UNH- 72-04



# Orientation System for Gamma Ray Astronomy Experiments

Report On

Orientation System Performance Test

NCAR Flight 659-P

4 February 1972

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This work was supported by NASA under Contract NGL-30-002-021

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## ABSTRACT

A new and rugged orientation system for use in gamma and X-ray astronomy has been built and test flown with favorable results. This system utilizes a versatile equatorial mount for pointing detectors with weights of up to 400 lbs.

## INTRODUCTION

The physics department at the University of New Hampshire has built and flown three orientation systems for gamma ray astronomy experiments. Both collimated and uncollimated NaI spectrometers are useful in the energy range 100 keV → 20 MeV but since no focusing telescopes are yet available in this energy range, it is only necessary to use pointing systems with modest directional accuracy (1° - 2°).

The first two orientation systems were used for orienting an 11" by 4" NaI(Tl) gamma ray spectrometer and are described in a report by L. E. ORWIG et al.[1]

The latest system, whose performance is described in this report, was designed to orient a ∿400 lb. gamma ray detector with an equatorial mounting arrangement. The system has been successfully test flown using a lighter ( ∿75 lb.) detector designed to measure X-ray polarization.

[1] Orwig, L. E.,A. P. Wood, P. E. Lavoie, "A Payload Stabilization and Attitude Control Platform for High Altitude Balloon Experiments," AFCRL-70-0543.

UNH FLIGHT 659-P

This is a report on Flight 659-P (February 1972) to evaluate the performance of the new University of New Hampshire gondola and to recommend improvements. The first part of the report deals with the physical construction of the gondola followed by its flight performance. Finally, the recommendations for future use are presented.

The construction of the gondola is achieved by an extensive use of high quality steel pop rivets to give aircraft-type construction to keep the weight as low as possible and still achieve the design goal of being able to withstand up to a 10-g force when landing. This type of construction was selected instead of heli-arc welding because the strength of the unit is limited by the heating effect of welding on the adjacent aluminum. This would not meet our design goal.

The gondola (see Figure 1) is designed in three modular sections for ease of construction and repair if required and to allow separation for work on individual sections. The top section is for mounting the equatorial mount as well as being the main load-carrying member. All weight is supported by the tapered vertical-frame plate. The second or middle section is for UNH electronics to work with the detector. The bottom section is used to house NCAR electronics which gives commands to the orientation system as well as data required to operate a balloon in flight. The modular sections are bolted together by stainless steel bolts

