Japanese Sounding Rocket Programme at Syowa Station, Antarctica*

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昭和基地における観測ロケット計画

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要旨：昭和基地におけるロケット観測計画は日本学術会議南極特別委員会が勧告し，国立科学博物館極地研究センターが実施に協力し，最終的に南極地域観測統合推進本部によって決定される．

昭和基地のロケット発射場に1969年1月に建物3棟を建設した（コントロールセンター，レーダーテレメーター室，組立調整室）．観測ロケットとして S-160（最高高度約 90 km）と S-210（約 120 km）の2種が選定された．1970年1月には発射台，ランチャー，レーダー設備などの設置を完了し，2月には S-160 JA 1, S-160 JA 2 の2機の飛しょうに成功した．この際電子密度およびオゾン密度の分布を高さ約 90 km まで測定した．1971年，1972年における上記2種のロケットによる観測計画も付記した．

Abstract: The programme of the use of sounding rockets at Syowa Station in Antarctica was proposed by the National Antarctic Committee of the Science Council of Japan. The Polar Research Center, National Science Museum, has taken the responsibility for detailed planning, co-operated by other organizations concerned. The programme has been officially approved by the Promoting Headquarters of the Japanese Antarctic Research Expedition under the direction of the Minister of Education.

The rocket range at Syowa Station was inaugurated in January 1969, erecting three buildings, namely, a control centre, a telemetry station, and a rocket assembly shop. Two kinds of rockets, S-160 (peak altitude about 90 km) and S-210 (about 120 km), were selected to be used in the initial stage of the research programme. In January 1970, a launcher was connected with the assembly shop and necessary equipment was installed for the first test launching of S-160. In February

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1970, two test flights for measuring electron density and ozone concentration were successfully accomplished, reaching to an altitude of about 90 km. Future programme of launching six S-210 and one S-160 in the austral winter of 1971 and 1972 is described.

1. Introduction

Japanese antarctic station "Syowa" is located on the East Ongul Island at 69°00′S, 39°35.4′E (geomagnetic co-ordinates: −69.6°, 77.1°), which is favourable for the research of upper atmosphere in many scientific disciplines. The use of sounding rockets and high-altitude balloons for the study of upper atmosphere has been keenly discussed since the reopening of Syowa Station in January 1966. It was January and February of 1969 when the launching of ten high-altitude balloons for cosmic rays study was carried out in conjunction with simultaneous release of balloons at Reykjavik in Iceland, the geomagnetically conjugate station. At the same time construction of the rocket range at Syowa Station was commenced with the erection of buildings.

In March 1967 the National Antarctic Committee of the Science Council of Japan made a recommendation to the Government on the use of sounding rockets at Syowa Station. In order to realize this proposal, the director of the National Science Museum took charge of planning, consulting with the Rocket Committee (chairman: Professor Takesi NAGATA) in the Special Committee for the Japanese Antarctic Research Expeditions (JARE) which is an advisory body to the director. The Department of Polar Research (Polar Research Center since April 1970) of the National Science Museum took an active part in executing the planning of the Rocket Committee. The first step for realizing the planning was to develope reliable launching vehicles for experimental projects and construction of a launching range at Syowa Station in the harsh antarctic environment. The official authorization and co-ordination was given by the Promoting Headquarters of the Japanese Antarctic Research Expedition under the direction of the Minister of Education.

It was decided to use a series of single-stage sounding rockets which were developed by the Institute of Space and Aeronautical Science, University of Tokyo. The rocket range was decided to be established in the western part of East Ongul Island, at about 500 m from the main buildings of the Station. This rocket range in its planning stage was briefly described by T. NAGATA (1968).

Three buildings for the rocket range, a control centre, a telemetry station, and a rocket assembly shop, were designed and built in Tokyo in the autumn of 1968. The buildings were disjoined and packed for the transportation from Tokyo

to Syowa Station aboard the icebreaker FUJI which left Tokyo on 25 November 1968. The buildings were erected at Syowa Station in January and February 1969 by the members of the 10th JARE led by KUSUNOKI.

