Transforming Space Transportation with Automotive Manufacturing Principles

Interstellar Technologies, a private Japanese aerospace company, is developing a vertically integrated space infrastructure combining orbital launch vehicles and advanced satellite communications. Its rocket, ZERO, is a two-stage vehicle designed and manufactured entirely in Japan. To scale production, Interstellar has partnered with Woven by Toyota, applying automotive manufacturing principles to rocket production. This collaboration, backed by a ¥7 billion (~$44 million USD) investment, aims to create Japan's first mass-producible launch platform.

In parallel, Interstellar is expanding its business into related areas as part of its vertical integration strategy. One example are the direct-to-device broadband communication satellites that have been selected for JAXA's formation flying program. By integrating launch and satellite capabilities, Interstellar offers a scalable, cost-effective model for sustainable space access in Japan and across the Asia-Pacific region.

INTRODUCTION

Japan's space industry is entering a pivotal phase of transformation, driven by a combination of governmental policy shifts, private sector innovation, and growing international demand. Led by the Japan Aerospace Exploration Agency (JAXA), Japan's space activities have gradually opened to commercial entities following the enactment of the Space Activities Act in 2016. This legal framework, combined with the government's Basic Plan for Space Policy, is intended to foster a sustainable commercial space ecosystem.

A key driver of this transformation is the astonishing growth in small satellite deployments. Global demand for small satellite launches has increased nearly 20-fold, from 217 satellites in 2016 to 4,517 in 2025. This surge has placed unprecedented pressure on launch infrastructure worldwide. In response, major spacefaring nations have ramped up their capabilities with the United States leading with 192 launches in 2025, and China following with 91. In contrast, Japan's launch frequency remains very limited, with only about 3 launches per year, underscoring the urgent need to scale domestic launch capacity.

Recognizing this challenge, the Japanese government has set a national target to achieve approximately 30 domestic launches per year by the early 2030s. This goal is not only essential for meeting domestic demand but also for positioning Japan as a reliable launch service provider for international customers in an increasingly competitive global market.

Interstellar Technologies is a pioneering Japanese company rising to meet this challenge. With its development of the orbital launch vehicle ZERO and its vertically integrated approach to satellite communications, Interstellar is addressing critical gaps in Japan's space launch ecosystem.

INTERSTELLAR TECHNOLOGIES

Born in 2013 Japan's northernmost prefecture Hokkaido, Interstellar Technologies is a pioneering private aerospace company in Japan focused on delivering affordable and frequent access to space. Established with the goal of reducing the cost barriers to space, Interstellar has steadily evolved from into a nationally recognized space launch provider backed by government support, including JAXA's preferred launch provider designation and the SBIR Phase 3 program, and strengthened by a three party business alliance with Toyota Motor Corporation and Woven by Toyota.

The suborbital legacy of MOMO

Interstellar's first milestone achievement came through the development of MOMO, a suborbital launch vehicle designed to reach altitudes above 80 km for microgravity experiments and technology demonstrations. In 2019, MOMO became the first privately developed Japanese rocket to reach space with an altitude of 113.4 km, a historic accomplishment that proved the viability of commercial spaceflight in Japan. To date, MOMO has reached space three times with two consecutive successes in July of 2021, validating key systems such as liquid propulsion engines, flight control electronics, and ground support operations.

The MOMO program provided a critical testbed for Interstellar's engineering and launch operations. Its relatively affordable cost and fast production cycle enabled the company to refine its core technologies while gaining practical experience with regulatory compliance, range safety, and recovery protocols. This iterative learning process laid the groundwork for the transition to more complex, orbital-class systems.

Figure 1 shows MOMO F7 Successful Launch from Hokkaido Spaceport in Taiki, Hokkaido, Japan

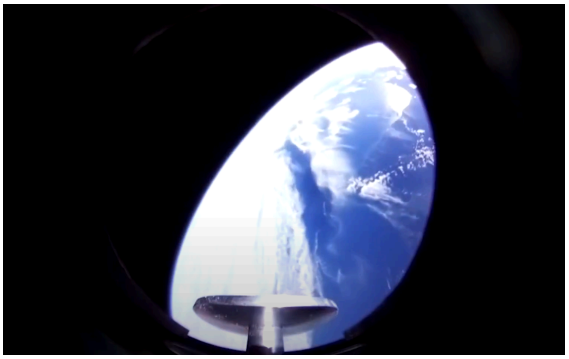

Figure 2 shows an image from on-board payload camera footage from MOMO F6 after payload release.

