CRAWLING ROBOTS ON LARGE WEB IN ROCKET EXPERIMENT ON FUROSHIKI DEPLOYMENT

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Abstract

It is one of the most important and critical issues to develop a technology to construct space huge transmitting antenna such as the Solar Power Satellite. The huge antenna have many useful applications in space, for example, telecommunication antennas for cellular phones, radars for remote sensing, navigation and observation, and so on. We are proposing to apply the Furoshiki satellite with robots to construct the huge structures. After a large web is deployed using the Furoshiki satellite in the same size of the huge antenna, all of the antenna elements crawl on the web with their own legs toward their allocated locations in order to realize a huge antenna. The micro-gravity experiment is planned using a sounding rocket of ISAS in order to demonstrate the feasibility of the deployment of the large web and the phased array performance. Three daughter satellites are being separated from the mother satellite with weak springs, and the daughter satellites deploy the Furoshiki web to a triangular shape at the size of about 20-40m. The dynamics of the daughter satellites and the web is observed by several cameras installed on the mother and daughter satellites during the deployment, while the performance of the phased array antenna using the retrodirective method will simultaneously be measured at the ground station. Finally two micro robots crawl from the mother satellite to the certain points on the web to demonstrate one promising way to construct RF transmitter panels. The robots are internationally being developed by NASA, ESTEC and Kobe University. There are many various ideas for the robots to crawl on the web in the micro-gravity. Each organization is independently developing a different type of the robots. Kobe University is trying to develop wheels to run on the web by pinching the strings of the web. It can successfully run on the web, though the issue is found to tangle the strings. The robot of Kobe University is mainly described in our presentation.

1. Introduction

Higher human activities naturally need much higher power availability. Thus, the demand of power will continuously increase in the future, so that the power shortage will occur on the ground. The idea of the Solar Power Satellite (SPS) was proposed by P. E. Glaser in 1968 to overcome the shortage. Figure 1 shows the Sandwich type of the SPS [2]. The SPS can supply a huge electric power generated by solar cells to the ground in the form of microwave. Very huge reflectors to collect the sunlight and a very large power generator and transmitter are required to supply electricity over 1 GW. Thus, the construction of huge space structures is one of the most key technologies for the SPS. The technology is very useful not only for the SPS but also for the coming space activities, geosynchronous platform, moon bases and so on. Further investigations and developments are required to establish the technology of the construction.

University of Tokyo has already developed the deployment scheme called by “Furoshiki Satellite” as shown in Fig. 2. The paper describes the concept of "Furoshiki Satellite," its application to phased array antenna, and the scenario of micro gravity experiment using a small sounding rocket. The idea of "Furoshiki Satellite", a large membrane or a mesh structure, say 1km by 1km in size, extends a huge Furoshiki by satellites which hold its corners. The attitude and the shape of the membrane or mesh structure are controlled by these corner satellites. This membrane is folded in a very small volume during launch and is deployed and controlled by a set of several satellites at its corners or using centrifugal force generated by rotating the central satellite. "Furoshiki" comes from the traditional Japanese light square-shaped lapping cloth, which can be easily folded and deployed by hands. It is expected that such a structure will reduce the weight per area of the space structure and, if the control technology is acquired, it can be efficiently folded to be launched and easily deployed.

