Techniques for rocket sampling of noctilucent cloud particles

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ABSTRACT

Particle sampling experiments utilizing sounding rockets were conducted in northern Sweden during August of 1962. Two successful flights were achieved, one in the presence of noctilucent clouds and one when no such clouds could be visually observed from the ground or from aircraft. The collecting surfaces were exposed between the altitudes of approximately 75 and 98 kilometers during ascent only. The instrumentation and performance of the rockets is discussed.

During the month of August 1962, a program for the sampling of noctilucent cloud particles was carried out in northern Sweden. The sampling was done by means of rocket-borne collectors. The techniques for rocket sampling of high altitude particles had been previously developed for micrometeorite studies (SOBERMAN, *et al.*, 1963) and were adapted to the special needs of this project.

Four rockets were utilized in this program. Because it was necessary to wait several days for the appearance of the noctilucent clouds and because of logistic problems, it was decided that the experiment should be designed for the relatively small, solid propellent Nike Cajun rocket. The payloads for the four rockets were identical. The sampling experiment was located on the forward end. Immediately behind this was an emulsion packet for cosmic ray studies. Behind the emulsion packet was mounted an auroral electron experiment. The results of these latter two experiments will be published elsewhere by the groups that were involved. The emulsion experiment was conducted jointly by AFCRL and Lund University and the auroral experiment by AFCRL and Kiruna Geophysical Observatory. Below the experiments were the batteries and electronics for performing the payload functions and transmitting information to the ground. A single horizontal magnetometer for crude attitude information and an accelerometer for monitoring vehicle performance was included in this section. Finally, since the collection experiment and the emulsion package required recovery, a recovery system was located at the aft end of the payload. This system included a parachute, a radio beacon, and dive brakes to slow the payload section after separation from the second stage Cajun rocket and allow the parachute to be deployed at a reasonable velocity.

The collection surfaces were mounted in two cans which were in the forward section. The surfaces were exposed by ejecting an outer tip (see Fig. 1) which sealed the entire forward section prior to this time. The ejection mechanism was a spring loaded latch device which was activated by a completely contained explosive device. The outer tip also served to give the payload a reasonable aerodynamic shape for the early portion of the flight. The sampling began at an altitude of approximately 75 km where this tip was ejected. Sampling was terminated at an altitude of approximately 98 km while the rocket was still ascending. This was accomplished by an explosively activated spring device. Here too, the explosives were completely contained. An inner nose cone rotated 90° to seal the collection cans and close the sampling ports for subsequent reentry. The parts of the

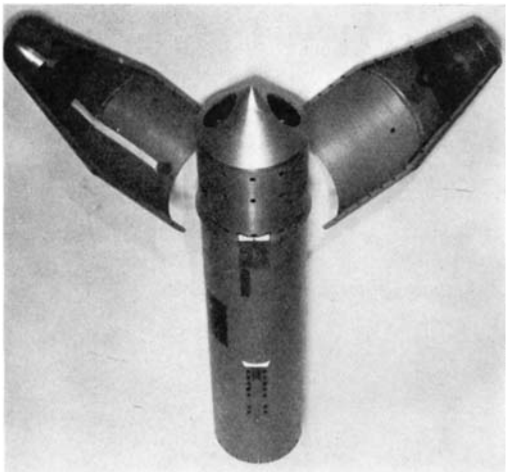

FIG. 1. Forward section of sampling payload with the sampling ports and the spring-ejected outer nose tip.

forward section of the payload are shown in Fig. 2 and 3 in their open and closed orientations.

The efficiency of the collection system was determined both theoretically and experimentally. For the nose cone in question moving at a velocity of 0.83 km/sec with a zero angle of attack at an altitude of 75 km (where the largest aerodynamic forces occur in the sampling altitude range) the deviation of the particles by the air flow in front of the openings was calculated. The particles were assumed to be spherical with a density of 3 gm/cm³. For each

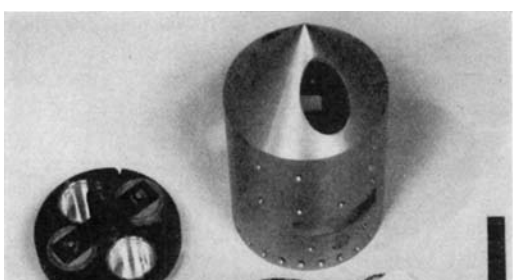

FIG. 2. Particle-sampling mechanism with collecting boxes in open position.

