RESEARCH INTRODUCTION

The quest for reusable space planes capable of flying dozens of repeat missions

Space can only be used effectively if we have fully reusable space planes to fly our space missions

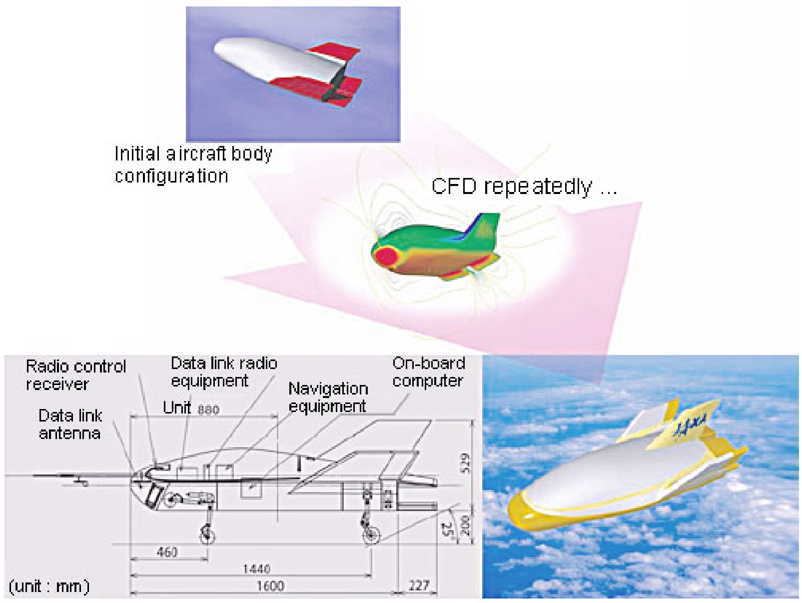
Rockets such as the H-IIA are used to transport loads such as humans and goods (payload) into outer space. Most space missions nowadays are launched with "expendable type" rockets designed to carry payloads only once, though some agencies such as NASA use space shuttles or space planes with reusable parts. With disposable types, however, the costs can be astronomical. One way to hold down costs is to create space planes (fully reusable space planes) capable of flying multiple repeat missions with only light and easy maintenance. The achievement of such a technology will further advance space development and space sightseeing.

Aircraft bodies with various configurations are now considered for adoption as fully reusable space planes (refer to here). The JAXA Institute of Aerospace Technology (IAT) is researching ways to realize a space plane configured to take off and land horizontally, like an airplane. Crafts with this configuration can exploit aerodynamic lift, improve the comfort of the crew during flight, and offer various other advantages. So far, the IAT has carried out demonstration experiments on reentry into the Earth's atmosphere, approaches to runways, and other maneuvers.

Lifting body - A configuration to enable flight without wings

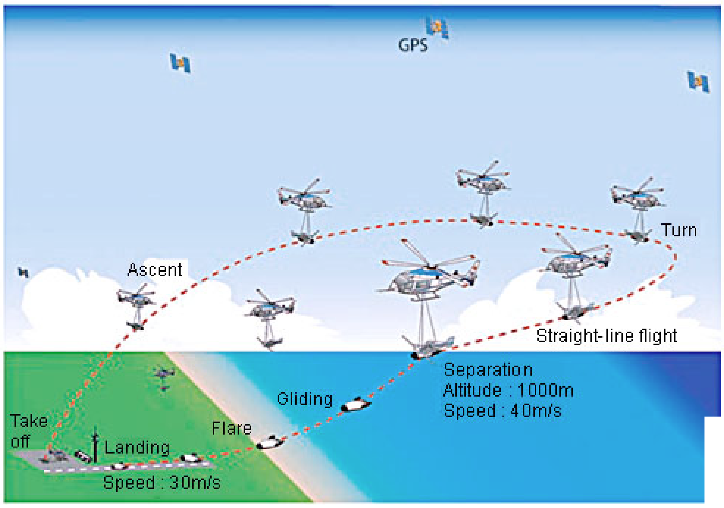
Demonstration experiments, etc. have revealed the high feasibility of a two-stage configuration with a lower stage that detaches in the upper sky, much like that of a rocket, leaving only the upper stage to carry the payload onward into space. One option being considered is an airplane-like configuration with wings and engines for the lower stage portion, used in combination with an upper stage portion mounted on a rocket's fairing (the upper end of the rocket where the payload stored). To research this option, we are now considering a "lifting body," a configuration that produces lift with the fuselage instead of the wings. The wingless structure of the lifting body enables the design of a small, simple structure of fairly light weight. An important problem that impedes the flight of the lifting body is a weakening of lift during landing, when the speed needs to be reduced. To solve this problem we plan to gather data on automatic landing technology based on a lifting body aircraft. We call the experiment LIFLEX, the Lifting-Body Flight Experiment.

