THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

Department of Aerospace Engineering
High Altitude Engineering Laboratory

Quarterly Report

HIGH ALTITUDE RADIATION MEASUREMENTS

1 October, 1966 - 31 December, 1966

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Abstract

This report is a summary of project activities during the period 1 October, 1966 to 31 December, 1966. Interferograms obtained on the May 1966 balloon flight have been analyzed, radiation spectra have been calculated, noise levels established and atmosphere temperature structure calculated. Details of a precise model of the earth for albedo purposes have been studied. Laboratory testing of the IRIS interferometer and preparations for the next balloon flight for earth radiation measurements are described.

I. Introduction

This is the 16th quarterly progress report on Contract No. NASr-54(03), covering the period 1 October 1966 to 31 December 1966. The project effort during this time was divided among the following tasks:

1. Analysis of balloon flight data.
2. Study of a model of the earth for albedo purposes.
3. Laboratory testing of the IRIS interferometer.
4. Preparations for the next balloon flight.
5. Report writing.

II. Analysis of Balloon Flight Data

Analysis of the IRIS interferometer data has continued. Spectra (500-2000 cm^{-1}) of outgoing earth's thermal radiation, as measured at 33.5 km altitude, have been calculated for several times during the balloon flight. The experimental spectra in the 600-750 cm^{-1} region have been compared with spectra calculated from theoretical CO_2 transmissivities, neglecting the effects of water vapor and ozone. The measured and calculated spectra show excellent agreement.

Errors in the experimental data have been studied by examination of blackbody calibration data taken at regular intervals throughout the balloon flight. Comparison of the measured blackbody radiance with radiances calculated from the Planck Radiation Law indicate a mean square error of $0.3 \cdot 10^{-7}$ W cm^{-2} sr^{-1}/cm^{-1} for a spectrum calculated from the average of three 10 second interferometer scans.

There is one spectral region in which data is poor because of vibrations arising from auxiliary instrumentation.

Systematic errors in the data due to errors in measuring the in-flight calibration blackbody temperatures are less than $1 \cdot 10^{-7} W \cdot cm^{-2} sr^{-1}/cm^{-1}$.

These results have been submitted in a Letter to the Editor of "Applied Optics" (see section VI for the title).

III. Study of a Model of the Earth for Albedo Purposes

The study of the reflectance and scattering of solar radiation by the earth has continued with the formulation of a precise model of the earth for albedo purposes. The model uses a set of basic time dependent bi-directional reflectance functions which are assigned to small regions of the earth's surface. The geometrical and physical nature of the model has been studied and outlined. The procedure for calculation has been indicated and an illustrative example has been worked out. A much more complete geographical climatological study is essential to complete the model.

These results are being incorporated into a technical report 05863-11-T which will be published soon (see section VI).

IV. Laboratory Testing of the IRIS Interferometer

Development and testing of the interferometer has proceeded with the basic goal of correcting instrument performance deficiencies which were noted on the last balloon flight.

The Globe D. C. motors used in the timer and scan mirror drive have been replaced by a Haydon brushless type to eliminate the electrical noise obtained on the last flight. The new motors are A. C. motors incorporating a small solid state oscillator on the motor frame. Due to the shape of the new motor, the mounting arrangement was modified mechanically.

Several attempts have been made to improve the performance and/or reliability of the mirror drive system:

1.) A new drive amplifier was built to replace the breadboard (actually a cake pan) unit now being used. However it has not been possible to make this new unit operate satisfactorily, so far.

2.) A differential transformer was tested as the feedback element in the drive amplifier system. Again (this was tried once before) it was not possible to obtain the proper phase adjustment for suitable damping in the system.

3.) A new drive system incorporating two separate coils in separate gaps, one for drive and one for feedback has been designed and will be tried in the near future.

A mechanical arrangement of a supporting frame and a set of two adjustable mirrors to permit measurements of sky radiance from the zenith to the horizon has been constructed.

