R E S E A R C H
INTRODUCTION

New technology for deploying satellite structures!

Deploying satellite structures in space

A satellite, a man-made craft to be launched into space, is covered with fairing to minimize aerodynamic heating during flight through the aerosphere, and mounted on the nose of a launch vehicle. A satellite components: a solar array paddle, antennas, radiators are desirable to be large for thier performance. Those components are mechanically deployed after entry into aerospace, necessitating design compromises with the fairing, which itself must stay within some size limitation (See Fig. 1). Yet the mechanical deployment requires complicated construction, and the weight of the mechanical sections considerably burdens the satellite.

Proposing the use of shape-memory polymer

To solve the above-mentioned problem, we are going ahead with a study on a deployment mechanism based on a shape-memory polymer to be used.

Uniquely, the shape-memory polymer can change or recover its shape when its temperature crosses over a threshold. By exploiting this property, we can design a mechanism to deploy a structural body after launch and entry into aerospace (See Fig. 2). The only precondition required to deploy a shape-memory polymer structure is heat. There is therefore no need for complicated mechanical parts, which facilitates the realization of a light-weight structure. There are problems, however, with insufficient strength and stiffness. To respond, our group has attempted to increase the strength and stiffness by combining the polymer with carbon fiber, a lightweight material with far greater stiffness and strength.

Our group assessed the performance of the test pieces with regard to the method for combining the two elements and method for folding (See Fig. 3), then conducted a series of studies to determine the proper temperature for deployment. From now on, our development work will take a course to determine a suitable composite structure that can be both compactly folded and smoothly unfolded.

Demonstration test on the exposed section of Satellite "KIBOU"

The shape-memory polymer most recently developed has the merit of withstanding space radiation. It is vulnerable, however, to atomic oxygen, an element abundant in the lower orbital path along which the international space station (ISS) and some of the earth-observation satellites travel. Because of this, the polymer degrades. Since we have been making long-term study on the

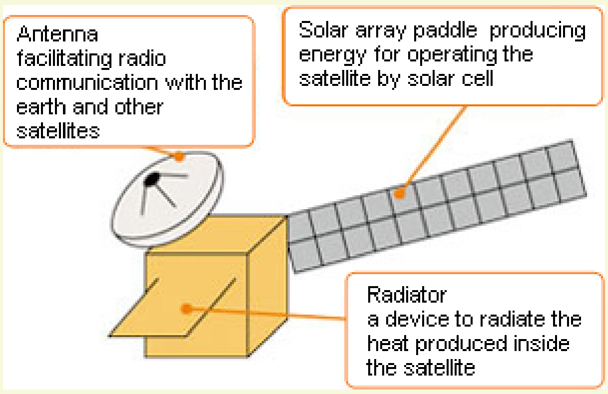


Fig. 1 Equipment to be deployed after launching

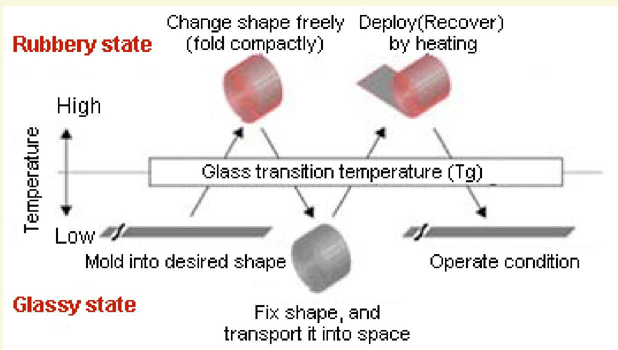
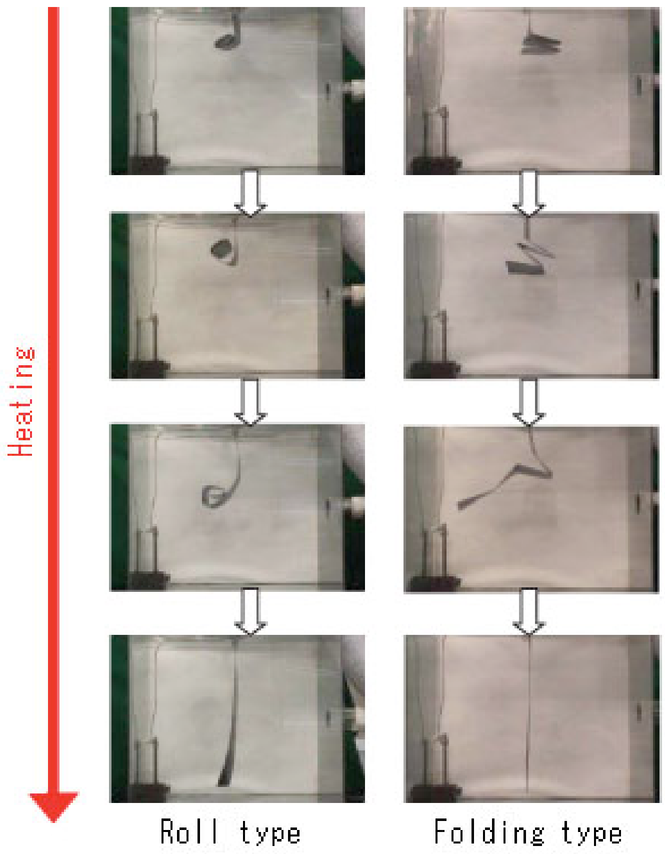


