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IMPROVED SCIENTIFIC BALLOONING APPLIED TO THE CRYO-SAMPLING EXPERIMENT AT SYOWA STATION

Nobuyuki YAJIMA[1], Hideyuki HONDA[1], Shuhji AOKI[2], Gen HASHIDA[3], Shinji MORIMOTO[3], Toshinobu MACHIDA[4] and Shoichi OKANO[3]

[1] *The Institute of Space and Astronautical Science, Yoshinodai 3-chome, Sagamihara 229-8510*
[2] *Faculty of Science, Tohoku University, Aoba, Sendai 980-0845*
[3] *National Institute of Polar Research, Kaga 1-chome, Itabashi-ku, Tokyo 173-8515*
[4] *National Institute for Environmental Studies, Onogawa, Tsukuba 305-0053*

Abstract: On January 3, 1998, a large balloon (30000 m^3) was successfully launched at Syowa Station for the cryo-sampling of the stratospheric atmosphere. The sampling system splashed down in the Lützow-Holm Bay and recovered by icebreaker SHIRASE. The cryo-sampling at Antarctica was the first trial in the world and the recovery of a heavy payload was also the first challenge at Syowa Station. A lot of new ballooning technologies were applied to this operation, such as compact balloon launching equipments, a reliable recovery system, a handy ground radio station for the balloon tracking and data acquisition and so forth. The realtime flight data could be received at National Institute of Polar Research (NIPR) in Tokyo by using the computer network via INMARSAT. At NIPR the collaboration members could monitor the entire process of the experiment at Syowa Station in detail and send some instructions and advice. This balloon experiment showed an extended possibility of a large scale scientific ballooning at Syowa Station. This paper deals with those newly developed balloon engineering technologies.

1. Introduction

It is widely recognized that a large scientific balloon is an effective tool for various scientific observations at Antarctica. The long duration balloon flight project, so called Polar Patrol Balloon (PPB), has been performed at Syowa Station since 1991. In 1991 and 1993, two balloons accomplished the perfect circumpolar flights of 38 days and 26 days, respectively, being flown in the stratospheric polar wind in a summer season (EJIRI, *et al.*, 1993; NISHIMURA *et al.*, 1994,). Those long duration balloon flights were successfully applied to various fields of scientific observations, such as aurora, electric and magnetic fields, NOx density in the stratosphere and so forth. In those cases, the balloon flew free without command operation after launching. Only the small amount of data of balloon flight and scientific observations were transmitted by ARGOS system.

Based on the successful results of the first stage ballooning at Antarctica mentioned above, a new balloon program was planned as the joint research program of Upper Atmospheric Physics Division and Physics and Chemistry of Polar Atmosphere Division of NIPR. This balloon program was approved as the 5 th five-year plan of NIPR. The air sampling was the first experiment in the new balloon program and it was conducted by NIPR and Tohoku University in collaboration with a lot of scientists concerned. The aim of this experiment is to collect air samples at 11 different altitudes in the stratosphere and to analyze minor constituents in the air at the laboratories of the collaborating scientists (HONDA *et al.*, 1996). The Institute of Space and Astronautical Science (ISAS) supported the balloon engineering and the related engineering for the scientific mission of this project.

This balloon experiment requires precise flight control, multi term tele-command operations and reliable recovery of the air sampler. These items are almost the same as those of the balloon operations carried out at the permanent balloon base, Sanriku Balloon Center (SBC) in Japan. Therefore, it is the most important problem how to perform such kind of large scale balloon experiment under the difficult conditions, such as limited logistics, luck of a well-trained balloon personnel and also short preparation period at Syowa Station. From the beginning of the project, the collaborating scientists have planned to improve experimental conditions so that all of them become accustomed for specific conditions at Antarctica. Those essential points are;

(1) Careful feasibility study on payload recovery based on the combined analysis of both the meteorological data and the acceptable flight patterns.

(2) Improvement of the ballooning equipments and facilities such as compact balloon launching tools, a reliable recovery system for a large payload, a handy ground radio station for the balloon tracking and data acquisition and so forth.

(3) Remote assist system for the balloon operation from NIPR's office in real-time *via* a satellite-rink computer network system.