Additional tests and developments were made. A piezo-electric device for maintaining adjustment of the fixed mirror was constructed and tested. It was unsatisfactory because of a high temperature coefficient of the crystal. A test was made of the "cats eye" mirror in the interferometer system. It was found to be unsatisfactory for a wide angle system such as the IRIS.

A new voltage balancing circuit has been installed in the gain switching circuit to improve the balance of positive and negative swings of the interferogram.

Preparations have been made for the installation of the new environmental test chamber which will be used before the next balloon flight for testing and calibration of the University of Michigan and Texas Instruments Co. interferometers. A water supply, water drain, suitable A. C. power, and improved structural support of the balcony on which it will be located, have been provided.

V. Preparations for the Next Balloon Flight

A. Mechanical Construction

Mechanical apparatus necessary for the next balloon flight was repaired and/or designed and constructed.

The gondola jet assembly used on the last balloon flight was cleaned and some new parts were ordered. The MRIR door assembly was also disassembled, cleaned and repaired.

A new 10 liter dewar flask has been received. Internal heater parts were designed, fabricated and assembled. It is anticipated that this dewar, used as a liquid nitrogen container, will provide for a longer period of operation of the University of Michigan interferometer.

Other parts which have been designed and constructed include.

1.) A new telemetry chassis.

2.) Free air temperature probes.

3.) Battery compartment framework.

4.) New ballast containers of 125 lbs total capacity (capacity as compared to 100 lbs previously used). The design requires less horizontal area than the previous unit did.

5.) A new photocell assembly.

6.) The chassis for the new gondola control unit.

7.) Camera control unit.

8.) Heater distribution chassis.

The layout of instruments on the balloon gondola has been made for all instruments except the Filter Wedge spectrometer and the T. I. IRIS interferometer. Details are shown in Figure 1. Plans for the layout of other instruments will be completed when the instruments become available.

B. Gondola Programming Unit (By R. F. Hooper)

A new solid state gondola programming unit with diode matrix board programming is being built to replace the one destroyed in the launch disaster of 26 May 1966.

The logic circuits utilize Radiation, Inc., 2Mhz logic modules. Multiplexing and controlling is accomplished with reed relays. The modules provide good noise immunity while the reed relays provide low "on" resistance, nearly infinite "off" resistance, and negligible offset voltage. The basic timing element is a 1Khz tuning fork oscillator. Precision time signals are added to the tape recordings at the ground station.

The programmer provides multiplexing, control, and some signal processing services. A few functions which are basic are fixed (not programmable) to avoid undue size and complexity. Most functions are controlled by the diode matrix board. Multiplexing is provided to extend the usefulness of the FM/FM telemetry system used on the gondola. Sixteen multiplex channels are provided, with up to eight inputs available on some channels. From one to thirty steps, each step from one to sixty-three seconds in length, may be programmed with appropriate diode pins. Additionally, a fifteen position submultiplexer is provided for occassional sampling of slowly changing data.

The control functions include both repetitive and "one time only" operations. Repetitive operations include camera operation, mirror position changing and other similar functions. "One time only" operations include door opening and closing and test procedures. Ten delays, providing up to 26 hours from "zero time" up to actuation, are available.

One of the advantages of the electronic controller is the elimination of high transient currents associated with the operation of solenoid stepping switch drivers. To fully expoit this advantage and to reduce the complexity of the master controller, auxiliary control boxes were fabricated to provide isolation between high current functions and the low level signals from the gondola.

The first of these is the camera control box. It is designed and constructed so as to isolate the high transient currents associated with camera operation from the master controller. A separate Silvercell battery is provided for camera operation. Time delay relays are used to provide one second square waves to the cameras. It is anticipated that this will provide more reliable operation than the capacitor discharge waveform previously used. Pulse length may be optimized for each camera.

Another interface unit controlling doors, mirrors, FAT booms, etc., was constructed. Again, the aim was to reduce the possibility of electromagnetic interference. A synchronous stepper with holding circuit is to be employed to control the MRIR solar calibrate mirror. The control box is separately powered.

A schematic diagram of the program matrix board is shown in Figure 2. Instructions for programming the unit are given in the appendix to this report.