UNH FLIGHT GONDOLA Flt.659-P

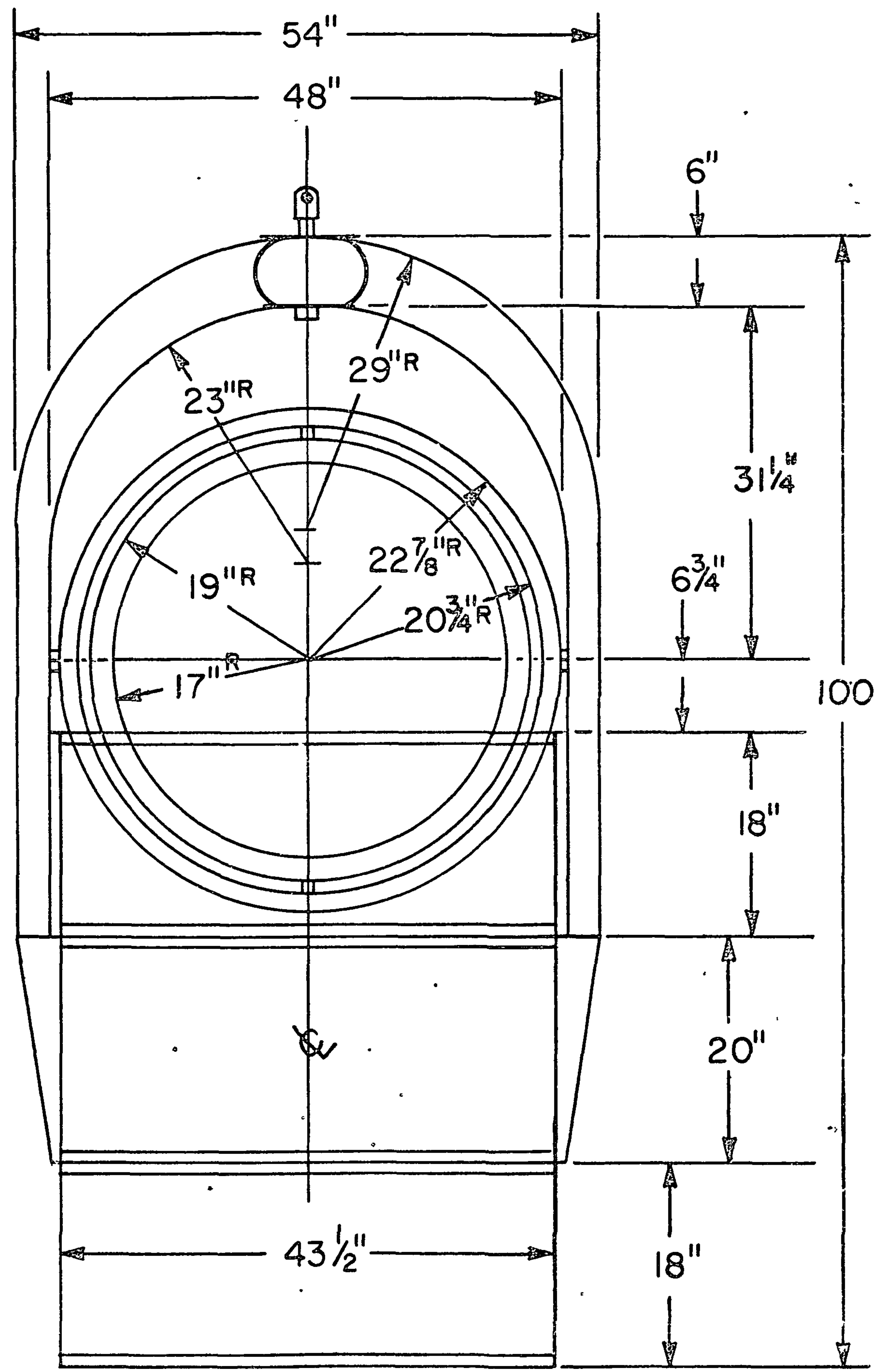
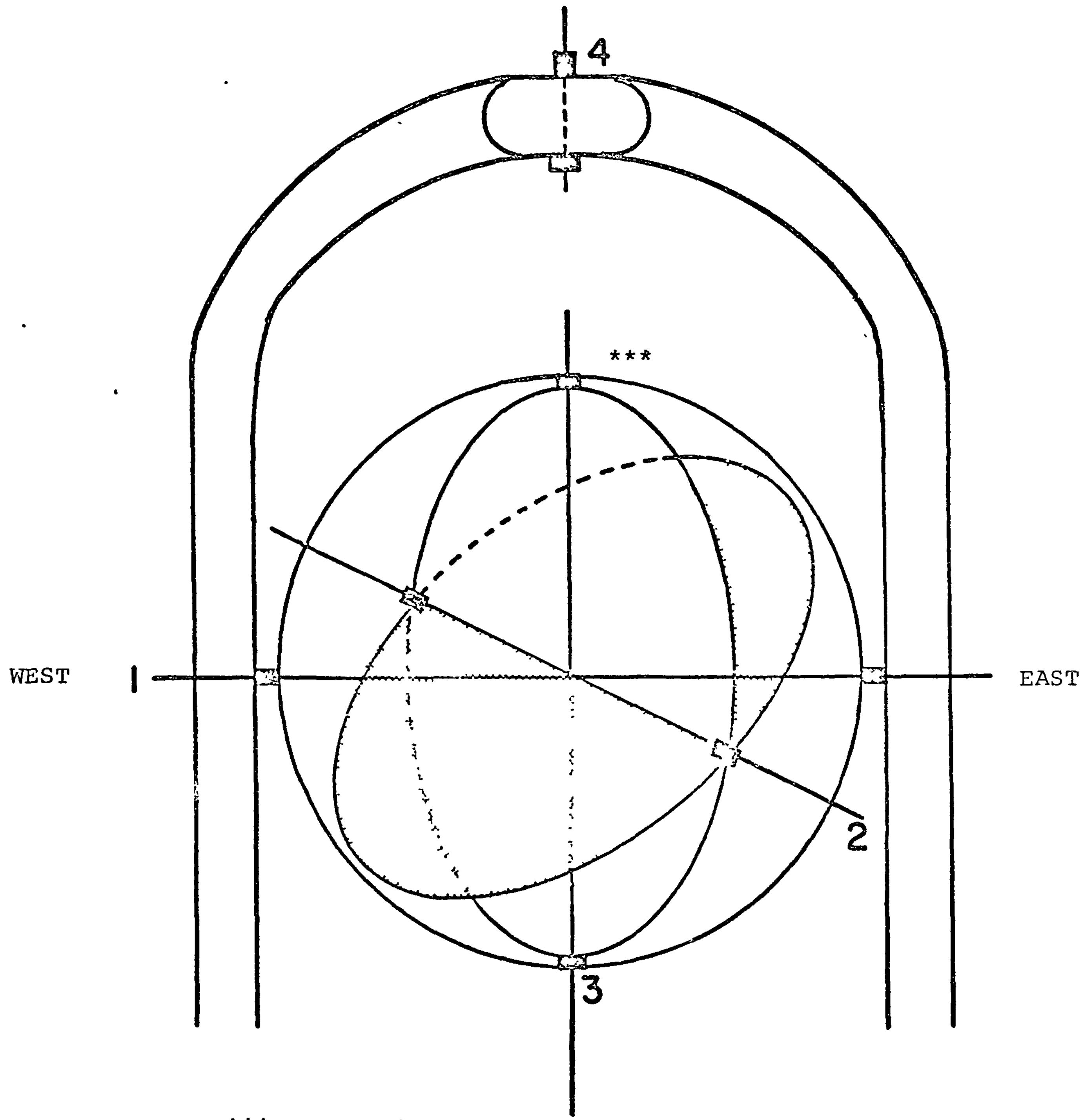



