Space Infrastructure Built with Launch Vehicle and Satellite Vertical Integration: Launching and connecting satellites in-house



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1. The vertical integration revolution

Interstellar Technologies began business in 2013 in the town of Taiki in Hokkaido. With our MOMO observation launch vehicle, we have achieved the distinction of being the first private enterprise to independently reach space and are a leading enterprise in the field of private space transport. Our current mission is to "Provide space infrastructure used in society," and we are developing our ZERO launch vehicle, which will launch small satellites into orbit. We are also working on the "Our Stars" communications service using low Earth orbit satellite constellations. This is the first attempt in Japan at vertical integration involving both a launch vehicle business and a satellite communication business (Figure 1).

This vertical integration gives concrete form to our vision of "bringing reform to space industries." The greatest limitation when building satellite constellations is the ability to launch large numbers of satellites into orbit. In particular, formation flying, which is described below, assumes the use of very large numbers of satellites, so our capability to launch them is a very significant factor. The barriers to entry for launch systems are very high, requiring huge investments of time and funding for development, but once we have overcome them, they will form a base for expansion into various businesses. Considering that satellite launch time frames are under pressure globally and new launches often take several years, having our own launch vehicles is directly related to our ability to demonstrate our technologies quickly. With the ability to perform development, transport and operation in one effort, we believe we can both increase development speed and lower costs. Our ability to promote the business has also improved steadily, with sales of our most recent series F reaching 20.1 billion yen and expanding launch vehicle manufacturing in collaboration with Toyota Motor Corporation.

2. Weaving a "giant antenna" in space

Recently there are accelerating efforts world-wide to unify terrestrial networks and satellite networks, such as the now-completed standardization of 5G Non-terrestrial Networks (5G NTN) by the 3GPP. As such, our goal with the "Our Stars" service is to increase the speed and capacity of direct-to-device (D2D) communication, in which devices such as smartphones and IoT devices connect directly to the satellite, without requiring dedicated terrestrial antennas. We aim to deliver the equivalent communications service from space, to locations that are difficult to reach with terrestrial networks, such as in the mountains, at sea, or in the air.

The core of our efforts is our original "formation flying" technology. Various issues with existing satellite technology provide background for this. Devices are small and have limited

Figure 1: Business overview



transmitting power for D2D, so the satellite must have a large-aperture antenna and high gain to establish a communication link. However, the antenna of a single satellite is limited in size by both the launch vehicle and the fuselage. Increasing the aperture would increase the size and cost of the satellite and having an antenna that expands to a large size increases complexity. Formation flying resolves these issues with the concept of "distribution". By having thousands or tens of thousands of ultra-small satellites flying cooperatively, with their relative positions and orientations controlled accurately, they can be made to act as a single, very large array antenna with high gain (Figure 2). Individual satellites are physically separate from each other, connected wirelessly rather than with physical wires, so we call this arrangement an "unwired phased-array antenna."

To implement this concept, we are currently engaged with two national R&D projects as central to our research. The first is Ministry of Internal Affairs and Communications (MIC) contract research titled "R&D for expansion of radio resources." It has the goal of establishing new methods to use limited radio frequency resources more efficiently, and we are conducting joint research with the collaboration representative, Microwave Factory Co. Inc., five universities, and the National Institute of Information and Communication Technologies (NICT). The second project is a JAXA Space Strategy Fund project called "Highly accurate satellite formation flying technology." We are working in collaboration with five universities on control technology that uses electromagnets to fly large numbers of satellites in formation with centimeter accuracy.

Results from these two programs are expanding steadily. In the first one, experiments demonstrated a proof-of-concept, using a terrestrial array antenna composed of many simulated satellites. In the second one, experiments have successfully simulated orbits with a position control algorithm at a scale of thousands to tens-of-thousands of satellites and tested operating principles on the ground.

3. Radio frequency and international systems environment

Implementing D2D satellite communication will involve a wide range of issues including the architectures linking antennas, satellite buses and terrestrial systems and also operations and regulatory issues. Among these, important upstream issues that determine prerequisites for system design and feasibility include defining radio frequencies and how to secure and use them. Non-geosynchronous satellite constellations based on formation flying with many devices involve many leading-edge issues that the ITU is engaged with, including frequency sharing and regulation, use of orbits, and interference that satellite businesses could have on terrestrial businesses. There is ongoing international discussion on the issues of Power Flux Density and Equivalent Power Flux Density (EPFD), regulation of the number of expected satellites and space sustainability, all related to the rapid increase in non-geosynchronous satellites.

In particular, D2D communication, with devices connecting directly to satellites, is currently one of the most actively debated themes at the ITU-R. At the World Radiocommunication Conference 2027 (WRC-27), Topic 1.13 Satellite Direct Communication (DC-MSS-IMT) is positioned as a communication method to fill-in areas where terrestrial networks cannot reach and during disaster. Study is progressing on system definition and issues such as coexisting and sharing frequencies with existing business. Our objective of providing broadband D2D using formation flying is also positioned among these types of international trends and we are watching the trends closely.

The initiatives described here would not be possible without the cooperation of many related parties. We look forward to cultivating space infrastructure that is useful in society as we continue to exchange ideas on issues such as international collaboration and consolidating systems for radio frequency use with all of you. We would be honored to receive any guidance or cooperation you may offer in these endeavors.

Figure 2: Low earth orbit communications constellation using formation flying



Cover Art



The Pride of Tokyo's Twelve Months : October, Autumn Foliage at the Takinogawa River

Tsukioka Yoshitoshi
(1839-1892)

Source: National Diet Library, NDL Image Bank
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