RECENT ACTIVITIES ON THE SCIENTIFIC BALLOONING IN JAPAN

J. NISIMURA and H. HIROSAWA

Institute of Space and Astronautical Science
Tokyo, Japan

ABSTRACT

Scientific ballooning in Japan has been organized by the Institute of Space and Astronautical Science, and about 15 balloons have been launched each year from Sanriku Balloon Center that belongs to this Institute. The balloon center is located in the northern part of Japan. The observations cover the field of X-ray, gamma-ray, infrared astronomy, cosmic rays, and atmospheric science.

Systems of long duration flights such as "Boomerang Balloons", and fine attitude control systems were developed and widely applied to the scientific observations.

International collaborative works were performed in Australia and Indonesia last year. Some details of these activities are reported and possible future collaborations with Brazilian balloon group are also discussed.

1. Introduction

Scientific ballooning using plastic balloons in Japan was started in 1953 by the cosmic-ray group in Kobe Universtiy. Later on, to meet the need of space science research group, a scientific ballooning group was established in the Institute of Space and Aeronautical Science, University of Tokyo, in 1966, when this Institute was founded. This institute is concerned with the development of rockets and satellites for the scientific observations. Thus, the scientific ballooning has been developed in close connection with the rocket and satellite projects. The institute was reorganized as an independent institute (ISAS) of the Ministry of Education in 1981.

Since the balloon group was started in this institute, about 350 balloon flights have been conducted for scientific observations and for development of balloon technology. The largest balloon so far developed had a volume of 200,000 m^3, which was launched and leveled at 42 km in 1973. This was achieved by the improvement of the plastic films used for the balloon, as well as the design of the balloon, the method of manufacture and the launching devices and methods. In this paper, descriptions are given on the items of balloon technology such as systems for attitude control and long duration flights developed by the ISAS, and a brief description is given on some results of scientific observations, and future prospect of international collaboration for the scientific balloonings in Japan.

2. Sanriku Balloon Center

Sanriku Balloon Center, founded in 1971, is located at 141°49'30''E, 39° 09'30''N, on the Pacific coast of the northern part of Japan. The location is shown in Fig.1. The launching fields are two crossed pavement strips of 120 m X 120 m and 25 m X 75 m. Since the fields are narrow, the static launching method is adopted. Recently, we use spool at the time of gas filling as in the case of usual dynamic launching method. At the bottom of gas bubble, we put collar. The bottom of the balloon is clumped by the launching device, and we let the balloon stand up by rolling down the spool after gas filling. The collar is used for the inflated balloon to withstand a surface wind, and taken off just before the launching. In this method, balloons are quite stable against the surface wind and a payload with a weight of up to 500 kg is launched without any trouble. We believe the method can be applied for a payload even heavier than 1,000 kg.

At the center of the launching field, a rotating table of 12 m diameter is situated, the launching device is placed on this table. The inflated balloon should be set in a position upstream in the surface wind relative to the payload. The rotating table is used to adjust the postion of the inflated balloon relative to the payload just before the launching.

The telemetory center is on a small hill about 1,000 m apart from the launching center. The telemetry systems now adopted are 6 ch FM-FM of IRIG or PCM systems of phase-lock type with bit rate of 16 k bit/sec. The usual carrier frequency is 1673 MHz, but in some cases the 298.1 MHz band is also used. The command system is 15 ch of the double tone type, with a carrier frequency of 72.3 MHz. A transponder system to find the location of the balloon has been adopted since 1968. Tones of 500 Hz and 5 KHz are sent for short duration by the command carrier. The tones are sent back through the command receiver and telemetry transmitter on board the balloon, and the range is observed by detecting the phase delay of those tones.

Duplicate systems for auto tracking using parabloas of diameters of 2 m and 3 m for the 1673 MHz band are installed at the telemetry center. With the aid of a computer, the location, altitude and ascending velocity of a balloon are calculated using the range and angle of azimuth and elevation data. The results are immediately printed and plotted on a map to show the location and flight condition of the balloon.

