Current Status of Research on Space Emergency Launch

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Abstract. The realization of space rapid emergency launch needs to be developed from rapid response spacecraft, rapid response vehicle and space rapid launch infrastructure, so as to constitute the organic whole of "trinity" and give full play to the effectiveness of the system. Rapid response vehicle and space rapid launch infrastructure are the mainly two aspects that closely related to the construction of space rapid emergency launch force. This article mainly focuses on the research and analysis of the development status of foreign space emergency launch force from the above two aspects.

1. Introduction
Space emergency launch refers to the space carrier after receiving the launch instruction, quickly complete the star Arrow docking, transport and testing, the payload launched in time into orbit, and can quickly prepare the ability of the next space launch. It is the key to fast, flexible entry into space, use of space, maintain space advantage, and crack the "space rejection" dilemma under wartime or sudden conditions.[1] The construction and development of space emergency launch force directly determines the self-recovery and self-enhancement ability of space countermeasure system.[2]

The further intensification of space confrontation, the urgent requirement of battlefield rapid perception and space power application, and the vulnerability reality of space system survivability make the space field have a strong demand for emergency rapid launch.[3] In recent years, in order to improve the operational space emergency launch capability, the world's space powers around the rapid response spacecraft, rapid response vehicles, rapid response to launch sites and other fields to actively promote the construction. At the same time, the rapid launch force that can support space warfare has been gradually built.[4]

After the development in recent years, China's emergency launch equipment and strength construction has made great strides. However, it is also deeply understood that the architecture, Organizational command mode, training method and vehicle test launch mode in the construction of the traditional equipment test Space launch team can not meet the realistic requirements of space emergency launch.[5] How to demonstrate and build a new combat force into space under the new situation and enhance the combat capability of the Space Emergency launch Force system is an important and urgent task that we are facing.[6]

2. Rapid response to space carriers

2.1. United States
America's superb power in the space field has led to its dominance in rapid response to vehicle research. [7] In the current three launch modes of land-based, Haiki and space-base emission, the space-based emission has the freedom of choice because of its great launch time, launch location and target orbit. Its launch costs are also highly potential for significant reduction. This is therefore ideal for fast response to launch requirements. [8] The PegasusXL rocket is currently the world's only active aerial launch vehicle, launching response time of 4 days, from the carrier take-off to the ignition launch of about 1 hours. Because it uses a multi-purpose assembly trailer for the archery docking using a horizontal assembly, the docking task can be completed quickly 3 hours before the launch, and can be achieved theoretically in any location around the world, as shown in Figure 1.

![Figure 1. PegasusXL launch timing and launch site of air-launched rocket](image)

The Airborne launch Assist Space Access (ALASA) project, which was cancelled at the end of 2015 as a result of the failure of successive tests, considered the use of level three solid rockets as an air launch vehicle for the project, using the F-15 and Boeing 747 as launch platforms. The goal is to develop an aerial launch system capable of rapidly responding to launch orders, deploying small satellites weighing about 45kg to low Earth orbit within 24 hours and completing the next launch preparation within 12 hours.[9]

In the area of land-based launch vehicles, the Office of the United States Air Force ORS invested in a new launch vehicle in 2013 dedicated to small satellite launches, named SPARK Rockets, also known as Super Strypi. [10] The SPARK rocket was able to meet the 24-hour on-demand launch requirements set by ORS and could be launched on a simple cement platform, but exploded during a failed flight in 2015.

The "Multipurpose Multipurpose Nano Missile System,mnms" program, which was launched in July 2010 by the United States Army space and Missile Defense Command[11], is a low-cost, multi-configuration based on existing missile technology. The multifunctional, fast-response simple rocket system takes only 24 hours from the receipt of the launch instruction to the completion of the launch, and the cost of a single launch of 1 million United States dollars.

The Sword (SWORDS) program, also led by the U.S. Army, is an acronym for "Soldiers in space-combatants fighting timely response vehicles." The project provides operational commanders with the capability to "launch as ordered" spacecraft, which, when completed, can send 25 kilograms payloads into 750-kilometer of low Earth orbit.

