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## STRATOSPHERIC MEASUREMENTS

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND  
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this contract was to obtain stratospheric data concerning the distribution of neutral constituents and ions by a series of balloon flights. The program logically separates into two distinct studies since two different balloon-borne instruments are used to obtain the data. Data concerning the neutral constituents are obtained by means of a liquid helium-cooled grating spectrometer system which measures the atmospheric emission as a function of altitude as the balloon ascends. Data concerning the charged species are (Contd)		

Item 20. Continued.

obtained by means of a balloon-borne quadrupole mass spectrometer system which samples and identifies ambient ions at float altitude or as the balloon descends. The two distinct measurement techniques and hence flight programs are discussed in separate sections of this review, each one complete on its own.

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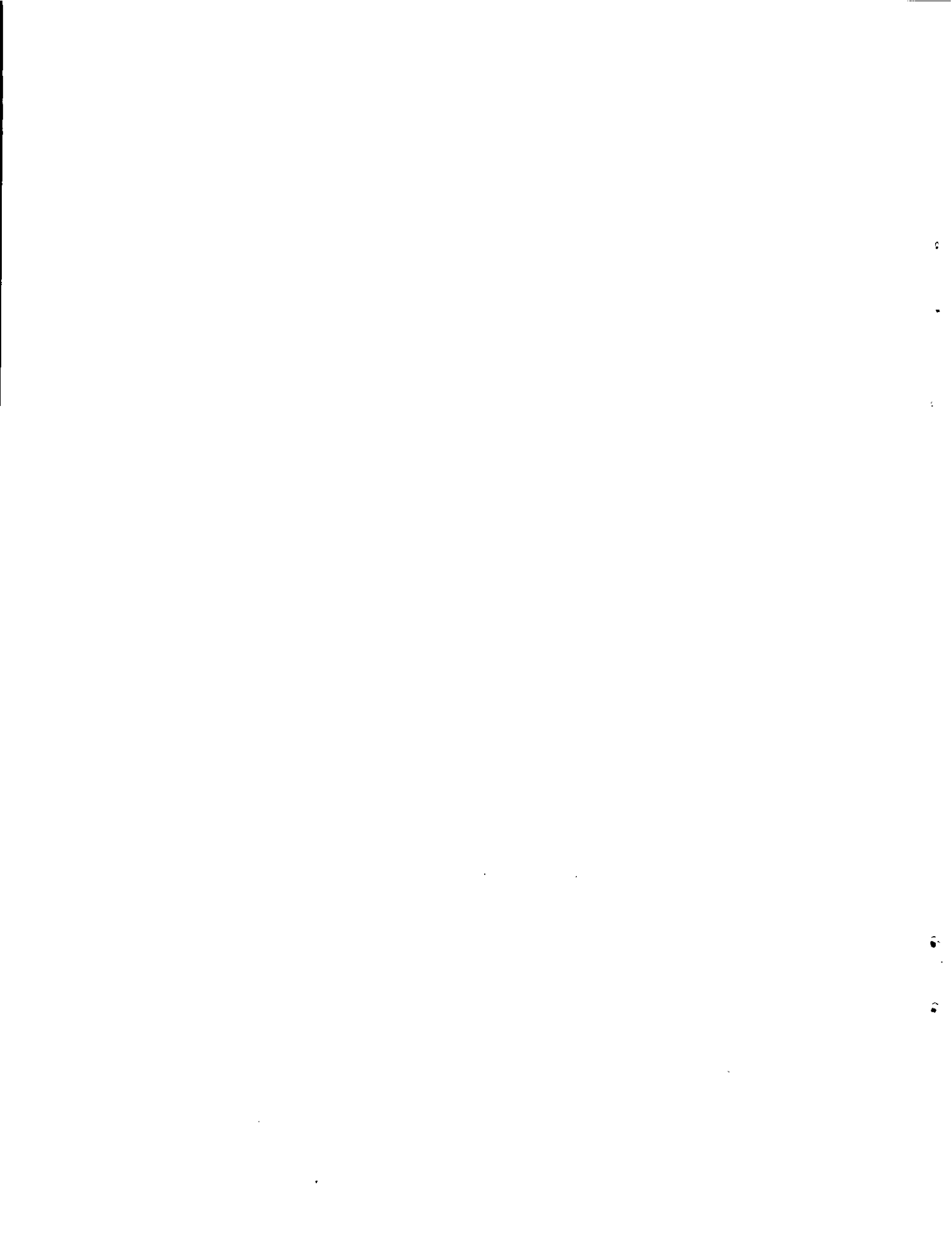
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# INFRARED EMISSION FLIGHT PROGRAM

## I. INTRODUCTION

The balloon flight series of 1975 and 1976 were designed and flown with two basic objectives. The first was to accumulate data on the distribution of several minor neutral molecules in both the mid-latitude and arctic atmospheres. The second was to obtain further data on the nature of the fluctuating infrared enhancements observed in the auroral zone.

The primary constituent data were to be collected with a helium-cooled grating spectrometer which measures the thermal emission of the various infrared active minor constituents, as well as with several auxiliary pieces of apparatus on various flights (ozonesondes, grab samplers, etc.).

The enhancement experiment was to be based on the nitrogen-cooled filter radiometer modified on the various flight series to explore various aspects of the phenomena. This unit was also to serve as an aid in separating spectral variations from temporal fluctuations in the data from the spectral radiometer and/or the Block interferometer.

Measurements showing these enhancements prior to 1975 all had been made at the same time of year (September), were limited to the  $11\mu\text{m}$  to  $12\mu\text{m}$  region, showed close time correlation over the maximum ( $4^\circ$ ) angular distance between the detectors, and were primarily filter measurements (bandpass  $\sim 0.5\mu\text{m}$  or greater).

Since the spectral nature of the fluctuations was probably a major clue towards identification of the mechanisms involved, our efforts were directed towards obtaining as much spectral information as feasible with the instrumentation available.

The angular extent over which complete correlation can be expected impacts upon the feasibility of certain experiments intended to define the altitude of the phenomena as well as giving further clues to the mechanism responsible for the radiation. Flights with a four-

detector linear array were intended to explore this aspect of the phenomena. Aximuth stabilization of the gondola served to separate spatial and temporal variations. A soft X-ray detector was aboard all gondolas to test for possible correlations between electron precipitation events and enhancements. A total of seven balloon flights were launched with various combinations of the instruments mentioned above, one at Holloman AFB and six in the vicinity of Fairbanks, Alaska. The Holloman flight was intended primarily as a test flight for the 1975 Alaskan series, although it also yielded mid-latitude constituent data. The flights of 1977 are discussed in the Final Report on Contract DAAD05-76-C-0740.

## II. BALLOON FLIGHT PROGRAM (1975-1976)

### A. The 1975 Flight Series

#### 1. 19 February 1975 Flight

A balloon flight payload assembled for the Alaskan series was flown on a checkout flight from Holloman AFB, New Mexico on 19 February 1975. The main instrumentation included the four-field filter radiometer and the BRL liquid helium-cooled spectral radiometer. Auxiliary equipment included an X-ray package (Barcus, University of Denver) and the azimuth stabilization system (Howell, Tufts University).

The spectral radiometer system functioned well on this flight, serving as a test of the system for the Alaskan operation, and obtained excellent atmospheric emission data. The constituent profiles obtained from this emission data have been published in a separate report. <sup>(1)</sup> It should be noted that no fluctuations were observed in the  $11\mu\text{m}$  to  $12\mu\text{m}$  region of the spectral data, although the window was  $\text{LN}_2$ -cooled and background levels were low.

The test flight pointed up two malfunctions in the filter radiometer system which needed correction before the Alaskan series. The first was a stoppage in the shutter drive system which occurred before the flight. Since this stoppage did not critically affect the test, the instrument was flown without the rotating shutter. The second problem was that all four-field outputs dropped out at approximately 12 km. At the time it was assumed that the LHe supply dewar had run out of liquid. However, checks after the flight showed that the detector preamps had been destroyed, possibly by an intermittent ground contact.

The shutter motor was serviced and a fault in its heater wiring corrected in preparation for the Alaskan series. The detector preamps were replaced and the ground system changed. Coincidence between the far fields of view of one of the four-field detectors and the spectral radiometer was established by simultaneous observation of the moon.

## 2. Alaskan Flight Series Preparations

Equipment and personnel arrived at Fort Wainwright, Alaska on 20 April 1975 in preparation for a series of flights tentatively scheduled to begin on 21 April. The flight payload contained two major instruments, the four-field filter radiometer and the liquid helium-cooled spectral radiometer, and several auxiliary apparatus including an X-ray package, a  $1.27\mu\text{m}$  radiometer and a PFMR ozonesonde. Orientation of the gondola was provided for with a Tufts University azimuth stabilization system and crossed magnetometer probes for independent azimuth information. Data recording was provided on-board by two digital tape decks and via S-band telemetry to stations at Poker Flats and in a van-mounted AFCRL Ground Station at Ft. Wainwright. In-flight commands and balloon control functions were via an AFCRL instrumentation package.

The flight series had two major objectives: to obtain altitude profiles of various minor constituents in the arctic atmosphere, and to obtain information on the spectral distribution of radiation enhancements previously observed at  $11.3\mu\text{m}$ . The instruments had been set up to meet these objectives.

The spectral radiometer was to measure atmospheric emission at both low and high ( $45^\circ$ ) elevation angles. The low angle data provided large optical paths to permit observations of weak atmospheric emitters. By rotating the spectral radiometer to  $45^\circ$  when fluctuations were observed on the four-field radiometer, spectral variations in the enhanced radiation could be separated from purely temporal fluctuations. In addition the scan of the spectrometer grating could be halted upon command to permit observation of the phenomena with essentially two radiometer systems. The spectral radiometer system utilized two detectors, one filtered for the first order of the grating ( $18\text{-}26\mu\text{m}$ ), the other filtered for the second order ( $9\text{-}13\mu\text{m}$ ). In this manner, the two wavelength regions were scanned simultaneously.

The four-field filter radiometer was also set up to investigate two spectral regions. The upper pair of detectors were filtered to respond to radiation from  $5.0\mu\text{m}$  to  $8.0\mu\text{m}$ , the lower pair were filtered for  $11.3\mu\text{m}$ . Therefore, the total instrument package could provide simultaneous data at  $1.27\mu\text{m}$ ,  $6.0\mu\text{m}$  and  $11.3\mu\text{m}$  in addition to the spectral scans of the  $10\text{-}12\mu\text{m}$  and  $18\text{-}26\mu\text{m}$  regions.

Preparations for the first flight of the series proceeded normally. Both major instruments were cooled (including the window on the liquid helium spectrometer) and calibrated. However, when the spectrometer window was cooled again in preparation for flight on 23 April, the window seal opened, which caused a major vacuum leak. It resealed upon warming, but opened again as the window was re-cooled. The window assembly was replaced, and when cold-cycled maintained a good vacuum. The weather forced cancellation of the flight scheduled for 25 April and re-cooling the spectrometer window for flight on 28 April again resulted in a major vacuum leak. Again the unit sealed itself when allowed to warm. Repair of the original window unit had been started, but would not have been completed for several days. Accordingly, it was decided to go ahead with the first flight without cooling the spectrometer window while repairs to the original window assembly were in progress.

### 3. 30 April 1975 Flight

The first Alaskan flight was launched at 0536 ADT on 30 April 1975 and reached a float altitude of 29.5 km at 0735. All major systems functioned well and data were obtained until power was turned off in preparation for termination at 1119ADT. The payload impacted approximately 70 miles northwest of Ft. Wainwright. Impact occurred in a heavily wooded area and, as a result, two of the small auxiliary instruments ( $1.27\mu\text{m}$  radiometer and on-board ozonesonde) were sheared from the gondola and temporarily lost in the deep snow. These were later recovered but were not usable for the succeeding flights of the series.

The major instruments were recovered in good condition and could be prepared for the next flight without substantial repairs.

#### 4. 5 May 1975 Flight

The repaired original spectrometer window assembly was completed by this time, so it was installed on the instrument. Cold-cycling of the window was successful and preparations were made for the next launch.

When the four-field filter radiometer was re-cooled, the shutter was found to be inoperable. Since the motor and drive train for the mechanism were operating properly, it was evident that the final drive link (a 1.8" delrin shaft) had been sheared. Since its' replacement meant disassembling the entire instrument and a delay of several days and the fact that the rotation of the shutter was not crucial to the experiment, for the next two flights the filter radiometer was without the rotating shutter. A minor benefit of this was the removal of the discontinuity introduced by the shutter, thus permitting longer periods of uninterrupted data for frequency analysis.

Preparations were continued and the second flight was launched on 5 May 1975 at 0448ADT and reached a float altitude of 36 km at 0706. Both major instruments functioned well during ascent, but the four-field radiometer lost sensitivity shortly after reaching float. Data from the spectrometer was recorded throughout the flight until power was commanded off before the termination at 1100 ADT. At the time of termination the package was 55 miles west of Ft. Wainwright.

The gondola was returned to Ft. Wainwright with both detectors on the spectral radiometer still cold and working. The four-field filter radiometer detectors appeared normal after re-pumping the detector dewar and filling it with liquid helium. It was therefore concluded that the loss of signal on these channels was a result of the exhaustion of the liquid helium coolant.

## 5. 16 May 1975 Flight

The payload was prepared for a flight scheduled for 8 May but during the pre-flight cooling of the spectrometer window a vacuum leak forced postponement of the flight. This window was replaced with the spare window assembly which had been re-worked and the unit was cold-cycled. This window assembly failed when cooled for the flight scheduled on 11 May. At this point it became apparent that field repairs on the window assemblies were not adequate to withstand the cooling to  $\text{LN}_2$  temperatures. A window assembly was therefore sealed and installed on the spectrometer to be flown uncooled. Flight preparations were completed and, after two cancellations forced by weather, the final flight in the 1975 Alaskan series was launched at 0451 ADT on 16 May 1975 and reached a float altitude of 29 km at 0720. All major systems functioned and data was recorded until termination at 0936 ADT. At the time of termination the balloon was 62 miles northwest of Ft. Wainwright. The gondola was returned in good condition.

### B. The 1976 Flight Series

The Alaskan series of 1976 was intended to obtain further data on the distribution of minor species in the arctic atmosphere, to provide information on the degree of correlation of the  $11\mu\text{m}$  enhancement over a larger angular extent than previously measured, and to provide further spectral definition of the phenomena. Two payloads were built up in preparation for this series. The A gondola consisted of the four-field filter radiometer (modified from 1975) and the helium-cooled spectral radiometer. The B gondola was to house the four-field filter radiometer and the nitrogen-cooled Block interferometer.

The four-field radiometer had been converted from a four-detector square array to a linear array and the view angle between the extreme elements of the array was increased as much as feasible without reconstructing the complete radiometer. The result was an array of four detectors at  $3^\circ$  spacings, giving an overall vertical spread of  $9^\circ$ . One

of the major problems associated with this modification to the linear array was the large tuning fork amplitude required to adequately chop the extended field. Delivery times did not permit the purchase of a suitable chopper, so it was necessary to modify the tines of an existing fork and then reestablish the proper resonant frequency by tailoring the masses of the tines. Considerable time and effort was required to establish a stable single frequency oscillation of adequate amplitude to completely modulate all detectors. The four-element linear detector (Ge:Hg) itself was not delivered in time to permit more than preliminary testing of the instrument before shipment to Alaska.