Table 1: MOMO Specifications

Specifications	Details
Vehicle Type	Single stage
Orbit	Suborbital
Altitude	80km to 100km
Length	10.1m
Diameter	0.5m
Total Weight	1,220 kg
Engine Type	Helium pressure-fed engine
Propellant	Fuel: Liquid Ethanol Oxidizer: Liquid Oxygen
Thrust	14kN (1.4 tons)
Payload Capacity	20kg

Orbital move and infrastructure

Building on MOMO's legacy, Interstellar is now developing ZERO, a small, orbital launch vehicle designed to carry payloads of up to several hundred kilograms to low Earth orbit. ZERO is engineered for high reliability, dedicated launch capability, and competitive pricing, specifically targeting the growing global demand for small satellite launches. Launches will be conducted from the Hokkaido Spaceport, one of the few sites in Asia capable of supporting both eastward and southward trajectories. This geographic advantage allows ZERO to accommodate a diverse range of orbital inclinations.

Interstellar is leading the development of Launch Complex 1 (LC1) in coordination with Taiki Town, the owner of the spaceport. Upon completion, LC1 will serve as Japan's first privately-led launch site for liquid-propelled orbital rockets and the second such facility in the country after the government-operated Tanegashima Space Center.

Interstellar aims to bridge the gap between Japan's limited domestic launch capacity and the accelerating needs of satellite operators, while reinforcing the nation's position as a regional space transportation hub.

ORBITAL LAUNCH VEHICLE ZERO

ZERO is a two-stage, expendable, orbital launch vehicle developed to provide a cost-effective launch services option in Asia for small satellites. Designed and manufactured entirely in Japan, ZERO represents a significant step toward building a self-reliant space transportation infrastructure that can serve both domestic and international satellite operators.

The vehicle is developed with a focus on manufacturability, reliability, and environmental sustainability. All critical systems, including propulsion, structures, avionics, separation mechanisms, and ground systems, are designed and built in-house by Interstellar Technologies, with engineering and testing conducted at facilities across Hokkaido and Fukushima. This approach allows Interstellar to maintain full control over design quality, streamline feedback cycles, and reduce development costs.

ZERO was selected as a JAXA preferred launch provider and supported by Japan's SBIR Phase 3 program, ZERO is designed to offer competitive pricing and dedicated

launch services to accommodate evolving satellite business models.

Figure 3 shows ZERO's launch simulation.

Propulsion systems and vehicle configuration

The ZERO launch vehicle utilizes the same engine across both stages to maximize production efficiency. The first stage is powered by a cluster of nine engines, while the second stage features a single engine optimized for vacuum performance.

The propulsion system, known as the COSMOS, is a liquid methane and oxygen engine utilizing a gas-generator cycle and regenerative cooling. Key technical specifications include:

- Thrust Performance: The first-stage engine delivers 13 tons of thrust, making it the largest methane-fueled rocket engine developed in Japan. The second-stage engine, equipped with a vacuum-optimized nozzle, produces 14 tons of thrust, placing it in the same class as the Japan Government H3 rocket's upper-stage propulsion.
- Pintle Injector: The combustion chamber employs a pintle-type injector, leveraging significant technical heritage and data accumulated from the MOMO series.
- In-house Turbopump: The engine features a proprietary single-shaft turbopump. This integrated design reduces complexity and weight, contributing to the vehicle's overall low-cost profile.

Figure 4 shows ZERO'S Turbopump designed and built in house at Interstellar's Obihiro branch in Hokkaido, Japan.

Biomethane fuel

A standout feature of ZERO's environmental focus is its use of locally sourced liquid biomethane as fuel. Produced from livestock manure in Hokkaido, this renewable fuel is liquefied at −160°C and offers comparable purity (≥99%) to conventional rocket-grade methane. By utilizing biomethane, Interstellar not only reduces its carbon footprint but also supports the regional circular economy. This initiative is one of the first of its kind globally and aligns with broader efforts to develop sustainable space launch operations.

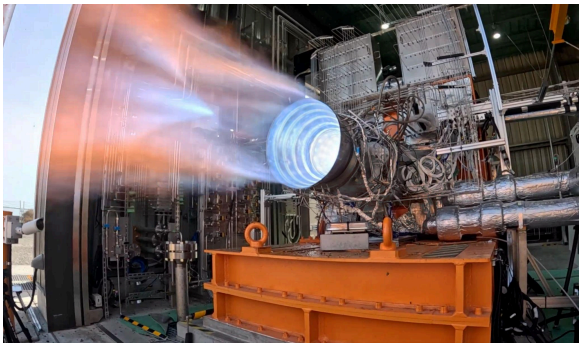

Figure 5 shows the COSMOS engine test using bio-methane as propellant.