Sanriku Balloon Center has also a mobile receiving station consisting of a 2 m diameter parabola for the 1673 MHz band for telemetry, command transmitter and computer, which was completed in 1978. Since a high mountain range is located on the west side of the Sanriku Balloon Center, the telemetry range is limited to 200 km in the westerly direction. The mobile station is placed at the mountainsite of Mt. Chokai located at Japan Sea Coast, making observations of the range up to 500 km east over the Japan Sea.

3. Attitude Control Systems

To meet the needs of scientific observations, a simple attitude control system was developed in 1968. The system is called "Control System using Twisting Suspension Rope". The principle is shown in Fig.2. The deviation angle of the gondola is detected by a sensor attached to a payload. Rotation of a motor attached to the bottom of the balloon is controlled in such a way so as to minimize the deviation angle. (Ref.1) The system has been successfully applied to the observations which require attitude control. About 50 observations have been performed using this device. The system is simple and low cost, but the pointing accuracy is limited to about 1 arc degree. In 1982, we planned to observe the possible existance of dust ring around the sun at a balloon altitude taking advantage of the time of soalr eclipse that occured over Indonesia in 1983. In this observation, the pointing accuracy was needed to be better than 1 arc min.

The group of ISAS and of Kyoto University (Ref.2) has been developing a fine attitude control system with a reaction wheel. The principle of this system is shown in Fig.3. It consists of a twisting motor and a reaction wheel. The twisting motor is used to reduce the torque of the suspensiton rope by decoupling the motion of the balloon, and it is also used to unload the speeding up of the reaction wheel. The combination of the optimum parameters for driving the twisting motor and the reaction wheel is essential to achieve a good pointing accuracy. We analyzed the control system to find those parameters, and the results were confirmed by the simulation with an electronic computer. The detailes of these analysis are found in the reference 3. In the observation at the time of eclipse, the pointing accuracy of about 8 arc seconds were achieved by this system, and we could clearly observe the dust ring arround the sun by the infrared detectors and silicon intensifier tube (SIT) camera on board the balloon.

More elaborate system of attitude control has been developed by using control moment gyro as a torquer by the group of Mechanical Engineering Institute. (Ref.4) The system consists of twin control moment gyro with roter of 3,000 r.p.m and moment of inertia of 15 cm in diamer. The system is useful to drive the large telescope on board the balloon, and successfully applied to the infrared telescope of 30 cm dia. and 50 cm dia. The later of the telescoper will be used to observe the infrared from the dark cloud in the Galaxy, and the observation will be performed in Australia early in next year. The pointing accuracy by this system was several arc seconds in a test experiment performed at Sanriku Balloon Center in 1980.

4. Systems for Long Duration Flights

Because of the narrow extent of land in the east-west direction in Japan, the duration of balloon observations and recovery after the long observations have been thought to be limited. However, the systems of balloon trajectory control and other systems for long duration flights have been developed, by ISAS group, the problem is resolved to some extent. As some details of the systems are already described in elsewhere (Ref.5), we present here only a brief review of those systems.

4-1. Control of the Balloon Trajectory

A strong jet stream appears at middle altitude over Japan in every seasons. At high altitude, say an altitude higher than 20 km, the easterly wind appears stationaly in summer season. With the aid of this wind pattern, the control of balloon trajectory was considered, and the possibility was analyzed in 1960. The principle is shown in Fig.4.

Once a balloon attains the level altitude, it moves to the west due to the easterly wind. When it approaches the boundary of telemetry range, the balloon is made to descend to middle altitude by valving the lifting gas. The balloon now moves to east by the wind at middle altitude. When it approaches the eastern boundary of the telemetry range, the balloon is made to ascend again by dropping ballast. The control is continued until the ballast is exhausted. The system is called "Cycling Balloon". In actual fact, during the test flights made in 1963, it was demonstrated that the balloon could be kept within a range of about 100 km from the receiving station for a period of 30 hrs.