C. Electronic Construction and Testing

The construction of other electronic apparatus has been begun. Included are:

1. A camera test unit for use in the laboratory. This unit is identical to the one which will be used on the balloon gondola.
2. The gondola camera control unit.
3. The gondola thermister distribution chassis.
4. Heat outlet distribution chassis and outlet strips.

New laboratory instruments received and tested include:

1. An E-H Research Laboratories Model 139B pulse generator. The adjustable rise and fall times on this instrument are needed for testing to insure reliability of logic circuits.

2. A Hewlett-Packard distortion analyzer, to be used in making dynamic distortion tests on the FM/FM telemetry system (in addition to static linearity testing now employed).

3. A Lauda Instruments unit for temperature control of fluids used in radiometric calibrations.

4. A Panametrics (formerly Parametrics) hygrometer. This unit will be used for measurement of laboratory relative humidity measurements.

Instruments repaired during this quarter were:

1.) A Digitec voltmeter system.

2.) A Tektronix oscilloscope.

3.) A Triplett 630-NS voltmeter.

D. Balloon Flight Planning Activities

The time set for the next balloon flight is not certain. It is estimated that instruments will all be available for a flight in February or March 1967. Balloon gondola construction and testing has been scheduled accordingly.

It is desireable that accurate measurements of atmospheric water vapor and ozone be available for the analysis of atmospheric radiation data obtained on our balloon flights. In order to obtain adequate coverage of the vertical distribution of these quantities during the time interval during which the balloon is at altitude, it is desireable that these measurements be made by auxiliary balloon sondes, rather than on the large balloon gondola itself. This arrangement also minimizes the problem of water vapor contanimation which is less severe on a small balloon system.

Arrangements have been made with W. D. Komhyr of ESSA at Boulder, Colorado to obtain several calibrated Carbon-Iodine ozonsonde units which he has developed and flown so successfully. These units will be flown on regular and several special Weather Bureau radiosondes before and during our balloon flight. Komhyr will analyze and evaluate the ozone data obtained.

It is planned to make similar arrangements with H. J. Mastenbrook of NRL for water vapor measurements.

IV. Report Writing

A letter to the editor has been submitted to Applied Optics. It is entitled "Fourier Transform Spectrometer-Radiation Measurements and Temperature Inversion," by L. W. Chaney, S. R. Drayson and C. Young.

Other reports being prepared are:

1. Chaney, L. W., Fundamentals of Fourier Transform Spectroscopy, University of Michigan, Dept. of Aerospace Engineering Technical Report No. 05863-10-T.

2. Bartman, F. L., The Reflectance and Scattering of Solar Radiation by the Earth, University of Michigan, Dept. of Aerospace Engineering Technical Report No. 05863-11-T.

VII. Future Work

During the next quarter, the project effort will include:

1. Data analysis.
2. Interferometer development.
3. Planning and construction of instrumentation for the next balloon flight.
4. Report writing.

APPENDIX

INSTRUCTIONS FOR PROGRAMMING THE GONDOLA CONTROL UNIT (BY L. W. CARLS)

(Refer to Figure 2 of this report)

A. The 5 x 10 Switching Time Matrix

This matrix is used to set the amount of time in seconds, for which each row of the 30 x 80 matrix will be switched on to the telemetry input. This matrix is a replacement for the Haydon timer which was used on past flights and is variable in one second increments from one to sixty-three seconds, except for thirty-two seconds.

A total of five diode pins must be used. The BCD equivalent of decimal seconds is programmed starting from upper left to lower right. The BCD number with the bar is used for all numbers except for the lowest number, the lowest number uses not bar. If less than five pins are needed for the BCD equivalent, the remaining pins are inserted in the same row as the highest BCD number. Only one pin can be used per column.

Example: Set the matrix for twenty-five seconds

Switching Time (sec.)

$\overline{32}$	.	.	.	.	.
16	.	.	.	.	.
$\overline{16}$	⊙	.	.	⊙	⊙
8	.	.	.	.	.
$\overline{8}$	.	⊙	.	.	.
4	.	.	.	.	.
$\overline{4}$	.	.	.	.	.
2	.	.	.	.	.
$\overline{2}$	.	.	.	.	.
1	.	.	⊙	.	.