The Block interferometer had not been operated since the fall of 1973. During the check-out for the 1976 series it was discovered that neither the reference laser nor the spare laser tubes would lase. Apparently the long inactive time period had permitted diffusion of helium out of the tubes. Attempts to locate a tube of the same type proved fruitless, so tubes of compatible dimensions but different electrode geometry were purchased. These tubes operated well at room temperature but required insulation and extra heat input to lase at LN<sub>2</sub> temperatures. However, the heating arrangement which had worked well with the original tubes apparently produced a gradient which destroyed the lasing action of the new models. It was necessary to enclose the tube in insulation surrounded by a heated 40 mil copper shield which was heavily insulated with styrofoam on the outside. This arrangement permitted sufficiently uniform warming to maintain laser action.

Preparations were started 22 April 1976 at Eielson AFB, Alaska for a flight series tentatively scheduled to begin on 26 April. The first flight was to be with the A gondola, including the usual auxiliary systems (the Barcus X-ray package, gyro azimuth control, synchro attitude read-outs and crossed magnetometer azimuth sensors).

Check-outs of the instrumentation after arrival at Eielson disclosed several problems. The vibrations in shipping had caused a loss of alignment in the reference channel of the interferometer, resulting in an insufficient white light signal to initiate the scan sequence. It was necessary to remove the optical cube from the dewar of the interferometer for realignment. In addition, the four-field radiometer had problems with microphonics and chopper stability, but checks on 28 April indicated that the unit had sufficient sensitivity to measure fluctuations.

1. 29 April 1976 Flight

The helium-cooled spectrometer check-out proceeded smoothly and the window was cooled without problem. Flight preparations were continued and the A gondola was launched on 29 April 1976 at 0438 ADT and reached a float altitude of 37.5 km at 0740. Sensitivity was lost on the four-field radiometer at approximately 10 km, apparently due to the failure of a detector bias cell. The helium-cooled spectrometer functioned very well and furnished data until the power was turned off at 0856 ADT in preparation for shutdown at 0905. The balloon position at termination was approximately 80 miles west of Eielson AFB. The instrumentation gondola was recovered in excellent condition.

2. 5 May 1976 Flight

The Block interferometer optics were realigned and returned to the cryostat. The instrument functioned normally when taken through a temperature cycle, so the B gondola was prepared for launch on 3 May. However, preflight cool-down disclosed problems with both major instruments. The scanning of the Block interferometer was occasionally erratic. The signal-to-noise output of the four-field radiometer was marginal, due to microphonic problems and low-level preamplifier oscillations. The flight was cancelled because of these problems and unfavorable weather conditions. The scanning of the Block instrument continued to deteriorate. Since identification of this problem required

removal of the optical cube from the cryostat and, thus, a considerable delay, the four-field radiometer was reinstalled in the A gondola and prepared for flight.

The package was launched at 0449 ADT on 5 May 1976 and reached a float altitude of 30 km at 0725. The chopper of the four-field radiometer failed at approximately 12 km, due to an open lead in the drive coil. The helium-cooled spectrometer again operated until power was shut off in preparation at termination at 0825 ADT. At this time the balloon was approximately 86 miles north northwest of Eielson.

### 3. 26 May 1976 Flight

Identification of the chopper problem in the four-field filter radiometer took some time since the fault was intermittent and occurred only at  $LN_2$  temperatures. Rectification of the problem required substitution of another chopper assembly which was shipped from Denver and then modified to meet the requirements of chopping in the linear array.

The drive failure in the Block interferometer was identified as due to a bad bearing in the assembly carrying the air-bearing supply bellows. The failure at the bearing had also resulted in a scoring of the shaft. Replacement of the bearings and cutting of a new shaft required the service of a local machine shop. These repairs were not completed before the flight series of Project Ashcan had begun, so D. U. personnel returned to Denver until the Ashcan series was nearly finished.

Alaskan operations concerning the atmospheric emission fluctuation flights were resumed on 21 May and the B gondola was prepared for flight. Preflight weather conditions at 0200 on 26 May were not encouraging due to high (20 kts) surface winds, but weather forecasts for the period remaining before the series cut-off dates were unfavorable. Consequently, flight preparations were continued. Launch preparations were delayed approximately 2 hours, during which the only

improvement in conditions was that the very low levels abated sufficiently to permit inflation of the balloon. The launch vehicle had to make a 90° turn to follow the balloon and was, therefore, unable to get the balloon and gondola in the proper orientation for launch before reaching the end of the runway. An attempt to tow the balloon back for a more favorable run failed when the release plate pulled free of the crane (~0645 ADT). The instrumentation package slammed into the ground before ascending. The impact severely damaged the antenna for the PCM telemetry, resulting in a very weak transmitted signal. This, coupled with a somewhat erratic scan (probably due to degradation in white light or reference channel alignment by the impact), made it impossible to record useful data from the Block interferometer. Excessive microphonic noise and low radiometric sensitivity (loss of detector alignment?) also negated the usefulness of the four-field radiometer data. The flight was therefore terminated over a favorable recovery area shortly after reaching float. The gondola was returned in good condition.

### III. SUMMARY OF RESULTS

#### A. The 1975 Alaskan Flight Series

Fluctuations were observed on all three of the 1975 Alaskan flights. These were most prevalent on the flight of 30 April, observed only briefly before the radiometer failed on 5 May, and were weak and less frequent on the 16 May flight. The predominant activity was in the  $11\mu\text{m}$  filter channels. The  $5.0\mu\text{m}$  to  $8.0\mu\text{m}$  channels showed enhancements only when  $11\mu\text{m}$  fluctuations occurred and then only part of the time. The maximum enhancements in the short wavelength channels represent radiances more than an order of magnitude below those of the  $11\mu\text{m}$  channels. These  $5.0\mu\text{m}$  to  $8.0\mu\text{m}$  fluctuations represent less than 10% of the 30 km background radiance levels in this region. A sample of the 30 April 1975 data is presented.<sup>(2)</sup> Complete four-field filter radiometer data is being prepared for magnetic tapes.

Fluctuation data is difficult to recover from the spectrometer channels for those flights where the window was not cooled. The radiance levels from the window exceed the fluctuation levels by a large factor and variations in the window temperature produced radiance variations greater than the fluctuations sought. Fluctuations were observed on the  $11\mu\text{m}$  spectrometer channel on the flight of 5 May in which the spectrometer window was cooled.

The spectrometer was also to be utilized to obtain constituent profiles to 40 km. To obtain this data the spectrometer field of view was set at a low elevation angle during ascent. This angle could be raised to coincide with the angle of the  $11\mu\text{m}$  detectors of the four-field radiometer by commanding through a series of elevation steps.

Enhancements were observed in the four-field radiometer channels before float altitude was reached. The command sequence necessary to elevate the spectrometer field of view was initiated somewhat before

maximum altitude was reached, but was not completed before float. Shortly after coincidence of the field of view was established, the four-field radiometer lost sensitivity. The time frame in which both instruments were operating with overlapping fields of view was therefore severely limited. Correlations were noted between the spectrometer and radiometer channels. <sup>(2)</sup> There was not, however, 100% correlation, indicating that the phenomena did not always extend across the entire 10-12 $\mu$ m atmospheric window. It should be noted that no variations were observed in the long (18-22 $\mu$ m) channel of the spectrometer.

In short, the 1975 Alaskan series provided data for neutral species concentration profiles in the arctic atmosphere, showed the enhancement phenomena to be much stronger in the 10.8-11.3 $\mu$ m region than in the 5.0-8.0 $\mu$ m region and not detectable in the longer wavelength region (18-22 $\mu$ m), and provided evidence (admittedly very limited) that the wavelength range involved can be less than the  $\sim$ 1 $\mu$ m bandpass of the four-field instrument filter.

#### B. The 1976 Alaskan Flight Series

No difficulties were encountered with the window assembly on the helium-cooled spectrometer during the 1976 series and the unit was flown twice with the window cooled. Spectral scans during enhanced periods were recorded over considerable time periods on both the 29 April and 5 May 1976 flights. The problems with the linear array of the four-field filter radiometer did not permit direct isolation of temporal from spectral variations, but the large number of scans permitted a statistical analysis of enhancement vs wavelength within the 10.0-12.5 $\mu$ m region where the enhancements were strongest or most frequent or both. Results of this study have been published. <sup>(2, 3)</sup>

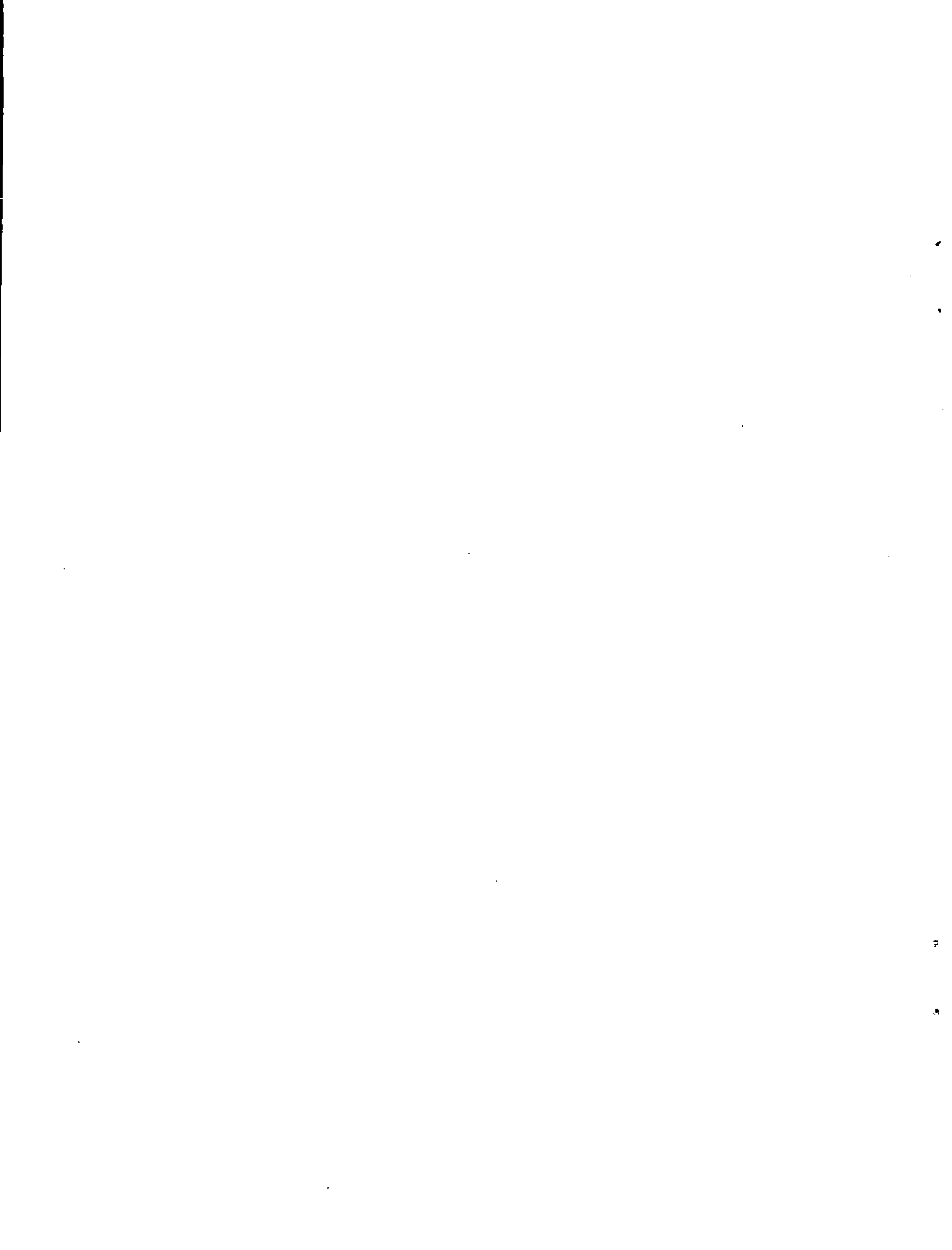
Constituent data were obtained on both the 29 April and 5 May flights. Most of the reduction effort was concentrated on the 29 April data since the flight went to 37.5 km and the signal-to-noise in the

data was excellent. The 5 May data has a peak altitude of 30 km and was somewhat degraded by microphonics due to the blower on the NO sampler flown as auxiliary equipment.

The flight series of 1975 and 1976 resulted in major progress toward the goals outlined with the exception that no additional information on the large angle correlations was obtained.

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# MASS SPECTROMETER PACKAGE FLIGHT PROGRAM

## I. INTRODUCTION

This final report describes balloon-borne flights of two separate mass filter packages that were constructed at the University of Denver as part of the U.S. Army-sponsored Combined Stratospheric Measuring Program (COSMEP). Both packages were carefully designed so that contamination of the atmosphere in the sampling region would be minimized. Also, to further ensure uncontaminated air samples, the package was either suspended several hundred meters below the balloon, parachute, and balloon control apparatus, or the balloon was valved so that the package descended at a controlled rate during sampling.

The first package was designed to detect ambient positive ions in one mode of operation (PI) and, using electron impact ionization, the neutral constituents in a second mode of operation (NM). It was constructed under U.S. Army-Ballistic Research Laboratories Contract No. DAAD05-73-C-0139, and has been described.<sup>(1)</sup> The PI/NM package was flown three times: 1 October 74, 7 July 75 and 21 September 75. No ion or neutral spectra were obtained during the first flight because of problems with the tape recorder and with high voltage noise. No ion spectra and only one set of neutral spectra were obtained at float altitude during the second flight. After some early difficulties, the package operated as designed during the third flight and data were obtained for both modes of operation. Results indicated that there was little if any water vapor contamination, but that the throughput needed to be increased in order to improve the signal-to-noise ratio in the PI mode of operation.

A second mass filter package designed to detect ambient positive ions in one mode of operation and negative ambient ions in a second mode of operation (NI) has been constructed under Grant No. DAHC04-74-G-0149 from the U.S. Army Research Office. This package has been

described. <sup>(2, 3)</sup> At this time the package has been flown a total of three times: 4 December 76, 22 June 77, and 10 September 77. No ion data were obtained on the first flight (essentially an engineering flight) because of an electrical failure. Positive ion data were obtained on the second flight and gave evidence for the presence of  $H^+(H_2O)_n$  ions for  $n = 4, 5, \text{ and } 6$ , corresponding to amu 73, amu 91, and amu 109, respectively. No ion data were obtained on the third flight due to a loss of pumping capability when the last of the liquid helium in the cryopump evaporated during the first sequence of sampling operations. Although one of these flights was supported by USARO, <sup>(3)</sup> all three flights are summarized here for the sake of completeness.

Significant changes to improve flight operation, to facilitate laboratory operation, and to increase the chances of obtaining data, were made to both packages as more experience was gained after each flight. These improvements are also described in this report.

