

## Using JAXA's equipment to develop an engine in Japan

### Actual-engine operation test advanced by JAXA

An aircraft engine consists of various components, such as a compressor to take air in and compress it, a combustor to mix air with fuel and combust it, and a turbine to harness the power of the high-temperature, high-pressure gas obtained from combustion. We begin our research and development on each component by developing a test prototype and using it to verify performance. Next, we incorporate the components together into an engine and conduct engine operation tests for another verification of performance.

The manner in which the control system interacts with the engine as a whole is very important. And the engine operation test is essential to the research on the control system. Japan Aerospace Exploration Agency (JAXA) has two types of engine operation testing equipment: turbo fan engine testing equipment and engine altitude performance testing equipment (Fig. 1). JAXA uses this equipment to research engine and control systems.

Engine operation tests must also be conducted to research engine noise, another challenging theme. Outdoor tests are effective for researching noise, as it is important to verify how noise generated from an engine is transmitted. Our group has conducted outdoor engine operation tests at the JAXA Noshiro multipurpose testing site in Akita Prefecture every year since fiscal 2004 (Fig. 2).

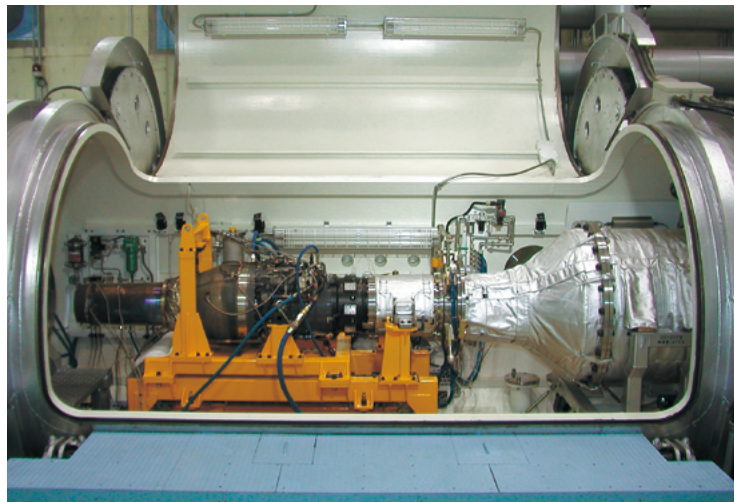
### Research on a control system with turbo fan engine testing equipment

The Jet Engine Technology Research Center is focusing its energies into intensive research on an engine control system called the "Full Authority Digital Engine Control (FADEC)."

The thrust required for an aircraft changes at different stages of flight, such as takeoff,

landing, or cruising. The role of an engine control system is to generate a required thrust and fly an aircraft safely. Important requirements for the future control system will be to detect (monitor) subtle changes in engine performance, properly control the aircraft under the current flight conditions, and fly the aircraft safely.

The future control system will need, for example, to monitor unavoidable unevenness in engine performance at the shipment stage, to detect the deteriorations to be



Equipment to simulate atmospheric conditions when an aircraft travels at supersonic speed at high altitude.  
Fig.1 Engine System Section



Fig.2 Scene from a noise-measuring test using YJ-69 engine at the Noshiro multipurpose test site in fiscal 2007

expected when an aircraft component nears the expiration of its service life, and to perform control suitable to each engine. Proper control will prolong the engine life while maintaining optimum engine performance. The efficient maintenance of the engine will reduce maintenance costs.

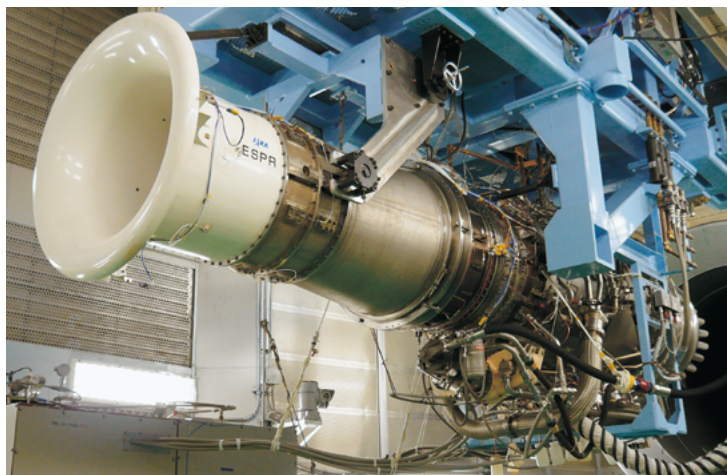
Our group has installed an "ESPR engine<sup>(\*)</sup>" in our turbo fan engine testing equipment to carry forward R&D on a future control system called the "advanced FADEC" (Fig. 3).