In the next austral summer, January 1970, supplementary work was carried out by the 11th JARE, and two test launchings of S-160 sounding rockets were successfully performed in February 1970. KAWAGUCHI was in charge of launching operation. The electron density profiles and ozone concentration in the polar ionosphere were observed by these flights. On 30 April 1971 measurements of electron density profile and ozone concentration were carried out by means of S-160 rocket by the members of the 12th JARE. It is scheduled to launch six S-210 sounding rockets in the austral winter of 1971, and one S-160 and six S-210 rockets will be launched in 1972.

2. Sounding Rockets

Currently being in use at Syowa Station are two types of single-stage sounding rockets, S-160JA and S-210JA, which are capable of placing a payload of 5.5 kg to an altitude of 90 km and 11 kg to 120 km respectively. Butadiene solid propellant is used from the viewpoint of low temperature characteristics.

S-160JA: Two test flights were made in February 1970 and one on 30 April 1971. The rocket of this type has been used for test experiments, but it will be used in the future when necessary. Its specifications are as follows:

Diameter	160 mm
Total length	3890 mm
Total weight	113 kg
Payload (probe only)	5.5 kg
Peak altitude	*ca.* 88 km

S-210JA: This is to be used as the main vehicle during the initial period of research programme in 1971–1973. Six of this type will be launched in 1971 and 1972, measuring the physical parameters of lower ionosphere along with the occurrence of aurorae. If necessary the nose-cone will be opened and the body will be subjected to spin. Its specifications are:

Diameter	210 mm
Total length	5110 mm
Total weight	255 kg
Payload (probe only)	11 kg
Peak altitude	*ca.* 120 km

There are two other rockets which will be used in the future; S-135 and S-

300, the former has been used since 1964 by the Japan Meteorological Agency for measuring wind and temperature up to about 60 km, and the latter has been tested at Kagoshima Space Center, University of Tokyo, but it is found that further study for its development is required.

3. Rocket Range at Syowa Station

In February 1969 three buildings were erected; control centre (6 m × 3.6 m), radar-telemetry hut (14.4 m × 6 m), and rocket assembly shop (12 m × 7.6 m). In the next year, the launching platform was connected with the rocket assembly shop and the launcher was installed in the centre of the platform. The radar-tracking equipment, telemetry receivers, ignition control system and other related instruments were installed to satisfy the minimum requirements for the test firing of two S-160JA sounding rockets. Two test flights were carried out with success in February 1970. In the austral summer of 1971 an additional installation was brought to the range, such as telemetry receivers, timer controller, probe controllers and other relevant instruments. In 1972, it is planned to erect a dome covering the launcher and a rocket motor storage, and to increase the number of channels of telemeter receivers.

3.1. Launching platform and launcher: There is a turntable 8 m in diameter in the centre of the launching platform at the same level as the floor of the assembly shop. A rocket carriage can be moved on rails from the assembly shop onto the launching turntable. Rotation of the turntable and movement of the launcher are remote-controlled. The dome which will be erected in 1972 is made of prefabricated pannels. It has a basement diameter 11 m and height 10 m, and a roof-door 2 m × 2 m in size will be opened by an oil pressure system before launching. The launching dome is air-conditioned. The launcher is capable of firing a rocket with a diameter up to 350 mm when a more larger launcher-rail is used.

3.2. Radar system: A radar-tracking system with a power of 10 kW is used to measure the azimuth angle, the elevation angle, and the direct range, as well as to record telemeter signals in two channels transmitted by PPM modulation.

3.3. Telemeter system: Receiving frequency is 290 MHz and the data in 12 channels will be recorded.

3.4. Control system: The control system consists of an ignition controller, a timer controller, and a probe controller. It is a matter of course that the control system was designed to be operated by a limited number of scientists of the expedition in the severe natural environment.