For an aircraft body to land without fail, the "aircraft body configuration" and "flight path" must be flawlessly planned and designed. In the LIFLEX program, work operations from the initial studies to the flight experiments will be completed in only three years (2005 through 2007). The aircraft body was also designed quickly, thanks in large part to the use of computational fluid dynamics (CFD). CFD determines complicated flows, such as the state of atmosphere around an aircraft body, based on numerical analysis by computer. With the help of CFD, work operations from aircraft body design and manufacture to flight experiments can be repeated time and again in a virtual world. This minimizes the time required for the actual building and testing of a model in a wind tunnel (equipment designed to make an air flow around a model and simulate the state of actual flights), thus shortening the design work overall (Fig. 1).



The initial aircraft body designed based on data accumulated by previous demonstration experiments had poor lateral stability and controllability. By repeating computer-based virtual flight experiments, we managed to improve the

Fig. 1 Study of aircraft body configuration by CFD



As the vehicle has no engine, it is suspended by a helicopter and carried up into the sky. Once separated at a specified location and at a specified speed, the aircraft body glides toward a runway on auto pilot, then makes an attempt to land.

Fig.2 Outline of the LIFLEX

The analyses and selection of most suitable flight path were also made in consideration of conditions such as the wind direction in the upper sky.

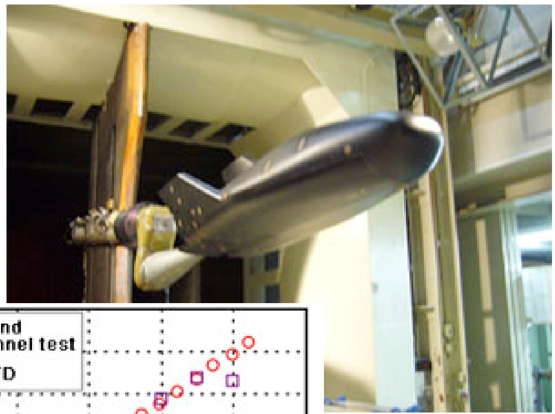
Flying the lifting body in the expansive sky over Hokkaido

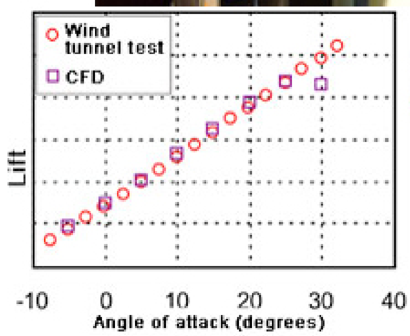
Fig. 2 is a schematic diagram of the LIFLEX to be conducted in the Taiki-cho Multi-purpose Aircraft Park (Hokkaido) in the fall of 2007.

In October 2006 we preliminarily flew a helicopter along the actual flight route to confirm that there would be no problem in the operation of the experiment. In November we followed up by performing a wind tunnel test and confirming the aerodynamic characteristics. The results of the wind tunnel test agreed well with the results of the CFD analysis (Fig. 3).

We are now conducting functional tests on the experiment system, including the experimental aircraft. This is bringing us surely and steadily closer to the actual LIFLEX experiments.