SWORD can be motorized transported by the C-130 transport aircraft, from the storage state to the launch preparation time does not exceed 24 hours, can be based on the mobile launcher on the very simple cement table, as shown in Figure 2. In addition, the "XS-1" pilot space aircraft, awarded the Spawn first contract on July 17, 2014, was designed to develop a fully reusable spacecraft that would achieve 10 launches within 10 days on the basis of reduced launch costs.
2.2 Russia

Russia's air launch project has stagnated since it was introduced in 1998, plagued by economic capacity constraints and financial crises. It was not until July 2012 that it was reported that the Russian government would restart the aerial launch project. The same reason has led Russia to have no corresponding new rapid response vehicle development plan in recent years. Russiese aktiewe vinnige reaksie voertue word hoofsaaklik verander deur intercontinental ballistiese Missiele, insluitend DNEPR, Start-1, Rockot reeks en Strela, die nuwe bekendstelling voertuig is hoofsaaklik die alliansie-2.1 V. Die eerste vier vuurpyle is almal omskep uit Russiese intercontinental ballistiese Missiele. Statistics show that in 2000-2009 years, the International Small satellite Launch field 1-50kg range, from the first Dnieper launch of more than 35%, fully reflects its launch reliability and safety. The launch area of the Dnieper rocket was prepared for 14 days. The founding number is motorized launched by vehicle launch, and the special launcher is mounted on the launch vehicle and can normally be used as a rocket storage device and transport device, and its launch preparation can be completed within 12 hours. Wuthering 2000 maiden voyage, fixed launch tower launch, because the use of Briz-KM upper stage, thus has a stronger capacity and orbit accuracy. The Sky Arrow adopts the launch well launch method, the launch preparation time is longer, the LEO ability is 1700kg. The Alliance -2.1V was a two-stage liquid light launch vehicle improved by Russia in recent years to meet the strong demand for microsatellite launches, on the basis of the Soyuz series, and successfully launched its maiden voyage on December 27, 2013. The rocket realizes the digitization of the control system, equipped with a new "Volga" advanced upper stage which can work for 24 hours and has multiple ignition functions, and the Alliance -2.1V Plan launch area preparation time is 2 days.

2.3 Japan

Although Japan is unable to develop the technology of rapid missile launch rocket modification because it does not have an intercontinental ballistic missile capability, it has still performed actively in the space field in recent years, proposing a number of aerial launches and new rocket development plans.

In 2010, JAXA presented an aerial launch vehicle project called NanoLauncher, based on sounding rocket technology, whose launch response time is expected to be within 24 hours. At present, the rocket has carried out engine test and electrical equipment test. Around 2011, Japan proposed the "Air Launch system enabling technology, ALSET)" program, the ultimate aim of which is to commercialize rapid aerial launches. The planned selection of C-130 transport aircraft, the launch vehicle using three-stage solid rocket, launch mode for the internal, with the launch pry of the umbrella stability method, LEO capacity 150kg, launch preparation time design of 24 hours. In the 2012, IHI Aerospace of Japan proposed a new concept of a μLambda launch vehicle with a view to sending small satellites at the 50kg level to low Earth orbit within 24 hours. In addition, the Epsilon
solid launch vehicle, originating in Japan's "Advanced Solid Rocket Program", was first flown on September 14, 2013 and its launch site was prepared for only 14 days, as shown in Figure 3.

![NanoLauncher ALSET Epsilon](image)

**Figure 3. Japan's rapid response rocket**

### 2.4 Other countries

With the continuous development of the concept and technology of rapid response space, a variety of new launch vehicles have emerged, most notably the ESA Vega carrier rocket, the New Zealand Electric rocket, and the Italian balloon rocket.

The Vega carrier rocket is the latest ESA developed four-stage solid-liquid hybrid medium rocket, one, tertiary is a solid rocket engine and four is a liquid rocket upper stage.[17] The lead time for the Vega rocket launch site is 27 days, and the launch area is prepared for 6 days. In addition, ESA has proposed the Vega's improved Rocket "Lyra", which has also entered the practical research phase.