Fig.2 Technology for building a shape-memory-polymer-based structure to be deployed in aerospace

themes of degradation assessment and durability consideration for materials when placed in the space environment, we will be conducting a study this fiscal year on durability improvement of shape-memory polymer composites against atomic-oxygen, with plans to make full use of the study results.

Future studies on the shape-memory polymer now scheduled include a "deployment test in the space environment" and a "test of stability in the space environment over a long period." As a provisional theme, preparations are now underway for an orbital test on "Space Inflatable Membranes* Pioneering Long-term Experiments (SIMPLE)" in aerospace." The SIMPLE mission is approved for launch in fiscal 2011 with the Exposed Facility of the Japanese Experiment Module "KIBOU" as a portion of the ISS. Preparations for the test are now underway.

*An "inflatable membrane" is a bag-like film structure that inflates with gas pumped in. Tokyo Dome is one of the better-known examples of this type of structure on earth.



The roll type has merits and demerits. It can be stored more compactly than the folding type, yet it imposes friction that may impede the deployment process. Furthermore, successive damage of the roll type has been observed in our tests (see the photo). The folding type, in contrast, can have sharp bends locally yet recover its original shape almost perfectly.

Fig.3 The actual course of the deployment test

[**Advanced Materials Group**]

(From the left end of the back row) Eiji Miyazaki, Shoichi Ichikawa, Yugo Kimoto, Junichiro Ishizawa, Hiroyuki Shimamura, Riyo Yamanaka
(Front row) Kazuyuki Mori

R E S E A R C H
INTRODUCTION

Research on the performance evaluation of heat-controlling materials with the aim of creating a database based on the adiabatic properties of the multilayer heat insulation blanket (MLI)

Temperature control is essential for a satellite

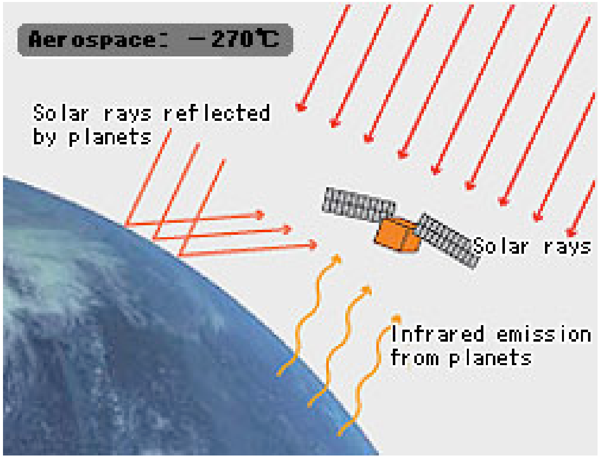
A satellite operating within aerospace as its workplace is continuously exposed to a heat environment different from that on the ground (Fig. 1). The temperature of the whole satellite body is determined by a balance between factors in the external heat environment such as sunrays, the temperature of aerospace, and the heat generated by the satellite itself. The temperature range required to secure normal satellite function must be clearly known in order to provide continuous insulation from heat and heat radiation. With adequate insulation, the equipment can be properly operated even in the critical heat environment of aerospace.

One constituent of the above-mentioned heat control system is the "multilayer insulation blanket" (MLI), a specific heat insulator now available in the market. Most satellite surfaces are covered with a golden or black MLI. (Fig. 2) The golden MLI acquires its golden hue from a structure of yellowish, aluminum-coated film (polyimide). With the further piling up of 10 to 20 alternate layers of fine plastic nets and thin plastic films, the MLI can provide excellent heat-insulating performance in the vacuum of aerospace.