2. Feasibility Study of Payload Recovery

Estimation of adequate wind profiles over Syowa Station was carefully examined at the first stage of this project. A capable recovery range is within about 55 km circle which is limited by the helicopter operation coverage. The flight trajectories were

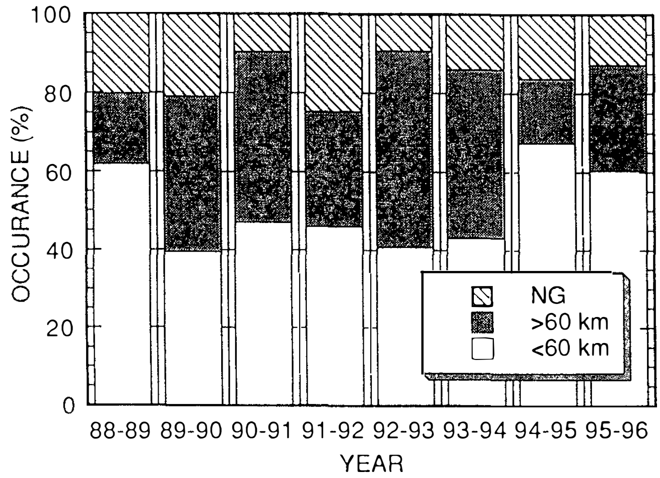

Fig. 1. Simulated occurrence of touchdown point distance from Syowa Station. (NG means within difficult area for recovery because of severe ice conditions.)

simulated using the wind data between 1988 and 1996 (about 80 observed wind profiles from December 20 th to January 31 st every year). Figure 1 shows the occurrence rate whether the touchdown points are within 60 km circle or not. It excludes the area where it is difficult to recover the payload because of severe sea ice conditions (see "NG" in Fig. 1). This figure shows that the payload can be recovered within 60 km circle with the possibility greater than 40%. According to this estimation there are two or more chances for balloon launching in a season. These chances also include good ground wind conditions. From 1995 to 1997, this estimation has been confirmed experimentally at Syowa Station using small balloons with the light payloads (HONDA *et al.*, 1996). These tests also aimed at training of the recovery operation using a helicopter.

3. Payload Recovery System

3.1. Balloon rigging system

A parachute system is necessary for payload recovery. Though, an exposed parachute is a part of a suspension train in a usual balloon flight, the long and complicated assembly of it is sometimes troublesome for safety launching. To simplify

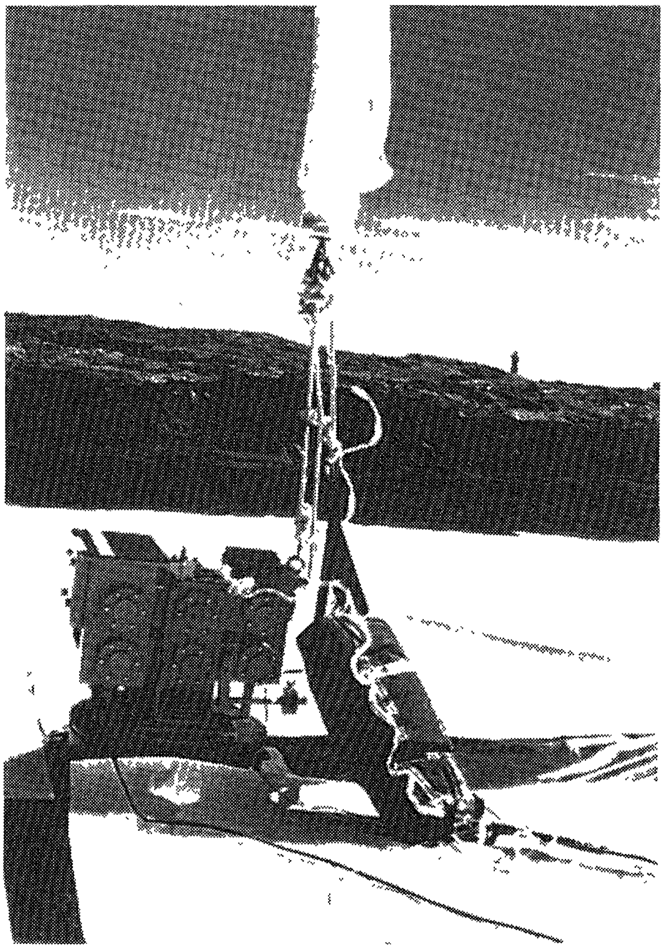

Fig. 2. Packed parachute attached to the balloon bottom.