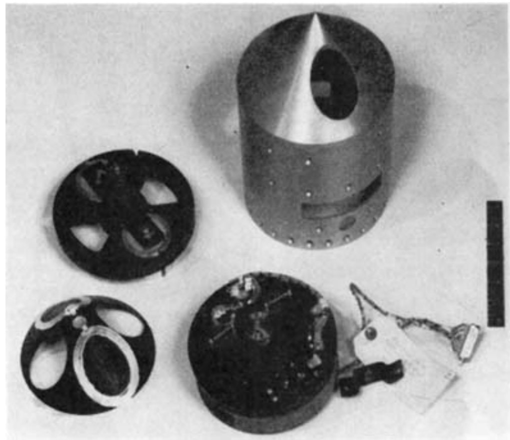

FIG. 3. Sampling mechanism in closed position.

particle size, the area in which a particle could enter the shock front and still pass through the sampling ports was then calculated. Radial symmetry was assumed in this calculation. The ratio of this area (as projected on a flat plane perpendicular to the axis of the payload) to the area of the sampling port (circular when projected on the same plane) expressed as a percentage was taken as the efficiency of the collection system for that particle size. The results of these calculations have been plotted in Fig. 4. These results were checked experimentally with wind tunnel studies on a model of the forward section of the payload. Nickel particles of various sizes (which were foreign to the normal dirt contamination) were injected into the air stream of the tunnel. The particles that entered the

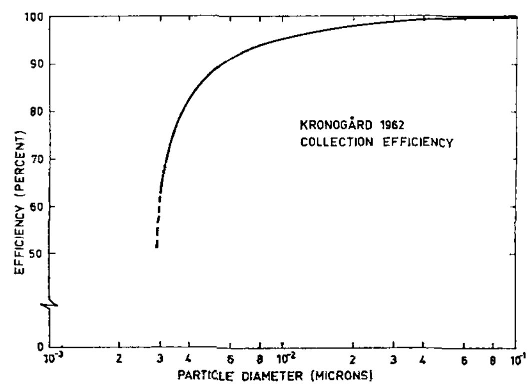

FIG. 4. Theoretically calculated efficiency of the collection system versus particle diameter.

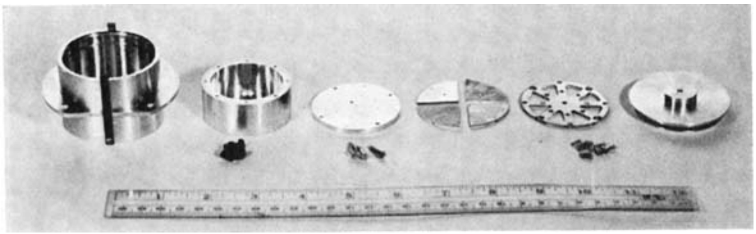

FIG. 5. Blown-up view of collection box showing the arrangement of the four sampling surfaces and the protecting cover.

sample ports were then analyzed for nickel. These tests were carried out in a different density regime and scaling of the results showed no cut-off down to the equivalent of 0.01 microns.

Four different surfaces were loaded into each collection can. The first was nitrocellulose, approximately 200 Å thick on which a thin aluminum coating was evaporated. This was supported by 200 mesh per inch copper screening. The second surface was also of nitrocellulose equally thick on which was placed a layer of fuchsin dye. The third surface was of pure indium metal approximately one micron thick which was evaporated on a lucite slide. The fourth surface was of calcium metal on lucite protected by evaporated coatings of parafin, aluminum, and silicone oil. The various surfaces were intended to (*a*) retain non-volatile particles (*b*) show if a volatile coating has been present on the particles (*c*) retain craters in the event if water were associated with the particles. The four surfaces were arranged as quadrants of a circular area 5 cm in diameter as shown in Fig. 5. They were covered with a lucite "hold down plate" which had eight openings, two for each surface. Each opening has an area of 81 mm² for particle impaction. Between the two openings on each surface a zone was milled out to a depth of ½ mm from below. Air could circulate over this area of the collecting surface but it was still shielded from direct impaction. This served as a control area for each sampling surface. The cans also included a silastic plug in the bottom through which a hypodermic needle could be inserted for analyzing the gas in the cans after recovery. The assembled can is shown in Fig. 6. The utmost care was taken in sample preparation and handling to minimize contamination. In all, sixteen collection cans were prepared in an identical fashion. The sampling portion of the payload was cleaned and the cans were positioned in a glove box prepared for this purpose. Details of the sample