Engineers must know the correct value of effective emittance in order to raise the thermal design accuracy of a satellite

Now that MLIs are adopted in most satellites, high design reliability is crucial.Though the performance of an MLI is determined by "effective emittance*", the emittance value selected in the practical design of a satellite is based mainly on past experience. Thus, a technique for measuring the correct value is desired.

To fit an MLI to a satellite, the MLI undergoes various processes such as "Overlapping" (joining the layers together), "sewing", "making vent holes," and so on. (Fig. 3A) Experience has shown that compared with an unprocessed MLI, a similar blanket treated by the above-mentioned processing for aerospace application, provides inferior heat insulation performance. The degree of change in the effective emittance, however, is still unknown. To clarify the degree of change, our team prepared measuring equipment to securely obtain correct measurement of



A satellite working in aerospace receives heat from various sources such as "direct solar rays," "solar rays reflected from earth or other planets," and "infrared energy emitted from planets."

Fig. 1 Heat environment of satellite

Fig. 2 External appearance of the "technical satellite for monitoring greenhouse gases (GOSAT)"

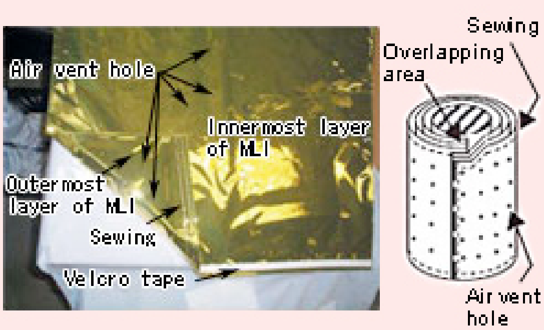
the effective emittance. Then, using an unprocessed MLI (without sewing or vent holes provided), we examined the influences on the effective emittance conferred by the overlapping method (Fig. 3B). These experiments successively clarified the influences of the sewing and the existence of vent holes.

Needless to say, we are now making good progress in our efforts to accurately measure and analyze the emittance.

Towards the construction of a database

An essential step, in incorporating the actual measurement into the practical design for a satellite, is to construct a highly accurate database for the MLI design. It is also indispensable, of course, to develop reliable methods for theoretical verification when constructing the database. To this end, JAXA took charge of a cooperative study to establish a measuring technique, to measure and analyze the information, and to turn the information into a database. Tsukuba University, meanwhile, was asked to propose the measurement technology and provide theoretical verification on an entrustment basis. This year, we intend to proceed with construction of the database based on research results hitherto obtained.

* Effective emittance : The effective emittance is an index of the adiabatic property of the multiplayer insulation blanket. Specifically, it shows the degree of change in the energy radiated from the surface of the object on which the subject MLI is fitted. The higher heat insulation performance becomes, the closer the value approaches 0. Though this factor is handled in a manner to similar the optical emittance, it differs from the latter in terms of the physical meaning.



A: Processed MLI for application to aerospace

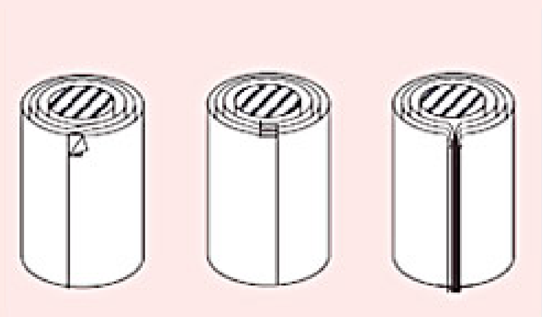

B: Various overlapping methods (when fitting the MLI to a cylinder)

Fig.3 Various processing applied to MLI

[Thermal System Group]

Haruo Kawasaki

RESEARCH INTRODUCTION

Digging into the ground of the moon

The next step for "KAGUYA"

In October 2007, the selenological and engineering explorer "KAGUYA," a surveillance craft launched by JAXA, arrived at its destination, the moon. Since then it has been continuously transmitting wonderful images of the moon surface from its orbit (Fig.1). Beside the images, KAGUYA also transmits useful information about the moon recorded by on-board equipment.

Now that KAGUYA has reached the moon and investigated the surface layer, the next investigation target, for a new orbiter, will be the internal structure. The apparatus and instruments being considered for the next investigations will be a "seismometer" to investigate the vibration of the moon, a "thermal flow meter" to examine the internal heat transfer, and so on.

A moon excavator will be indispensable

Owing to the scarcity of atmosphere, temperature difference between night and day on the moon is distinctive. For this reason, it might be difficult to obtain detailed and accurate measurements with measuring instruments installed on the moon surface. Fortunately, sand ("regolith") with excellent heat-insulating properties covers the whole surface of the moon. If the measuring instruments can be buried at least 1 m deep under the ground, it will be possible to take measurements that satisfy the above-mentioned requirements without interference from heat. Further, underground installation has the advantage of firmly and stably fixing the measuring instruments.

