was actually successful but is now considered classified, or has been classified for other reasons.

Still, it is clear from China's official space plans and the overall trends of the industry that China fully intends to develop reusable launch vehicles including spaceplanes. These developments have several implications for the United States in both the civil and military domains.

First, China is serious about competing with the United States and other countries in the burgeoning space tourism industry, both for profit and for prestige. China will likely have tourism-capable spaceplanes within the next decade (at least for suborbital flights) and stands to capture a hefty market share by 2030. In the more distant future, spaceplanes will be an attractive possibility for civilian hypersonic travel around the world, and China will likely be a major player in this field as well. A majority of China's current spaceplane projects already list tourism and point-to-point transportation among their primary goals. Civilian spaceplane travel is also a possible area of future U.S. cooperation with China, just as civilian aviation already is.<sup>128</sup> Although some of the technologies involved are sensitive, coordination and joint development will be beneficial if spaceplanes are to become part of a global civil transportation network.

Second, reusable launch vehicles such as spaceplanes are a way for China to reduce costs for launching satellites and other space-based assets and to increase the frequency of launches. They will therefore increase China's profit margin for its launch services and enable it to accomplish major goals more quickly in space, such as deploying satellite constellations. However, reusable rockets offer alternative ways to achieve the same effect, while other technological developments such as rapid-launch rockets and additive manufacturing may reduce the time and expenses needed for each rocket launch and reduce the relative advantage offered by spaceplanes. On balance, it does not appear that spaceplanes are likely to become China's most cost-effective means of launching space assets in the future.

Third, the unparalleled on-orbit maneuverability of orbital spaceplanes will make them more attractive to China as a means of servicing (and if necessary, recovering) satellites. This application of the technology for civilian purposes does not have major implications for the United States, except in the general sense that it improves the reliability of China's satellite systems. However, the same feature of spaceplanes can bring China significant military advantages in space that the United States will have to counter. Spaceplanes can be deployed

as anti-satellite weapons platforms, using means such as robotic arms and onboard weapons to target American satellites. They can also be used for military reconnaissance, with their maneuverability making them more difficult to track. Finally, future military spaceplanes could be used as platforms for space-based weapons that can strike targets on Earth more rapidly than missiles. Both this capability as well as the potential use of spaceplanes as hypersonic weapons could erode the United States' strategic deterrent, as it would allow China to strike faster than anti-missile systems can react.

Spaceplanes have an additional use as technology demonstrators and platforms for scientific experiments. They can therefore help China test sensors and communication systems for the next generations of spacecraft, civilian and military-use satellites, and weapon systems.

Given China's current level of spaceplane development, however, these points only represent likely functions of the technology. None of China's spaceplanes appear to have been fielded in a regular, operational form so far. Other related or supporting technologies such as reusable rockets are also still under development. While this may change in the coming decade, these programs continue to display clear borrowing from Western designs such as the Space Shuttle, X-37B or SpaceX rockets, rather than pathbreaking or entirely novel designs. This makes it likely that China will remain behind the curve for the foreseeable future when it comes to keeping pace with U.S. space technology.

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