▲ Preliminary test by helicopter (October, 2006)
The flight route, experiment procedure, data transmission, reception, etc. were confirmed.





▲ Wind tunnel test (November, 2006)
Fuji Heavy Industries Ltd. ´s 2 m x 2 m Tests in the low-speed wind tunnel confirmed flight characteristics, etc. Agreement with CFD analysis results was also confirmed.

Fig.3 Preliminary test by helicopter and wind tunnel test

[Future Space Transportation Research Center]

Taro Tsukamoto

RESEARCH INTRODUCTION

Research on reusable engines to be loaded on space planes

Reusable space transportation is difficult

We will soon arrive at the 50th anniversary of the launch of the world's first artificial satellite, in 1957. In the years since that fateful day, the design principles for rockets and their engines have changed relatively little. The rocket engine must burn and inject fuel and oxidizer amounting to as much as 80 to 90% of the total weight of the rocket, in order to generate the necessary kinetic (velocity) energy to transport a payload making up less than a few percent of the total weight of the rocket into outer space. Once the tank is spent of its fuel and oxidizer, it must be jettisoned with the mounted engine to lighten the weight sufficiently to transport the payload to its destination.

The space shuttles that came into service in the 1980s were first trial as a reusable transportation system that was expected to engender a revolution in space transportation. Yet complete reuse continued to elude the engineers, even when they were able to build engines that performed almost at the upper limits for rockets. Thus, the shuttles had to jettison their external tanks. Takeoff required a solid rocket booster with poor efficiency. This engine also had to be jettisoned, though eventually it could be recovered and reused. As it turned out, immeasurably high maintenance costs and other factors drove up the cost of shuttles past the cost of conventional rockets.

Research on scramjet engines

efforts to drastically reduce costs through complete reuse, the Combined Propulsion Research Group has been researching a "scramjet" engine designed to use oxygen in the atmosphere as an oxidizer. The rocket engine efficiency is the highest when liquid hydrogen is used as fuel and liquid oxygen is used as oxidizer. Liquid oxygen accounts for 70% of the total weight of the rockets, hence the air (oxygen) in the atmosphere for breathing during flight will reduce the oxygen load sizably. The weight reduced using this technology gives the designers the leeway to fit the body with wings, alighting gear, and other equipment necessary for returning to earth intact, and thus realizes reuse.

The scramjet engine is a ramjet engine designed for flight at very high speeds. Ramjet engines work by compressing the air using the momentum of the air