## II. PI/NM PACKAGE

### A. Package Specifications

Since the PI/NM package is fully described in reference 1, this discussion will be brief. The heart of this package is the rf quadrupole mass filter along with the associated electronics required to drive the filter and to control filter operations. There are two modes of operation: detection of ambient positive ions (PI) and detection of neutral constituents (NM) using electron impact ionization. The mass range is 1-150 amu, which can be covered in a continuous sweep at the rate of 300 amu per second. For 10 msec at the end of each scan the filter operates in a high-pass mode where ions of amu  $> 117$  are allowed to traverse the filter. Also, any one of the 150 amu positions can be selected by telemetry (TM) command for fixed peak (FP) operations.

The quadrupole assembly and ionizer are off-the-shelf Finnigan Instruments Corporation units. The rods are 0.64cm diameter and 14cm long. Operating frequency is 2.7MHz. Input power requirements of the solid-state rf/dc generator are less than 20w. Resolution is adjustable and can be set to be better than one amu.

In the PI mode of operation the ambient ions are individually counted, while in the NM mode the ions are measured as a current and individually counted in alternate scans. The detector is a Johnston Laboratories 20-stage electron multiplier with maximum gain of  $10^8$ , mounted on-axis. In the current mode of operation the multiplier is operated at about half the voltage that is used for the count mode. Counts are accumulated in time intervals that correspond to 0.2 amu in order to give one amu resolution.

The atmosphere is sampled through a valved 0.01 cm diameter orifice having a conductance of about  $10^{-3}$   $\ell$ /sec., and a width-to-thickness ratio of approximately 10. The vacuum seal is made by seating a polyimide plunger onto a polished area of the tungsten carbide orifice plate centered at the orifice. After bakeout ( $250^{\circ}$  C maximum) pressures in the  $10^{-9}$  Torr range are easily maintained. The tungsten carbide plate is insulated from the rest of the package in order to allow for a "draw-in" potential if needed to compensate for possible charge buildup on the package. Five preselected values between 0.0 v and -10.0 v are available. Unless a different voltage is requested by TM command, the plate remains at 0.0 v. The valve, which is solenoid controlled, is open for about 6 seconds for a NM operation and for about 10 seconds for a PI operation.

Titanium sublimation pumping is used to handle the bulk of the gas load. Pumping of the noble gases, mainly argon, is accomplished with a liquid-helium cryopump. A 2  $\ell$ /sec VacIon pump also helps, but its main purpose is that of providing for pressure measurement in the mass filter chamber. Excess heat generated by the sublimators is conducted to the gondola walls for rapid dissipation, permitting a duty cycle of 20%. Total pumping speed is about 560  $\ell$ /sec.

The basic unit of time for the on-board command electronics is one minute; i. e., at the beginning of each new minute the circuitry is reset and no knowledge concerning operations during previous or future minute intervals is required. The master sequencer is capable of storing 512 minute block commands, which is sufficient for an 8-hour flight. Scan operations will occur during the minute block specified by the master sequencer. In addition, TM commands are able to override the on-board program in that a programmed operation can be cancelled or replaced with a different operation. An operation can also be initiated where none was scheduled. Fixed peak operations must be TM commanded.

Measurements in support of the mass filter data include ambient pressure, ambient temperature, cosmic ray detection, solar ultra-violet detection, and internal package temperatures. All of the above outputs are sampled once each minute and are both recorded on-board and telemetered to the ground station. In addition to the minute-block sampling, the analog signals are sampled every 0.91 second. This information is continuously telemetered to the ground station where it is converted back to analog form for display on strip chart recorders. The on-board tape recorder is a 7-track unit and uses standard-size tape reels. The telemetry data handling is compatible with the equipment at the National Scientific Balloon Facility (NSBF) to provide real time data analysis.

The gondola (0.82 m high, 0.86 m long, 0.70 m wide) is constructed of stainless steel with most structural support being supplied by the removable top. All removable sections are sealed with silicon o-rings so that outgassing products and helium from the cryopump can be vented several meters up the load line. This minimizes contamination of the atmospheric samples to be analyzed. A ballast deflection shield is mounted on top of the gondola. Suspended 0.4 m below the gondola is a 1.8 m x 2.4 m stainless steel 1.25 cm mesh screen. This serves a two-fold purpose as it provides a field-free region which minimizes the effect of any charge build-up on the gondola and it combines with four energy absorbing stainless steel legs to protect the gondola on impact after normal flight termination. All parts except the screen, the legs and the bottom of the gondola are coated with a white epoxy paint that is highly reflective in the very near infrared but is a good emitter in the 10 micrometer wavelength region. This prevents excessive heat build-up in the gondola. At launch time the total package weight is about 240 kg.

## B. Flights

### 1. 1 October 1974 Flight

#### a. Flight Details

The package was trucked to Palestine, Texas and arrived at 1800 on 22 August. Set-up and mass filter checkout with the on-board tape recorder was completed on 25 August. The TM package from NSBF was received on 27 August and TM checkout was started. It was soon discovered that the PROM that had been purchased for the on-board encoder was defective and a replacement was ordered. After the new PROM was installed, over two weeks was required to interface the TM package with the command electronics in the package and to get the software for the NSBF PDP-11/20 computer in shape to allow for limited real time data analysis. This was the first time the system had been operated as a "whole".

After much delay (about 10 days) due to rain and high wind conditions, the package was launched for the first time at 0130 CDT on 1 October 74 by NSBF personnel. The main balloon [ $3.29 (10^5) \text{ m}^3$ ], parachute, and NSBF balloon control electronics were launched in their conventional over-the-shoulder procedure. Because of the 300 m load line that separated the above from the gondola, a tow balloon ( $496 \text{ m}^3$ ) was used to assist in the gondola launch. While the main balloon was launched, the tow balloon supported the gondola and the launch crew walked with the gondola until the main balloon was nearly overhead. The gondola was then released so that it was rising when the main balloon, which was rising faster, overtook it. At 1500 m the tow balloon was separated cleanly and about 2 1/2 hours later, the package reached float altitude at 40 km. The flight path was almost due south from Palestine. Flight termination was initiated at 0830 and the gondola impacted near Huntsville, Texas. The package was recovered in excellent condition and returned to the NSBF that same day.

b. Flight Anomalies

This launch was the first from the new launch pad at NSBF that required use of the control tower for pre-launch checkout. Due to an intervening hill there was no line-of-sight path between the package and control tower, and it was not possible to do the complete pre-launch checkout because of poor down-leg communications. However, the package appeared to be operating normally and it was declared ready for launch. Shortly after launch, communications improved and the housekeeping data were printed out each minute as they arrived in the control tower.

About one hour after launch (15 km altitude) the mass filter commenced doing operations. According to the housekeeping data, they were PIFP operations at maximum FP value under TM command. No TM commands of any kind were given at that time and the on-board program was checked after recovery and found to be correct; i.e., no on-board operations were commanded. These spurious operations continued throughout the flight. It was later found that the multiplier high voltage had arced to ground through the RTV insulation on the high voltage feedthrough. It is believed that this was the cause of the spurious operations as later laboratory tests indicated that mass filter operations could sometimes be induced by turning the high voltage on or off and they were always PIFP operations at maximum FP value.

Since the ambient pressure at the time of the first spurious operation was about 90 Torr, the pumping system could not maintain operating pressure in the mass filter chamber when the valve opened. Except for the external arcing of the multiplier high voltage, the multiplier itself could have been destroyed. There may have been arcing between the quadrupole rods and the shield during operations, as a shield by-pass capacitor was later found to be shorted. Also, the

titanium filaments were found to be crystallized, presumably from operation at high pressure.

Repeated operations also caused the pumping surfaces of the mass filter chamber to overheat. One of the titanium filament feedthroughs was later found to be leaking badly and the excess heat could have been the cause. Failure of the NSBF transmitter shortly before termination and problems with their pressure transducers may also have been caused by overheating.

There was a problem with the tape recorder in that the tape slipped off the guide posts, entangled, and did not advance. This either happened at launch or enroute to the launch pad. Consequently, it was impossible to do a complete post-flight analysis of the malfunctions.

#### c. Auxiliary Measurements

As far as one can determine from the limited data obtained during the flight, the cosmic ray detector, ultraviolet detector, and outside temperature sensors performed as designed. The outside temperature thermistor assemblies were furnished by Atmospheric Sciences Laboratory.

#### d. Results and Discussion

Except for occasional synchronization dropouts the real-time housekeeping data display worked as planned and was extremely helpful in monitoring the progress of the flight. No positive ion data or neutral molecule data were obtained due to the difficulties discussed earlier.

It was concluded that an environmental chamber test would be necessary before the next flight.

e. Repair and Modifications

Experience gained in preparing the package for flight suggested several modifications to the package that would be useful for laboratory tests as well as checkout in the field. These changes were made shortly after the package was returned to the University of Denver.

The main power on-off switch was replaced with a double-throw center-off switch to facilitate use of an auxiliary power supply. A 10A ammeter was wired into the main power line to allow one to monitor package total current. Switches were installed in series with the logic control lines for the two titanium sublimation pumps and in series with the power supplies for the ionizer filament, VacIon pump, multiplier high voltage, and tape recorder. This allows one to run the mass filter or to test circuitry without concern for duty cycles, depleting charge in the batteries, or advancing the tape recorder. Test jacks were installed so that the current through the titanium filaments could easily be monitored and adjusted. The switch for the tape recorder supply voltage was also wired so that power may be applied to the tape recorder without applying power to the rest of the package. This provides a way to maintain tension on the tape during transit to the launch site and lessens the possibility of the tape becoming entangled.

Other modifications were also made to the tape recorder to improve its reliability. A brake was installed that actuates as soon as the tape drive command ends. This prevents tape overshoot. Also, additional retainers were added to strategic places to prevent the tape from slipping off the guide posts. After these modifications, vigorous shaking of the recorder did not entangle the tape and no more problems have been encountered with the tape drive.

A Varian valve was installed between the cryopump and the mass filter chamber. This allows one to isolate the cryopump. In case of a flight scrub one does not have to worry about keeping the dewar cold until the next flight attempt. Any condensed gases (including CO<sub>2</sub> frost

if used) can then be contained in the cryopump and recondensed so one does not have to connect the mass filter chamber to an external pumping system during the interim.

Some of the studs that are used to fasten the mass filter chamber to the gondola base plate developed leaks in the welds. Consequently, the test cap that allows one to do sampling operations in the laboratory could not be pumped out properly and the pressure of the test gas could not be maintained. New studs were welded into the base plate and the base plate surface was polished to improve the cap seal.

Originally, only the two ends that dissipate heat from the titanium pumps and the gondola top were painted white. After the first flight the styrofoam insulation in contact with the unpainted sides showed evidence of overheating. Hence, the two removable sides were also coated with white epoxy paint to give better temperature control.

A new titanium filament assembly was purchased from Varian to replace the one that developed the leak.

Modifications to the orifice valve and valve drive assembly were continually made to improve reliability.

In order to provide for one-piece construction to eliminate the possibility of contact potentials and to provide for a more reliable vacuum seal, an orifice plate was EDM machined out of tungsten carbide.

Two aneroid switches were installed in the open command line from the command electronics to the solenoid drive board. This prevents the valve from opening at low altitudes in the event of spurious commands. The switches, wired in parallel for reliability, activate in the neighborhood of 16 Torr.

#### f. Laboratory Tests

Considerable time and effort were spent in trying to increase the ion counting rate. Although amu 109 had clearly been observed in laboratory tests during May 74, the counting rate was much lower than expected. However, it was very difficult to estimate the ion density one

might expect to be present in the test cap because of the geometry and unknown water vapor concentration. During subsequent tests in preparation for the second flight, distinct amu values were seldom observed under similar conditions, although counts were often observed for amu > 117.

In order to perform the successful May 74 tests, a test cap with inside dimensions of 32 cm diameter and 9 cm depth with appropriate electrical feedthroughs and valved outlets was constructed. The open end of the cap was fitted with an o-ring so it would seal against the gondola bottom plate when evacuated. Necessary plumbing to measure cap pressure with a 3 Torr MKS capacitance manometer and to trap the forepump with LN<sub>2</sub> was also constructed. A 700 $\mu$  curie Am<sup>241</sup>  $\alpha$ -particle source was taped to the mass filter bottom flange such that when the valve was open the  $\alpha$ -particles traveled roughly parallel to the flange face through the sampling volume. Zeolite was put in the bottom of the test cap, the cap was evacuated, and then "zero" air was admitted to the desired test pressure of about 3 Torr. The orifice plate in use at that time was made of hardened Ketos steel that was chrome-plated. Best results were obtained with -30 v applied to the accelerator plate and ground potential on the orifice plate.

Since few ions were ever observed with the  $\alpha$ -particle source, a hot filament ion source was constructed that could be placed in the test cap. A thoriated-iridium filament made it possible to maintain relatively high cap pressure without danger of filament burnout. By maintaining pressures in the test cap below 100 millitorr it was possible to make measurements without the need for using the titanium sublimators as the auxiliary pumping station could maintain safe operating pressures in the mass filter chamber. Also, the valve could be left open continuously so ion currents could be measured with electrometers. The front end of the quadrupole (ionizer and accelerator plate) was essentially used as a faraday cup and, by changing potentials,

both negative and positive currents to various parts of the structure could be measured. With an emission current of  $500\mu\text{A}$ , the ion current measured with the faraday cup was on the order of  $9(10^{-10})\text{A}$ .

The results of tests conducted with the filament ion source in the cap demonstrated that the original design parameters were correct in that the quadrupole assembly was not mis-aligned, the entering ions were well-focused, the operating potentials had been chosen correctly, and a high percentage of the entering ions were actually passing through the entrance to the quadrupole. This implied that the low counting efficiency was not in the mass filter assembly itself but that the ions were not getting through the orifice in the first place.

It was speculated that a possible cause of poor ion transmission through the orifice could be due to electric fields produced by contact potentials since the 3 mm diameter orifice disc was of different material than the plate. Another possibility was the orifice disc material itself, since it is generally recognized that molybdenum is the preferred material for the electrodes in an Einzel lens. The following combinations of orifice disc material and orifice plates were compared: (1) the original plate which was machined from Ketos steel, heat treated to harden it, and then chrome plated, with a nickel disc spotwelded into the center; (2) the same plate with a molybdenum orifice disc; (3) a hardened Ketos plate with a nickel disc spotwelded into place before the chrome plating was done; (4) a hardened Ketos plate with a molybdenum disc in place before the plate and disc were then completely coated with molybdenum by sputtering; and (5) a one-piece assembly where the plate and orifice were EDM machined from a block of tungsten carbide. All orifices were on the order of  $100\mu\text{m}$  diameter.

No significant differences were observed in the ion throughput for any of the above combinations. Hence, the tungsten carbide orifice

plate was installed for the next flight because of its superior reliability in making a vacuum seal.

The combination of tests described above entailed several weeks of effort since the mass filter chamber had to be removed from the gondola and the bottom flange removed each time the orifice plate was changed. Then, after reinstallation in the gondola, the mass filter chamber had to be pumped out and the cap also had to be installed and pumped out. To put it simply, the instrument was designed for flight operation, not for laboratory operation.

These tests made it obvious that more time and effort would be required to investigate the problem of ion transmission through small orifices. Consequently, a grant was obtained from ARO to study the problem and the results of that study have been reported in detail.<sup>(4)</sup>

## 2. 7 July 1975 Flight

### a. Flight Details

The package arrived via truck at Palestine, Texas late in the evening of 19 June. Mass filter checkouts including the up-leg TM were completed on 21 June. No problems were encountered. Further checkout and the environmental chamber tests had to be delayed until the NSBF TM package was finally received late on 26 June. After a complete package checkout the environmental tests were conducted on 30 June and 1 July.