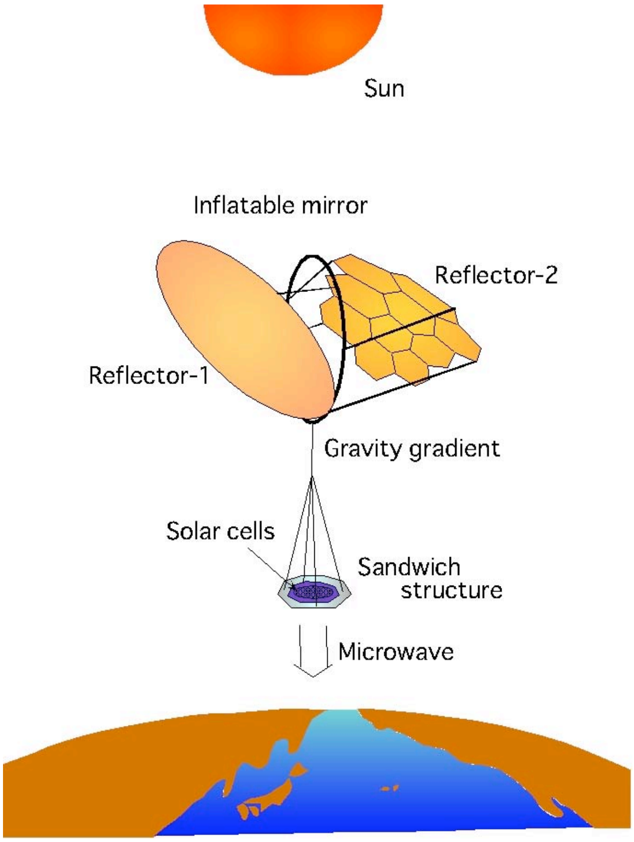

Fig. 1 Cocept of Sandwich SPS.

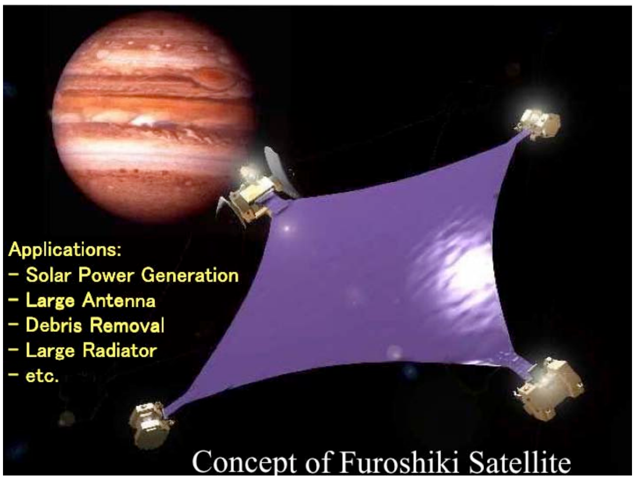

Fig. 2 Concept of Furoshiki satellite

This is one of promising systems' concept of the future large solar power satellite or large antenna, because quite a large area can be obtained without any hard structure, and the weight will not depend very much on the size. To demonstrate the feasibility of the extension of large mesh structure and phased array performance, micro-gravity experiment is planned using a sounding rocket provided by ISAS, Japan.

2. New scheme to construct huge structures

It is quite evident that huge structures are necessary and essential for the Solar Power Satellite (SPS), because the sizes of the microwave transmitters and the reflectors are over 1 km. The recent Space Station is composed of many metal frames, which costs very expensively because of its heavy weight. We propose here a new scheme to construct the Sandwich structures and the reflectors for the SPS. The new scheme is to build the huge space structures with very light materials in order to reduce the cost of the construction. We have already proposed the the Furoshiki satellite as shown Fig. 3. The several small satellites can hold and draw all the edges of a huge mesh at the same size of the structure at the beginning of the deployment. After the deployment, the whole system starts rotation in order to keep the tension of the mesh. Several robots, which are launched after the deployment and docked to the satellites, bring inflatable structures to make rigid frames in the huge structure as shown in Fig. 4. Many launched robots can crawl on the mesh to the allocated positions. All the robots work as an antenna element for the huge phased array antenna as shown in Fig. 5. This construction method is very cheap and flexible and expected to apply many useful structures in space.