Figure 1

to facilitate easy break down of the gondola for installing various pieces of electronics. This design also provides for physical protection to all systems flown on the gondola. The modular section design enables us to repair part of the gondola if it is damaged with a minimum of manhours required. All parts of the gondola with the exception of the gears and shafts are constructed of aluminum from 1/16" to 1/4" thick. Basic gondola weight is 230 lbs.

The maximum measurements of the gondola (see Figure 1) are 100" high by 54" in diameter. The usable area of the gondola is 94" high by 43 1/2" in diameter. The payload is oriented by means of a gimbal-type equatorial mount which can hold a package of 32" maximum diameter and a weight of 400 lbs.

The equatorial mount is very useful as it can be used to fly from any latitude with presetting of axis (1) of the mourt (see Figure 2). This setting is selected by the flight latitude and is locked in position with a friction-type locking device. Axis 1 is also the east-west orientation which is maintained by using a magnetometer for reference and Axis 4 is decoupled from the balloon by a swivel and a correction drive rotated the package until it is at the east-west reference or null. Axis 2 is set for the declination of the celestial source and normally is locked into position. Axis 3 is the hour angle or right ascension which is controlled by command to point at the celestial source for the particular hour of the flight. If the particular experiment needs more than just hour angle corrections, Axis 2 is unlocked and command driven




*** Equatorial axis shown for gondola at North Pole

1 Axis set for flight latitude

2 Axis for declination of celestial source

3 Axis for hour angle

4 Axis for rotation for East-West null

Figure 2

along with Axis 3 so now there is right ascension and declination control along with the fixed east-west reference. The right ascension and declination are command controlled from the ground and can be moved in increments of 1° - 10° - 90° independent of each other. The position of these angles is measured by means of 9-bit shaft encoders.

These units are of a brush-contact design with a 1° resolution, built and designed by UNH for less than half the cost of commercially available units. They are also more rugged than their commercial counterpart, so they may be used for more than one flight reliably.

Directly below the oriented payload section there is a space 20" high by 43 1/2" in diameter with a stressed-aluminum membrane base plate which is used to hold experiment electronics, batteries, and the telemetry transmitter for flight data. The bottom side of this membrane serves as the top of the third section (see Figure 3), 18" high by 43 1/2" in diameter, which is used to house the electronics which receives the commands for operation of the balloon and the commands for various functions of the flight gondola.

The 9-bit encoder gives us 1° angle readout resolution; one revolution equals 360° and this information is read out by 7-segment readouts in the system ground station. Thus the operator will know the pointing angles at all times at a glance.

This data is transmitted to the ground via a VHF transmitter using subcarrier oscillators. A 3.9 kHz subcarrier oscillator is