Fig. 2 Excavating system (prototype manufactured in fiscal 2007

The Structures and Mechanisms Group is proceeding to research and develop a specific mechanism/ system that will autonomously crawl into the sand and bury the instruments deep in the ground. One excavating system we are now examining consists of a motor and wheel incorporated into the excavator body. The wheel

Fig.1 A distant view of the earth from the moon surface (photograph taken by KAGUYA)

is driven by a motor, and the torque* obtained is used to autonomously dig into the ground with a screw-like rotating motion.

Because of its simple construction, this excavating system can be designed with a light weight. And because the drive section is wholly enclosed, there is no risk of corrosion or malfunction due to regolith clinging within the drive mechanism.

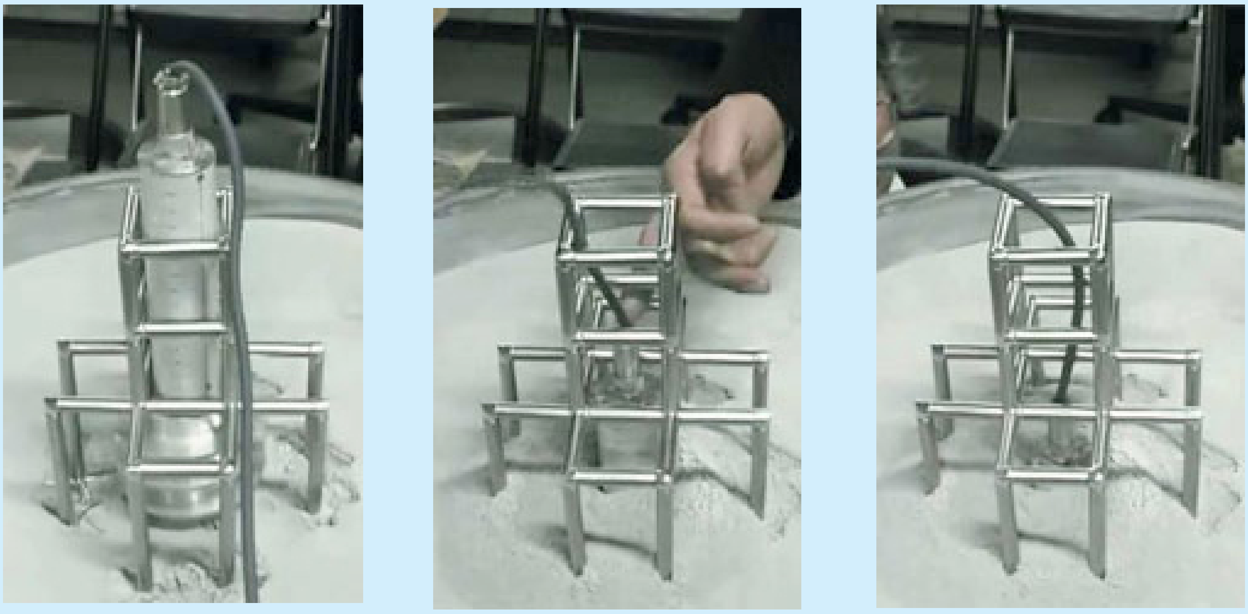
Towards the development of a practical excavating mechanism

In fiscal 2007, a prototype was made to carry out excavating tests using regolith-like sand on earth (Fig. 3).

The test result convinced us that the mechanism can dig down far enough to fully bury the excavator.

There were several problems, however, including a shortage of motor driving force. To fix these problems we will be reinforcing the driving force and further improving the drilling mechanism this year. We are also planning to prepare a test environment where the excavation test can be conducted to a depth of 1m or further.

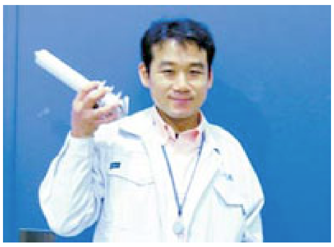
* Torque : A force exerted around the axis of rotation when a wheel is turned.



Start of excavation　　After 5 minutes　　After 10 minutes

The excavation was performed with a regolith-like sand (fly-ash). As a result, we confirmed that the prototype could completely burrow itself into the sand within about 10 minutes. During the excavation, the body of the system is held with a support structure to prevent it from overturning.

Fig. 3 The test status



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Susumu Yasuda