Since it was desirable to subject the electronic circuitry to temperatures that might be encountered during actual flight, the two removable side panels and the styrofoam insulation inside those panels were not installed for the environmental tests. That allowed one to simulate flight temperatures and pressures concurrently by using only the refrigeration unit for cooling. Otherwise, cold vapor from LN<sub>2</sub> dewars would have had to be admitted into the environmental chamber.

An ascent rate of 265 m/minute was simulated until a chamber pressure of 65 torr was attained. This pressure roughly corresponds to the tropopause where the difficulties on the previous flight started to occur. The refrigeration unit, started shortly after "launch", cooled the chamber to  $-11^{\circ}\text{C}$  at this time. Good air circulation was maintained by large fans. This pressure and temperature were maintained for more than half an hour, then ascent was continued to a pressure near 2 torr. At this time the temperature had warmed to  $+9^{\circ}\text{C}$  because of the reduced efficiency of the cooling unit. After a few minutes, cooling was stopped and heating started. Chamber temperature was held near  $30^{\circ}\text{C}$  for eight hours before the chamber was vented. The package performed flawlessly during all of those tests so it was then readied for flight.

Launch was scheduled for dawn on 5 July. It was so damp and foggy that morning that water was literally dripping from the gondola on the launch pad. During checkout it was noticed that excessive current was being drawn from the main power supply. Removal of the test cap revealed a hot solenoid and the flight was aborted. It was apparent that moisture condensation on the solenoid-drive circuit-board caused a transistor to turn on which in turn supplied current to the solenoid. Fortunately, it was the "close" solenoid instead of the "open" solenoid that was activated.

A further difficulty arose during transport of the package back to the building because the rf quadrupole drive, which worked on the pad, pegged the drive current meter during a scan operation. After extensive tests, it became apparent that the difficulty was probably inside the mass filter chamber and the rf drive unit was removed. Continuity checks revealed a 5.6 ohm "short" between one set of quadrupole rods and the quadrupole shield. Experience indicated that the short was probably caused by a tiny fiber so it was decided to

try and burn the short out with a large current. That succeeded and the package was again readied for flight.

The package was launched at 0634 CDT on 7 July using the same procedure as was used for the previous flight. Balloon sizes and package weights were the same. The tow balloon was separated cleanly at about 1.5 km and the package ascended to the requested float altitude near 40 km in about 2 1/2 hours. The flight path was almost due west from Palestine. At 1215 cut-down was initiated by the chase airplane and the package impacted just north of the Midland-Odessa airport. The package landed in good condition but was pulled over on one side when the NSBF balloon control package failed to separate from the mass filter package. The NSBF package barely cleared the highway just west of the mass filter package impact location and was suspended in the air by the 300 m load line which was draped over the power lines along the road. The initial shock pulled the mass filter package over on its side. Recovery proceeded smoothly and the package was taken into Odessa where it was picked up by University of Denver personnel the next day and returned directly to Denver.

b. Flight Anomalies

At about 23.8 km (~22 torr ambient pressure) the valve opened as indicated by the sudden overload in chamber pressure readouts. Since the housekeeping status did not indicate a sampling operation the titanium sublimators did not turn on. There was a possibility that the pressure readout could have failed so no operation was commanded which would have given a valve close command at its conclusion. That would have turned the sublimators on and applied voltages to the quadrupole rods and the chances of obtaining data could have been destroyed. It was hoped that the cryopump could eventually handle the gas load if indeed the valve had opened.

Shortly before the package reached float altitude, a PI sampling operation (with the high voltage off) was commanded in hopes of closing the valve. The pressure readouts remained at maximum. This command was repeated, again with no success. After float altitude was attained the on-board master sequencer initiated several operations. At the conclusion of one of the operations, the pressure suddenly dropped indicating that the valve had closed. The valve did not open during following operations and it was later discovered that the open solenoid had burned out. The source of the problem was traced to a defective solder joint in the command electronics. This caused a continuous open command to the solenoid drive circuit and as soon as the aneroid switch closed the valve opened. Current continued to flow through the solenoid which was designed for intermittent operation, and it soon burned out. The other solenoid was then able to close the valve at the next close command.

The command electronics, in addition to the preprogrammed operations, often asked for extra operations. No-operate commands had to be given to stop these or, once started, they continued every minute. Since the logic circuitry malfunctioned only during operations, and for the most part while the high voltage was on, a prime candidate for the source of the problem was high voltage arcing. However, no evidence for arcing was found, either external to or inside the mass filter chamber. No other reason for the extra operations could be found either.

The heater for the rf quadrupole drive transformer opened up during the flight or before launch so the transformer temperature could not be controlled. However, this did not appear to adversely affect the rf drive during the flight. Since this was entirely a day-time flight, the gondola did not get as cold as on the previous flight.

### c. Auxiliary Measurements

After all tests were completed but before flight the cosmic ray detector circuitry stopped functioning properly. Repair would have caused a delay so it was disconnected for the flight.

The temperature sensors both worked well. Variations in the two readings showed that the package was either swinging or rotating or both during most of the flight. The temperature values appeared to be too warm, probably because of the sensors close proximity to the gondola.

The uv detector worked as designed. From data after impact it was possible to determine the exact time the package was pulled over on its side.

### d. Results and Discussion

At the time of the flight it was not apparent that any NM or PI data had been obtained. However, analysis of the on-board data tape after return to Denver resulted in the finding that two NM scan operations had taken place at package times of 0430 and 0435 while the valve was held open. Quantitative interpretations of the data were not possible due to the much higher than normal pressure in the mass filter chamber at the time of these operations. However, there was no evidence for any mass peak at amu 18 which indicated that a minimal amount of water was present in the vicinity of the gondola. It appears that the efforts expended in keeping a clean package were successful. Large peaks corresponding to amu values of 14, 16, 20, 28, 32, 40, and 44 were present as expected. See Figure 1 for details. All other successful mass filter operations took place after the valve had closed for good.

As soon as the valve closed the pressure in the mass filter chamber quickly came down indicating that the pumping system can survive considerable overloads. It is estimated that when the valve first opened the cryopump could maintain a pressure on the order of  $4(10^{-3})$  Torr

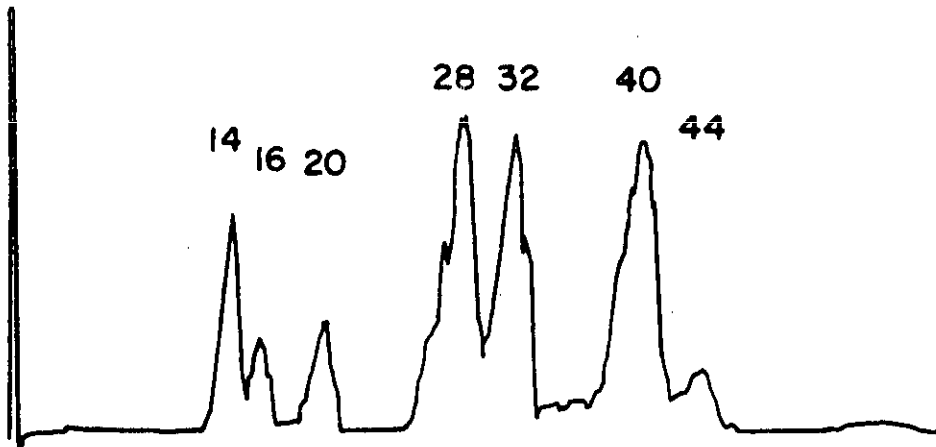


Figure 1. NM Scan Data, 7 July 1975.

and if the pumping speed did not deteriorate the pressure should have been near  $3(10^{-4})$  Torr at float altitude.

The real time data analysis program worked as planned and the housekeeping and analog data were again invaluable in following the progress of the flight.

e. Repair and Modifications

The mass filter chamber was opened and inspected to try and find the reason for the short that had been deliberately burned out in Palestine. No evidence remained; however, several very small flecks of titanium compounds were apparently peeling off the inner wall and baffle pumping surfaces and this could have been the source of the problem. Hence, the quadrupole assembly was removed from the mass filter chamber and the titanium compounds were stripped from the walls and baffles with an acid solution. Several of the titanium filaments were showing signs of age and they were replaced.

A new solenoid drive circuit board with an improved layout was designed and constructed to try and prevent further problems of the type that caused the first launch attempt to be scrubbed.

For some time the analog multiplex switches were giving trouble in that they would become defective for no apparent reason. They were replaced with integrated circuits that had more current capacity. Also, germanium diodes were added to all the switch inputs to ensure that no negative transient voltages could be destroying the integrated circuits.

After other minor repairs to the integrated circuit boards they were all coated with Dow Corning 630 protective coating. It was hoped that this would keep moisture, such as is often encountered at Palestine, from adversely affecting circuit operation.

The rf drive unit was completely checked out and a defective operational amplifier was found to be the cause of the heater malfunction during the flight. This was replaced. In order to have a better feeling

for the actual temperature in the rf drive unit a sensistor in a bridge circuit was installed on the cannister. Up to this time, only the heater current had been monitored.

The original main battery pack was no longer able to maintain the required output for a sufficient length of time so a new set of batteries was purchased. Also, the NiCads for the filament supply were replaced for the same reason.

The cosmic ray detector circuitry was repaired.

f. Laboratory Tests

Extensive laboratory tests were not undertaken after this flight. After the mass filter chamber was reassembled the usual checks and necessary adjustments were made to make sure everything was in working order. Several calibration NM operations with "zero" air in the test cap were completed. Also, Freon 114 was used to check the scan ramp of the rf drive unit to pinpoint the location of the mass peaks.

3. 21 September 1975 Flight

a. Flight Details

Departure from Denver for Palestine, Texas was on 1 September with arrival late on 2 September. Unloading, setup, and checkout took place on 3 and 4 September. Everything checked out satisfactorily except for a slight leak in the valve seal. However, the leak was not considered to be large enough to delay the flight for repair.

On 6 September the NSBF telemetry package was received and checked out. Because of the demand for the control tower and computer by other groups, it was difficult to schedule a satisfactory environmental test. However, an abbreviated test was conducted on the morning of 7 September. In addition to the environmental tests described for the 7 July flight, it was decided to check out the package for operation at high temperatures also, since data from the 7 July flight indicated the gondola inside temperature was considerably higher than anticipated.

Since the control tower was not available for the heat part of the test (preparations for another flight that evening were in progress) it was conducted without the benefit of the housekeeping real-time readout. It was possible to give a few operation commands from the tower, and it appeared as if some of these commands were not getting through. This was later found to be true from the on-board tape analysis, but other people were on the same frequency at the same time so the commands could have been blocked out. No other malfunctions occurred until the temperature on the converter base plate became somewhat higher than it had been during the 7 July flight. At these higher temperatures some operations that were commanded did not take place even though analysis of the on-board tape indicated that the commands were received.

Since the control tower was not available for another extended environmental test and the system did not malfunction at temperatures expected during the flight (using the 7 July flight as a reference) it was decided to pack the package as for flight and then do a 10 hour simulated flight (except for real-time data) in the building. This was primarily to ensure that the malfunctions observed during the environmental chamber test would not now occur at a lower temperature. This simulated flight was conducted on 9 September and no malfunction occurred. Again the converter base plate temperature was as high as that encountered on the 7 July flight. After rigging the package, it was declared ready for flight and NSBF was so informed.

Launch was scheduled for the morning of 11 September, but had to be scrubbed due to high wind conditions. Inclement weather forced postponement until 16 September and again the launch had to be delayed, this time because of heavy rains. On 17 September the package was transported to the pad for an anticipated launch. However, the housekeeping data was incorrect and a one-hour delay was requested to attempt

to fix the problem. NSBF granted the request. One side of the gondola was removed, the repair was completed (a bad connection in a circuit board connector), and the system was checked out and ready for launch within the hour. NSBF then proceeded with inflation of the tow balloon, completed it, and were ready to start inflating the main balloon when the line on the tow balloon separated. Since no other tow balloon was on hand the flight was aborted.

Another tow balloon was obtained by the next morning but inclement weather precluded another launch attempt until the morning of 21 September. Checkout on the pad proceeded smoothly and NSBF launched the package at 0740 CDT. The wind was 6-8 knots with gusts up to 10 knots, but the launch, while spectacular, was never in doubt. Balloon sizes, package weights and launch procedure were the same as for the 1 October 74 flight.

The tow balloon was separated cleanly at about 1.5 km altitude and the package reached float altitude of 40 km in approximately 2 1/2 hours. The package remained almost overhead before slowly drifting to the south and a little to the west during the 5 1/2 hours of sampling operations. At 1530 the flight was turned over to NSBF personnel for termination.

Commands to separate the line between the balloon and the parachute were transmitted from the control tower and from the chase airplane, both on the primary frequency and then on the back-up frequency. None of the commands effected separation. These circuits had been demonstrated to work by command from the airplane while the package was on the launch pad. The back-up timer was set to activate about 1600, but this also failed to produce separation. All of its parts, including batteries and wires, were separate from the radio-controlled device. During the evening NSBF personnel attempted various techniques to separate the line including sending out a back-up

airplane with another command transmitter and varying the frequencies that were transmitted. None of these efforts succeeded. By 2400 the balloon had settled down to about 30 km where the winds were near 40 knots from about 80°. When it became clear that the balloon and package would cross an international border and could eventually be lost in the Pacific NSBF personnel made the decision to separate the line between the package and the parachute. This command was transmitted at about 0400 on 22 September and the package free fell from 30 km. The package impacted near Comstock, Texas, about 16 km from the US-Mexican border. Although the package was demolished the on-board data tape was retrieved in reasonably good condition. One might note that according to the official NSBF flight report, the package was recovered in poor condition.

b. Flight Anomalies

Considerable difficulty was encountered in obtaining a real-time display of the mass filter operations due to the fading in and out of the down-leg TM signal. This fadeout continually caused loss of synchronization and the computer program had to be restarted each time. It is believed the package flight path (almost directly overhead for a major portion of the sampling operations) was responsible for most of the difficulty. A strip chart recording was made of the received TM signal strength and it showed a periodic variation, probably due to package rotational oscillation. It should be emphasized that the communications problem was entirely separate from the problems encountered at flight termination time. Because of TM transmission problems and loss of synchronization only five operations were recorded in real-time.

Some problems again occurred with the command electronics during the first few sampling operations in that the logic circuitry was getting reset before the operation was completed. At first it was reset

before the valve open command was given so the valve did not open. Then it was reset after the valve had opened so the valve did not receive a close command. When the latter occurred an attempt was made to close the valve by turning the high voltage off and then commanding an operation. The circuitry was not reset during the operation and the valve closed. The high voltage was turned back on, a PI scan operation commanded, and then the mass filter made it through a complete operation without the circuitry being reset. There was one more case when the valve remained open and the above sequence was repeated. After that the package worked beautifully except for one operation where the circuitry was reset before the valve opened and one later operation where the valve apparently jammed and did not open. The reason that the command circuitry was reset before the end of the sampling operation remains unexplained. No problems of this nature appeared during environmental or other tests.