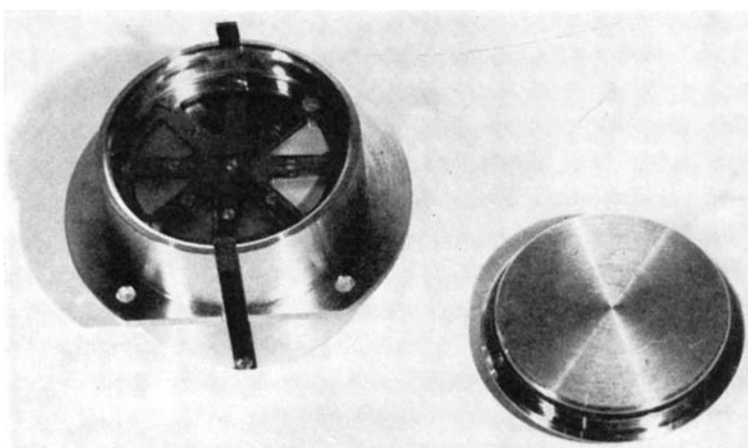

FIG. 6. Assembled sampling box.

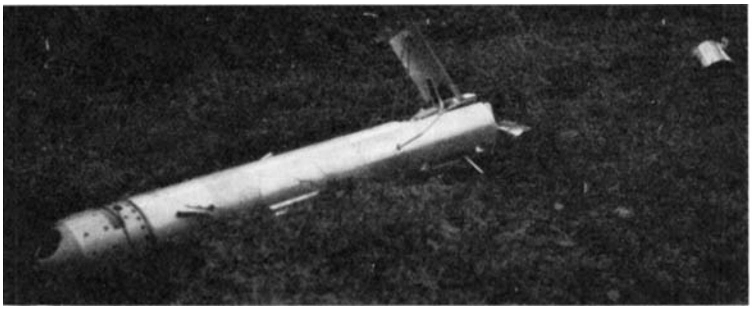

FIG. 7. The first rocket, launched on 7 August 1962 after landing in soft bog.

preparation and handling are given in paper B. After assembly of the sampling portion of the payload, it was protected until launch by a sealed plastic bag. After the payload was mounted on the rocket, it was covered by an additional plastic bag through which warm, dried filtered air was circulated. Atmospheric friction also served to "scrub down" the outer surface of the payload during ascent. All four payloads were prepared in an identical fashion.

All four flights were launched from the Kronogård Range in northern Sweden. This range is located at latitude 66° N and longitude 19° E. The first rocket was launched on 7 August 1962, at 0147 hours local time in the presence of increased ionospheric absorption but no visible noctilucent clouds. The absence of the clouds was ascertained by a number of airborne and ground observers strategically located around northern Sweden. All collection payload functions occurred as scheduled by the preset timers and monitored by the telemetry system. On descent, however, the parachute failed to open. Fortunately, the payload appeared to have been slowed down by falling in a "flat spin" and subsequently landed in a soft bog (see Fig. 7). The payload was localized by a three station "sound ranging" system and was recovered within an hour. It was found that the sampling cans were sealed and intact. The "softness" of the landing can be indicated by the condition of the nuclear emulsion pack which, except for one corner which was slightly damaged, was found "light tight" and in usable condition.

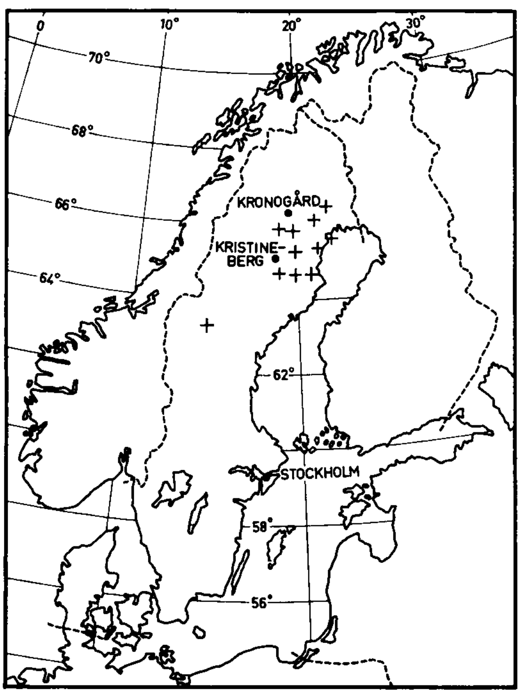

FIG. 8. Map of Sweden showing the airborne and ground observation stations which reported the noctilucent cloud display on 11 August 1962.

