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A MEASUREMENT OF THE ENERGY SPECTRA OF COSMIC RAYS FROM 20 TO 1000 GeV PER AMU

For the periods April 1, 1993 through September 30, 1993

and

October 1, 1993 through March 31, 1994

(NASA-CR-195246) A MEASUREMENT OF THE ENERGY SPECTRA OF COSMIC RAYS FROM 20 TO 1000 GeV PER AMU Semiannual Report, 1 Apr. 1993 - 31 Mar. 1994 (Alabama Univ.) 16 p

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Semi Annual report on NAGW-2023 for the period 1 Mar 1993 through 30 Sep 1993

An instrument to measure the charge and energy spectrum (20-1000 GeV/a) of the Cosmic Ray species O to Fe.

During the report period the BUGS-4 instrument was completed, and the maiden voyage took place on the 29th of September from Fort Sumner, New Mexico. The successful flight of a large spherical drift chamber is a unique first for the sub-orbital balloon program. Unfortunately the instrument was consumed by fire after striking a power line during landing. However, whilst at float altitude, circa 24 hours of data were telemetered. In this report the pre-flight preparations, and flight operations are described.

1.0 Science tests

1.1 Reflectivity in region B

Since it was some time since region B had been fabricated, there was concern that the UV reflectivity had degraded. Some white blemishes were observed on the bottom of region B. These were removed with alcohol. Attempts to use commercial reflectometers were compromised by the curved surfaces. Such measurements, although of interest do not directly indicate the photon recovery. Measurements were made by ratio: an attenuated pulsed UV laser (337nm) was directed into a flight tube with wavelength conversion aerial, and then into region B. A cross check was made by using the visible light from a Am/NaI light pulser, and correcting for the known variation with wavelength. These gave a recovery of (4%) which was consistent with geometric calculations.

1.2 Energy and drift time calibration region B

The energy calibration of the gas scintillation response in region B was made using the 104.58 MeV, and 80.18 MeV fission peaks, from a weak (40 pico-curie) 252Cf source. A correction for the 50 μ gm/cm**2 gold foils that covered the source was made. For the chosen gas mixture (200 torr Ar, 1.5 torr N2, and 50 torr He) this gave a signal 7% of a diametric 200 GeV/a Fe nucleus. The source was mounted on the wall of region B. Since the fission fragments stop in a few centimeters of the flight gas mixture the maximum drift time (1000 micro-seconds) was determined.

2.0 Technical Pre-flight

During the early summer of 1993 the final mechanical and vacuum integrity work on BUGS-4 was completed. The dedicated electronics was installed, and exercised. The instrument was shipped by commercial air-ride truck to the NSBF facility at Fort Sumner, New Mexico. A number of in-field modifications were made before the flight.

2.1 Electronics

All the electronics was delivered on time. The tube high voltage supplies were unacceptably noisy as delivered. The problem was corrected by paying careful attention to return current paths, and by replacing the metal face plates, which contained the output HV connectors, with insulators.

2.2 Extraction of the gas Cerenkov component from region B

As reported in the previous semi-annual report a LeCroy 6880B waveform digitiser was purchased to sample the gas Cerenkov/scintillation signal in region B. Tests of this instrument showed that it could either be used in a manner where it self calibrated, or without self calibration. The former approach was unacceptably slow, whilst the latter had unacceptable performance. The instrument was returned to LeCroy. In order to sample the two signals a 12 tap delay line was constructed with 10 ns samples. Due to the poor timing information from Regions A, and C the network was gated so that it covered the anticipated signal times in region B.

2.3 Photo-multipliers in region B

To optimize processing of the gas Cerenkov signals in region B, fast Hamamatsu (R 1250) photo tubes were installed. These 14 stage tubes were mated to the novel FET base design which provided both a fast AC coupled anode (rise time 2ns), and a DC path for use with the slowly varying drift signal. The Hamamatsu tubes had two problems: after-pulsing, and oscillation. Half of the first batch were replaced by Hamamatsu, because of after-pulsing, and all tubes showed the phenomenon: fig 2.3a. Oscillation in the output was also observed (fig 2.3b), whether the tube was operated with the FET base or a factory specified resistor base. The after pulsing in the flight set was small (10% of the primary), and the oscillation was compensated for by increasing the ADC sample time. The impact of these changes on the flight data has still to be ascertained.

2.4 Mini-bugs

The small scale version of the full instrument (MINI-BUGS) which we re-furbished prior to flight operation was a valuable diagnostic for the gas mixture in region B. Field operations in Fort Sumner were initially frustrated by unexpectedly feeble drift signals. The HV probe, which had been removed for shipment to avoid damage, was first suspected, and several test performed. Mini-bugs was used to verify the gases we were employing were not contaminated , and to check the effect of atmospheric leakage. Further investigation of the BUGS instrument revealed that the probe vacuum seal to be leaking a small amount of air into Region B. The condition was corrected, allowing restoration of normal drift pulses and preparation for the instrument for the flight.