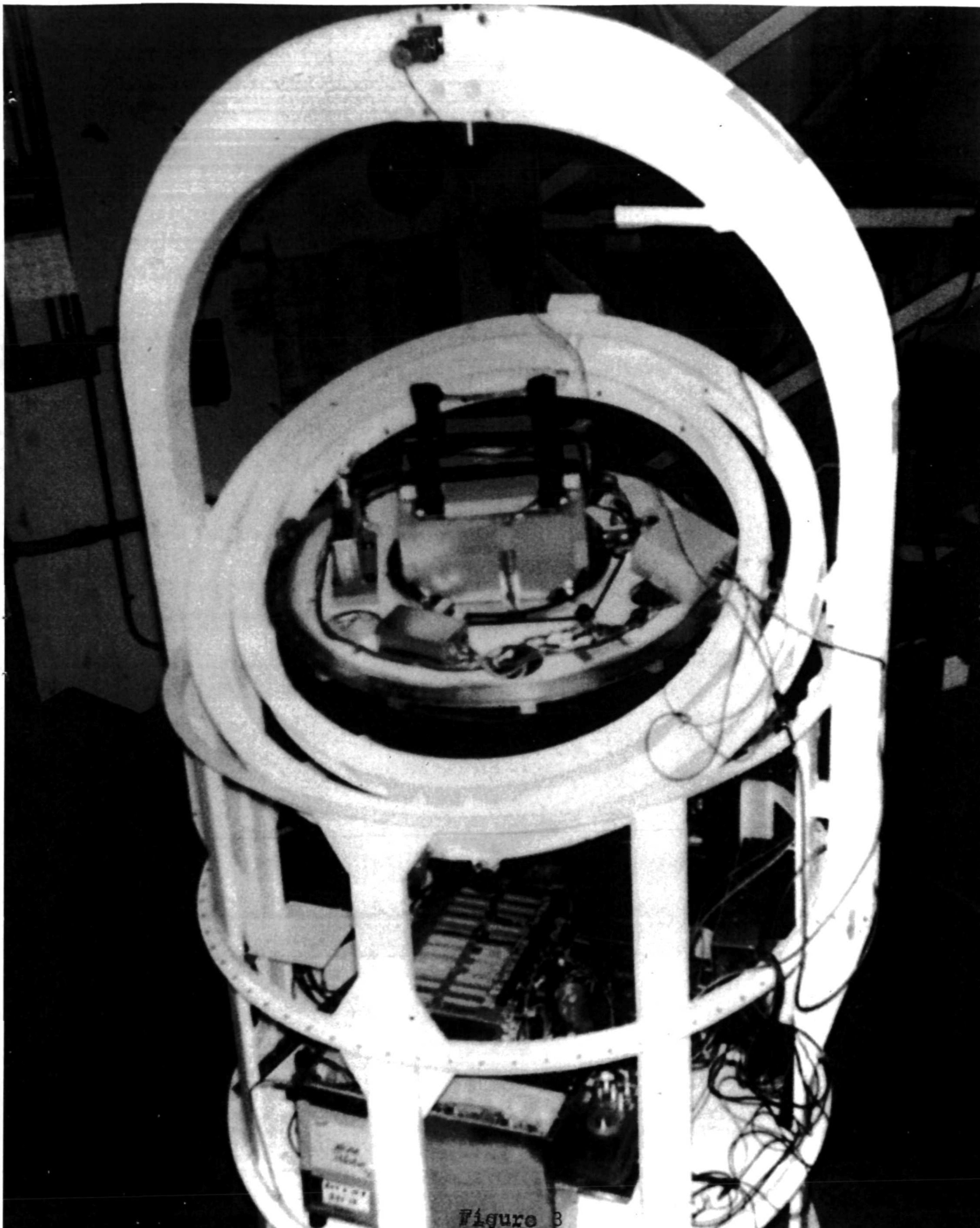


Figure 8

used for the clock pulses to synchronize the flight unit and the ground station. A 5.4 kHz subcarrier oscillator is used to carry the data from the angle encoders along with other digitally encoded information as to which parts of the orientation system are activated and other information needed to keep the platform and package operating in its designed manner. The displayed data is updated every two seconds for a very continuous status of the flight instrument. The overall pointing accuracy should be better than ±2°, which is more than adequate for present-type gamma ray detector systems.

The complete payload platform is oriented by means of a fixed magnetometer referenced to the magnetic North. The magnetometer gives an error voltage which corresponds to the positional error in the platform from the desired reference direction. This error voltage serves as the drive for a small DC servo motor which is pulsed to conserve power. The motor is used to drive the gondola against an inertia reaction boom. This is done via a worm-drive gear box. The boom consists of a long length of structural aluminum with weight on the ends to give inertia for the platform to work against to bring it back to reference. The pulse system for the correction drive is designed to vary the pulse repetition rate for the varying amounts of error signal so the larger the error signal the faster the package corrects toward its reference point thus helping to eliminate oscillations. The corrective drive is powered by command from the ground and usually is turned off on ascent and turned on only when pointing of the system is desired to conserve power.

On 4 February 1972 the gondola described above (see Figure 4) was launched from Palestine, Texas at 2150 GMT. The launch weight of the gondola, including crush pads and exclusive of NCAR flight electronics, was 578 lbs. For this flight the inertia boom was 15' long with 15 lbs. of lead on each end. The complete system was isolated from the balloon and flight train by means of a low friction swivel. The balloon used was 11.1 million cubic feet. The altitude achieved was 130,000 feet which was planned float for this flight, and the flight duration was less than desired due to very high winds at this altitude. The usable data at float was approximately three hours because of the range limits of the telemetry. The payload was recovered in a ravine 40 miles southwest of Roanoke, Virgina, on 6 February 1972. The physical damage to the entire gondola was extremely slight.