The second rocket was launched on 11 August 1962 at 0240 hours local time, this time in the presence of a visible display of noctilucent clouds. The display was observed from a number of airborne and ground observation stations as indicated by the map in Fig. 8. A photograph of the display looking north from the Kristineberg Station is shown in Fig. 9. Due to a commutator malfunction, a portion of the telemetry signal was lost (including the magnetometer data and function monitoring) from a portion of the flight. However, all other systems appeared to have worked and the payload was recovered within ½ hour after launch (see Fig. 10). Here too, the cans were found to be sealed and intact.

FIG. 9. Display of noctilucent clouds on 11 August 1962 photographed in direction North from the Kristineberg observation site.

The third rocket was launched on 19 August 1962 at 0159 hours local time in the presence of noctilucent clouds. All went well until the point where the payload and the second stage Cajun were to separate. Separation failed to occur. The dive brakes consequently remained closed and the entire configuration continued to fall unimpeded to the ground. Telemetry continued right up to the time of impact. The payload was found to be unusable.

The fourth flight, launched on 31 August 1962 at 0158 hours in the absence of visible noctilucent clouds behaved much as the third with separation failing to occur. This flight also was found but in an unusable condition. However, these latter two flights by coming down

FIG. 10. Second sampling rocket on 11 August 1962 after landing.

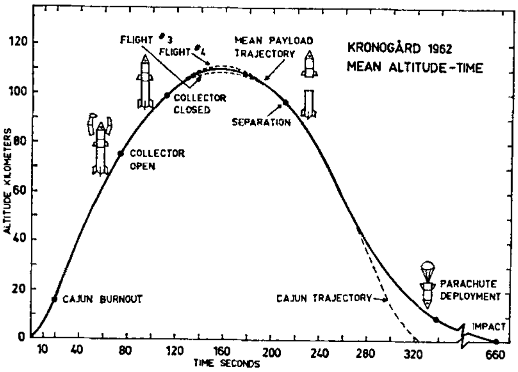

FIG. 11. Time-altitude curve for flights 3 and 4.

in an unimpeded fashion yielded impact times from the receipt of the telemetry signal. These impact times could be used to reconstruct reasonably accurate trajectory information. Since this is the best available trajectory information, a mean flight history for all four flights has been constructed from these data. The accelerometer data and impact points appear to indicate that all four flights had similar profiles up to the point of second stage separation. (There is less than 2 % variation between flight III and IV). The time-altitude curve of

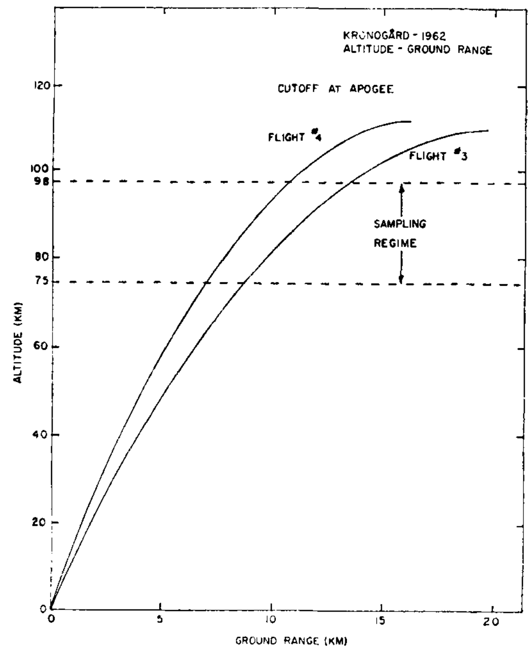

FIG. 13. Range-altitude curve for flights 3 and 4.