The "Boomerang Balloon" is a general extention of this "Cycling Balloon". In this system, ascending balloon is stopped once at a middle altitude by valving. The balloon moves with a speed of 150 to 200 km/hr to the east. Before approaching the telemetry range limit, i.e. about 500 km, the balloon is made to ascend to proper level altitude by ballasting. After the balloon attains the new level altitude, it moves back slowly to the receiving station. Termination of the observation is made at a place appropriate for the recovery. The principle of the system is shown in Fig.5. With this system, 20 to 30 hrs observations are normally achieved, if the balloon is launched in between the middle of May and the beginning of June. The longest record by this system was 64 hrs in 1980. An example of the trajectory of the Boomerang Balloon is shown in Fig.6, in which an observation of primary electrons in cosmic-rays was performed.

With the completion of the mobile station, another boomerang system became avairable in 1980. With the help of the mobile receiving station placed at mountainsite near Japan Sea coast, the balloon is tracked from this receiving station over the Japan Sea. Within the range of telemetry, the balloon is made to descend by valving and to stay by ballasting at an appropriate altitude, where the westerly wind predominates. The payload was recovered near the sea coast (Fig.7,8). In this system, reascending ballast release is not required as in the case of usual "Boomerang Balloon", nor is valving during ascent. Thus the control system is simple and there is a further benefit of reducing the weight of ballast at launching time. There is also a possibility that the trajectory of the balloon is made to extend to pacific side and to reasend to perform the large scale "Cycling Balloon".

4-2. Flights at Turn around Period

As in the ususal case in other countries, we have achieved our longest flights at a turn around period over Japan. It appears in May and September, and lasts for a week or so. The starting date of the period changes from year to year, and exact prediction of the appearance date is most essential to perform this kind of long duration flights.

In 1975, we needed to perform the long duration flights to observe the gamma-ray bursts, and succeeded to have flights of 55 hrs and 65 hrs. In 1977, we performed 79 hrs flight, and the payload was recovered on the mountain site at 150 km west from Sanriku Balloon Station.

4-3. Relay Balloon

The principle of the "Relay Balloon" is similar to that of telemetry link through satellite. In stead of using a satellite, a balloon is used as relay station to link another balloon which itself is outside the telemetry range from the ground staion as shown in Fig.9. The test flights by this system were conducted in 1976, and the technique has been applied to scientific observations. The telemetry ranges are found to be extendable up to 1,200 km by this technique. Satellite link system of ARGOS was also tested in 1983, and we are planning to use this system for scientific observations extending the telemetry range over the Pacific Ocean.

4-4. Auto Ballasting System

In such a long duration flight as "Relay Balloon", or "Satellite Link", the balloon itself stays outside the telemetry range of the ground station. We need auto ballasting system to keep a balloon at a level altitude. The ballasting system is required to drop the minimum amount of ballast for the balloon to keep the level altitude. Therefore, we developed an automatic ballasting system in 1979. The system consists of a balloon ascent meter, which can measure the ascending or descending speed of the balloon with a sensitivity of 1 cm/sec. The details of the system is found in the Ref.5.

5. Systems for Micro-gravity Experiment

To meet the requirement of scientists to have a facility of Micro-gravity experiments, a system was developed by ISAS group by utilizing a high altitude balloon. In this system, a chamber of rocket shape is released at a balloon altitude by taking advantage of low air density at high altitude. The chamber drops with almost as a free fall for 10 - 20 sec after the release, because of the small air resistance at high altitude. Test experiments started in 1980, and finally the system was used for a scientific observation in 1983. The size of the chamber in the last experiment was 52 cm in dia., 220 cm in length, and its weight was 275 kg. Two 8 mm movie cameras are equipped in the chamber, as well as the telemetry transmitters. $2.9 \cdot 10^{-3}$ g was observed at 10 sec after the release, and $1.4 \cdot 10^{-2}$ g at 20 sec. Afterwards, the chamber was decelerated by reefed parachute of ring slot type, and safely recovered on the sea. (Ref.6)

The experiment performed was the observation of the brain activity of a fish and the change of its attitude at the time when the direction of the illuminating lights was changed under the micro-gravity. The observation was successful. We believe the system is useful to microgravity experiments in various fields, which require such facilities.

