

# On-Orbit Supply to Artificial Satellites

## Aiming for commercialization of on-orbit services using robotics technology

IHI AEROSPACE Co., Ltd. is considering the business of propellant supply and equipment replacement services for on-orbit satellites, using robotics control technology in addition to long-proven space business, i.e., mechanical and propulsion systems.



Image of on-orbit satellite services

### What are on-orbit satellite services?

In the past, the lifetime of an artificial satellite has been determined by the volume of propellant or the lifetime of each equipment/component. In recent years, along with the movement of reducing operation cost, the need to extend the lifetime has been increasing.

On-orbit satellite services refer to a business that provides a satellite whose lifetime is about to end with services for extending its lifetime. The services such as, mainly, supplying propellant and replacing equipment allow the lifetime of the satellite to be extended. By utilizing such services, a satellite owner can extend the period of using a satellite, and thereby receive benefits such as an increase in profits gained by using the satellite and a reduction in satellite replacement cost.

In order to provide the on-orbit satellite services, a rendezvous/docking function of capturing a satellite traveling on orbit, a robot arm function of providing actual services,

and a propellant supply function of supplying propellant are required. The various services are provided using a service satellite having these functions. IHI AEROSPACE Co., Ltd. (IA) is aiming to provide satellite service providers with (1) the rendezvous/docking function (2) the robot arm function, and (3) the propellant supply function used for the on-orbit satellite services.

### Three functions for implementing services

#### (1) Rendezvous/docking function

The rendezvous/docking has to be performed in such a way as to eliminate the differences in position and flight velocity between two satellites. For this purpose, robotics control is required, such as sensing the position and velocity of the other satellite with sensors to correspondingly adjust the position and angle of a mechanism and accommodating a load at the time of contact to prevent bound.

## (2) Robot arm function

In order to provide the services to a satellite, it is necessary to do careful work without any fail, such as to cut a thermal control material for the satellite (a gold film on the surface of the satellite), to remove the cap of the propellant inlet port, and to connect a propellant supply line and control valves. A robot arm used for the work needs control (such as compliance control) of suppressing a generated load so as to be able to flexibly move. In addition, various tools for doing various types of careful work are also required.

## (3) Propellant supply function

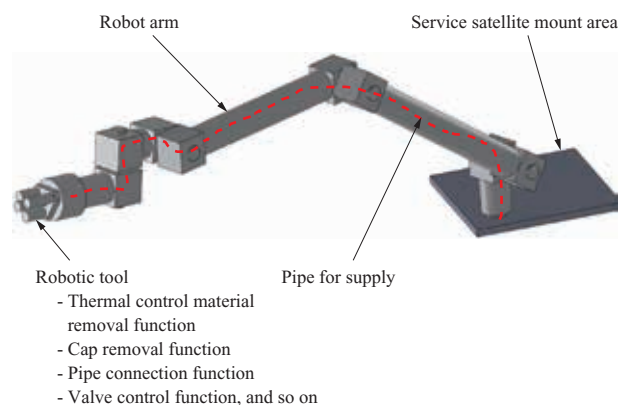
In order to supply propellant to multiple satellites, a large tank for transporting a sufficient amount of propellant to orbits is required. In addition, after docking, it is necessary to inject propellant while resisting the internal pressure of a propellant tank of the other satellite, as well as to pressurize the propellant tank within a range not exceeding allowable pressure. Accordingly, the supply work must be done while finely adjusting pressure. A pipe is also connected using a robot arm, so it is indispensable to lay not an undeformable pipe usually used in a satellite but a flexible pipe on the robot arm so as not to prevent the movement of arm joints.

## IA's challenges

IA has taken charge of many space mechanisms and systems. Therefore, IA has many achievements on technologies for fabricating machines so as to satisfy space specifications, and has leading technologies in Japan as well. IA is currently working on combining robotics control technology with such technologies and thereby establishing robotic technology satisfying space specifications.

Although the robotics technology seems to be an extension of industrial robots, a robot arm used in space is different in various respects from that for ground use. First, the robot arm must be lightweight. If the robot arm is heavy, a required amount of propellant to be supplied cannot be loaded. Also, electric power used by a satellite is limited by the amount of electric power generated by solar cells, and therefore only a small amount of electric power is distributed to drive the robot arm. Further, since in space, operation is carried out under special environment influenced by vacuum, heat, radiation and so on, a robot developed for ground use cannot normally operate. Therefore, the robotics technology for space use is special technology completely different from one for ground use.

The satellite services are currently progressing toward commercialization mainly in US public and private sectors, and thought to be put into practice in the first half of the 2020's. Once the satellite services are put into practice, the extension of the lifetime of a satellite by the satellite services is thought to be established, and service satellites as infrastructure for providing the services can be expected to have a constant demand.



Conceptual diagram of robot arm for on-orbit satellite services

## Global development

When thinking about future global development, we are feeling some sense of crisis because it may be difficult to win competition only by offering a single function having many competitors, such as the mechanical or propulsion system having been taken charge of by IA. There is also a situation where depending only on national services, which has been the main part of business so far, does not seem to lead to further growth. Under such a situation, if the special functions of satellite services can be provided by combining the robotics technology with the IA's mechanical and propulsion system technologies, strong competitiveness can be obtained.

IA is working on the acquisition of the space robotics technology necessary for the satellite services while communicating with state organs and overseas satellite manufacturers. We think in the future we would like to provide satellite service providers with high level functions to become a company involved in global satellite service business.

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