When the gondola had nearly reached the desired float altitude, the correction drive system was turned on to bring the platform to the desired pointing attitude. Approximately 30 seconds after turn-on the system had rotated from its free position to near its desired reference pointing position or null. Nine minutes from turn-on the platform achieved a maximum plus or minus deviation from null of $\pm 5°$, and at 12 minutes the platform achieved its flight deviation from null of $\pm 2°$. This period is due to incomplete decoupling of balloon from the platform (see Figure 5).

The pointing of the payload for this system used only the right ascension drive to keep the detector on the desired course. The payload declination was fixed to that of the source being

Figure 4

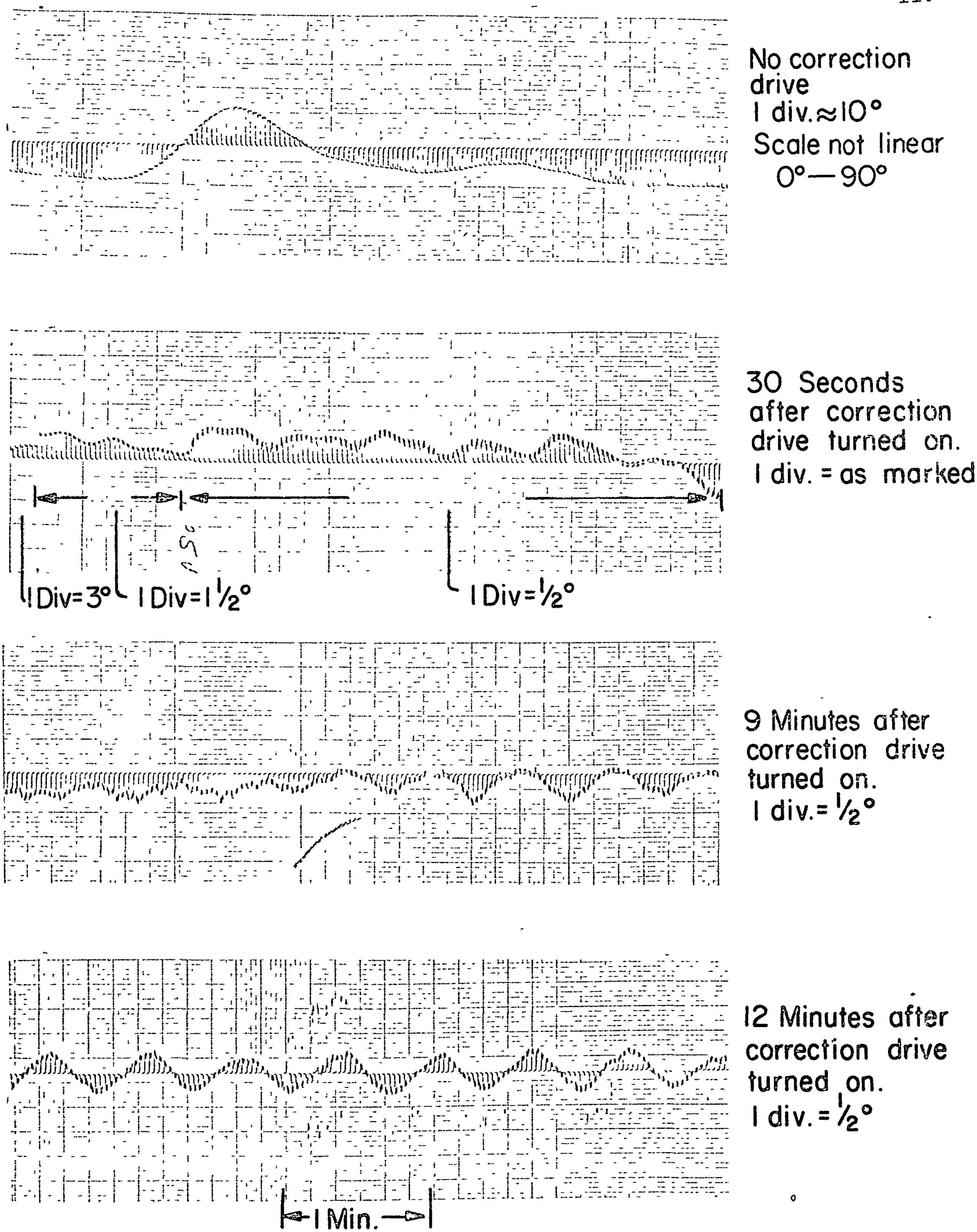

No correction drive
1 div. ≈ 10°
Scale not linear
0° — 90°
30 Seconds after correction drive turned on.
1 div. = as marked
1 Div = 3°
1 Div = 1 1/2°
1 Div = 1/2°
9 Minutes after correction drive turned on.
1 div. = 1/2°
12 Minutes after correction drive turned on.
1 div. = 1/2°
1 Min.