2.5 Thermal tent

Due to one atmosphere of freon-12 in region C, which condenses at -21.62F (-29.79C), it was necessary to ensure the instruments temperature remained above this level. Detailed calculations in Huntsville showed the best thermal control could be obtained by covering the instrument with insulation (ethafoam 220), and employing an aluminised mylar tent. The tent was designed to shield the instrument from direct sun light, and collect infra-red from the earth during darkness. As the mylar tent was relatively fragile, a thickness of insulation sufficient to protect the instrument in case of tent failure was specified. However, the large, about 6 m diameter, tent proved too difficult to handle on the launch vehicle in the presence of 10-15 knot winds typical of pre-launch conditions. The tent was not used.

2.6 Gas filling

The gas filling rigs performed satisfactorily. The Freon-12 gas was added into region C by a simple displacement technique using a water manometer to both measure the pressure gradient, and as a safety device to protect against over-pressure. The Freon charge was monitored by weighing the original cylinder. Freon exhausted from region C was collected in a large plastic envelope, and then captured with a commercial recovery rig. There was insufficient time available to employ the refractometer in any of the gas regions. However, the device was tested, with samples, and found to be operating correctly.

2.7 GSE Display software

The GSE display software which was written in Microsoft 'C' by the graduate student (Mr. Petruzzo) performed adequately. It allowed us to calculate a crude square root scatter plot of signals in region A, against those in region C, and also to display primary, and amplified drift signals during the flight.

3.0 Flight operation

3.1 Mission trajectory

Bugs-4 was launched at 17:57 (GMT) on the 29th of September. Its trajectory was complex, but generally due east. Figures 3.1a, 3.1b, and 3.1c show the altitude, temperature, latitude, and longitude as measured by the CIP. Internal temperature data, and comparison with calculation will be discussed in subsequent reports.

3.2 Telemetered data

The on-board telemetry functioned correctly, with a mean data rate of 6 events per-second. Each event consisted of 144 twenty four bit words. The telemetered data was streamed to three exabytes in a triple redundant manner.

3.3 Electromagnetic interference

Although we performed extensive electromagnetic compatibility tests before launch there was some interference between science and flight operations commands, causing gain-swtiching in the instrument.

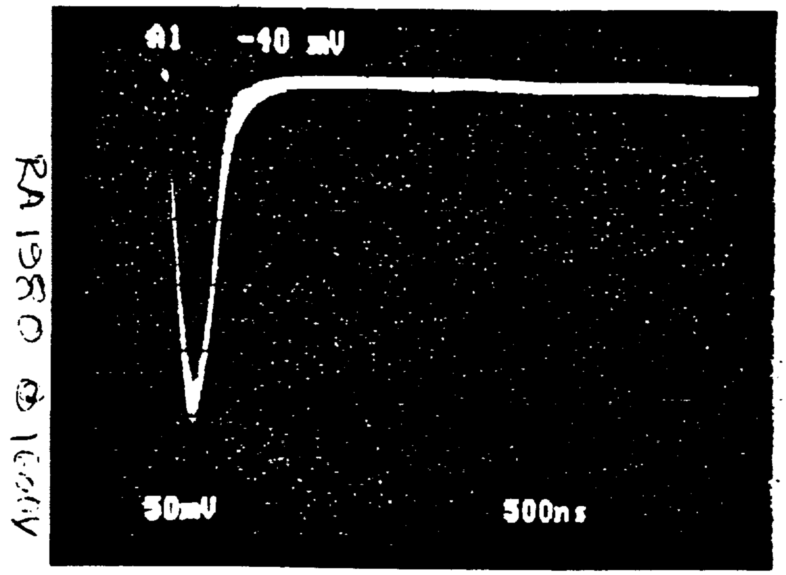
3.4 Landing

The instrument was brought down after circa 24 hours at float altitude. Descent operations went to schedule: the balloon was severed from the instrument; the parachute opened at the appropriate altitude; the parachute was cut away from the instrument on landing. Observers in the chase plane observed that the instrument struck a power line, and it is believed that sparks from the severed line ignited the scrub. The fire was spread by strong ground winds. A chemist with the recovery crew indicated there was little natural fuel for the fire, but the ethafoam 220 insulation caught fire, and the instrument was consumed. Tests with small samples of ethafoam 220 indicate it ignites easily, and evolves many joules of heat as it burns. Though the risk of such fire appears very low, experimenters should be aware of the flammability of ethafoam and be encouraged to examine the use of non-flammable insulation.

Figure Captions:

Fig 2.3a After pulsing in Hamamatsu (R1250) photo-multipliers
Best
Worst
Fig 2.3b Oscillation in Hamamatsu (R1250) photo-multipliers
Fig 3.1a Flight altitude during Bugs-4 flight
Fig 3.1b External temperatures during Bugs-4 flight
Fig 3.1c Flight latitude, and longitude during Bugs-4 flight

Best



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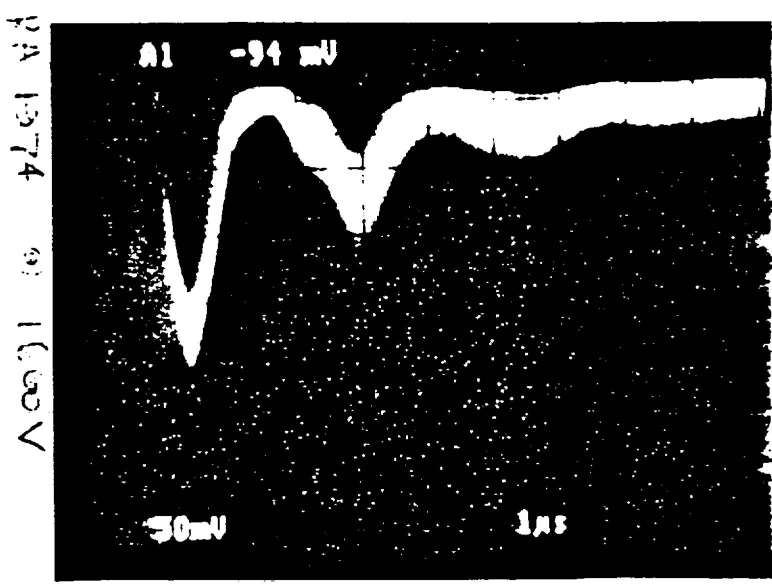