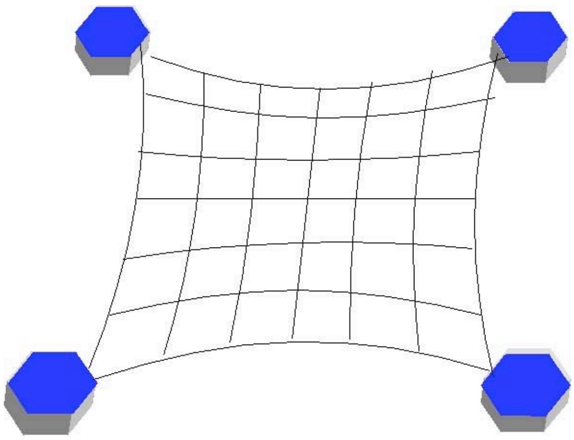

Fig. 3 Phase I: Deploument by Furoshiki satellite

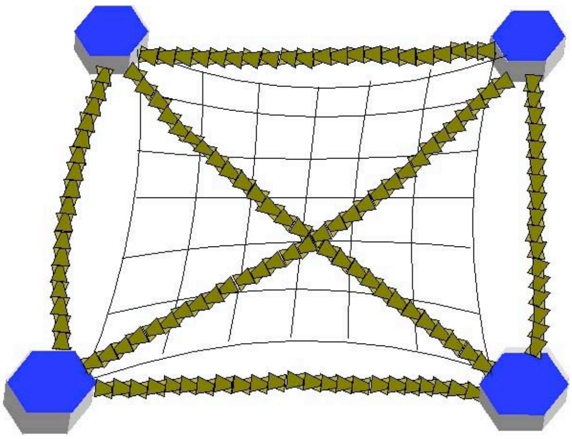

Fig. 4 Phase II: Frames by inflatable structures

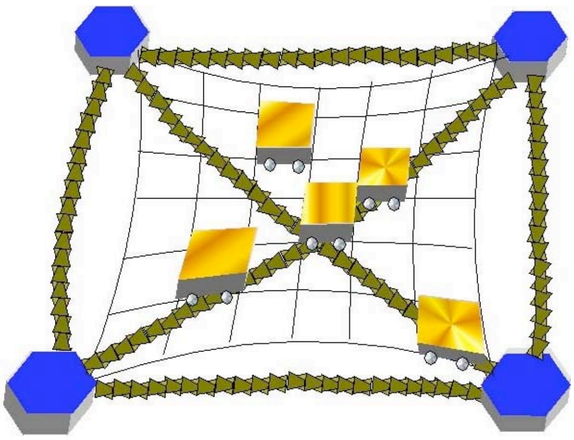

Fig. 5 Phase III: Construction of antenna elements by crawling robots

3. S-310-36 Sounding Rocket Experiment

A S-310-36 sounding rocket is planned to be launched in July, 2005 to verify our newly proposed scheme to construct huge structures under microgravity condition in space. The rocket experiment has three main objectives, the first objective of which is to verify the Furoshiki deployment system, the second is to test the retrodirective antenna system to correct the distortion of the structures in a long range from space to the ground [3] and the last is a microgravity test of the crawling robots on the deployed mesh. Figure 6 shows the configuration of the payload section. The payload section is composed of four sections. The mesh is installed at the top section and the two robots are in the box at the second section under the mesh. The daughter sections at the third section are attached to the mother section, while the momentum wheel is stored in the bottom section. The telemeters and the timer are in the CI section under the payload one. The three sections above the daughter ones are covered by a nose cone.

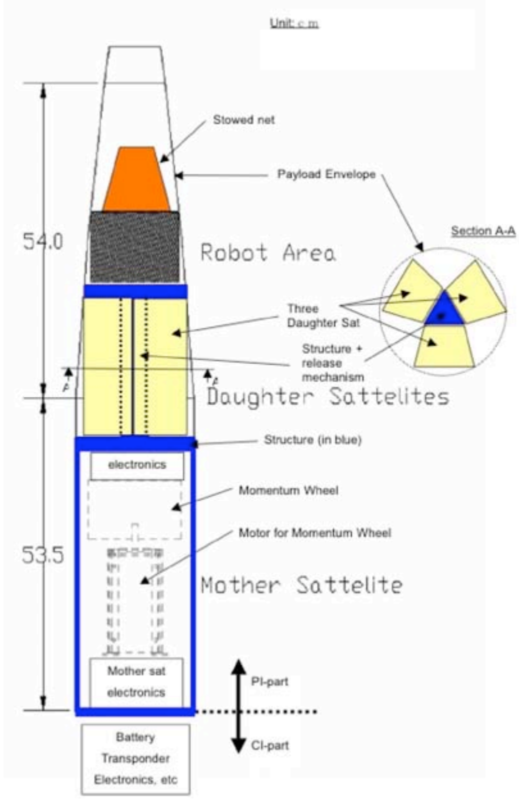

Fig. 6 Configuration of the payload section.