6. Scientific Observations

Perhaps it would be necessary to describe recent scientific results by balloon observations in this report. However, by shortage of the paper, I just present a list of the flights in 1983 in Table 1 and 2, and some detailes of each subjects and the results will be presented at the meeting.

7. Future Prospect on the International Collaboration

Because of the limitation of the geographic condition in Japan, we spend much efforts to perform the international collaboration. The collaborative flights have been successfully performed in Australia, India, Indonesia, U.S. and Sweden in these past ten years.

One of the projects which we wish now to realize is the collaborative transoceanic flights with Chinese group. We are planning to launch the balloon from Kyushu Island, to float it over the East China Sea, and to recover it near Shanghai or Nangking area. The total stroke of the trajectory in this project is beyond 1,000 km depending on the recovery area, and thus we can expect a long duration flight. (Ref.7)

Other project now under preparation by the National Polar Institute is the Polar Patrol Balloon. The project is of circumpolar balloons around the pole, and to observe the particular phenomena occuring over the polar region. We investigate the meteolorogical feasibility, and found it takes a few weeks to round the pole, if we launch a balloon near 70° S in summer season, assuming its level altitude is 30 km. (Ref.8) Because there is no sunset in this season, we consider it is possible to use a zero pressure balloon on which we equip auto ballasting systems. The tracking of the balloon will be made by utilizing ARGOS system, and the observed data will be accumulated on board memory of 20 M Byte. These data will be transmitted to the ground after the balloon comes back near the receiving site. The power supply for the payload is considered to be enough by the solar battery on board the balloon, just as in the case of satellites. Since the polar patrol balloon is a new facility for the observation in polar region, we expect the system will be promissing to explore the phenomena occuring over polar region.

For the collaborative work with Brazilian balloon group, we have been discussing on the possibility for the balloon technology as well as collaborative observations taking advantage of long duration flights such as Racoon in Southern Hemisphere.

References

1. H.Hirosawa, J.Nishimura, S.Ohta and Y.Ohtsuka, 1971 Proc.9th ISTS, p.1095
2. N.Hiromoto, T.Maihara, K.Mizutani, N.Okuda and H.Shibai, ISAS Report p.603
3. J.Nishimura, Y.Koma and S.Ohta, 1984 Proc.14th ISTS in print.
4. J.Nishimura, N.Yajima, S.Kokaji and S.Hashimoto, 1880 Scientific Ballooning II, Pergamon Press, p.127
5. J.Nishimura and H.Hirosawa, Ibid. p.239
6. M.Namiki et al., 1982 Proc.13th ISTS in print.
7. J.Nishimura, H.Akiyama and D.Yamanaka, 1982 Proc.13th ISTS 1227
8. J.Nishimura, K.Tsuruta, M.Kodama and H.Fukunishi, 1984 Proc.14th ISTS in print.

The contents in Ref.3,6,8 are to be published in Scientific Ballooning IV, Pergamon Press in 1984.

Table 1. List of Balloon Observations(1983)

No.	Date	Experiment	Balloon	Altitude (km)	Remarks
1	'83.8.28	Air Sampling	B_{15}	28.6	Recovered
2	8.30	Aerosol Sampling	B_5	27.9	Recovered
3	9.2	Far-Infrared	B_{50}	34.4	Recovered
4	9.4	Solar Telescope	B_{50}	30.4	Recovered
5	9.6	Micro Gravity	B_{50}	32.0	Recovered
6	9.23	Geomagnetic Field	B_5	20.5	Recovered
7	9.26	Stratospheric Turbulence	B_5	24.6	Reel Down 1km
8	9.28	Argos System	B_1	20.0	Satellite Link