Figure 5

observed. The commands to execute changes in angles were given in 1° and 10° increments. The 90° command was not used in flight as the corrections were always less than 90°. The pointing angle of the system was displayed on the ground station and an occasional error was noted when command for a 1° would effect no change in the readout. When the next command for 1° was given,a 2° change was noted in the readout. A log was maintained at all times documenting the response of the pointing system to commands given, thus eliminating questions dealing with the pointing direction of the detector (see Figure 6).

As the balloon was reaching the limits of telemetry contact from Palestine, the detector was rotated in hour angle ahead of the desired pointing angle to allow time for the downrange telemetry station to take over commanding the package and recording the data. Due to circumstances not yet clearly understood, the downrange station never was able to command the package but telemetry data was recorded. Since no command could be transmitted to the package, the payload was not turned off as is normally done to save the batteries from possible over discharge damage. On 5 February 1972 when the recovery crew arrived at the package, the system was turned off at approximately 12 noon. All batteries were in a fully discharged state but subsequent testing indicates that no damage was incurred and the batteries are ready for future use.

The electronics for the orientation and control of the payload pointing (see Figure 7) is enclosed in an aluminum box 3 1/8" wide, 14" long, 8" high, and insulated with 2" styrofoam, covered with

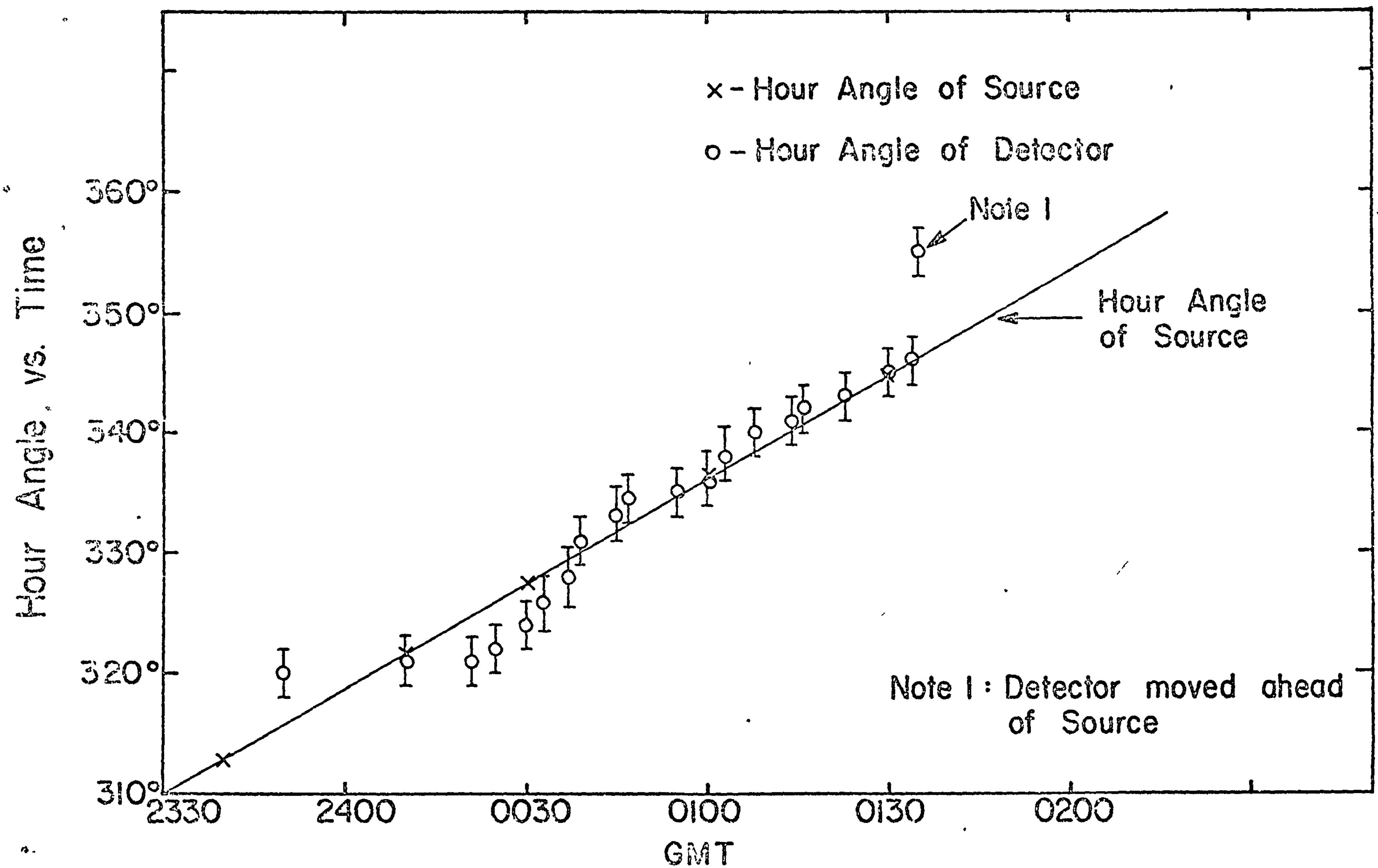

x - Hour Angle of Source
o - Hour Angle of Detector
Note I
Hour Angle
of Source
Note I : Detector moved ahead
of Source
Hour Angle vs. Time
360°
350°
340°
330°
320°
310°
2330
2400
0030
0100
0130
0200
GMT