#### c. Auxiliary Measurements

The cosmic ray detector functioned properly during the early part of the flight, but then its output began to fluctuate widely. Since the ionization current should have been quite constant at float altitude, the data are not believed to represent real ionization due to cosmic rays.

Variations between the two temperature sensor readings again showed that the package either swung or rotated during most of the flight. Package motion was further verified by the periodic variation in TM signal strength discussed earlier. As on previous flights the temperature values were warmer than expected.

The uv detector worked as designed.

#### d. Results and Discussion

A total of 35 mass filter operations were commanded during the flight. Of these, 14 were not successful due to problems discussed in

section b. The 21 successful operations included 7 NM scan operations, 8 PI scan operations and 6 PIFP operations.

From the NM operations, 32 current-mode scans of excellent quality were obtained and the co-added result is presented in Figure 2. Note the lack of any peak at amu 18. There were 27 count-mode scans of excellent quality. These were co-added and are shown in Figure 3. Again there is no evidence for a peak at amu 18. (Note that peaks at amu values 28, 32, and 40 produced saturation count rates as expected.) The  $O_2$  and A isotopes at amu values 34 and 36, respectively, have been used to establish that the sensitivity of the instrument to the detection of minor neutral constituents is 40 ppmv.<sup>(5,6)</sup> That is, at 40 ppmv the signal-to-noise ratio is unity. This is also the upper limit of the water vapor content of the sampled stratospheric atmosphere. Even if the gondola had carried aloft enough water to raise the water vapor number density to 40 ppmv, that amount of water changes the expected positive ion distribution a negligible amount.<sup>(6)</sup> We can conclude from these results that the efforts to build and fly a clean sampling package have succeeded. The sensitivity to minor neutral constituents can be improved significantly by placing the detector in an off-axis position to reduce the background from ion-source photons. For these first flights, the on-axis configuration was used to maximize the sensitivity to atmospheric ions.

The results of the PI scan operations are presented in Figure 4a. The 19 available scans for each operation were co-added but no amu peaks were distinguishable, and the total number of counts hardly varied for the different orifice plate voltages. The lack of observable ion peaks is not too surprising after the difficulties that were encountered in the laboratory ion sampling tests discussed previously. However, these numbers are useful as an upper limit for the background counting rate in the PI mode.

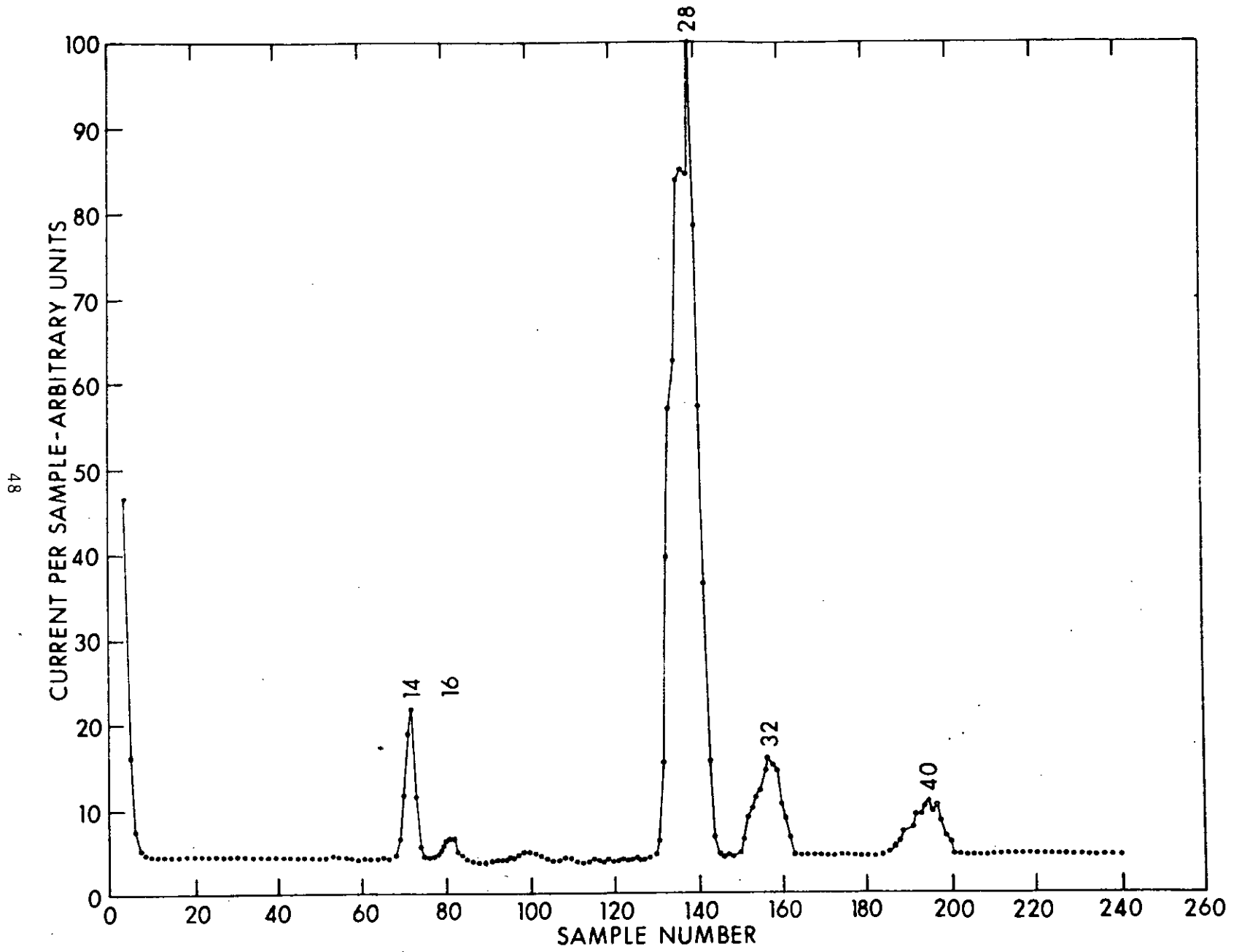


Figure 2. NM Scan Data, Current Mode, 21 September 1975.

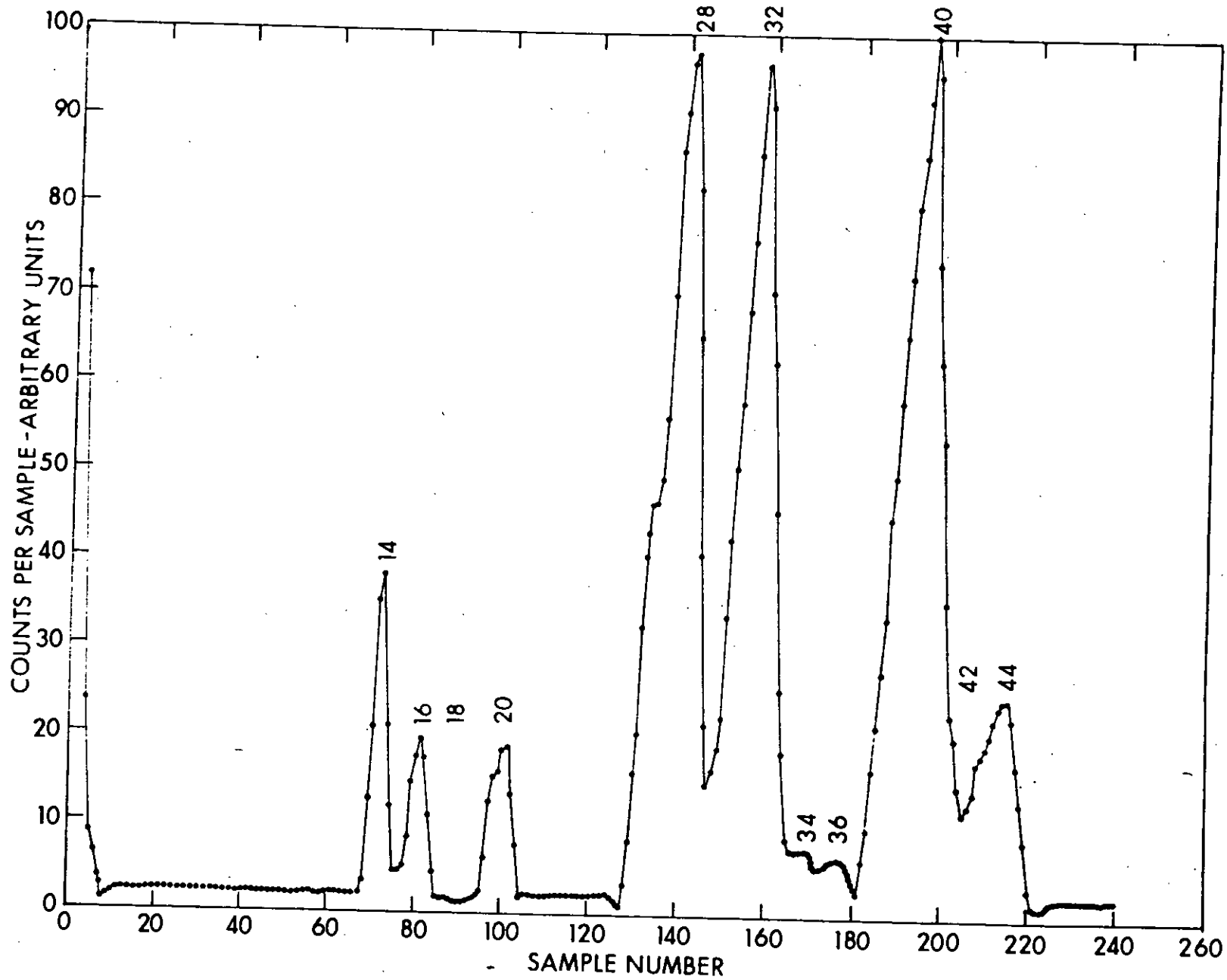


Figure 3. NM Scan Data, Count Mode, 21 September 1975.

<u>CDT</u>	<u>Plate Voltage</u>	<u>Counts (19 scans)</u>	<u>Counts/sec</u>	<u>Counts (amu &gt; 117)</u>
1133	0 v.	45	4.7	0
1204	-20	36	3.8	0
1211	0	41	4.3	0
1212	-20	46	4.8	0
1219	-20	40	4.2	1
1229	-5	38	4.0	1
1240	-1	38	4.0	2
1245	-0.5	38	4.0	2
Average		40	4.2	

Figure 4a. PI Scan Data, 21 September 1975.

<u>CDT</u>	<u>Plate Voltage</u>	<u>AMU</u>	<u>Counts</u>	<u>Counts/sec</u>
1254	- 0.5 v.	55	48	5.0
1259	"	73	50	5.3
1304	"	91	46	4.8
1309	"	109	35	3.6
1314	"	108.4	49	5.1
1338	"	118	32	3.3

Figure 4b. PIFP Scan Data, 21 September 1975.

PIFP operations were commanded for amu values 55, 73, 91, and 109 in an attempt to detect  $H^+(H_2O)_n$  ions. The results are shown in Figure 4b. The fixed peak counting rates were slightly higher than the upper limit background counting rate of 4.2 counts per second obtained from the scan operations but not statistically significant. A background operation at amu 118 showed the lowest counting rate, but this is the only true background operation that was successful. The operation at amu 108.4 was commanded after the amu 109 results showed that most of the counts appeared in the two lowest of the five channels. However, with the resolution of 3-4 amu at the high amu values the peak should not have been this sharp. One must conclude that a higher orifice conductance is required to increase the ambient ion throughput and hence the signal-to-noise ratio.

### III. PI/NI PACKAGE

#### A. Package Specifications

The PI/NI package has been fully described;<sup>(2, 3)</sup> hence, this discussion will be brief. This instrument has the capability of detecting ambient positive ions in one mode of operation and ambient negative ions in a second mode of operation. The mass range is 1-150 amu which can be covered in a continuous sweep at the rate of 300 amu per second. In addition, any one of the 150 amu positions can be selected by TM command for FP band-pass operations. Provision is also made for holding the mass filter dc voltage at the value of the shield voltage ( $V_g$ ) during either a scan or FP operation while the rf voltage behaves normally. This results in a high-pass filter where only ions with mass greater than the cutoff value of  $M_0$  traverse the quadrupole. In the FP mode  $M_0$  is selectable between amu 1 and amu 117 and remains constant during the operation. In the scan mode  $M_0$  sweeps from amu 1 to amu 117; i.e., all ions are allowed to traverse the quadrupole at the beginning of the scan but only ions with amu > 117 are allowed through at the end of the scan. A maximum number of 8 amu values may be selected for FP band-pass and/or FP high-pass operations and programmed into a read-only memory. The on-board master sequencer can be quickly programmed before launch with the desired number and order of the preselected FP operations and either type of scan operation. Of course, TM commands can be used to override the on-board master sequencer.

The quadrupole and detection assemblies are identical to those described in section II-A. However, the ionizer that was in front of the quadrupole is replaced by an Einzel lens. Also, only the count mode of detector operation is used. A simple hot-filament ion source was con-

structed and is mounted to one side of the Einzel lens so that residual gas analysis can be performed. This also allows one to easily check the system for proper operation before launch.

The tungsten carbide orifice plate was one of the few components in the PI/NM package that survived the free-fall intact. In order to increase the through-put, the orifice diameter was enlarged to 0.03 cm so the conductance is now about  $9(10^{-3})$  l/second. To accommodate the possible need for both positive and negative "draw-in" potentials on the orifice plate, a D/A converter was added to the command electronics, and voltages in 160 mv steps between -20v and +20v are available. The desired voltage is selected via TM command.

When the valve is controlled by the on-board command electronics it is open for 15.3 seconds for each operation. However, the valve can also be controlled by TM command so it can be opened and closed at will.

In order to handle the large neutral gas load a liquid helium cryopump with pumping speed greater than 5000 l/second is an integral part of the mass filter chamber. The hold time is about 4-1/2 hours. A 2 l/second VacIon pump also helps to pump atmospheric helium but its primary function is to monitor the chamber pressure during flight.

Measurements in support of the mass filter data include ambient pressure, ambient temperature, cosmic ray detection (electrons with energies greater than 1 MeV and protons with energies greater than 10 MeV can be detected), atmospheric electrical conductivity, and internal package temperatures. All of the above outputs are sampled once each minute and are both recorded on board and telemetered to the ground station. In addition to the minute-block sampling, the analog signals are sampled every 0.37 second. This information is continuously telemetered to the ground station where it can be converted back to analog form for display on strip chart recorders. The on-board tape recorder is a

7-track unit and uses standard-size tape reels. The TM system was constructed at the University of Denver and is described in the Final report for USARO grant #DAAG29-76-G-0133.

The gondola (0.76 m high, 0.89 m long, 0.84 m wide) is constructed of aluminum except for the bottom panel which is 304 stainless steel. All 6 sides are removable but are sealed with silicone O-rings so that outgassing products can be vented several meters up the load line. The helium gas from the cryopump is vented separately (also up the load line). The stainless steel landing gear is identical to that used for the PI/NM package except that no screen has been included. All parts except the landing gear and the gondola bottom panel are painted with a white baked-on enamel to prevent excessive heat build-up in the gondola. When prepared for launch, the total package weight is about 205 kg.