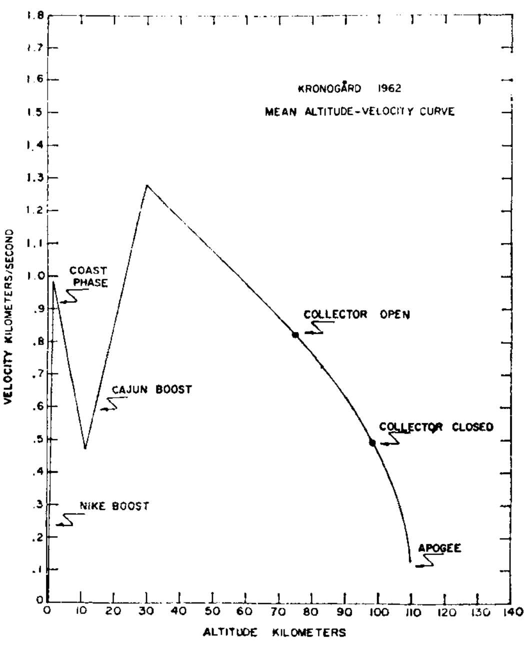

FIG. 12. Velocity-altitude curve for flights 3 and 4.

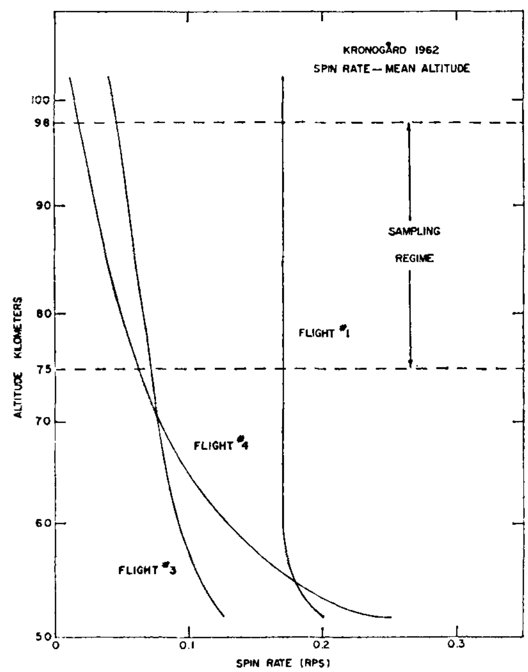

FIG. 14. Spin rate of flights 1, 3 and 4 versus altitude. For flight 2 no spin-rate data were obtained.

Fig. 11 and velocity-altitude curve of Fig. 12 are therefore to be taken only as indicative for the successful flights (I and II). The flight paths were close to vertical as can be seen from the mean range-altitude curve of Fig. 13. As was previously discussed, spin data was not obtained for flight II. The spin histories of flights I, III, and IV are presented in Fig. 14. As can be seen there is some variation. A mean would be a spin of approximately 0.1 revolutions per second. Since the payloads carried only a single magnetometer, the attitude information is extremely crude. The data from flight I indicates that this vehicle remained vertical to within 6° during the sampling period. Flights III and IV were far less stable and "yaw" angles of 30° and higher were possible. Although no magnetometer data exists for flight II, indications from the sampling results (as will be discussed in the subsequent papers) lead to the conclusions that this vehicle also "yawed" considerably during the sampling.

The results of the sampling experiments are discussed in the subsequent papers (ref. B–E). The technical details presented here are used in the interpretation of those results as described in HEMENWAY, SOBERMAN and WITT, (1964).

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REFERENCES

SOBERMAN, R. K., *et al.*, 1963, Smithsonian Contributions to Astrophysics, Vol. **7**, p. 89.

HEMENWAY, C. L., SOBERMAN, R. K., and WITT, G., 1964, Sampling of noctilucent cloud particles, *Tellus*, Vol. **16**, pp. 84–88.

B. Electron-microscopic Studies of Noctilucent Cloud Particles, by C. L. HEMENWAY, E. F. FULLAM, R. A. SKRIVANEK, R. K. SOBERMAN and G. WITT. *Tellus*, **16**, I.

C. Composition Analysis of Noctilucent Cloud Particles, by G. WITT, C. L. HEMENWAY, N. LANGE, S. MODIN and R. K. SOBERMAN. *Tellus*, **16**, I.

D. Calcium Film Indicator of Moisture Associated with Noctilucent Cloud Particles, by I. LINSCOTT, C. L. HEMENWAY and G. WITT. *Tellus*, **16**, I.

E. Simulation of Ring Patterns observed with Noctilucent Cloud Particles, by R. A. SKRIVANEK and R. K. SOBERMAN. *Tellus*, **16**, I.