4. Results of Test Flights of S-160 JA Rockets

As was mentioned before, two S-160 rockets, S-160 JA1 and S-160 JA2, were launched on 10th and 17th February 1970. The Langmuir electron density probe and the ozone photometer were installed in the first rocket (JA1) and the Langmuir probe only in the second one. Logistics aspects of this launching are reported by KAWAGUCHI *et al.* (1971), with a summary of observed results. Details of observed results were reported by HIRASAWA, NAGATA, KAWAGUCHI and HIRAO (1970) and HIRASAWA, TOHMATSU, NAGATA and KAWAGUCHI (1970).

The first rocket was launched in a magnetically quiet condition, and the second during a small positive bay 40 gamma with ionospheric absorption 0.5 dB. The profile obtained by JA2 shows about 3×10^3 to 2×10^4 electron/cm^3 higher than that by JA1 in the 78–87 km height range. It was deduced that the energetic electrons (or protons) with energy of about 100 keV (or 1 MeV) penetrate down to the 70–90 km hight in the polar ionosphere with a flux of about 10^6 electron/cm^2/s to enhance the D- and lower E-region ionization during the positive bay event in the daytime.

The decrease in the ozone density between 40 and 70 km was expressed with an exponential function, and the results suggested that the ozone density profile in the polar region seemed to be essentially similar to that ever obtained in middle latitudes.

On 30 April 1971 the third rocket (S-160 JA3) was launched in the daytime and reached to an altitude of 83 km in calm weather with air temperature of -6°C. The electron density and temperature probe and ozone photometer were operated during this flight.

5. Future Research Programme

Between 1971 and 1973 a series of measurements will be carried out with emphasis on direct measurement of physical quantities during the occurrence of aurora, assisted by observations on the ground. Objects of measurements by means of sounding rockets are electron and ion densities, electric and magnetic fields, ultra-violet emissions, energetic particles, X-rays, and radiowave in aurora.

Research programmes for 1971 and 1972 are listed below. Programme for 1973 is under consideration, but probably S-210 will be used mainly for measuring physical parameters to reveal the physical nature of aurora in relation to the electro-magnetic disturbances in the outer region.

Programme for 1971 (Six S-210JA)

Rocket Number	Launching Time	Experiment (measurement)
	Subject: Electro-magnetic structure of aurora	
1	Magnetically disturbed night	Fluxgate magnetometer (2 elements) Double probe (electric field)
2	Disturbed night	Optical pomping magnetometer (total force) Radio receiver (VLF, 6–10 kHz) Ionization chamber (auroral ultra-violet ray, 1140–1304Å)
	Subject: Dynamics and energy transfer of aurora	
3	Quiet night	Ionization chamber (auroral ultra-violet ray) Scintillation counter (X-rays more than 4 keV)
4	Disturbed night	Ditto
	Subject: Ion chemistry of aurora	
5	Daytime	Photometer (ozone distribution, absorption of 2500 Å and 2900 Å) Radio frequency probe, electron probe, and Langmuir probe (electron density and temperature)
6	Disturbed night	Ditto

Programme for 1972 (Six S-210JA)

	Subject: Electric current disturbance in the lower ionosphere	
1	Disturbed daytime	Fluxgate magnetometer (magnetic field, two elements) Aurora photometer (5577 Å and 4278 Å) Radio frequency probe, electron probe, and Langmuir probe (electron density and temperature)
2	Disturbed night	Ditto
	Subject: Ionization source in the lower ionosphere	
3	Disturbed night	Radio frequency probe, electron probe, and Langmuir probe (electron density and temperature)

		Scintillation counter (X-rays more than 4 keV)
		Ionization chamber (auroral ultra-violet ray)
4	Ditto	Ditto
5	Ditto	Radio frequency probe, electron probe, and Langmuir probe (electron density and temperature)
		Ionization chamber (auroral ultra-violet ray)
		Aurora photometer (5577 Å and 4278 Å)
	Subject: Ion chemistry of aurora	
6	Disturbed night	Mass spectrometer (ion composition, mass number 10–70)

(One S-160 will be launched in disturbed daytime to measure ozone and electron density)

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