The rocket motor will be separated from the payload section to reduce the momentum of the payload, while the nose cone is released 55 sec after the launch. The payload section is precisely stopped to spin by the momentum wheel for the deployment of the mesh. The mesh will be tangled in case the spinning of the payload section cannot perfectly be stopped. The three daughter sections are separated by springs to deploy the mesh installed on the top of the mother section. The daughter sections may be bounced toward the mother section without a position control. Therefore the daughter section has a gas jet to stop the rebound and keep the strength of the mesh.

The microwave transmitters are turned on to radiate the microwave toward the ground according to the pilot signal transmitted from the ground station. These transmitters have a retrodirective antenna system to control precisely the direction of the microwave toward the transmitting antenna of the pilot signal. The retrodirective antenna system can decide the output phases of the microwave by conjugating the received phases of the pilot signal.

The two robots start to crawl toward the separated daughter sections on the mesh after the deployment as shown in Fig. 7. Four cameras observe walking of the robots, which is transmitted via a telemeter to the ground.

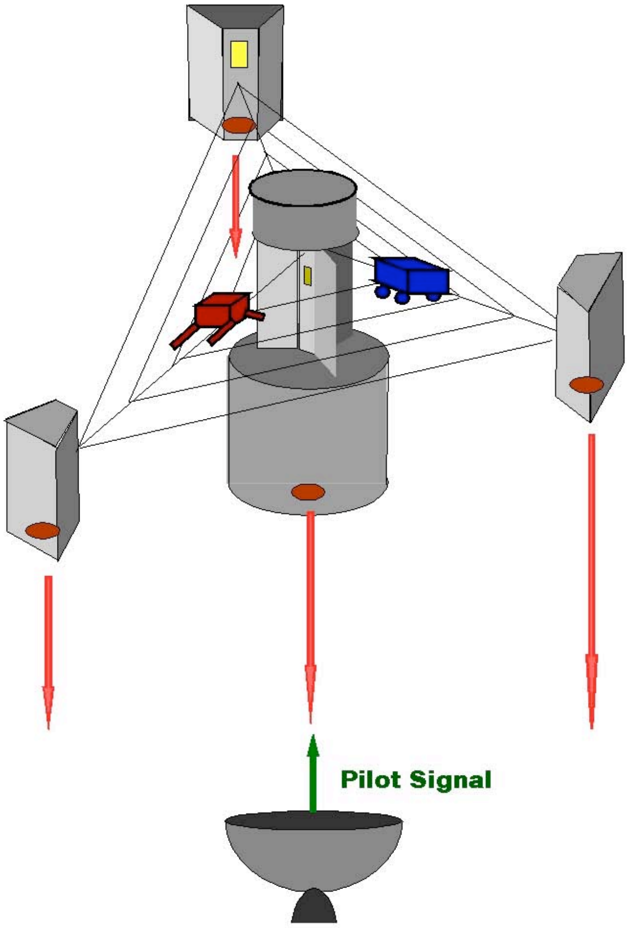

Fig. 7 Conceptual view of the rocket experiment

4. Crawling Robots on the Web

It is very difficult for robots to crawl on the waving web in the microgravity environment. The robots can easily move on the mesh on the ground, because the gravity pushes the wheels of the robots to the mesh and runs on the mesh as indicated in Fig. 8. In the microgravity environment, there is no force to push the robots to the mesh. Subsidiary wheels at the opposite side of the mesh are necessary to keep the robots attached to the mesh as indicated in Fig. 9. However, there is no method to support the subsidiary wheels at the opposite side, because the supporter must pass through the mesh. If so, the robots cannot cross the wefts of the mesh in Fig. 10. Our new idea is to move the subsidiary wheel to the space between the wheels shown in Fig. 11, which can support the subsidiary wheel. The mesh can pass through the wheels as shown in the figure. The picture in Fig. 12 shows our developed robot, which can succeed in passing the wefts of the mesh between the wheels wish supporting the subsidiary wheel.