## B. Flights

### 1. 4 December 1976 Flight

#### a. Flight Details

The package was trucked to Holloman Air Force Base, New Mexico and arrived in the afternoon of 29 November. Since the first item on the schedule was to be an environmental chamber test, the package was unloaded and set up for checkout in that building. Checkout proceeded smoothly and the environmental chamber test was scheduled for 1 December. Actual flight conditions with regard to pressure and temperature were simulated as closely as possible during the test. However, the cryopump was not filled, the valve was not cycled, and neither the receiver nor transmitter were used. The command encoder and computer were simply hard-wired to the proper circuitry in the package TM.

Float altitude pressure of about 2.2 Torr was reached in about 2-1/4 hours and a series of commands to initiate mass filter operations

were given. According to the housekeeping data displayed on the CRT readout, the package was working properly. The multiplier high voltage supply was turned on and off several times to see if this would produce noise that might affect the logic circuitry. No effects were seen. After about 1-1/2 hours, the heat lamps were turned on to warm the package and the environmental chamber was slowly brought up to atmosphere. No serious malfunctions were evident during the test or upon post-test inspection. Temperatures inside the gondola warmed up some during the "flight" as expected but remained well within tolerance. After completion of the test, the package was moved across the base to the balloon flight operations building.

Since the HAFB receiving equipment was to be an integral part of the down-leg TM, the command encoder, the CRT display and the NOVA computer with its associated components were taken directly to the second floor where their TM apparatus is located. The up-leg transmitter was taken to the roof of the building and wired directly to the command encoder in the TM room.

After the mass filter chamber was connected to the auxiliary vacuum system, pre-flight checkout was continued. This included a test of both the up-leg and down-leg TM systems and was the first time that the system was operated as a "whole". Everything was in order so the final packing and rigging was done on 3 December. As compared with the PI/NM package one should note how much faster this package was made ready for launch since we did not have to wait for others to furnish us with on-board TM equipment.

The package was launched for the first time at 0730 MST on 4 December 1976 by HAFB personnel. Since this was to be primarily an engineering flight, optimum conditions for atmospheric purity were compromised in order to simplify launch and reduce cost. The gondola

was suspended about 1 m below a load bar on which ballast boxes and other HAFB apparatus were also suspended. Between the load bar and the  $3.29 \times 10^5 \text{ m}^3$  balloon was the 28 m long parachute. The package was launched according to the procedure preferred by HAFB personnel; i.e., the balloon is filled downwind from the crane that holds the gondola. After the balloon is released, the crane operator waits until it is almost overhead, then he positions the gondola under the balloon and maintains this position until the gondola is released from the crane. Launch proceeded smoothly and float altitude near 42 km was attained in about 2-1/2 hours. After 1-1/2 hours at float altitude the liquid helium in the cryopump was gone so the flight was terminated. The gondola impacted in a cotton field near Lamesa, Texas and was immediately pulled over on one side by the load bar. The cosmic ray ionization chamber was badly damaged by the load bar, but the rest of the package suffered little damage. It was returned to HAFB late on 5 December.

#### b. Flight Anomalies

During pre-launch checkout on the runway, the TM commands were not getting through to the package. It soon became evident that the trouble was with the transmitter on the roof of the flight operations building. Some component in the transmitter circuitry apparently became too cold even though the temperature was well within the manufacturer's quoted tolerance. A few minutes with a heat gun solved the problem.

At the time of the first mass filter operation, the pressure readout indicated that the valve did not open. Valve control was then taken over by TM and after several minutes and many commands the valve opened. Since the cryopump was easily handling the gas load at this altitude, the valve was left open until the sampling operations were over. It is quite possible that the difficulty was not with the valve but with the failure of the open command to reach the valve drive circuitry. The

major venting of the gondola takes place through a check valve during ascent. When the pressure differential becomes less than 26 torr this valve closes and the remaining overpressure is vented several meters up the load line. With the small diameter tubing (1/4" o.d.) used for this flight it could take many minutes before the gondola pressure reached 16 torr at which time the aneroid switch would close and allow the open commands to get through.

After about 1/2 hour at float altitude the flight profile called for the balloon to descend at a rate of 1 to 1.5 meters/second until termination. However, HAFB personnel could not get the balloon to descend and it remained near 42 km. It is not known why the balloon failed to descend since the recovery crew reported that the valve was in the open position.

Although not noticeable during the flight, two other malfunctions were discovered when the package was undergoing post-flight inspection back at the University of Denver. The +150v and -150v lines were shorted to each other on one of the circuit boards in the card nest so that they read +1.3v and +3.4v, respectively. Without these voltages the rf drive would not work so no ions could be detected. It is not known when this happened; however, the temperature measured at the DC/DC converter box took a sudden unexplained 4<sup>o</sup>C rise about an hour after launch. The other temperatures in the gondola did not show this increase. The extra heat could have come from the +150v and -150v converters since they would have been overloaded if shorted.

The on-board tape stopped advancing shortly before float altitude was reached. This malfunction was caused by a burned-out relay that controlled the capstan drive motor.

#### c. Auxiliary Measurements

The cosmic ray detector output was characterized by extremely sharp and large fluctuations. It is not believed that these are real. However, the average value did seem to be a reasonable result.

Although the temperature sensors worked well, the ambient temperature reading again was higher than expected at float altitude. All other outputs seemed quite normal except for the anomalous temperature rise at the converter box mentioned above.

#### d. Results and Discussion

Except for the transmitter malfunction when first turned on, the TM system worked extremely well throughout the flight. The CRT display was very effective in monitoring the housekeeping data. No positive ion data were obtained due to the difficulties discussed earlier.

#### e. Repair and Modifications

Some difficulty was encountered in lifting the cryopump out of the mass filter chamber. The lateral support wires had broken due to the fact that the dome of the outer radiation shield yielded on impact. The radiation shield was moved back into place by tapping with a hammer and new lateral support wires were installed. However, when the cryopump was mounted in the mass filter chamber the system could not be pumped down. A leak was discovered in the thin-walled stainless steel tubing where it joins the helium dewar. Repair was attempted with Torr Seal and was successful at room temperature, but it failed when liquid nitrogen was put into the dewar. Consequently, the cryopump had to be cut apart so a new stainless steel tube could be welded into place. Then it had to be cleaned, aligned, and welded back together. It was hoped that a larger dewar could be constructed in time for the next flight but construction delays prohibited that.

A new circuit board was constructed to replace the one on which electrical breakdown had occurred. Several integrated circuit chips on other boards were also found to be defective and had to be replaced. Apparently, their failure was caused by the electrical breakdown.

The sampling valve had to be completely disassembled and cleaned since it was full of dirt from the Texas cottonfield. No damage was sustained.

Since the ASL thermistor assemblies were demolished on impact, a different system for temperature measurement was designed which would be more compatible with the package electronics. A single thermistor of the type used in the ASL system was mounted in an inverted cone. A screen was placed over the open end of the cone to shield it from rf radiation. The cone was then suspended about 40 cm below the gondola by a stainless steel tube. The whole structure was painted white. The thermistor makes up one leg of a bridge circuit whose output is linear from  $-30^{\circ}\text{C}$  to  $+20^{\circ}\text{C}$ . A differential amplifier is used to make the bridge output signal compatible with the analog sampling circuitry. Calibration is accomplished by using a known resistance in place of the thermistor.

The high sensitivity part of the VacIon readout circuit was found to be giving a pressure reading that was too low. Replacement of a defective diode in the feedback circuit of the output amplifier cured the trouble.

A new cosmic ray ionization chamber was constructed and filled with argon to 8 atmospheres pressure. The erratic output observed during the last flight might have been due to the inability of the electrometer amplifier to accommodate to the rapid temperature changes encountered. After the package was at float altitude for 1/2 hour the cosmic ray detector output became much more stable. A different type of electrometer amplifier that is less sensitive to temperature changes was installed.

In order to facilitate package checkout and laboratory testing an LED readout for monitoring housekeeping was designed and constructed. The desired housekeeping word is selected by presetting a counter with external switches. The selected word is then decoded from binary to octal and displayed on the 7-segment LED readout.

#### f. Laboratory Tests

Hold time tests were completed on the reconstructed helium dewar. Resultant hold times were about 4 1/2 hours.

Calibrations were performed for the new circuits and checked for the old circuits where appropriate.

#### 2. 22 June 1977 Flight

##### a. Flight Details

The package was trucked to Holloman AFB and arrived in the afternoon of 23 May. The truck was off-loaded that same afternoon and the auxiliary vacuum system was connected the next morning. Package checkout was started shortly after. Two problems came up. First, the plate voltage housekeeping readout did not agree with the value commanded with the TM encoder. This was traced to a defective integrated circuit. Second, the on-board master sequencer did not reproduce the program exactly as it was loaded. Some of the program code for a given minute block operation was appearing one minute later than the rest. Several of the NiCad cells that make up the continuous 5 v supply for the memory were found to be low. After charging with an external power supply they functioned properly and no more difficulty was encountered. Final adjustment was made to the multiplier high voltage power supply to ensure that the output pulses were of sufficient amplitude to be counted. Residual gas ions generated with the hot-filament ion source were used to produce the pulses.

The auxiliary vacuum system had to be disconnected twice before launch; once to fit the landing gear and again to weigh the package.

Launch was scheduled for 0500 on 27 May. Checkout on the launch runway proceeded smoothly and the balloon was inflated. During the launch, but before the package was released, the back-up timer (part of the balloon control electronics) started its termination sequence. Fortunately, the crew chief noticed this and did not pull the pin that would have launched the package. However, all of the ballast was

deposited on the runway and the balloon was cut loose from the payload. The balloon was later located in the mountains east of Alamogordo, New Mexico.

Air Force personnel installed a different back-up timer and checked out their whole system. The mass filter package was connected to the auxiliary vacuum system and also checked out again. Everything seemed to be in order so the next launch attempt was scheduled for 1 June at 0300. The early time was necessary to avoid interference from the base radar which was to commence operation at 0800.

Preflight checkout on the launch runway was completed without encountering any malfunctions. However, after the balloon was inflated and during the final fill of the helium cryopump, the back-up timer again went into termination sequence and the flight again had to be aborted. Although the balloon was not launched and efforts were made to salvage it, they failed.

Since the timers used on these two launch attempts were of a new design, it was decided to take the mass filter package out away from the building, suspend it on the crane, and simulate launch conditions except for the balloon. It was hoped that if there was an interference problem between our TM system and the Air Force electronics it would show up during this simulation. This test was done on 2 June. The mass filter command electronics was started at 1300 and the package was then moved to the test site south of the flight operations building. Various commands were transmitted from the TM room during the test period and the on-board transmitter was on for most of the period. By 1618 no malfunctions of any kind had occurred and the package was returned to the building. Since the Alaska series of flights was imminent, another launch attempt was delayed until further notice.

The mass filter package and auxiliary vacuum system were moved to one corner of the flight preparation room and connected. In order to maintain a good vacuum in the mass filter chamber the auxiliary

vacuum system was left on. A sheet of polyethylene was draped over the mass filter gondola to keep dust out.

After return on 17 June, package operation was checked out once again. The NiCad cells for the master sequencer were again found to be low so they were charged. Everything else seemed to be in order and launch was scheduled for 0730 on 22 June.

While the package was being readied for pickup by the launch crane, a 1.5 kg steel block that was an integral component of the overhead hoist popped loose and fell a distance of about 8 m onto the top of the gondola. No internal damage was discernible although the aluminum frame was slightly deformed. At the time it appeared that the gondola skin had suffered a puncture, but this later turned out to be false. Fortunately, no one was injured.

Checkout on the launch runway again proceeded smoothly with no malfunctions, and the package was launched at 0725 MDT. The actual flight train configuration was the same as that used for the earlier flight on 4 December 1976 except that the package was suspended 1 m further below the load bar. Launch procedure was the same. After the package was released the load bar momentarily hung up on the crane boom. They were separated by rapid backwards acceleration of the launch crane with a modest shock to the load bar. No apparent damage was detected.

The weight of the package (205kg) plus flight control equipment, parachute, and ballast gave a total payload of 460 kg. With the  $8.2 \cdot 10^4 \text{ m}^3$  balloon an altitude of 32 km was attained at which the ambient pressure is 6-7 Torr. The flight plan requested float altitude to be maintained for about 30 minutes followed by a 2.5 m/sec descent to 25 km at which time the flight was to be terminated. The actual flight profile was quite close to this plan. The flight was terminated at 1044 MDT with impact occurring at 1123 MDT 13 km north of Truth or

Consequences, New Mexico. Except for the cosmic ray ionization chamber the package was recovered in good condition and returned to HAFB later that day.

It should be noted that the new back-up timer was not used for this flight so there is a possibility of further malfunctions with that timer if the source of the malfunction is not discovered.

b. Flight Anomalies

Approximately midway in ascent (one hour after launch), a spike was observed in the VacIon output, which had been calibrated to measure vacuum chamber pressure. Shortly thereafter, growing noise was observed, followed by full scale deflection. TM commands were unsuccessful in restoring normal conditions. As a consequence, vacuum chamber pressure could not be monitored and valve openings thus could not be confirmed by corresponding pressure changes. No unusual behavior had been detected in the earlier environmental chamber test, nor during the first flight.

Although ions were counted in several FP band-pass modes of operation and in one scan mode of operation, no ion counts were obtained in the FP high-pass mode.

c. Auxiliary Measurements

Although the initial cosmic ray detector output appeared to be abnormally high, values obtained from shortly before launch until impact were typical. The new electrometer amplifier performed much better in that the output was not characterized by the extremely sharp and large fluctuations observed previously.

The new thermistor assembly for ambient temperature measurement worked very well and it was much easier to convert the data to temperatures. Compared with data obtained with rockets, the values obtained at altitude were about 30°C higher, even during the valved descent portion of the flight.

All other outputs seemed quite normal. Temperatures in the gondola mostly ranged between 30°C and 40°C throughout the flight. Gondola bottom skin temperature varied from -4°C during passage through the troposphere to 37°C at float.

#### d. Results and Discussion

After the mass filter package was returned to Denver, the vacuum chamber was tested for the presence of residual gas. Residual gas pressure in the chamber was definitely greater than one Torr. The auxiliary vacuum system was then connected and the mass filter chamber was tested for leaks. No evidence of a leak was found. Hence, one must conclude that the valve was open at least several times during the flight, since a residual pressure increase of about 0.1 Torr could be expected at 7 Torr ambient pressure per normal mass filter operation.

A total of 28 mass filter operations were commanded during the flight. Of these, 14 were PIFP high-pass operations and no valid data were obtained for reasons which will be discussed in section f. For completeness, these data along with the data from the 12 PIFP band-pass operations are presented in Figure 5, chronologically in accordance with on-board time (OBT). At the time of launch (0725), the OBT was 0056:30; i. e. 56 minutes 30 seconds. The numbers represent the actual counts in the format displayed on the CRT after computer summation. Each channel corresponds to 0.23 amu. The center channel is located at the denoted amu. Except for the first, total counting time per channel is 3.06 seconds. Counting time in the first channel is reduced to 2.55 seconds to eliminate possible noise counts from opening of the valve. Also provided in Figure 5 are the atmospheric pressure in Torr and the corresponding "pressure" altitude.

Two PI scan operations were commanded just before flight termination. The results from the first of these operations are presented in Figure 6. Each of the 765 channels corresponds to 0.23 amu.