The Electron rocket, developed by Rocket Lab in New Zealand, was launched for the first time in 2017, powered by an electric engine of battery energy, and all of the rocket's main equipment is manufactured in one of the carbon fiber materials printed by 3D printing technology, with a payload of approximately 150Kg. The rocket was simply demanding of the launch site equipment and its first launch was launched from a private launch site in New Zealand.

In 2017, Spain's Zero2Infinity company tested its first balloon launch rocket, Bloostar, which was developed.[18] The rocket, which was launched by balloons over the international sea near 25Km, is an aerial launch technology that, together with launch preparation time, has a Bloostar launch time of only 9 hours and does not require a special launch site, with a flexible launch method, as shown in Figure 4.

![Figure 4. Electron and Bloostar](image)

### 3. Construction of emergency launch ground system

For conventional space launch activities, the Space launch site is an integrated ground guarantee and quality control system to ensure the smooth launch of the launch vehicle, which is responsible for the
assembly, storage, detection, measurement, control and launch of the carrier, spacecraft and other important duties, and is an important part of the space system.[19] However, for the construction of Space emergency launch Force, the original launch site function is no longer fully suitable. For the construction of ground system under the condition of emergency launch, the US military ORS office has put forward the following requirements: First, Gaurou rod, low cost flight termination system; second, highly reliable GPS/inertial navigation tracking system; Third, space-based communication, control system; Four is a fast ballistic analysis tool; and five is a reliable launch site security technology.[20] In the construction of emergency launch ground system, the construction of the United States and Japan is at the forefront, and the construction of emergency launch sites by other space powers is rarely reported.

3.1 United States
The United States has the world's only aerial launch vehicle, its ground security system is very simple, basically and military airports are not much different. At the same time, all kinds of launch vehicles modified by strategic missiles also have natural space emergency launch capability, ground support facilities have reached the wartime standard, and the newly developed various rapid launch launch vehicles, its ground support system is also very convenient.

The development of Pegasus XL proves the flexibility and rapidity of the selection of aerial emission launch points.[21] Carrier can reach the arrow unit decoration 3-4 days before launch, complete the arrow docking and inspection, the rocket and payload docking using horizontal assembly mode, assembly by the horizontal haulage car to drag the rocket to the carrier under the belly of the rapid docking, as shown in Figure 5.

![Figure 5. PegasusXL rocket Transport and assembly ground device](image)

The Minotaur series of launch vehicles, converted from intercontinental strategic missiles in the United States, now enable rapid launches of 12 hours, 6 hours and 1 hours. Mainly because it maintained a good launch state at the launch site, to achieve the launch vehicle's combat readiness duty. For example, to achieve a 12-hour rapid launch, the Minotau rocket needs to be stored horizontally and the load is in advance in the fairing. Achieve a 6-hour rapid launch, the rocket level stored in the transporter and has been docked with the payload, to the launch pad can be launched after the vertical. For a rapid launch of less than an hour, the rocket has docked with the payload and is erected in the launch well, or has been docked with a payload in a vertically movable storage.

The Scorpio series rocket being developed in the United States has the ability to launch quickly because of its multifaceted features of its ground support system. These features include the ability of
the launch vehicle to be assembled near the main launch site,[22] vertical assembly on a reusable launch bracket and movement on the launch stand, the rocket design for easy fast movement and handling, the need for a gantry tower and service tower during transfer and launch, and the rocket being mounted in two standard truck trailers. The launch pad has a mass of less than 1000 kg, the number of people involved in the launch is less than 20, and the launch pad with flight interface is simple to achieve information interaction between arrow fields.

3.2 Japan
Japan's launch site construction took full advantage of Japan's artificial intelligence technology, giving the rocket a powerful self-inspection capability, while reducing the number of control personnel at the time of launch. Japan's Epsilon Rocket Autonomous Test System is designed to enable rocket testing to be performed "conveniently at any time, anywhere".[23] Using the autonomous test function based on artificial intelligence technology support, the detection, launch and control of the rocket is completed by a single laptop computer anytime, anywhere through the network, and the so-called mobile launch control technology is proposed, which greatly shortens the launch preparation time and reduces the ground operator. To make ground equipment more compact, eventually, the Epsilon rocket launch preparation time reduced to seven days, ground control personnel reduced to eight people, the use of a laptop can achieve rocket launch control, while the modular rocket structure determines the test launch process update, as shown in Figure 6.