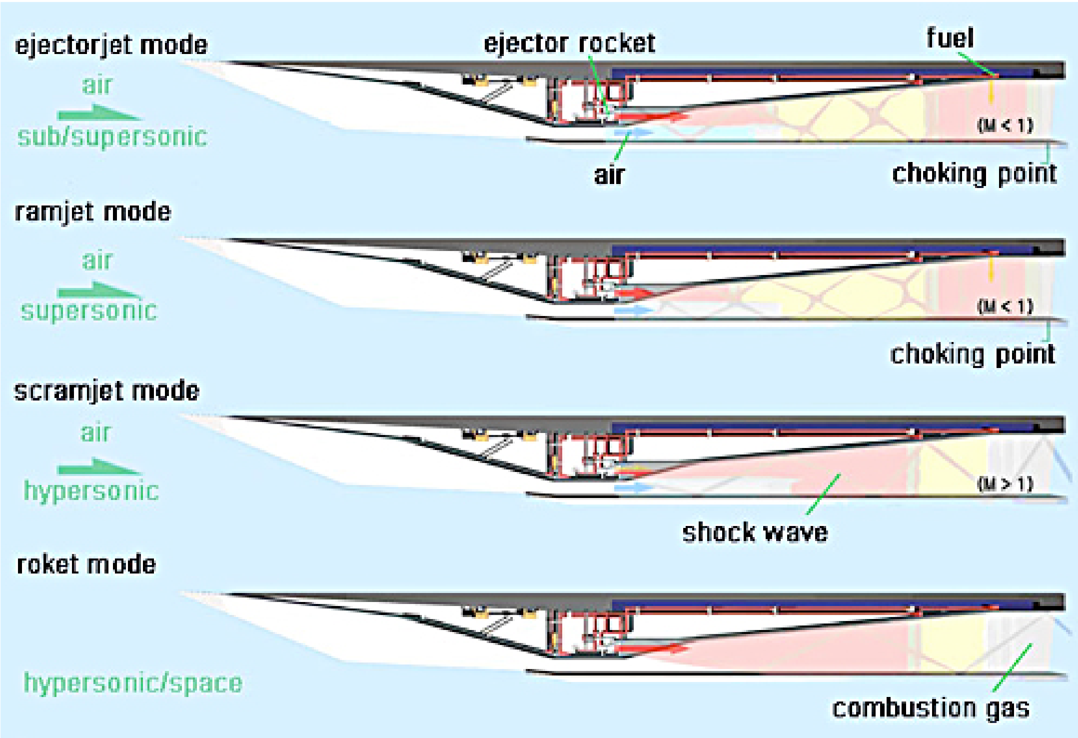


Fig. 1 Operation mode of the combined-cycle engine

flowing in. In a normal-speed regime, the speed of an airflow flowing into the combustor after compression drops to a value equal to or less than the speed of sound. In a very high-speed regime, on the other hand, an airflow flows into the combustor while remaining at supersonic speed. Thus, the ramjet engine operating in the regime is called a "Supersonic Combustion Ramjet Engine (SCRamjet Engine)." Earlier we used a wind tunnel on the ground to test the engine performance in a high-speed airflow. We found, as a result, that the engine could achieve a thrust force and fuel efficiency higher than that of rocket engines during simulated flight at Mach 4 to 8[*1]. We are now researching ways to generate thrust force during flight at Mach 8 to 12 in order to bring the performance up to even higher-speed regimes.

Research on a more advanced engine-the "rocket-ramjet combined-cycle engine"

To use a scramjet engine we must cope with an inescapable problem. Thrust force cannot be generated when air has little momentum (when air is stationary or moving at only low speed). Thus, a scramjet engine is incapable of generating the force necessary to take off from a stationary position. To solve this problem we have proposed a "rocket-ramjet combined-cycle engine," a scramjet engine with rocket engines embedded in its flow pass. Performance evaluation tests on this new engine model are now underway. The engine accelerates the vehicle on which it is mounted using the thrust force generated by the embedded rocket engines during the period from takeoff up to acceleration to supersonic speed. The momentum of rocket exhaust is expected to generate an ejector effect by which the surrounding air is breathed into the flow pass, and the combustion using this air is expected to enhance the thrust force. When the vehicle is accelerated to a sufficient speed, the rocket-ramjet combined-cycle engine is used as a ramjet. Next, once the vehicle reaches hypersonic speed, the engine is used as a scramjet. During the operation as either ramjet or scramjet, the rocket engine is used at a reduced thrust level as an igniter or as a fuel injector. The schematic design in Fig. 1 shows the state inside the engine in different usages (operation modes).

The engine model under testing is about 3 meters in length. Two rocket chambers with thrust levels of 2 kN using gaseous hydrogen and gaseous oxygen are embedded inside. The tests commenced under a sea-level static condition (a condition with no spray of air) and are now advancing based on our understanding of technical challenges in design (e.g., design improvements to enhance the ejector effect). Figure 2 shows the state of the engine during the test. We plan to continue testing at higher flight Mach numbers, to enhance performance based on improvements, and to further our understanding of technical challenges in control, especially when the operation mode is switched.

(Sadatake Tomioka)

*1 Mach number : a value of speed expressed as a ratio relative to the speed of sound. Speed of sound = Mach 1

Engine exhaust appears on the right side.

Fig. 2 Combined-cycle engine model tested under a sea-level static condition

[Combined Propulsion Research Group]

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