Fig 2.3a After pulsing in Hamamatsu (R1250) photo-multipliers

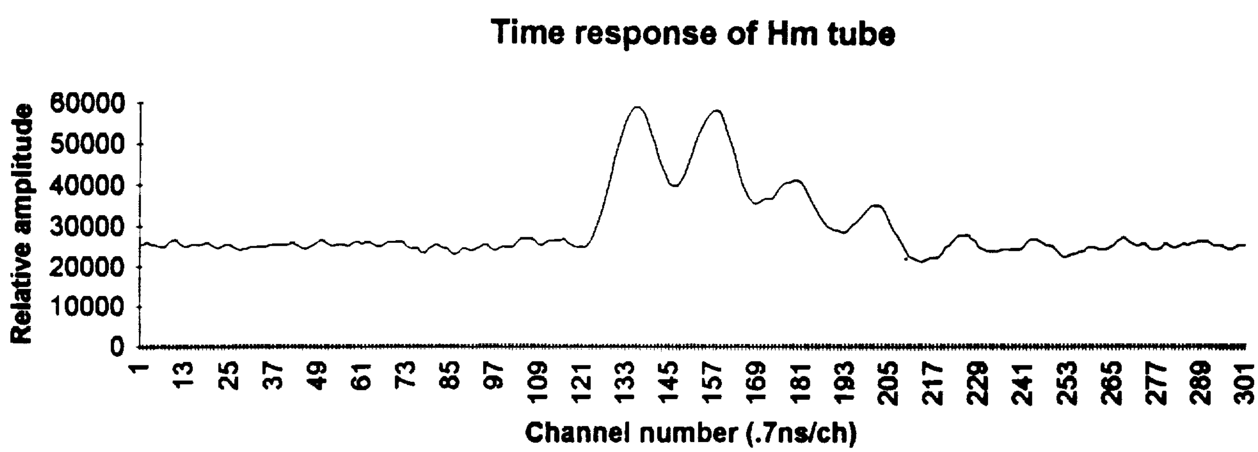


Fig 2.3b Oscillation in Hamamatsu (R1250) photo-multipliers

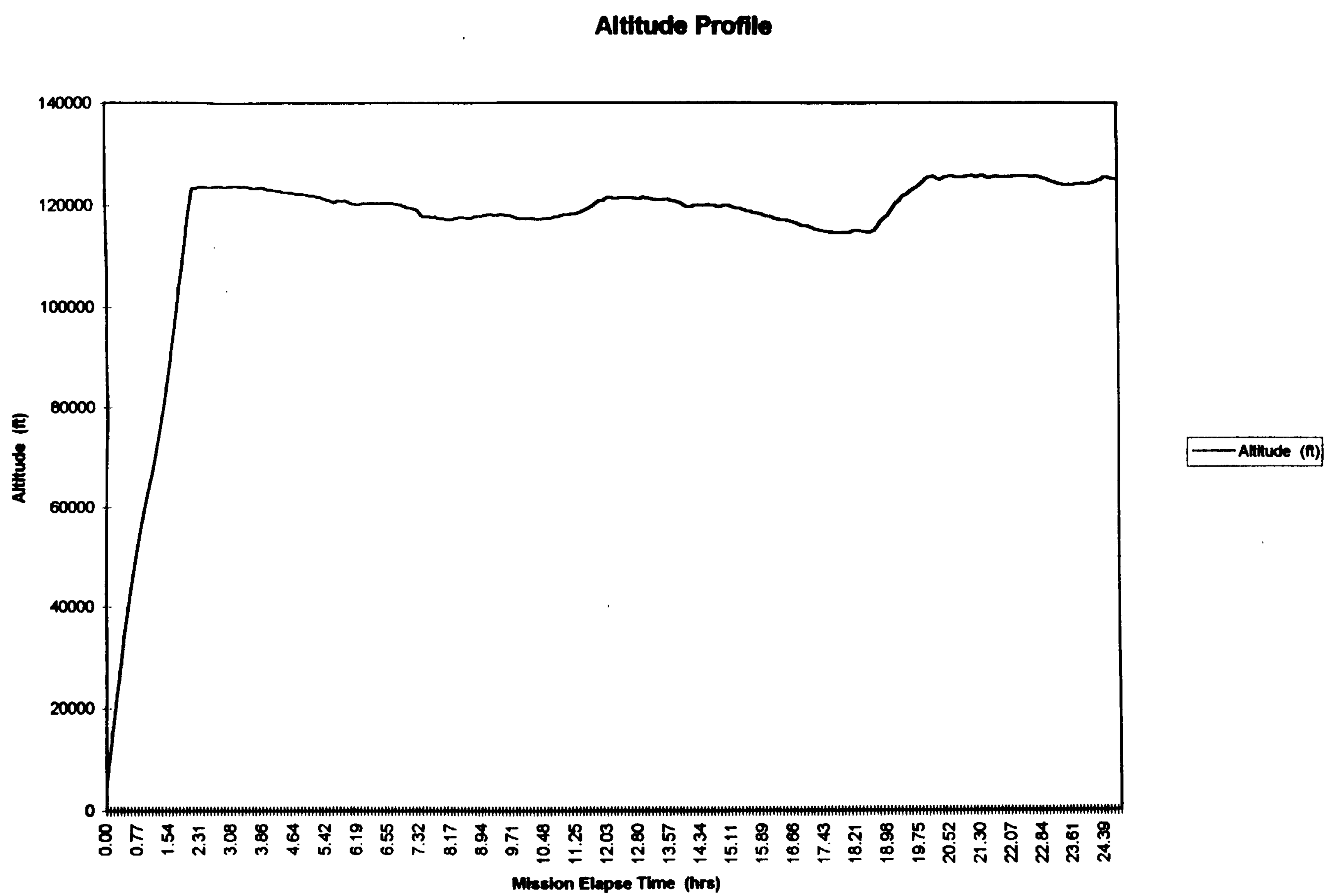


Fig 3.1a Flight altitude during Bugs-4 flight

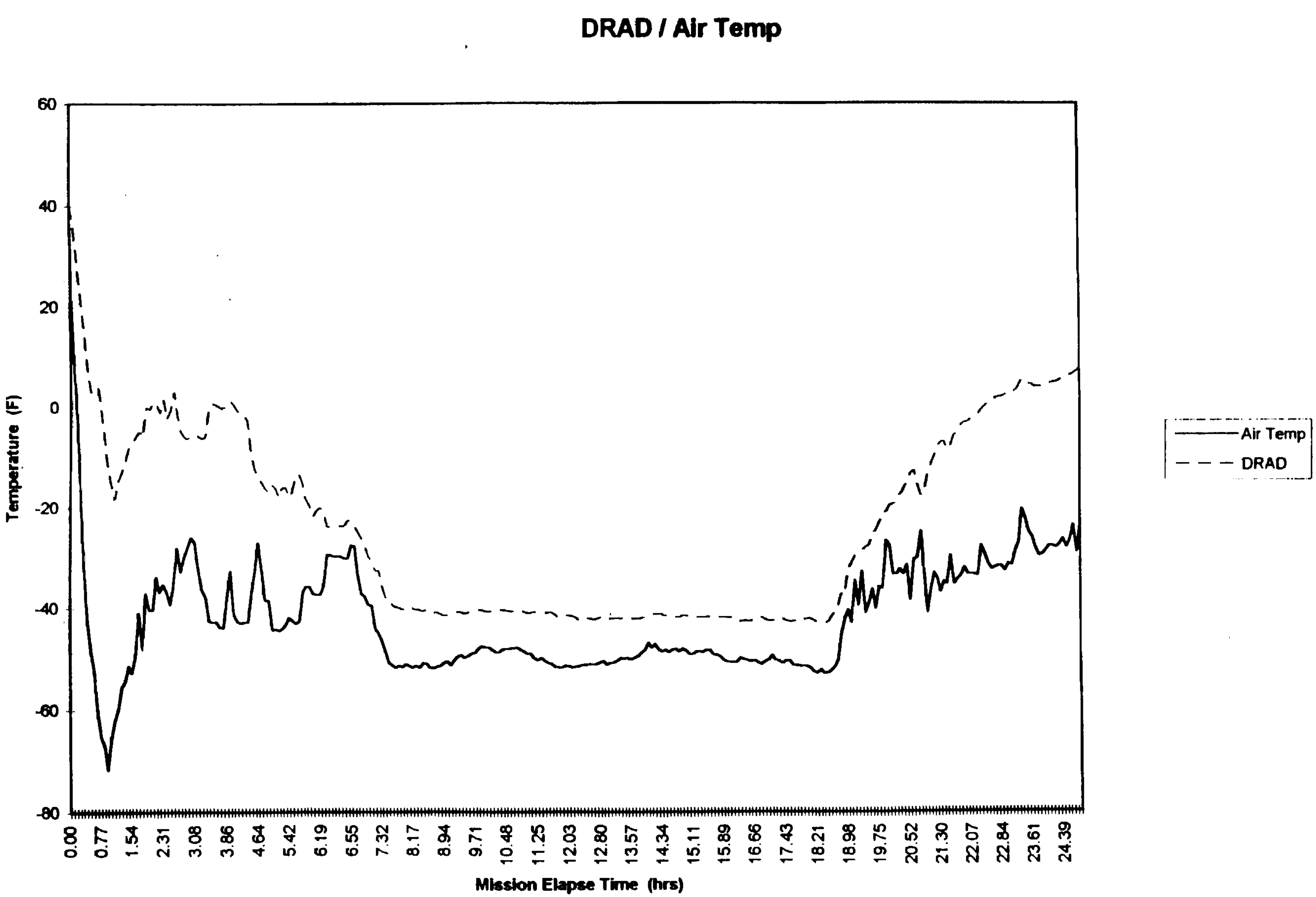


Fig 3.1b External temperatures during Bugs-4 flight

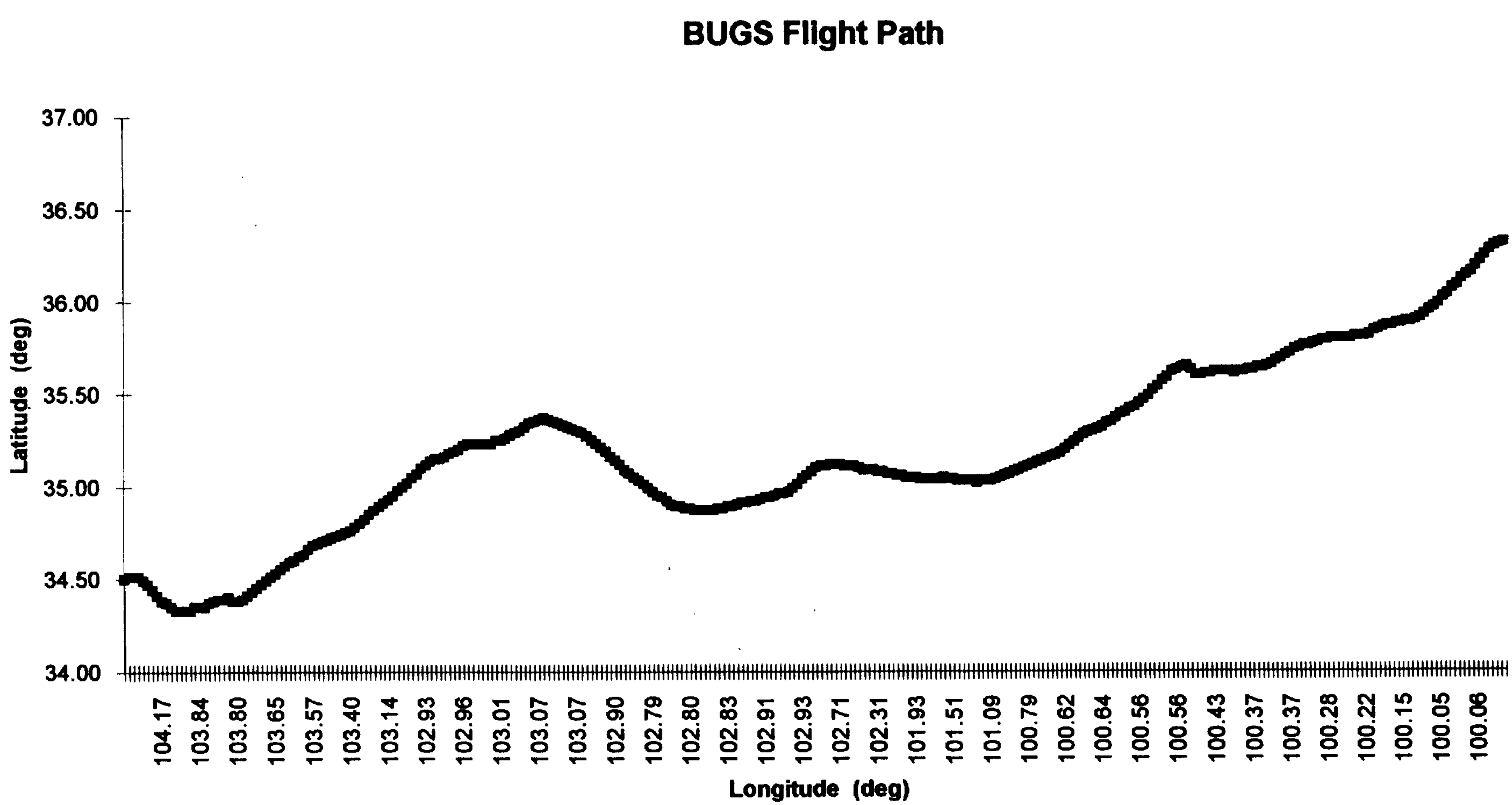


Fig 3.1c Flight latitude, and longitude during Bugs-4 flight

Semi Annual report on NAGW-2023 for the period 1-Oct-1993 through 28 Feb 1994

An instrument to measure the charge and energy spectrum 20-1000 GeV/a of the Cosmic Ray species O to Fe

Introduction

The Bristol University Gas Scintillator (Bugs-4) made its maiden flight from Fort Sumner, New Mexico on the 29th of September 1993. Although the instrument was destroyed on landing, data were telemetered for about 24 hours whilst at float altitude. In this report the first results of the analysis are presented, with particular emphasis on the performance of the large 2 meter diameter drift chamber. The flight of such a large drift chamber is a notable first for the sub-orbital balloon program. Although the analysis is still at a preliminary stage, the present results, especially the performance of the large central drift chamber, are encouraging. The reduction of the flight data tapes, and preliminary analysis of flight data are presented.

1.0 Brief review of BUGS-4

1.1 Modus operandi of BUGS-4

Since BUGS-4 is a complex detector we include a precis of its operation. The detector is shown schematically in fig 1.1. A high energy cosmic ray transversing regions A, B, and C generates several signals: A Pilot Cerenkov signal from regions A, and C; a scintillation signal in region B, and an amplified scintillation when the liberated charge reaches the high electric field region close to the central electrode. Cosmic rays exceeding 20 Gev/a also liberate a freon Cerenkov signal from region C, and those exceeding 70 GeV/a a gas Cerenkov signal from region B. All these signals are optically mediated and obtained from the 40 photomultiplier tubes in the instrument.