![Figure 6. Epsilon's mobile launch control technology and launch flow](image)

4. Status of domestic research
Emergency launch vehicle of China has developed rapidly in recent years and has nearly become the world's leading. In September 2013, the successful launch of the "Fast Boat One" carrier rocket marked the first full launch satellite rocket integrated rapid response space vehicle.[24] "Fast Boat" rocket for the three-stage solid power and last-stage liquid-boosting series layout, the use of vehicle-mounted mobile launch mode, with a multi-star launch capability, can be launched by the launch vehicle in the ordinary hard ground, does not need complex launch tower, greatly simplified the launch safeguards, the test personnel greatly reduced, the launch cycle can be shortened to 7 days.

The small liquid rocket CZ-6 has completed two launch tests since September 2015 and its rapid response characteristics have been fully verified. The CZ-6 launch vehicle fully applies a new generation of launch vehicle technology,[25] streamlines the launch test process and launch mode, relies on the ground launch support equipment, greatly shortens the launch cycle, meets the requirements of rapid space launch, its launch preparation time is only 7 days, and can carry out "one arrow and twenty stars" multi-star launch, and its reliability is very high.

Also in September 2015, the launch cycle of the small solid rocket CZ-11 can be shortened to 24 hours, compared with the launch of conventional launch vehicles, its launch cycle is significantly reduced,[26] has reached the standard of emergency launch. After receiving the mission order, the rocket can complete the star arrow technical preparation and launch within 24 hours, in which the launch time at the launch point is not more than 1 hour, with "day launch" capability, the rocket for the
first time to achieve the full arrow storage and environmental autonomy of the launch vehicle, has carried out three launches so far, with all-weather, non-reliable launch. Can be launched on any flat surface.

The successful "Tiantou-2" solid launch vehicle, which took place in March 2017, uses a mobile launch mode, has a rapid response launch capability and low launch support requirements, and is a new type of launch vehicle that meets the needs of multi-mission, multi-purpose satellite launch.

From the emergency launch force construction, china has no precedent to follow, the space emergency launch force construction law, combat training methods and other basic elements of force construction has not yet been fully practiced, is in the groping stage. In the face of the new goal of improving the new quality combat effectiveness, it is urgent to learn from the experience of the space launch force of advanced space powers, especially the construction of emergency launch force, in order to accelerate the generation of China's emergency launch combat capability.

On June 5, 2019, China successfully completed the "One Arrow, Seven Stars" maritime launch technology test using the Long March XI carrier rocket (CZ-11 WEY) in the Yellow Sea, which is the first time that China has carried out space launch at sea, filling the gap of China's launch vehicle at sea and providing a new launch mode for China's rapid entry into space. Sea launch perfectly solves the problem of drop zone and provides the possibility for the realization of equatorial launch. The maritime launch realized the technical fusion of "space and offshore", broke through the key technologies such as maritime launch stability and wireless communication reliability, and comprehensively verified the technical process of sea launch, laying the foundation for the subsequent large-scale sea launch in China.

5. Summary
Rapid mobile launch of launch vehicles is mainly based on land platform and space platform. Space-based launches have faster response capabilities and greater flexibility compared to land-based launches. Currently, air-launched rockets are mainly researched in the United States and Russia. Among them, the United States is developing a built-in rapid-reach air-launched rocket based on the SpaceX air-launched rocket, and also put forward the development plan of stratospheric air-launched vehicle system. The flight launch vehicle, which also has air-launched capability, is being developed by Russia.

Because of the high cost of launch vehicle manufacturing and launching, how to reduce costs has become a new direction of research. Finding the best combination between short launch time, large payload and low cost is the best state of space rapid launch technology.

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