Figure 6

ORIENTATION ELECTRONICS

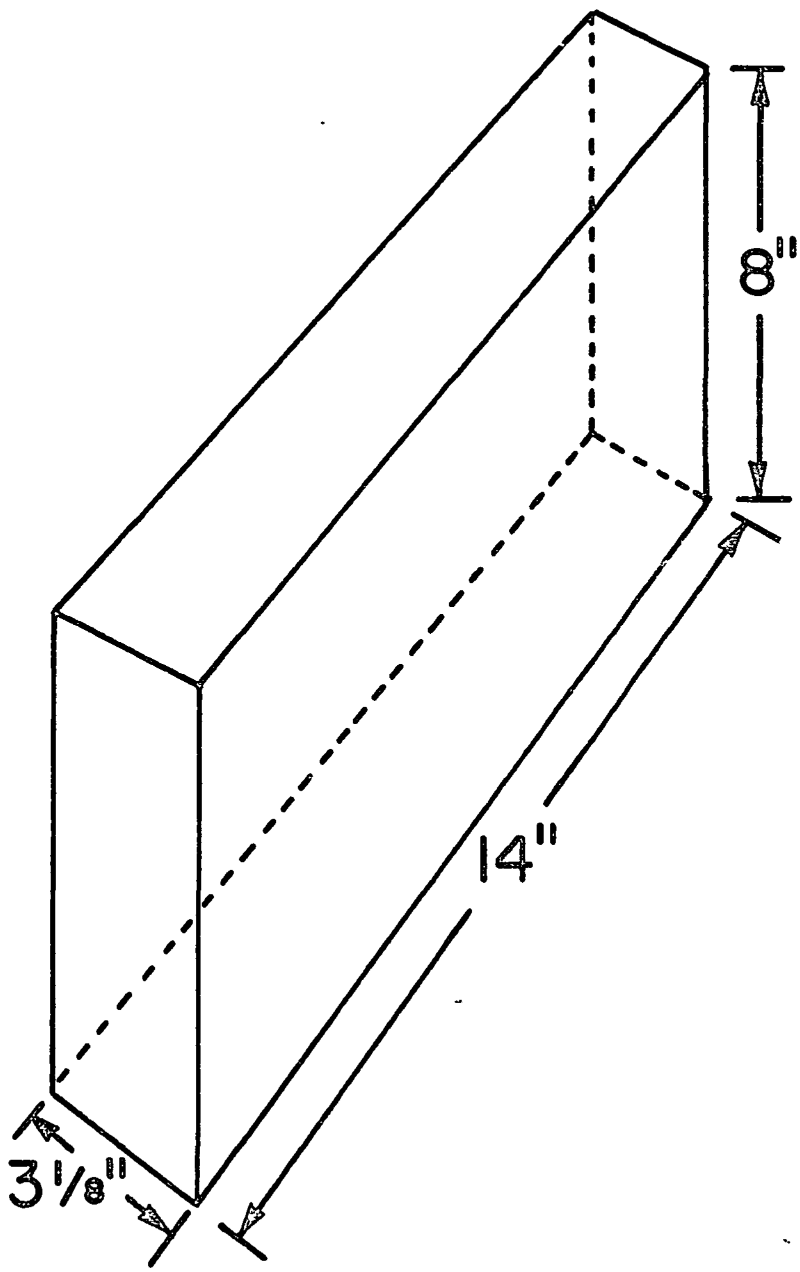



Figure 7

aluminum foil and painted white. The power consumed by orientation electronics ≈12 watts. External heater power of 18 watts was provided if needed. This power was thermostatically controlled to apply heat if the temperature dropped below 15°C. The temperature of the orientation electronics was well within design tolerance (see Figure 8). At launch it was 29°C, reaching a maximum temperature of 37°C and minimum temperature of 27°C. This verifies that external heat was not needed. The outside frame temperatures for this flight ranged from 13°C at launch to -36°C and -49°C. This proves the quality of the temperature control system of the orientation electronics.