2.0 Data reduction

2.1 Conversion to VAX readable format

During flight, data were written as 144, twenty four bit words per event to exabyte tape. Science and engineering temperatures, pressures etc. frames were identified by the trailing word. These data were read, and converted in two independent methods, as an error check, to a form suitable for the analysis packages running on VAXstation 4060 platforms. The hardware and software of the analysis engine is well matched: a few minutes processing per hour of data.

3.0 Preliminary analysis

3.1 Flight temperature profile

In fig.3.1 we show the measured temperature data from all regions of Bugs-4 along with the calculation performed by Sverdrup. The Sverdrup calculation, which was made for a sunset launch, has been shifted to align the measured and calculated maximum. The agreement between the calculated, and measured data is good. It is hoped that knowledge of the temperature variation will be a useful handle for addressing changes in the electronic processing. Such investigations have still to be performed.

3.2 Drift Processing

Good information from the drift chamber is essential for successful analysis of the flight data. This detector provides path length information which corrects the pilot signals in both regions A, and C, as well as the primary scintillation signal in region B. Because of its importance it has been the focus of preliminary analysis. A suite of artificial intelligence routines(AI) have been developed to process the events. The routines check for multiple drifts, any electronic artifacts, and then calculate the drift time using a software constant fraction discriminator. The algorithms perform the following:

1. Correct for overflow conditions. The amplitude of the drift was digitised to 2**8. Events which overflow are detected and corrected.

2. Check for pre-amble events. The electronics samples the average preamble signal level, and sets a leading edge detector, to exclude such events.

3. Check for multiple wave forms in drift. Multiple drifts are detected and rejected.

4. Good events: have a positive gradient then a negative gradient.Any other wave forms are rejected.

5. Set up the constant fraction discriminator waveform: delay and invert drift waveform, and then add back. The zero crossing is determined, and the impact parameter calculated.

A typical drift signal is shown in fig. 3.3. In the preliminary data analysis we have concentrated on processing pristine events. We have excluded events with small pre-ambles, and with multiple drifts even when it is possible to select the appropriate signals. There are some bit artifacts: abrupt jumps in amplitude by 64 channels. These and tarnished events will be processed in subsequent analysis. Events at large impact parameters pass through more pilot than those at small impact parameters, and hence generate a relatively high pilot signal. In region B the situation is reversed: large impact parameters pass through less gas, and hence generate relativelylow signals. Corrections for both conditions are easily applied once the impact parameter is known. Preliminary scatter plots of regions A, and C against impact parameter do indeed show an increase in amplitude as the impact parameter increases. Scatter plots of region B against impact parameter behave in the opposite manner. The present state of analysis is encouraging, and bodes well for later work.

3.3 Regions A and C

Most analysis effort has been directed towards region B, and extracting the impact parameter, which is needed to understand the response of these regions. The analysis, and extraction of an element spectrum from regions A, and C are still at a preliminary stage. The situation is complex as the laser fibre tests, made before flight, indicate there is a substantial latitude dependence in the pilot response. A simple vertical cutoff model gives a rigidity of 4.1 GV at Fort Sumner, NM, corresponding to kinetic energy of 1.19 GeV/a, and a pilot signal in region A and C which is about 80% of saturation. The effects of slowing in the atmosphere further reduces this, especially for the iron group. Since the pilot response is not saturated, the charge spectrum in A and C is blurred to this degree. Extraction of the element spectrum will require a detailed understanding of the scintillation response in region B. Optimum performance of regions A and C also requires a detailed understanding and correction of all instrumental effects: adc offset changes, gain drifts, temperature variation (see fig 3.1) etc. A detailed investigation of these is underway. and is receiving the highest priority in the current phase of the work.