Table 2. International Collaborative Flights(1983)

No.	Date	Experiment	Balloon	Altitude (km)	Remarks**
1*	'83.5.4	Heavy Primaries	B_{30}	32.0	32 hrs.
2	5.8	Galactic Infrared	B_{15}	27.0	
3	5.10	Boomerang	B_{30}	32.0	30 hrs.
4	5.13	Atmospneric Electricity	B_{15}	29.0	
5	5.18	Galactic Infrared	B_{15}	27.0	
6	6.5	Test Flight	B_5	28.0	
7	6.11	Solar Eclipse	B_{15}	30.6	

* Launching Site
1-5: Alice Springs, Australia
6-7: Watukosek, Indonesia

** allrecovered.

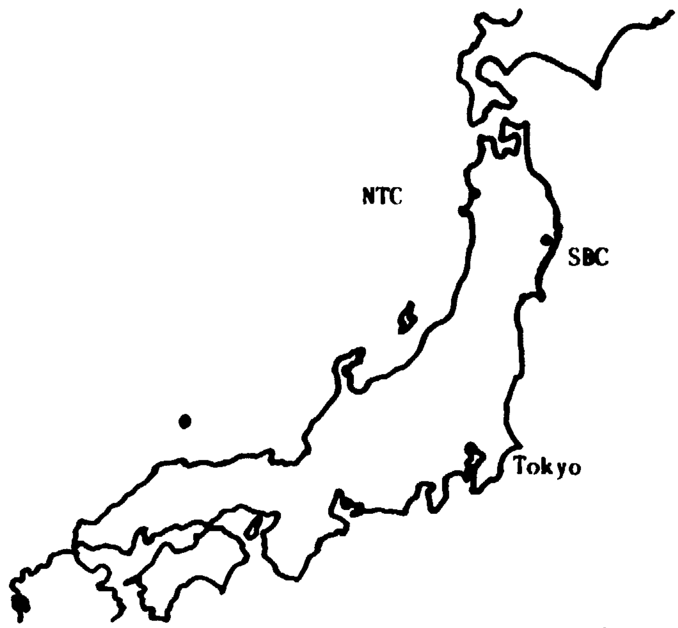

Fig.1 Location of Sanriku Balloon Center

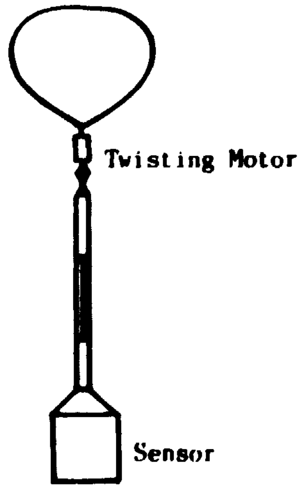

Fig.2 Control System with twisting motor