### Contributing to the domestic development of the future engine

We have advanced the research on the control system using YJ-69 engine manufactured by Teledyne, USA. Modifications to our facilities have enabled testing with a more sophisticated ESPR engine, an activity that will bring the control system closer to practical use.

In the future we will contribute to the domestic development of an engine by advancing our research towards the construction of an "advanced FADEC" that can be incorporated into the actual engine.

(\*) ESPR engine : A research engine fabricated and developed on an experimental basis in two international projects promoted by the New Energy and Industrial Technology Development Organization (NEDO) of the Ministry of International Trade and Industry (the present Ministry of Economy, Trade and Industry): "Research and Development on Super/Hyper-Sonic Transport Propulsion System (HYPR)" and "Research and Development on an Environmentally Compatible Propulsion System for Next-Generation Supersonic Transport (ESPR)." Ishikawajima-Harima Heavy Industries Co., Ltd. (the present IHI Corporation), Kawasaki



We will use an ESPR engine to continue research and development on an "advanced FADEC" that can be incorporated into an actual engine.

Fig.3 ESPR engine installed in the turbo fan engine testing equipment

Heavy Industries, Ltd., Mitsubishi Heavy Industries, Ltd., the National Aerospace Laboratory (the present JAXA), and other organizations also participated in these international projects. These Japanese manufacturers developed the major part of the ESPR engine. This engine has almost the same structure as that of the turbo fan engines now installed in large airliners. The ESPR engine is designed and fabricated on the assumption of flight at a speed three times the speed of sound (Mach 3).



[ Jet Engine Technology Research Center]  
Engine System Section

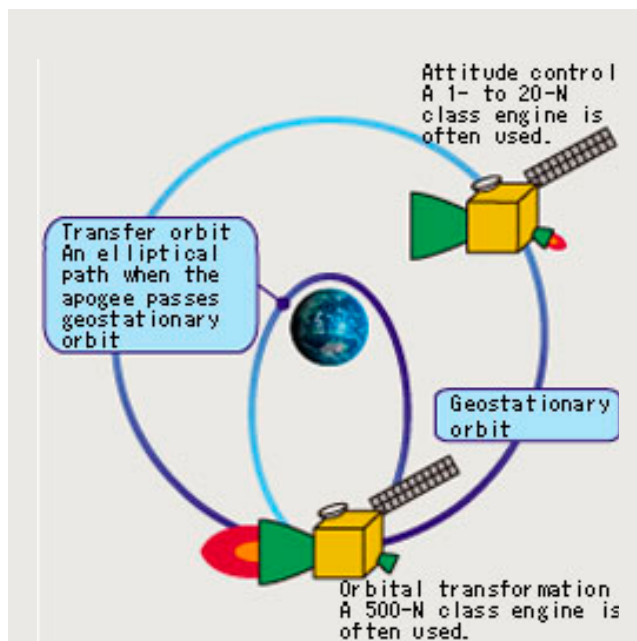
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## R&D on the bipropellant engine system for orbital transformation and attitude control of spacecraft

### Artificial satellites use different engines for different purposes

The artificial satellites designed for exploration of other planets and for geostationary orbit at an altitude of 36,000 km are built with two types of onboard engines. One of the engines is large and the other is small. Each plays a different role. When a geostationary satellite is launched by a rocket, it has yet to reach its transfer orbit. In ensuing day, it must reach a stationary orbit on its own. This is why the geostationary satellite is equipped with an orbital maneuvering engine with large thrust.