3.4 High energy events

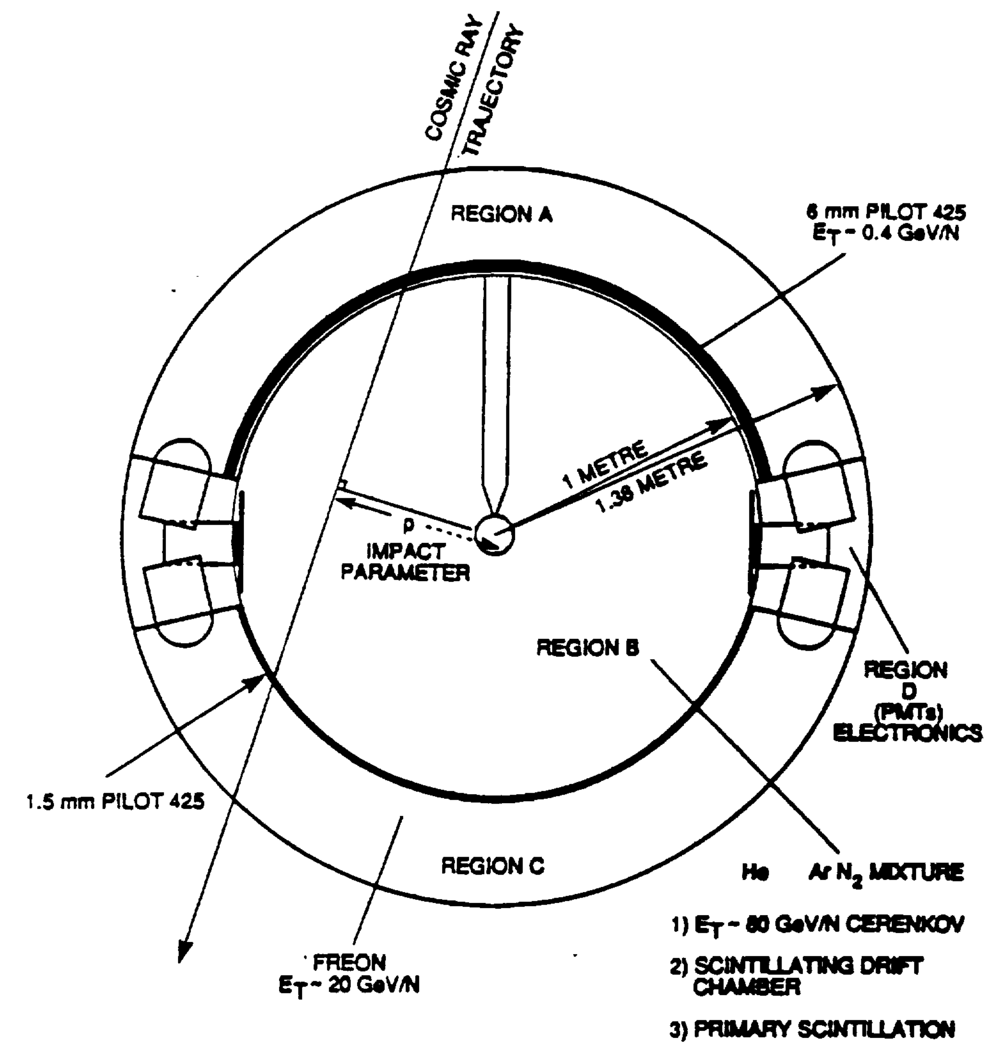
The instrument has gas Cerenkov radiators both in region C with a threshold of 20 GeV/a), and in region B with a threshold of 70 GeV/a. Extraction of information from these two gas Cerenkov radiators will be performed after the performance for the plethora of lower energy cosmic rays is understood.

Figure Captions:

Fig 1.1 Schematic diagram of BUGS-4: Bristol University Gas Scintillator 4

Fig 3.1 Measured and calculated temperatures during Bugs-4 flight

Fig 3.3 Typical drift signal
Output from software constant fraction routine



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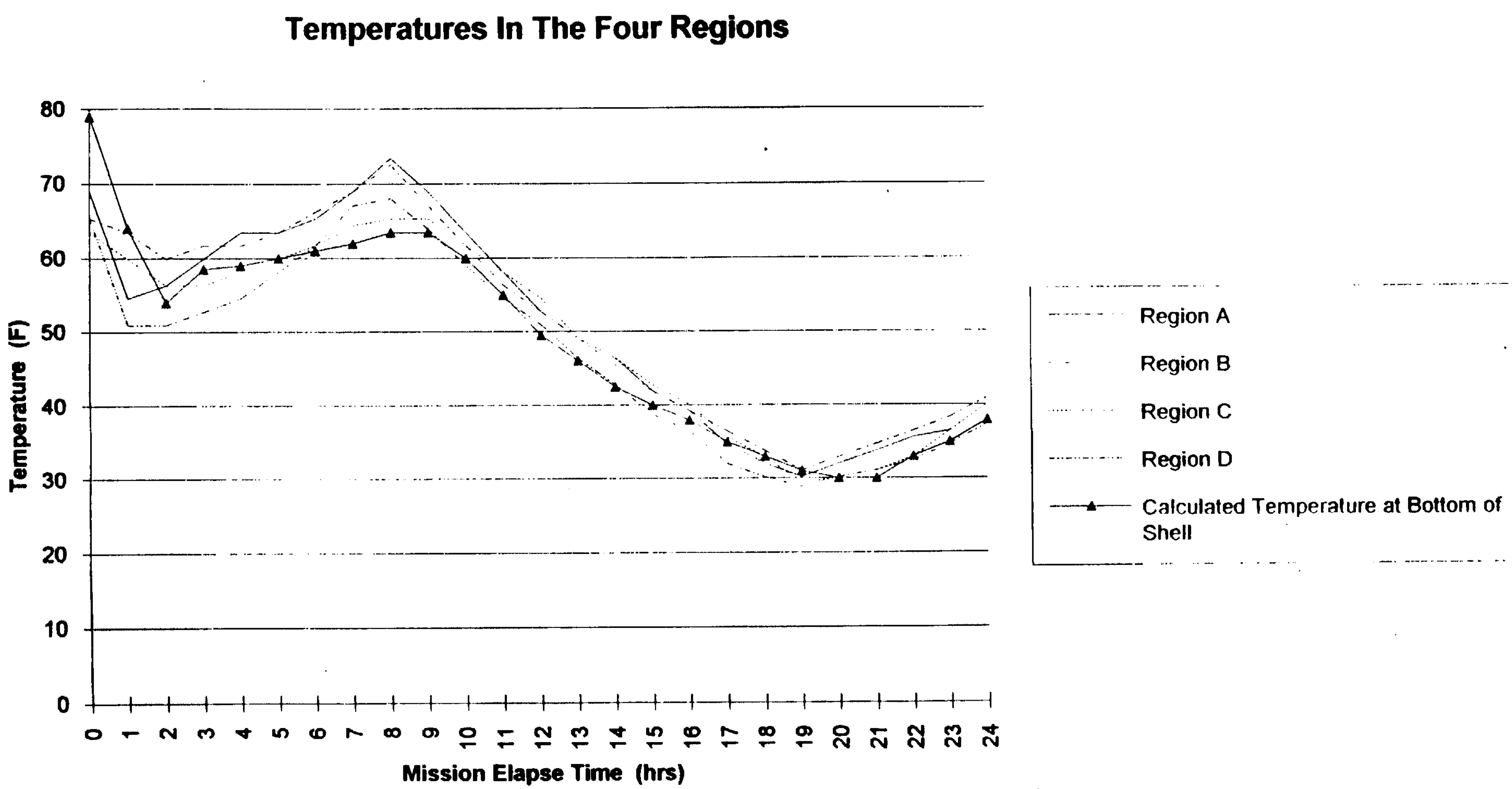