the rigging system, a packed parachute was used to shorten the payload suspension train. Similar to a manned parachute, this one is installed in a small bag together with flight termination devices (rope cutters) and a parachute deflation mechanism. The latter mechanism is executed when a payload touches down, so that a parachute does not pull down and drag a payload on the ground by a strong wind. Those were assembled beforehand at ISAS. Therefore, the field task turned to be quite easy, that was; one side of the pack was connected to the balloon bottom and the other side to suspension rope respectively. Figure 2 shows the packed parachute attached to the bottom of the balloon.

3.2. *Shock absorber*

It was predicted with a high possibility that the payload was to touchdown on hard sea ice. To protect the air sampler from great landing shock, shock absorbers made of aluminum honeycomb were attached to the gondola.

4. Ground Support Systems

In order to reduce preparation tasks at Syowa Station, new ground support systems were developed and employed in this experiment. Some of them had been prepared in PPB project. Most equipments were actually tested at SBC when the special training was planned for the members who were to join the launching operations at Syowa Station.

4.1. *Helium gas system*

The helium gas injection system was redesigned so as to inflate a balloon in shorter time. About 100 cartridges are used for one flight. All cartridges are connected each other in two stages, that is, at first each 8 cartridges, which are mounted in a container, are connected together by a small manifold, and next, its output is joined to a large manifold. Then the output of this manifold was led to a balloon inflation hose by way of a control valve. As a result the conductance of gas system was significantly improved.

The gas pressure sensor and temperature sensor were set near by the gas system. The buoyant force was calculated there by the hand-held computer. In addition, the data were transmitted to the operation room at Syowa Station by a voice transceiver and then sent to NIPR through the computer network as described later. The members at NIPR also computed the buoyant force simultaneously as a cross-check. As a result, the exact amount of helium gas was injected in the balloon. The ascending speed profile was the same as estimated one. Figure 3 shows the helium gas system under operation.

4.2. *Spool car and launcher*

These two machines are the same that were used for PPB experiments. Only one exception is the renewal of the caterpillar car on which the spool is attached.

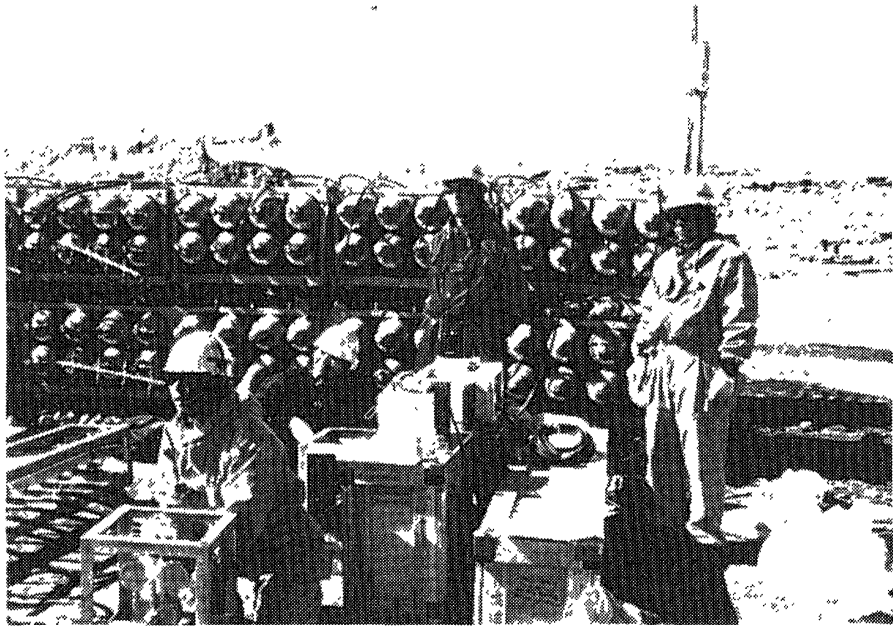

Fig. 3. Helium gas system under operation.