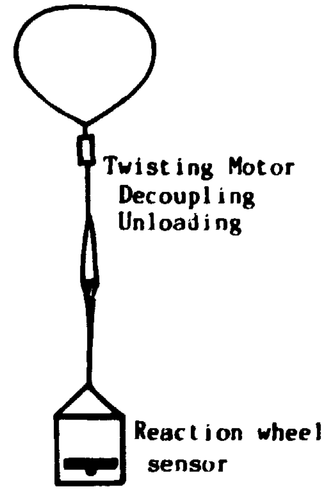

Fig.3 Control System with a reaction wheel

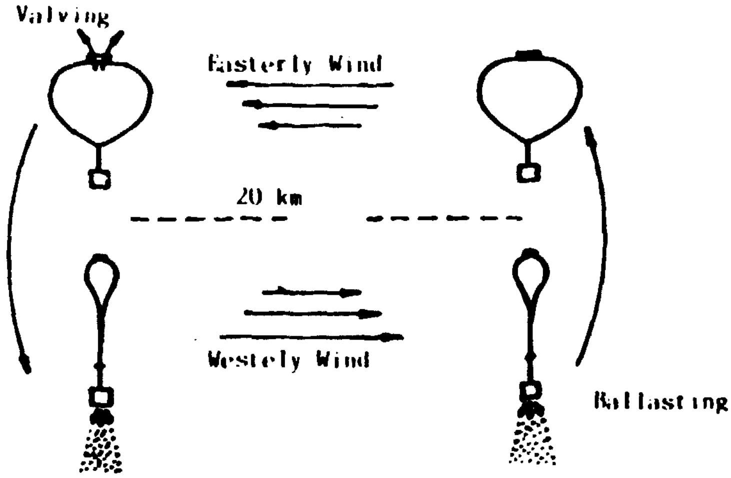

Fig.4 Cycling Balloon

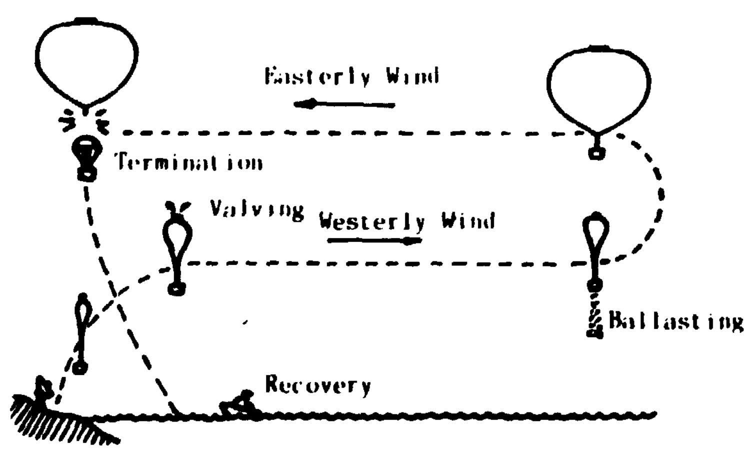

Fig.5 Boomerang Balloon

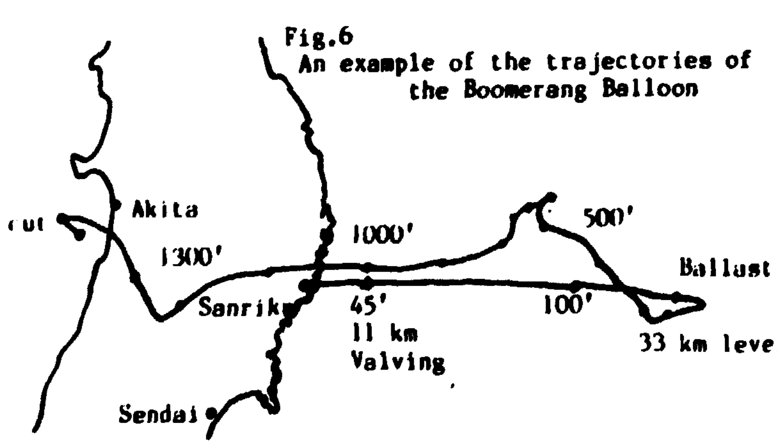

Fig.6
An example of the trajectories of the Boomerang Balloon