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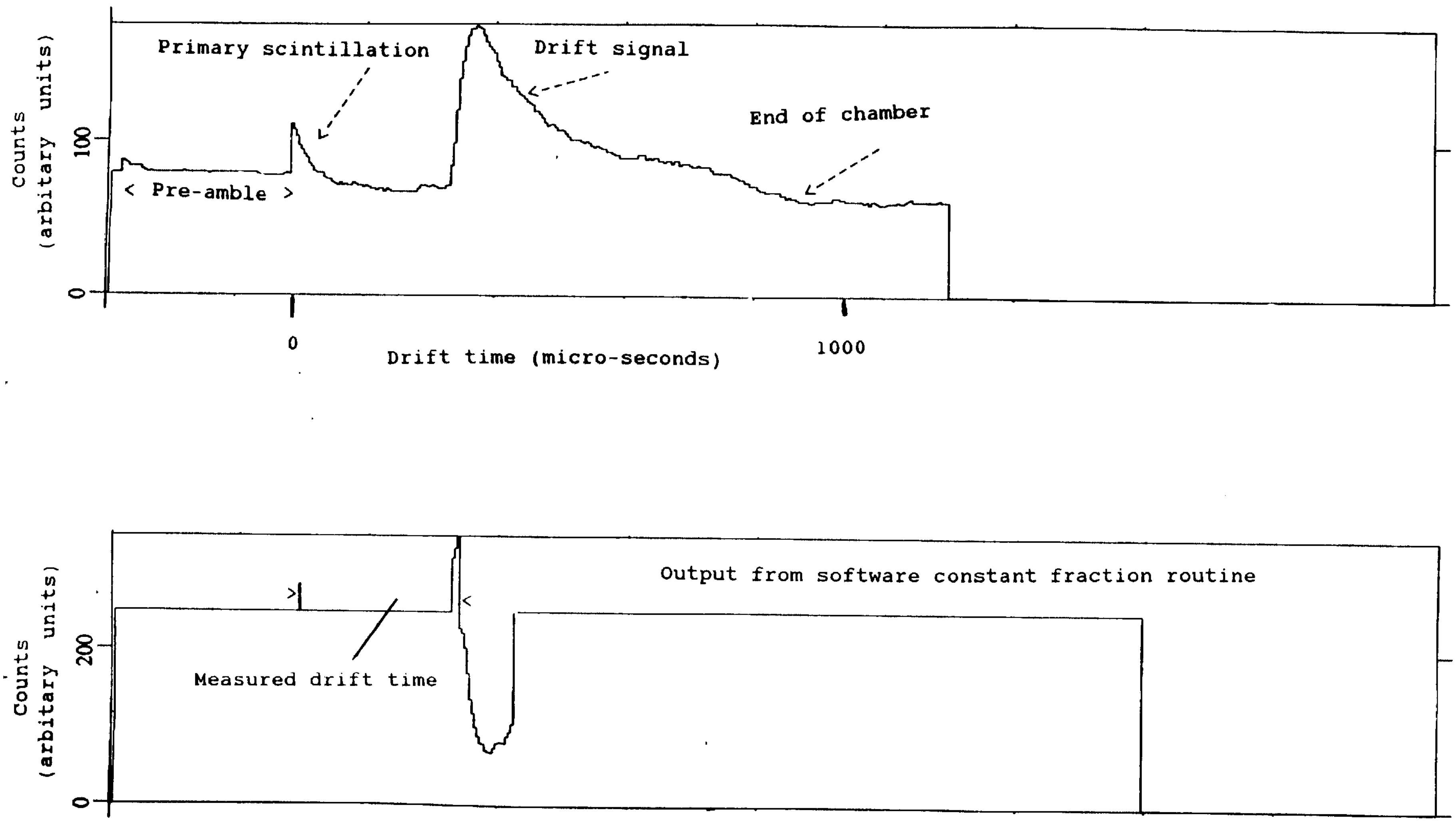

Fig 3.3 Typical drift signal