4.3. Balloon tracking and receiving system

The new tracking system is based on the positioning data sent from the on board GPS receiver. The ground computer calculates the elevation and azimuth angle of the telemetry antenna using the data of the latitude and the longitude of both the balloon and Syowa Station. The telemetry and the tele-command antenna are mounted on the simple 2-axis drive mechanism and the angle of those axes are controlled by the computer. This new system is quite simple and compact. Total system except antenna

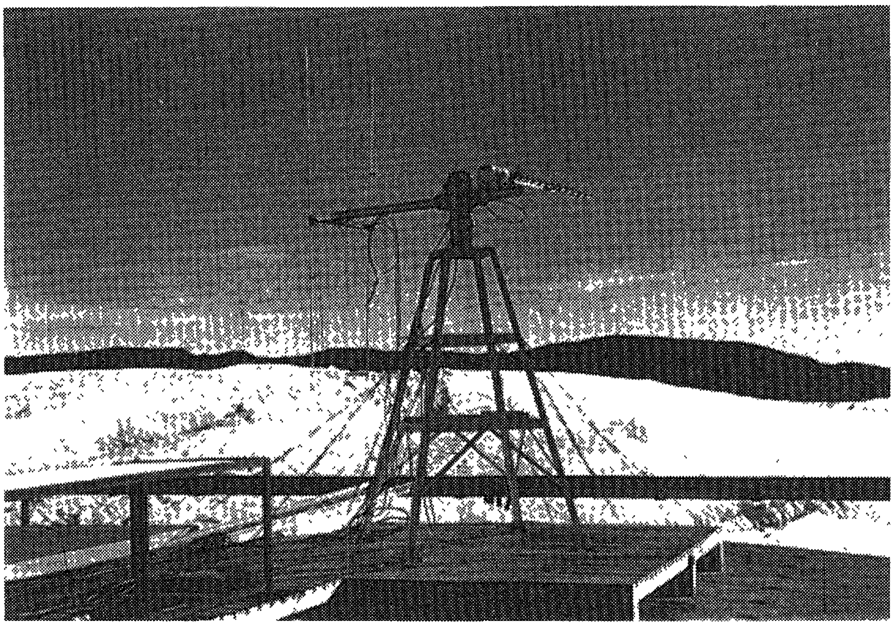

Fig. 4. The telemetry/tele-command antenna system mounted on the building.

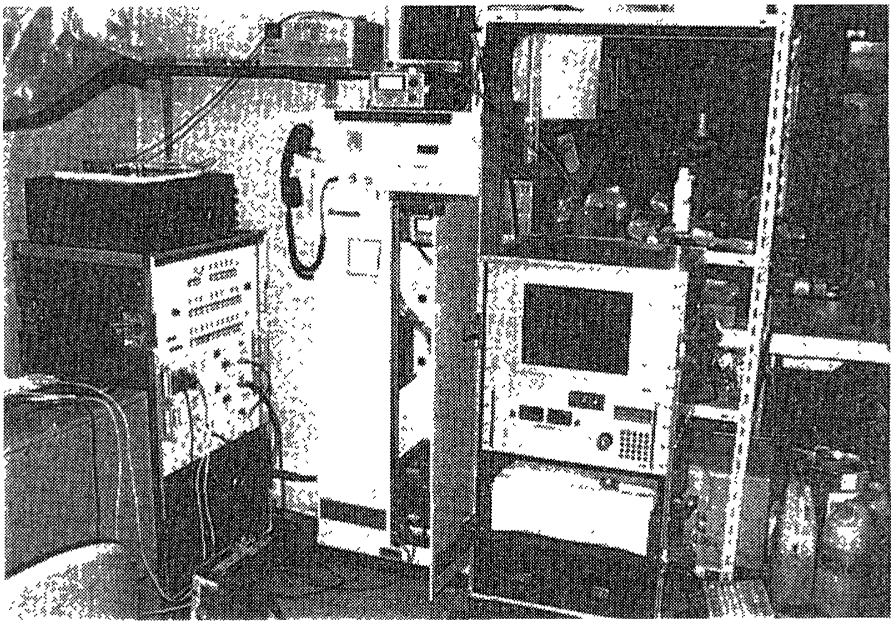

Fig. 5. The radio station set up in the operation room at Syowa Station. (The left rack is to store the telemetry receiver, the tele-command switch box and the data demodulators. The center rack is the command transmitter and the right rack is the antenna controller and the personal computer with the display.)