Though there are no major changes proposed in the current design, some corrections should be made for future flights. Improvements can be made in the correction drive. While the system did maintain the ±2° pointing accuracy, the correction drive response was slower than desired. An adjustment in the correction drive sensitivity and a better decoupling from the balloon flight train should be attempted. It might be possible to eliminate some of the hour angle error of ±1 - 2° by a gear box with less play. Some readout error is undoubtedly due to the encoder which should be improved noticeably by a more accurate alignment of the encoder brushes. Another improvement, or check, on pointing accuracy could be the use of another magnetometer, camera, or solar sensor of some design to verify the pointing direction.

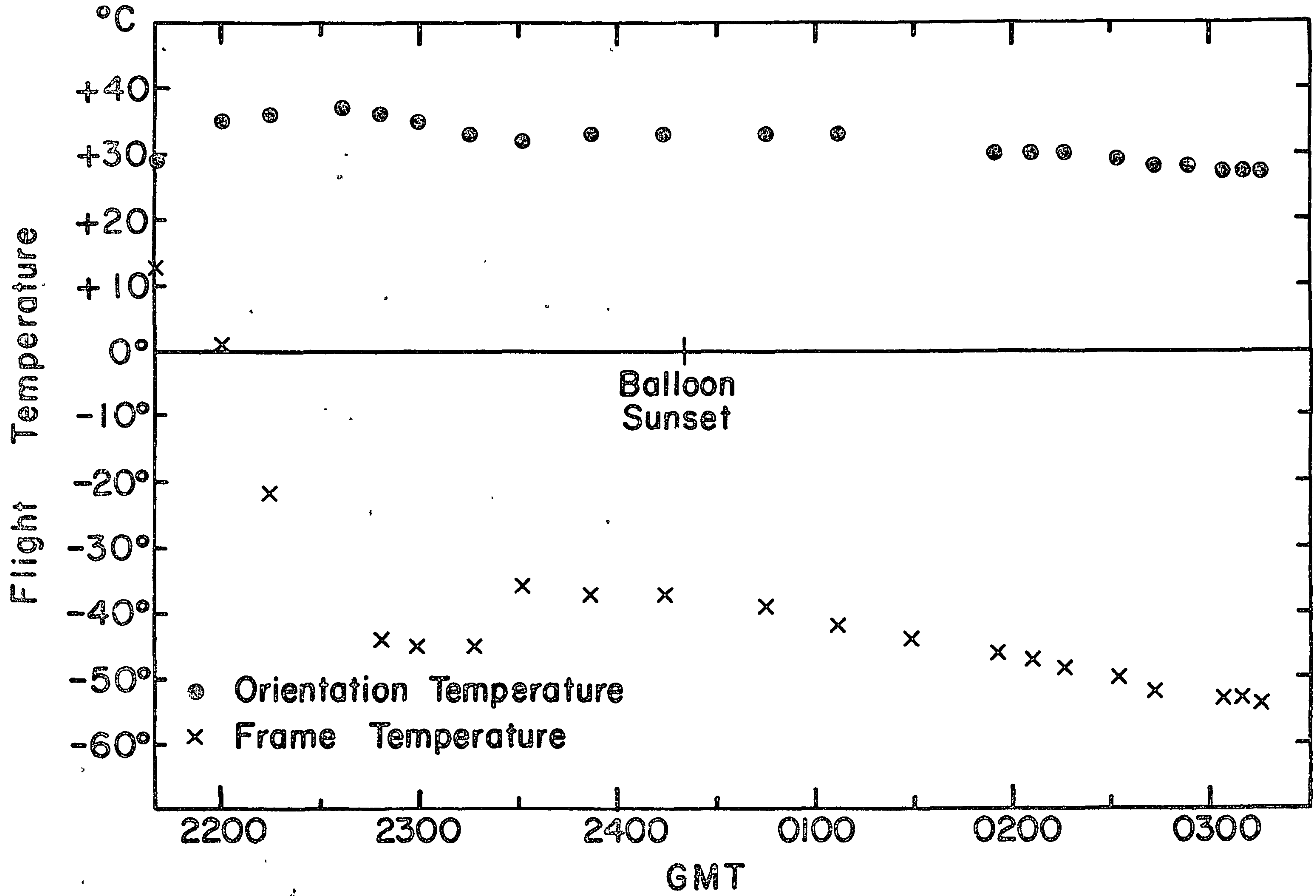

°C
+40
+30
+20
+10
0°
-10°
-20°
-30°
-40°
-50°
-60°
Flight Temperature
Balloon
Sunset
Orientation Temperature
Frame Temperature
2200
2300
2400
0100
0200
0300
GMT

Figure 8

Last, but not least, the reason for the lack of downrange command link to the system should be investigated and the problem eliminated.

As the results of the test flight for the completely new gondola and orientation system show, there were no serious problems; thus the system operation must be classified as a success.