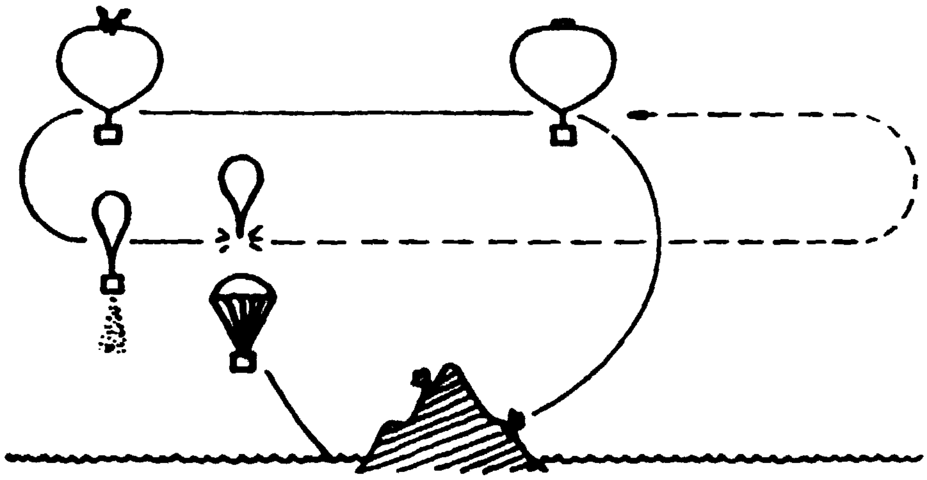

Fig.7 New Boomerang Balloon

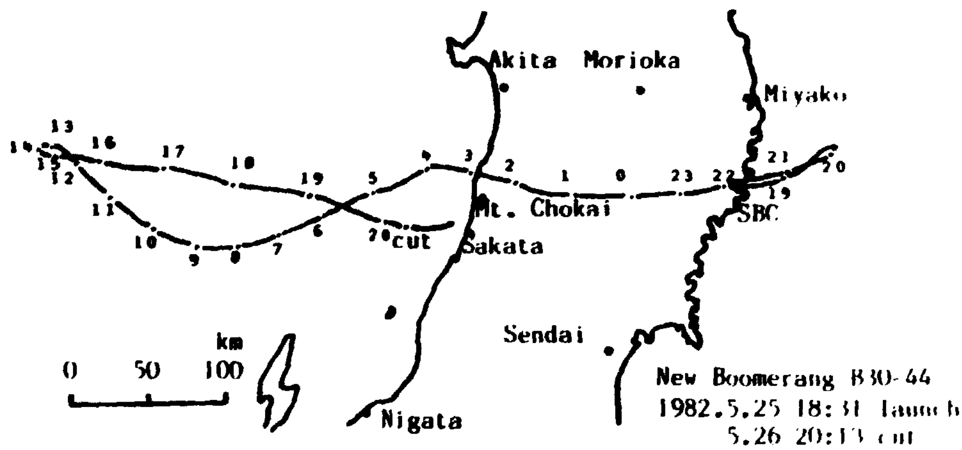

Fig.8 Trajectory of New Boomerang Balloon

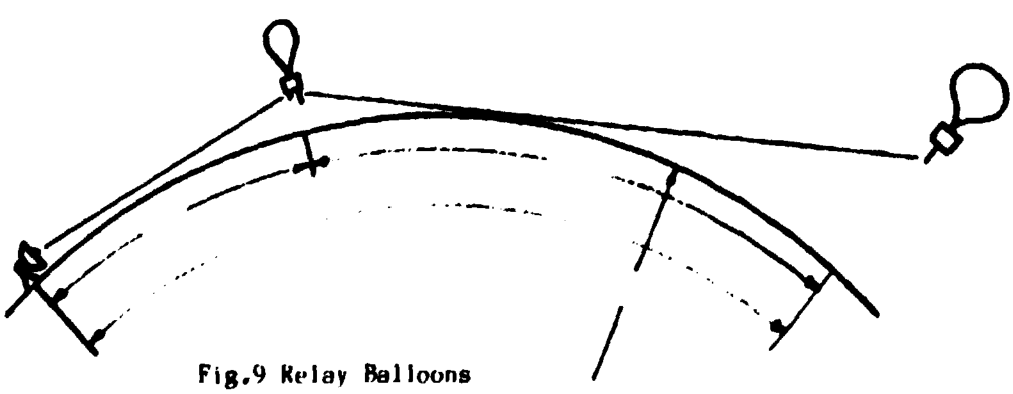

Fig.9 Relay Balloons

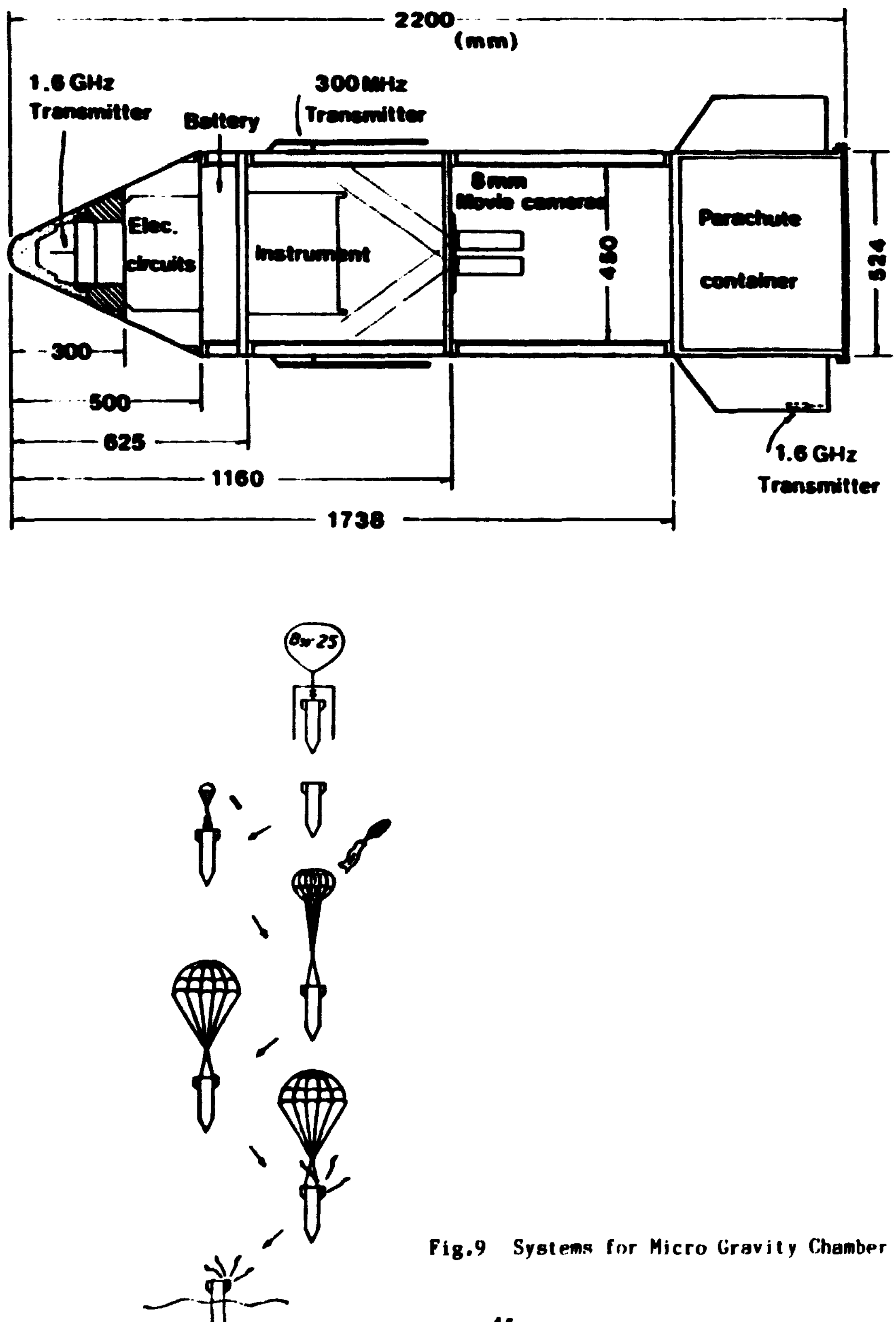

Fig.9 Systems for Micro Gravity Chamber