assembly is installed in the handy racks. The internal cables are connected each other in the rack beforehand, so that the system can be used at any time. The project members were well trained in Japan how to operate it and then they carried it to Syowa Station by themselves. Figure 4 shows the antenna and its drive system attached on the top of the building. The tracking and receiving electronics systems were set up in the operation room as shown in Fig. 5. Owing to the elaborate preparations in Japan as mentioned above, all of these constructions and test-run were finished only in one day at Syowa Station.

5. Remote Support System of Balloon Operations

To support the balloon operations directly at NIPR in Tokyo was planned in high priority, because it was thought to be difficult that the operation is executed only by inexperienced personnel who join the expedition. To realize this plan, the bilateral data communication in realtime is essential. Fortunately NIPR has already established the computer network between Syowa Station using INMARSAT. The realtime data transmission by means of this network is applicable to a balloon experiment. The diagram of this system is presented in Fig. 6. A workstation in the operation room at NIPR was programmed so as to access a set of the latest telemetry data stored in the main workstation at Syowa Station once in 20 s. The data lists and graphical charts were displayed in the same forms at both places. Then the members at NIPR could monitor all of the data as if they were at the operation room at Syowa Station. To exchange the character massages from both sides was also available by means of a built-in function of UNIX. In addition, for urgent contacts a telephone line was kept

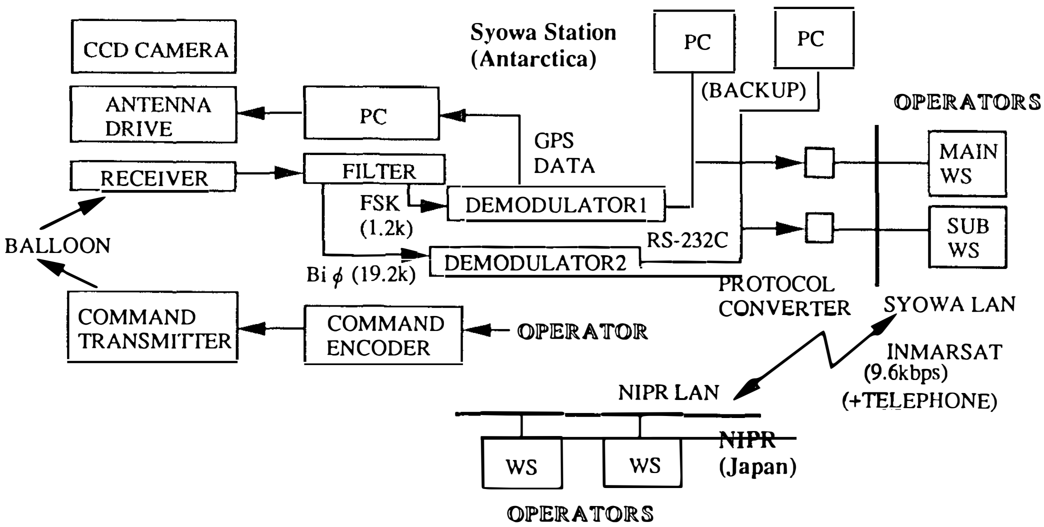

Fig. 6. The diagram of the ground support system which contains the remote support system by means of a satellite-link computer network.

holding on as a precaution against serious troubles. Fortunately, it was not used for this purpose.

As for the tele-command operation, it was executed by the staff at Syowa Station under the suggestions of the members at NIPR. Both sides exchanged important data each other for the confirmation of the command operation every time when the staff at Syowa Station sent one command item.