B. <u>The 5 x 10 Switching Position Matrix</u>

This matrix is used to determine the number of rows of the 30 x 80 matrix which will be used before the cycle is reset and restarted. This matrix in conjunction with the 30 x 80 matrix is a replacement for the main programming ledex which was used on past flights and is variable from one to thirty positions except for position sixteen.

Unlike the switching time matrix, this matrix needs only the number of pins required to make up the BCD equivalent of the decimal number of positions desired. Only one pin per row and one pin per column is needed with the bar being used for the higher numbers and not bar for the lowest number. If only one number is used then it must be not bar.

Also, only the first four columns may be used, that is, a maximum of four pins is used.

C. <u>The 30 x 80 Function Selection Matrix</u>

The first sixty columns of this matrix are used for switching the telemetry inputs. The last twenty columns are used for other functions such as camera operations, sub-multiplexing, etc.

The number of rows used is dependent upon the setting of the switching position matrix.

The division of the first sixty columns is as follows:

Channel 1	Column	1 to 8
2	"	9 to 16
3	"	17 to 20
4	"	21 to 24
5	"	25 to 27
6	"	28 to 30
7	"	31 to 33

Channel 8	Column	34 to 36
9	"	37 to 39
10	"	40 to 42
11	"	43 to 45
12	"	46 to 48
13	"	49 to 51
14	"	52 to 54
15	"	55 to 57
16	"	58 to 60

These channel numbers do not necessarly correspond to IRIG channels but may for convenience.

For each channel only a certain number of pins may be used. This number is equal to the number set into the switching position matrix. Also only one pin, per row, per channel may be used. This is to prevent feeding two or more signals to one channel at the same time. The column assignments are indicated in Figure 2 and the order of programming will follow from the flight requirements.

The last twenty columns (61 thru 80) are programmed when those functions are required to be used and are self explanatory.

Important: For columns 71, 72, 73, 74, 75, and 79, two adjacent positions per column cannot be used, there must at least be one hole skipped between vertical placement of pins.

Note: For column eighty which is for camera lamps, some testing must be done to determine whether one pin located at the time of camera operation is sufficient to turn the lamp on in time, or whether the lamp will have to be turned on by a pin located one position sooner than the time required to ensure the lamp is turned on when the photo is taken. Also a pin should be in column eighty whenever a camera is programmed to operate. The actual coding sequence is accomplished by fixed circuitry and is repeatable every hour.

D. The Sub-Multiplexer

The rate of sub-multiplexing is fixed at one sample per second. There are eight monitor groups with fifteen inputs per group available for use. If all fifteen inputs are used in a group, this imposes a lower limit on the setting of the switching time matrix. The time at which sub-multiplexing occurs is determined by the diode pins in column 79 of the 30 x 80 matrix, with the restriction that no two adjacent holes are used. Also, sub-multiplexing occurs only in those channels which are programmed to accept a monitor group at that time.

The assignments of the sub-multiplexer are shown in Figure 2.

E. The 10 x 40 Delay Matrix

This matrix provides eight delays for items such as start of camera operation, door opening and closing, etc. Two additional delays have been added and are the third and fourth 5 x 10 matrix as marked.

Up to five pins may be used to determine the time from which the control unit is started to the time at which the function will occur. The delay assignments are listed at the end of this instruction manual.

For each delay only one pin per row and one pin per column may be used.

F. Starting the Control Unit

The following steps should be performed in order when starting the control unit:

1.) Both count switches should be in the stop position.

2.) Plug in both the +18 and -18 volt supply; never have one battery in long without the other battery being in.

3.) Turn both lamp switches on.

4.) Reset both sections. All lamps should be off.

5.) Turn both lamp switches off.

6.) Put programmer count switch in start position. The programmer will not start until the time code generator count switch is in the start position.

7.) Put time code generator count switch in the start position.

Note:

1.) The flight position of all toggle switches is in the down position.

2.) The lamps may be turned on at any time to check the sequence but should be turned off to conserve power.