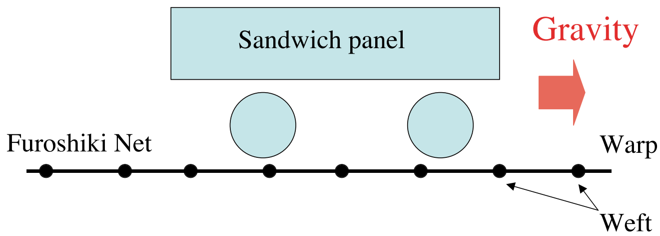

Fig. 8 Robots can run on the mesh on the ground

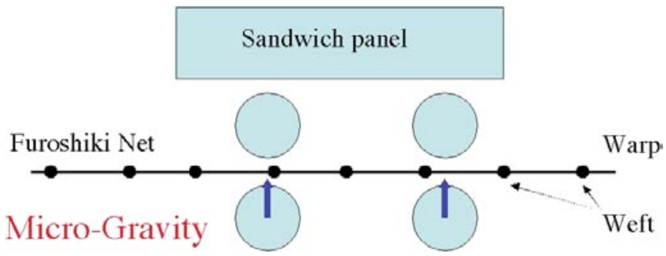

Fig. 9 The subsidiary wheels are required to crawl for robots under the microgravity condition.

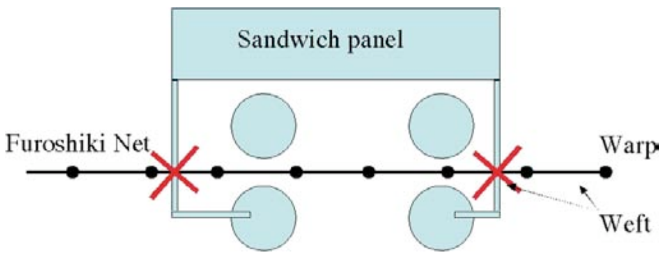

Fig. 10 The subsidiary wheels cannot be supported due to the wefts of the mesh.

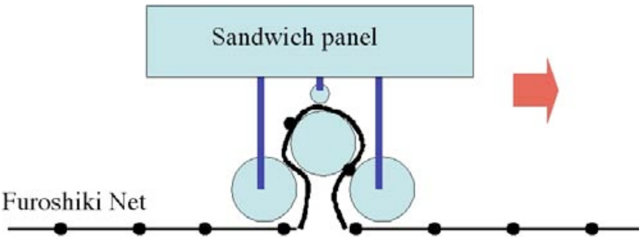

Fig. 11 New configuration of the wheels in our robot

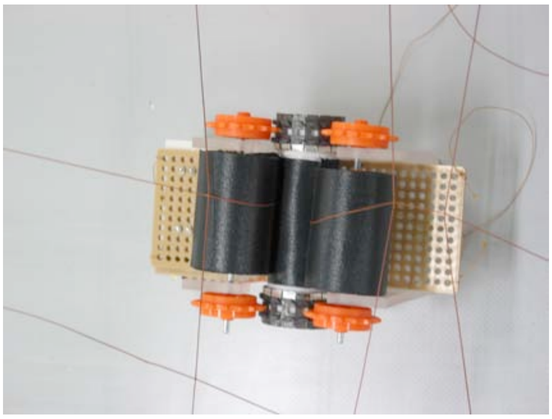

Fig. 12 Picture of our robot

4. Conclusion

We are launching the S-310-36 rocket to verify the newly proposed scheme to construct the huge structures for many useful applications using the Furoshiki satellite with the crawling robots. Especially, the new configuration of the wheels for the robots is successfully verified to crawl on the mesh.

References

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