6. Progress of Experiment

The cryogenic air sampling balloon was launched on January 3, 1998. The payload took off quite smoothly. At first the balloon passed through the strong wind region with rather high ascending speed of 340 m/min and then slowed down to normal speed of 300 m/min after it passed through the tropopause. The air sampling operation was accomplished at 11 different altitudes according to the prearranged procedure.

The payload splashed down on the surface of the sea about 42 km away from Syowa Station. The air sampler was easily found using a helicopter immediately, because the on board GPS positioning data could be received as low as 200 m altitude. As the gondola was on the sea, it could not be picked up by the helicopter at that time. Three days later the icebreaker Shirase finished the unloading operation and the payload was recovered by the ship. Though the gondola bumped the corner of the large ice block and fell into the sea, all devices in the gondola were protected by the shock absorber as shown in the photograph of Fig. 7. All sampling cylinders were recovered without any damage.

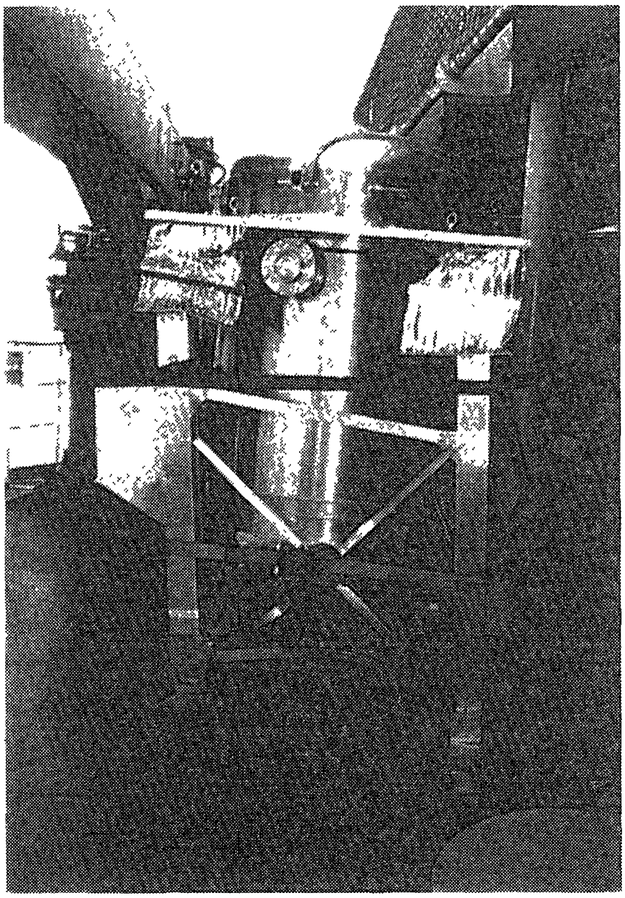

Fig. 7. The outside appearance of the air sampler which was recovered and picked up on the deck of SHIRASE.

7. Conclusion

The cryogenic air sampling operation was accomplished successfully at Syowa Station. This project pioneered in the new field of scientific ballooning at the polar region. To collect the large amount of stratospheric air samples at Antarctica was the first trial in the world. The recovery operation of a heavy payload was also the first challenge at Syowa Station. The ground support systems, such as compact balloon launching equipments, reliable recovery system, the handy ground radio station for the balloon tracking and data acquisition etc. were newly designed simple and compact. As a result, the project staff can use them easily without the direct attendance of any specialist of ballooning at Syowa Station. Those improved ballooning technologies led this balloon operation to success. The remote support system by means of the bilateral realtime data transmission between Tokyo and Antarctica also played an important role on the success of this balloon experiment. Owing to the adequate timely comments and suggestions from NIPR, the project staff at Syowa Station could accomplish complicated operations step by step with firm confidence. Such kind of computer network application will be applicable to a lot of scientific experiments to be carried out at the polar region.

The successful result of this balloon experiment means that a large scale balloon operation including payload recovery is feasible at the polar region without a skilled staff of ballooning in case adequate facilities and remote support systems are available. Authors wish that this new scientific ballooning will be improved more and more for a lot of scientific activities using large balloons at Antarctica.

Acknowledgments

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