ZERO's First Flight Clients

Interstellar announced in October 2025 the 8 clients (7 payloads and 1 separation system company) onboard ZERO's first flight. The 7 payloads are CubeSats developed by educational programs coming from Japan, US and Singapore. All aiming to demonstrate new technologies and provide hands-on STEAM education through real-world space missions.

Towards mass production

As the global space economy continues to accelerate, the demand for frequent, reliable, and cost-effective launch services is reaching unprecedented levels. Satellite communications, driven by applications such as IoT, broadband internet, and mobile connectivity for aircraft and vehicles, are placing increasing pressure on the world's launch infrastructure. Yet, traditional rocket manufacturing methods remain limited by low production volumes and high costs, creating a significant bottleneck in scaling access to space.

To address this challenge, Interstellar is leveraging Toyota's world-renowned expertise in mass production, lean manufacturing, and supply chain optimization. The alliance aims to apply the core principles of automotive efficiency, refined over decades, to the aerospace sector. With Woven by Toyota's backing and technical collaboration, Interstellar is developing a high-quality, scalable rocket production system that optimizes cost without compromising safety or performance.

With a ¥7 billion (~$44 million USD) Series F investment from Woven by Toyota, Interstellar is taking significant steps toward building Japan's first mass-producible rocket platform. By merging the worlds of automotive and aerospace, Interstellar is charting a new course for scalable, sustainable space access in Asia and beyond.

The Alliance with the Toyota Group

Interstellar, Woven by Toyota, and Toyota Motor Corporation have signed in August 2025 a three-party business alliance agreement to detail the companies collaboration on ZERO's development. The key areas strengthened by this alliance are:

1. Collaboration with Toyota and its affiliate, Toyota Motor Hokkaido, a longstanding partner with expertise in the mass production of automotive transmissions, to manufacture engine key components, including the combustion chamber and turbopump, for ZERO's first flight unit. The companies are also co-developing new manufacturing processes to reduce costs and accelerate production timelines.
2. To further enhance vehicle performance through weight reduction, Interstellar and Toyota are

collaborating on developing new manufacturing methods for Interstellar's in-house developed propellant tanks. These tanks store liquid biomethane fuel and liquid oxygen oxidizer, and are made from A2219, a high-strength aluminum alloy that requires advanced welding techniques.

3. The companies are working closely to establish a comprehensive, efficient production system that accommodates the necessary coordination of the approximately 100,000 individual parts that a single ZERO vehicle requires.

Figure 6 shows the COSMOS engine being assembled by Interstellar's and Toyota Motor Hokkaido's Engineers.

Figure 7 shows the inside of ZERO's tank under development at Taiki Headquarters.

Table 2: ZERO Specifications

Specifications	Details
Vehicle Type	Two stage
Orbit	42.2deg - SSO
Length	32m
Diameter	2.3m
Total Weight	71t
Engine Cycle	GG Cycle
Propellant	Fuel: Liquid Methane Oxidizer: Liquid Oxygen
Thrust	130kN (13 tons)
Payload Capacity	LEO 1,000kg

SATELLITE COMMUNICATIONS

In parallel with its main mission of launch vehicle development, Interstellar Technologies is expanding its business into related areas as part of its vertical integration strategy. One example of this is the development of next-generation satellite communications systems with the goal of enabling direct connectivity between satellites and ground-based devices, such as smartphones, vehicles, and IoT terminals.

A key pillar of Interstellar's satellite strategy is its participation in the High Accuracy Satellite Formation Flight Theme under the Space Strategy Fund led by the Japan Aerospace Exploration Agency (JAXA). As part of this national initiative to enhance Japan's global space competitiveness,

Interstellar has signed a commissioned research contract with JAXA to develop innovative formation flying technologies. These technologies will enable the precise coordination of large constellations of ultra-small satellites functioning collectively in orbit.

The project is a collaborative effort involving five leading Japanese engineering universities: The University of Osaka, Institute of Science Tokyo, Nara Institute of Science and Technology, Shonan Institute of Technology, University of Aizu.

As Japan's first space company pursuing a fully vertically integrated business—combining both launch vehicle and satellite communications development—Interstellar is uniquely positioned to capitalize on the synergies between these domains. Satellite communication systems often require frequent, precise, and flexible launch schedules, and ownership of a dedicated orbital launcher gives Interstellar a significant strategic advantage over satellite-only firms.

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