OBT	Operation	PV(v)	Counts					AP(torr)	Altitude(kn)
0259	amu > 10	0	0	75	0	2	4	6.7	32.0
0301	amu > 50	0	0	0	1	0	1	6.7	32.0
0303	amu > 100	0	0	2	0	0	0	6.7	32.0
0305	amu 9	0	0	0	1	0	0	6.7	32.0
0307	amu 55	0	1	0	0	0	0	6.8	31.8
0309	amu 73	0	108	174	281	487	324	6.9	31.7
0311	amu 91	0	130	425	560	342	337	7.1	31.5
0313	amu 109	0	0	0	0	0	0	7.2	31.4
0315	amu 9	0	0	1	0	0	1	7.2	31.4
0320	amu > 10	-0.5	0	0	0	1	0	7.3	31.3
0322	amu > 50	-0.5	7016	6644	28351	35005	20622	7.0	31.6
0324	amu > 100	-0.5	0	0	0	0	1	7.3	31.3
0326	amu 9	-0.5	2716	394	11555	18555	15984	7.2	31.4
0328	amu 55	-0.5	0	3	0	0	0	7.4	31.2
0330	amu 73	-0.5	0	0	0	0	2	7.5	31.1
0332	amu 91	-0.5	0	0	0	0	0	7.6	31.0
0334	amu 109	-0.5	2	1	4	1	3	7.7	30.9
0336	amu 9	-0.5	0	1	0	0	0	7.8	30.8
0341	amu > 10	-1.0	1	0	0	0	0	8.1	30.6
0343	amu > 50	-1.0	0	0	0	0	5	8.4	30.4
0345	amu > 100	-1.0	0	0	0	0	0	8.6	30.2
0347	amu > 10	-1.0	0	0	0	0	0	9.0	29.9
0349	amu > 10	-1.0	0	0	2	0	0	9.3	29.7
0354	amu > 10	-5.0	0	0	0	0	0	9.8	29.3
0359	amu > 10	0	0	0	0	0	1	10.8	28.8
0404	amu > 10	-20	0	0	0	0	0	12.3	27.8

Figure 5. PI Band-Pass and High-Pass Data, 22 June 1977.

OBT : 0408  
 PV : -0.16v  
 AP : 13.8 torr  
 Alt : 27.2 km

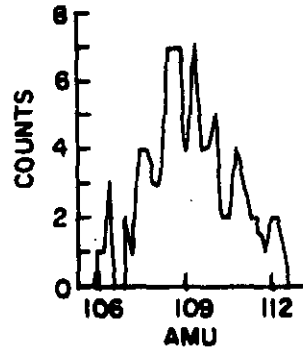
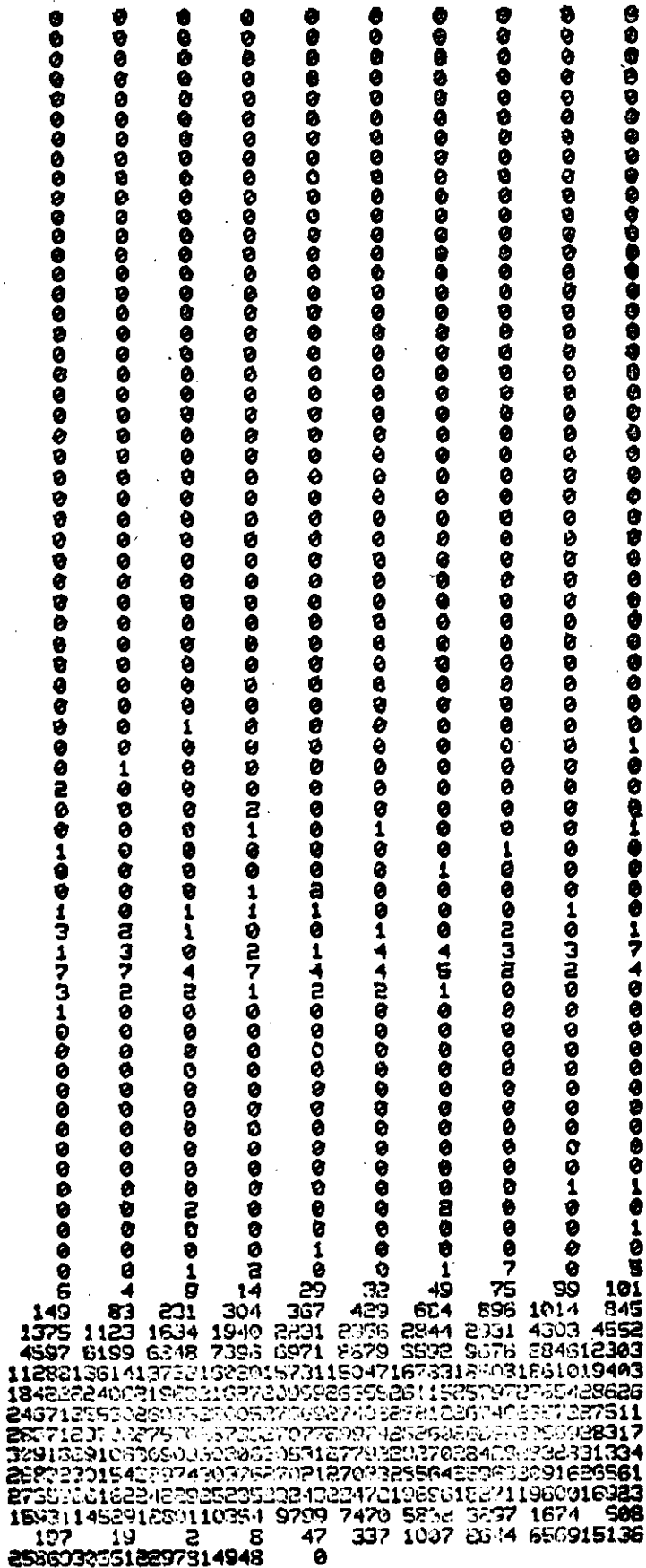


Figure 6. PI Scan Data, 22 June 1977.

Starting in the upper left hand corner and reading from left to right, the channels represent masses from amu 1 to amu 176. (See Figure 7 for the quadrupole drive calibration as determined by the analysis of gases with a range of molecular weights.) The number in each channel is the co-added sum of the last 29 of 30 scans that occur while the valve is open. The first scan is neglected because of possible valve noise. In order to compare the numbers that appear in each channel of the scan data with the numbers that appear in the corresponding fixed peak channels, the former must be multiplied by 150.

The striking feature of Figure 6 is the absence of any counts before channel 350 (amu 81) and then again from channel 500 (amu 115) to channel 590 (amu 136). This implies that the background counting rate is extremely low. The counts above channel 625 (amu 144) are known to be produced when the rf pickup amplitude exceeds the threshold of the counting circuitry. Consequently, one is led to believe in the validity of the counts centered at channel 473 (amu 109). The peak width at half-maximum is about 3-4 amu as expected for the resolution used for this flight. One might also suspect that the single and double counts observed in the channels near 400 (amu 91 is at channel 395) are ion counts also, since multiplication by 150 gives numbers of the same magnitude as those observed in band-pass operations of 0309 (amu 73) and 0311 (amu 91). This lends credence to the belief that the numbers obtained in those two band-pass operations are also valid. No counts below amu 150 were observed in the second scan operation. However, the valve could not have opened for this operation since the ambient pressure was sufficiently high to deactivate the aneroid switch in the valve open command.

Since no valid ion data could have been observed in the high-pass modes of operation, any counts obtained in those channels are obviously noise. The same can be said for the background operation at 0326. Note the similarity to the results of the 0322 operation. It

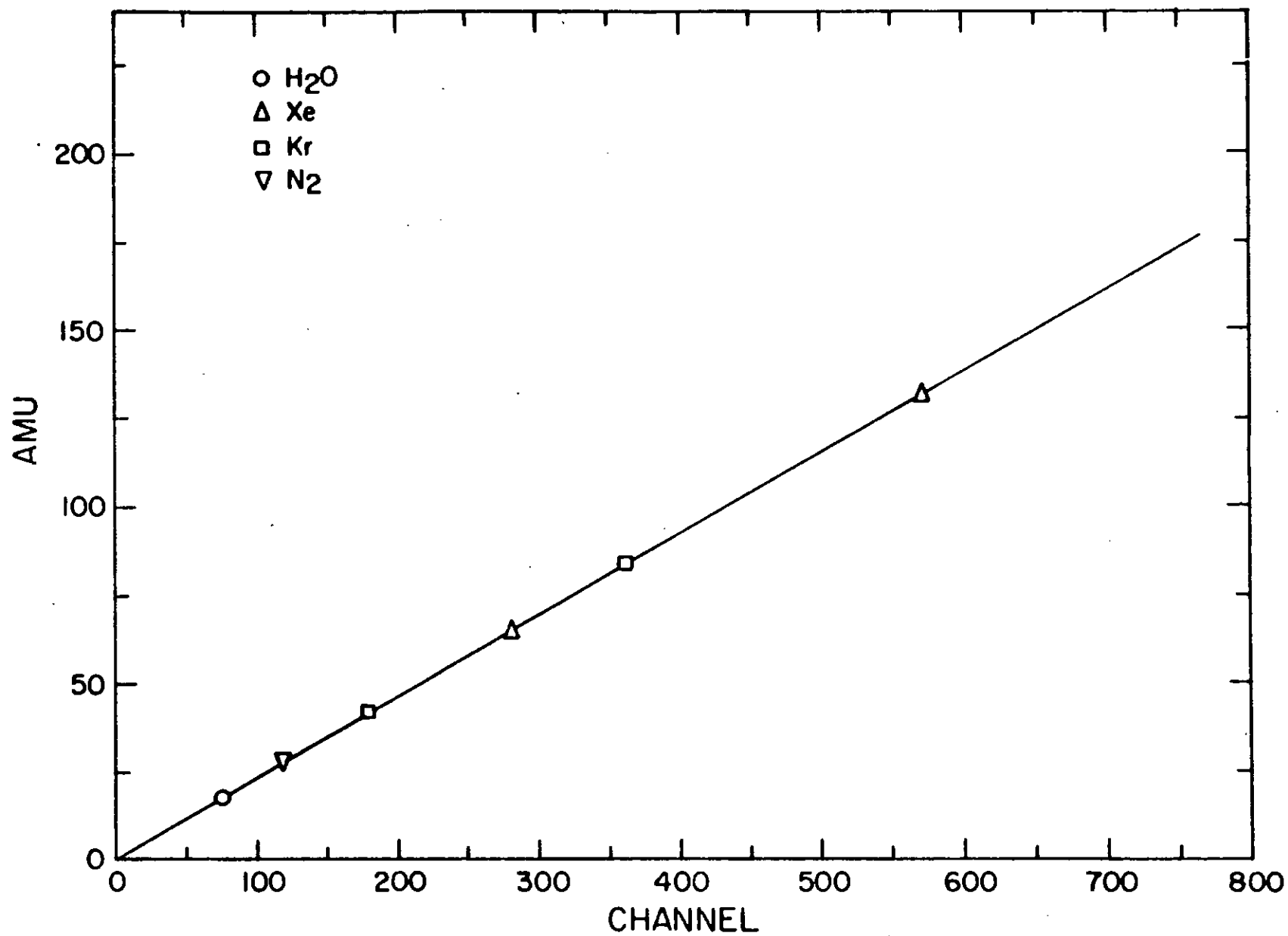


Figure 7. Quadrupole Drive Calibration.

is believed that noise caused the mass filter to perform a PIFP operation at maximum amu value. This has occasionally been observed to happen in the laboratory and the result is rf noise that is above threshold for the counting circuitry. The disparity in the numbers between channels is not real nor are the numbers themselves due to fold-over in the computer. The background operation at 0336 is also invalid since no open command was given to the valve.

For the operations at 0309 and 0311, the numbers are interpreted to be valid ion data since they compare favorably with the numbers obtained in the data scan operation. For comparison purposes with the other channels, the numbers in channel 1 could presumably be multiplied by  $6/5$  to take into account the shorter accumulation time discussed earlier. However, according to the I. D. code that is transmitted with the data, the numbers in channels 1 and 2 of the 0311 operation should be multiplied by  $3/2$  for comparison with the remaining channels. Evidently the command (TM) to open the valve was given late. This means that some extra counts from the opening of the valve could be present in either channel 2 or 3 depending on the exact time the valve opened.

One hesitates to say that the counts observed during the operation at 0334 could possibly be valid. However, the count total and distribution among channels makes this operation stand out from the other operations where few counts were obtained. It should be noted that the VacIon high voltage power supply was turned off for this and the preceding operation at 0332. It was on for all other operations.

For the remainder of the operations, one can only surmise that the valve did not open; or no ions, or ions of different amu than those looked for, were in the volume of gas sampled. The operations where data were obtained are summarized in Figure 8.

Since the balloon, parachute, and the balloon control equipment were in close proximity to the gondola, it could be argued that the

MDT	AMU	PV (v)	Altitude (km)	Descent Rate (m/sec)	Counts/sec
1034	73	0	31.7	1.7	90
1036	91	0	31.5	1.7	135
1059	109	-0.5	30.9	1.0	0.7
1133	109	-0.16	27.2	2.8	360*
----- 9 -----	Average Background				----- 0.14

\* Scan Operation

Figure 8. Summary of PI Data, 22 June 1977.

cluster ion population was substantially influenced by outgassing. Hopefully, this problem was minimized during the descent portion of the flight. The normally very dry conditions expected at HAFB did not materialize for this launch, as it rained some while the package was on the runway and the package ascended through an overcast.

e. Repair and Modifications

The mass filter package was given the usual extensive post-flight checkout. No malfunction as occurred during flight could be found with the VacIon pump or its associated circuitry. It worked normally. Characteristics similar to those during the malfunction have been observed with other VacIon pumps when they developed an internal short. Consequently, a new VacIon pump was purchased and installed.

The vacuum chamber was disassembled and the quadrupole assembly removed and inspected. One electrical feedthrough in the multiplier shield was found to be slightly loose so it was spot-welded back into place. Everything else in the quadrupole assembly was in order.

As before, the radiation shield moved down relative to the cryopump during impact and the cryopump lateral support wires were broken and had to be replaced. Fortunately, no leak resulted from repair of the cryopump assembly.

The solenoid mounting plate was bent on impact and had to be straightened. No permanent damage was sustained. As usual the valve was completely disassembled and cleaned thoroughly.

A bracket was installed between the top of the command electronics card nest and the main gondola frame to give additional support to the card nest.

A modification was made to the 3 circuit boards that comprise the master sequencer so that the clocks on all 3 boards must advance simultaneously. This prevents the on-board program from getting out of time since a spurious clock pulse must now advance the clocks on all three boards whereas before they were independent. Also, the

resistor in the trickle charge circuitry for the NiCad cells was decreased from 1M $\Omega$  to 100k $\Omega$  to increase the charge rate.

Some modifications were made to the command electronics so that the multichannel analyzer could be used for FP operations also.