Once the artificial satellite reaches its geostationary orbit, it no longer needs a large thrust. Instead, it uses an attitude-control engine (thruster) with small thrust to correct gradual deviations from its orbit due to disturbances such as the gravity of the sun or moon (Fig. 1).<sup>(\*)</sup>



A geostationary satellite is launched into transfer orbit (an elliptical path when the apogee passes geostationary orbit) by a rocket. After launch, the geostationary satellite uses an orbital-maneuvering engine to reach the geostationary orbit. Once it reaches the geostationary orbit, it needs to alter its trajectory with an engine (thruster) to correct deviations from the orbit caused by various disturbances.

Fig.1 The role of the engine on an artificial satellite

### Results of the domestically-produced orbital maneuvering engine

The moon probe Kaguya was launched in September 2007 and reached its lunar orbit in October. When it moved along its route from the earth and decelerated for entry into the lunar orbit, it used an orbital-maneuvering engine (Fig. 2) with a thrust of 500 N. This engine was developed by the Propulsion Group and IHI Aerospace (IA). It fulfilled its function and performed as planned in carrying Kaguya to the moon in safety.

Kizuna, an ultrahigh-speed internet satellite launched in February 2008, is equipped with an engine manufactured by IA. This is a more fuel-efficient engine based on technology acquired through the development of Kaguya's 500-N engine. The engine performance is unrivalled. Some of these engines have been exported to U.S. satellite manufacturers. Others have been installed on board Japanese satellites such as the JCSAT-9 and -10. These engines are tried and true.

### JAXA is steadily advancing the domestic development of a bipropellant thruster

The orbital-maneuvering engines installed on board Kaguya and Kizuna employ bipropellant engine systems with hydrazine and MON3<sup>(\*)</sup> as propellant.<sup>(\*)</sup> Hydrazine and MON3 require no special ignition devices, as they ignite spontaneously when they come into contact with each other. Bipropellant systems can be used in pulsing or steady-state modes. They have a very versatile and high performance. For these reasons, the bipropellant thruster is used for the orbital-maneuvering engine artificial satellites. In parallel with the development of the orbital-maneuvering engine, the Propulsion Group has advanced the development of a 22-N thruster (Figure 3). This tried-and-true thruster has been installed on board the Optus-D1 (Australia) and Telkom-2 (Indonesia).

The attitude of a satellite is adjusted by controlling the thrust from the pulse injection of the thruster. The thruster must operate stably over a wide range of firing



A: 500-N engine



B: Circumlunar satellite Kaguya

Fig. 2 The same type of 500-N orbital-maneuvering engine as that installed on board of Kaguya

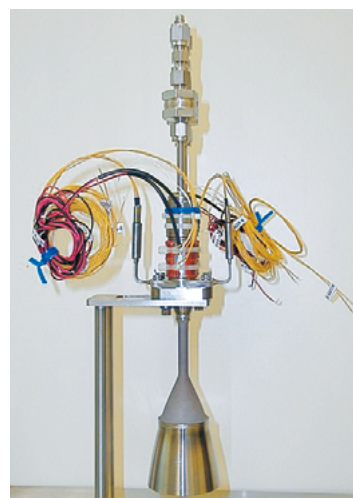
times, from very brief ones of several tens of milliseconds to very long ones of several thousands of seconds. Today's engine designs need smaller thrusters that can be operated within wider operating ranges, in order to meet requirements for lightweight satellites with more accurate attitude control. To realize these designs, JAXA is researching and developing a new 10- to 20-N class thruster.

The Propulsion Group is enhancing the performance of artificial satellites by developing various types of satellite engines.

(\*1) A thruster is installed on board almost all application satellites and geostationary satellites.

(\*2) MON3 : A mixture of dinitrogen tetroxide with 3% nitrogen oxide

(\*3) In addition to a bi-propellant thruster, a mono- propellant type using a catalyst and an electric propulsion type using electricity are available for artificial satellites (refer to page 5).



(Photo: offered by IHI Aerospace)

Fig.3 22N bipropellant thruster using hydrazine and MON3 as propellant



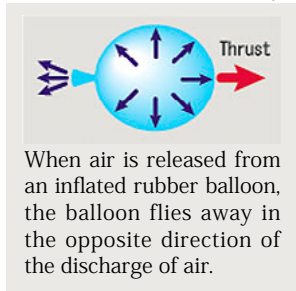
[ Propulsion Group ]

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## "Aircraft engine" and "satellite engine"

An aircraft flying through the air and a rocket or satellite flying through space have very different shapes and working environments. Yet both types of vehicles must use the force to move forward (thrust) based on the same principle.