#### f. Laboratory Tests

Extensive tests were run to determine why no ions were observed in the high-pass mode of quadrupole operation during the flight. It was finally discovered that the voltage on one pair of the quadrupole rods was not being held at the value of the shield voltage as required during FP high-pass operations. The voltage was actually going to the value it would assume during a band-pass operation. Since the voltage on the other pair of rods was being held at the shield voltage value, no ions could possibly traverse the quadrupole rods in the FP high-pass mode. This design error in the quadrupole drive circuitry was corrected. It should be noted that for scan operations, the high-pass mode did work properly, but none were commanded during the flight.

Cryopump hold time tests were completed after the final assembly of the mass filter chamber. Resultant hold times were comparable with those obtained previously.

Calibrations were checked for the rf drive scan ramp and the outside temperature measuring circuit.

### 3. 10 September 1977 Flight

#### a. Flight Details

The package was trucked to HAFB and arrived in the early afternoon on 4 September. Off-loading was completed and the mass filter chamber was connected to the auxiliary vacuum system that same afternoon. Package checkout that could be accomplished without the computer and TM was completed on 5 September. On 6 September the computer and associated equipment was moved upstairs and set up in the flight control room since the equipment in the TM room was being

modified. Computer and TM checkout was satisfactory so final adjustments and checks to the package were completed on 7 September. After weighing of the package was completed on 8 September, the gondola was buttoned up except for the two ends, one required for access to the control panel and the other for connection to the auxiliary vacuum system.

Launch was scheduled for 0530 on 9 September. However, during pre-flight checkout on the runway, no counts were observed during the PI scan. Since the launch crew also had problems with their checkout and the runway had to be cleared by 0600, the launch was scrubbed at 0450. When the package was returned to the building, the counting circuitry was normal. However, later that afternoon during a TM check, no counts were observed. The problem was found to be an intermittent connection in the card nest coaxial connector with the result that the output of the pulse amplifier was not always coupled to the counting circuitry. The connector was bypassed with a separate coaxial cable for temporary repair and the flight was rescheduled for the next morning.

In order to minimize contamination from the balloon and its associated control equipment, a 135 m reel-down assembly was installed between the mass filter package and the load bar. Since this gave an additional weight of 73 kg, the ballast load was reduced to 68 kg from 91 kg for partial compensation. The  $8.8 (10^4) \text{ m}^3$  balloon was valved so that after reaching float altitude near 32 km, data would be taken while the package was descending at about 2.5 m/second.

Pre-launch checkout went smoothly and the package was launched at 0435 MDT. Float was attained about 0625, flight path was to the west, termination occurred at 0857, and the package impacted at 0925.

Recovery took some time (the package was not returned to HAFB until late on 11 September) since a road had to be constructed in order to get to the package. Impact was on about a  $45^\circ$  slope with the result

that the landing gear failed to function properly. The bottom skin of the gondola, opposite the sampling valve, hit a boulder and was badly dented. Also, the top skin of the gondola was badly pockmarked from falling ballast.

#### b. Flight Anomalies

Fifteen minutes after launch, the chamber pressure readout as measured with the VacIon pump moved off zero [ $7.5 (10^{-9})$  torr] and slowly increased to about  $1.8 (10^{-7})$  torr until 20 minutes later, when it suddenly jumped to maximum and remained there. The high voltage supply was turned on and off several times to no avail, so the supply was turned off for the remainder of the flight. It is not certain whether this early increase in pressure reading was real or a malfunction. (Post-flight checkout revealed that the high voltage power supply was defective.)

The helium cryopump went dry with a resultant loss of pumping capability shortly after float altitude was attained. It is probable that a good helium fill was not obtained, although indications were positive.

#### c. Auxiliary Measurements

The outside ambient temperatures measured at altitude during this flight are about  $30-35^{\circ}\text{C}$  colder than temperatures measured during the 22 June 1977 flight at corresponding altitudes and agree much more closely with temperature data obtained from rockets. One must conclude that the balloon has a tremendous influence on the local environment since the only difference between the two flights is the extra 135 m of load line. This flight did ascend in the dark but sunrise at float altitude occurred about 10 minutes before the package reached there. This same temperature difference is observed in the bottom skin temperature measured during the two flights. Skin temperature was mostly less than  $-4^{\circ}\text{C}$  until near the end of this flight compared with a high of  $37^{\circ}\text{C}$  during the previous flight.

The gondola internal temperatures did not vary much during the flight and resembled those recorded on 22 June, even though the bottom skin was much colder.

A new cosmic ray ionization chamber was not constructed before this flight so the package was flown without this instrument.

#### d. Results and Discussion

The package reached float altitude of 32.5 km at 0230 OBT and the first on-board operation commenced on schedule at 0242. (Twenty-four minutes of OBT were run off during pre-flight checkout.) Plate voltage was set to -0.16 v for the first sequence of operations and then changed to 0 v for the second sequence. During the second sequence it became quite apparent that the chamber pressure was too high for operation but several more operations were commanded.

After the mass filter package was returned to Denver, residual gas pressure in the vacuum chamber was determined to be several Torr and somewhat higher than on the previous flight. The chamber could only be pumped down to about  $10^{-5}$  Torr indicating a leak. Earlier, the valve sector gear had been observed to be slightly rotated from its normal closed position so less than normal pressure was applied to the polyimide plunger. This probably resulted from the hard impact. When the gear was moved to its normal position chamber pressure dropped considerably. This leak could account for some of the residual pressure, but probably not more than half. Thus, it was ascertained that the valve had indeed opened during operations.

High-pass and band-pass data are presented in Figure 9 in the same format used for the 22 June 1977 flight report. It appears that chamber pressure increased sufficiently to cause multiplier breakdown during the 0258 operation. The logic circuits were being reset and the counting periods were not of the right length or the right number. Noise from high voltage arcing can produce this effect. Post-flight checks

OBT	Operation (amu)	PV (v)	Counts					AP (torr)	Altitude (km)
0242	> 10	-0.16	12	13	2	5	4	6.40	32.27
0244	> 50	"	16	6	2	0	5	6.18	32.50
0246	> 100	"	2	3	4	3	11	6.21	32.47
0248	9	"	2	3	2	1	2	6.27	32.40
0250	55	"	0	2	3	9	5	6.08	32.61
0252	73	"	6	2	2	3	0	6.14	32.54
0254	91	"	3	16	7	2	8	6.08	32.61
0256	109	"	2	6	2	7	20	6.11	32.57
0258	9	"	1	455	74926	65444	65260	6.18	32.50
0305	> 10	0	(2050) 0	0	0	(4096) 0	(7432) 0	6.43	32.24
0307	> 50	"	645	1310	2847	20998	27602	6.50	32.17
0309	> 100	"	~3(10) <sup>7</sup> in each					6.63	32.04
0311	9	"	0	0	0	0	0	6.63	32.04
0313	55	"	0	42	0	0	0	6.69	31.98
0315	73	"	0	1	1	0	0	6.73	31.94
0317	91	"	~2.7(10) <sup>7</sup> in each					7.05	31.64
0319	109	"	"					7.21	31.49
0321	9	"	0	0	0	0	0	7.24	31.46
0328	> 10	"	0	0	0	0	0	7.95	30.84
0332	> 10	-0.31	0	0	0	0	0	8.44	30.45
0336	65	"	~2(10) <sup>5</sup> in each					9.44	29.71
0340	9	"	0	0	0	0	0	10.48	29.03
0345	55	0	0	0	0	0	0	12.03	28.12
0349	73	"	~3(10) <sup>7</sup> in each					13.23	27.50
0353	33	"	0	14	0	0	0	14.36	26.96
0356	55	"	~3(10) <sup>7</sup> in each					15.59	26.42
0401	55	"	0	7	0	0	0	17.08	25.82

Figure 9. Band-Pass and High-Pass Data, 10 September 1977.

show that there is no count output from the multiplier using a hot filament ion source.

The PI scan at 0300 (see Figure 10) also indicated electrical break-down in the quadrupole, as noise started near amu 71 while none was observed four minutes earlier at amu 109. This apparent rapid rise in pressure probably resulted from pumped gas desorbing from the warming cryopump. After this time, the count numbers obtained were either mostly zeroes or near the maximum counting rate, depending on the voltages applied to the quadrupole rods. The PI scan at 0323 showed noise onset at amu 77. The last scan at 0404 showed noise onset at amu 63.

During the 0356 operation the valve was deliberately not opened and the multiplier high voltage was turned off halfway through the operation to see if there was a change in the count output. None was observed. This was the expected result. The high voltage was turned off midway through the 0401 operation also (with valve open) and again no change was observed in the output. The change in output from maximum to essentially zero counts at the same amu is due to the variability of the onset of noise. This also shows up in the scan outputs.

From first glance at Figure 9, one might suspect that the counts observed from 0242 to 0256 are valid. The operations at 0242, 0244, 0254 and 0256 have total counts three to four times the number of counts in the background operation at 0248. However, on closer inspection, 10 of the 12 counts and 10 of the 13 counts in the 0242 operation appear in single 667 microsecond blocks of data. The same is true for 13 of the 16 counts at 0244, 13 of the 16 counts at 0254 and 12 of the 20 at 0256. This type of distribution is indicative of noise. It seems more likely that the residual pressure in the chamber was already high due to warming of the cryopump. Also, background counts from the 22 June flight were either zero or one, both at amu 9 and during the PI scan.

OBT: 0300  
PV: -0.16v  
AP: 6.21 torr  
Alt: 32.47 km

78

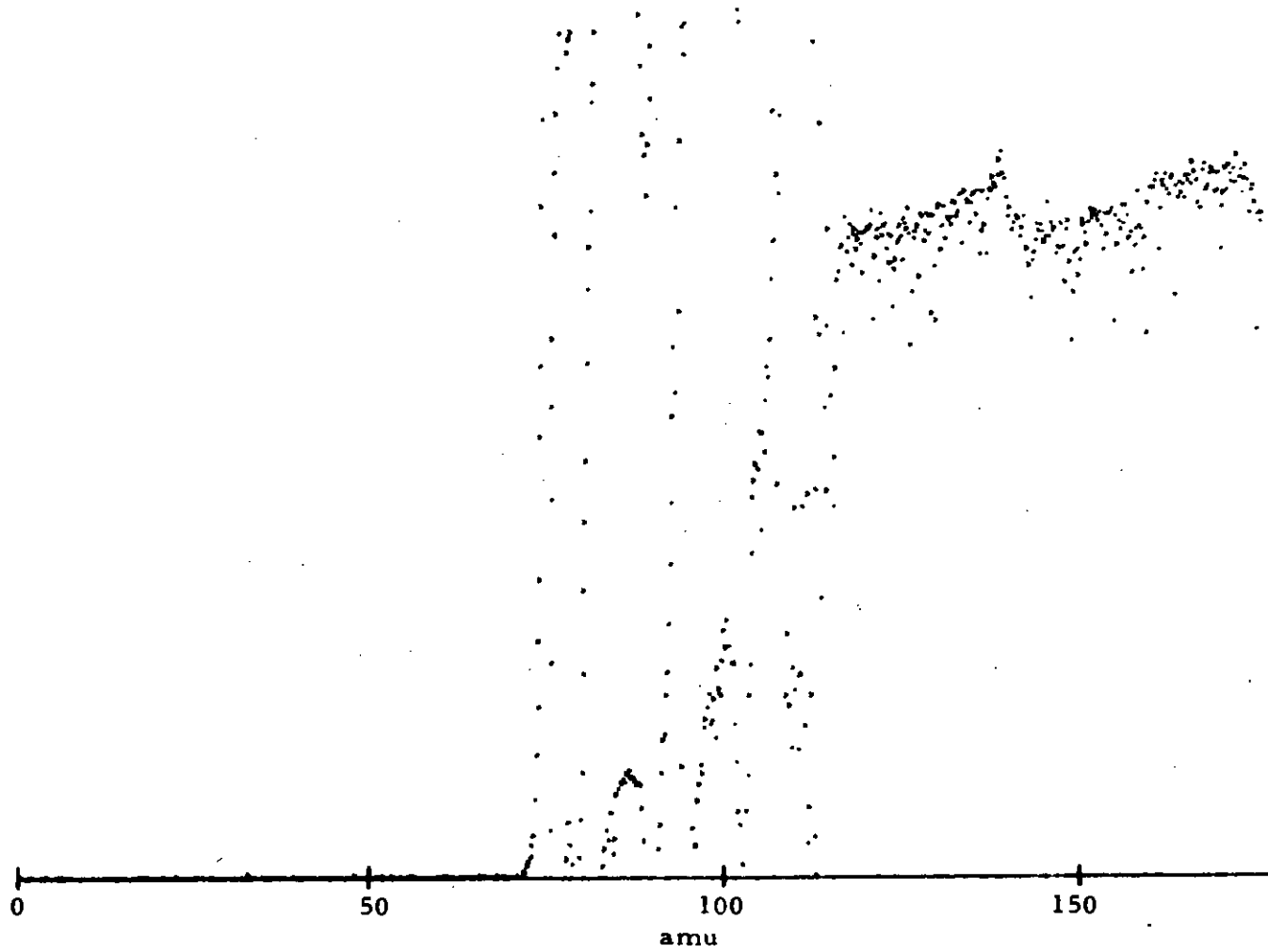


Figure 10. PI Scan Data, 10 September 1977.

A discrepancy in TM and OB-tape results showed up at 0305. The tape results were all zeroes, the non-zero TM results are shown in parentheses in Figure 9. Some transmission problems occurred at this time and the numbers on the tape are believed to be correct.

It should be noted that the first sequence of operations took place shortly after float altitude was attained and the balloon and package were still "bouncing".

In conclusion, no ion counting data were obtained during this flight due to the premature loss of pumping capability. Interesting temperature results were obtained.

#### e. Repair and Modifications

Before another flight with this instrument can be attempted, several repairs will have to be made. In addition to the anticipated damage to the landing gear assembly, other damage sustained upon impact includes the following: the plexiglass cover for the tape recorder was smashed, a terminal board was broken, a bracket from the card nest to the gondola frame was bent, the bottom gondola skin was dented, the thermistor assembly was destroyed, and the antennas were badly mangled. These will all have to be repaired or replaced. Also, the gondola top will have to be repainted and a new cosmic ray ionization chamber constructed. A new high voltage power supply for the VacIon pump will have to be purchased and installed. The electron multiplier will have to be rejuvenated or replaced.

Several modifications would be desirable. A larger dewar for the cryopump would increase the hold time. This would facilitate launch since the liquid helium could be topped off before the balloon is inflated. A longer sampling time would also be available which would be useful if it is desired to take data at float altitude instead of, or in addition to, the sampling that is done while the balloon is descending.

At the present time, the NI mode of operation is not functional. Since higher multiplier voltages than anticipated are necessary to produce the desired signal-to-noise ratio, electrical breakdown is occurring inside the mass filter chamber in the NI mode. Either some redesign of the pulse counting circuitry to filter out the unwanted rf pickup from the quadrupole or redesign of the structure inside the mass filter chamber may be necessary. One could possibly go to a channeltron type of ion detector so the high voltages could be kept to lower values. Some redesign will also have to be done to the high voltage switching circuits so that the logic circuitry does not get reset when the voltage switches. Switching takes place whenever the mode of operation changes between PI and NI. A longer switching time constant will probably be sufficient to eliminate this problem.

f. Laboratory Tests

The usual hold time tests for the cryopump will have to be done before another flight attempt. Also, a new thermistor will have to be calibrated and other calibrations will have to be checked.

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