When you inflate a rubber balloon and release it, it flies away, discharging air. The balloon is driven forward by the force obtained from the reaction when it discharges air (Fig.1). Aircraft and spacecraft fly in the same way.



When air is released from an inflated rubber balloon, the balloon flies away in the opposite direction of the discharge of air.

Fig.1 Principle in flying

### ■ Aircraft engine

A jet engine is widely used as an aircraft engine. A jet engine consists of an intake to take air in, a compressor with an impeller to compress the air, a combustor to mix the compressed air with fuel and combust the mixture, a turbine to drive the compressor with the energy of the air expanded by the combustion, and a nozzle to discharge the expanded air with great force.

An aircraft engine reaches peak efficiency when it emits gas (jet) at a velocity equal to the velocity of the aircraft itself. Higher efficiency means that the aircraft can carry more passengers and cargoes to distant places with less fuel. An ordinary passenger airplane flies at 80 to 90% of the speed of sound (Mach 0.8 to 0.9). Since the speed of a jet aircraft exceeds that of sound, it isn't efficient to install a jet engine on board of a passenger airplane. To enhance the efficiency,

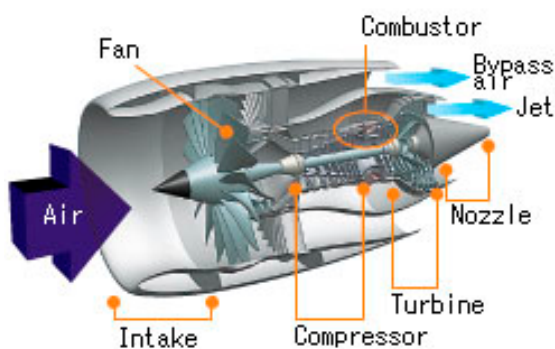
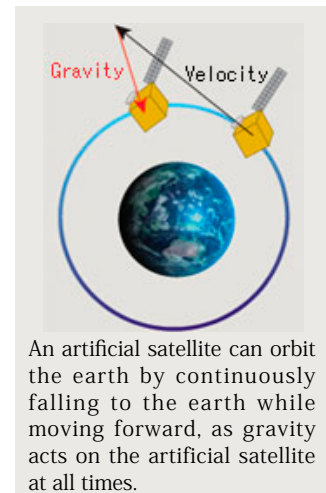


Fig.2 Turbo fan engine

turbo fan engine has been devised (Fig. 2). This engine is equipped with a large impeller called a "fan" at the front. Most of the air is bypassed through the sides of the engine, and the air is mixed with the jet to decrease the emission speed of both the air and jet to a speed commensurate with the flying speed of the aircraft. A high-bypass turbo fan engine, which bypasses a larger amount of air, is installed on the large passenger airplanes in service today.

### ■ Satellite engine

Outer space is a giant vacuum almost wholly devoid of matter such as atmospheric air. Therefore, the air drag is very low. If a satellite has a high orbit, its speed will hardly change. An earth-orbiting satellite constantly falls to the earth by gravity. Once an initial velocity of the required level is given, the satellite will be set in a continuous orbit around the earth without a constant thrust from the engine (Fig. 3). But the orbit needs to be corrected from time to time, as various disturbances will lead to orbital deviations.



An artificial satellite can orbit the earth by continuously falling to the earth while moving forward, as gravity acts on the artificial satellite at all times.

Fig.3 Movement of an earth-orbiting satellite

There are three types of engines (i.e., thrusters) to correct the orbit: the monopropellant thruster, bipropellant thruster, and electric propulsion.

The monopropellant thruster obtains thrust by gasifying a propellant with catalyst and ejecting the gas from the nozzle. The bipropellant thruster obtains thrust by combusting two types of propellants through a chemical reaction and ejecting expanded gas from the nozzle. The latter thruster can obtain greater thrust than the former.

The monopropellant and bipropellant propulsion systems use chemical energy to obtain thrust, while the electric propulsion uses electric energy. Electric propulsion is poor at generating great thrust, but it has very high fuel efficiency.