3.) With both count switches in the stop position, any time and programming and sub-multiplex position may be set into the control unit.

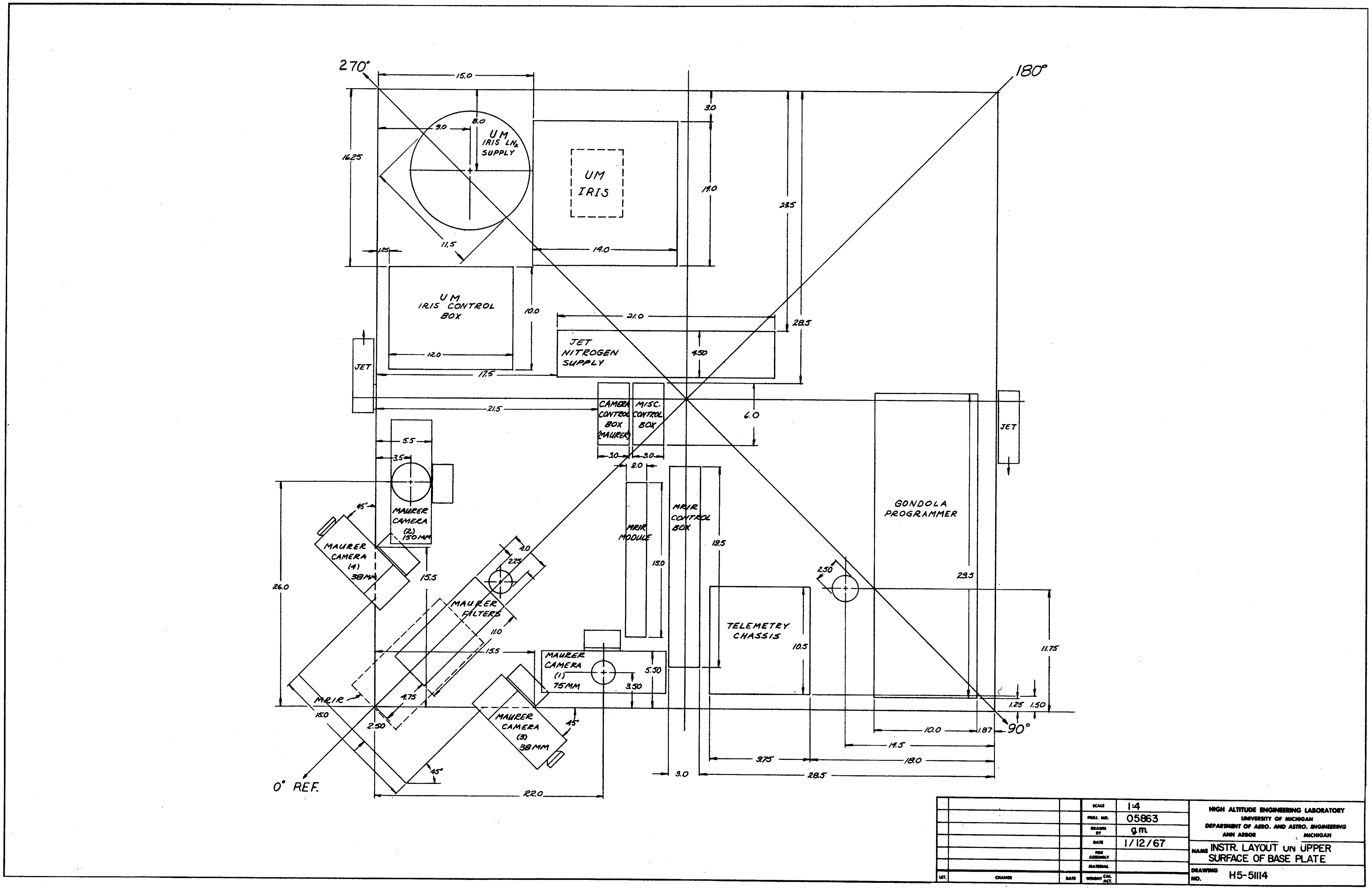
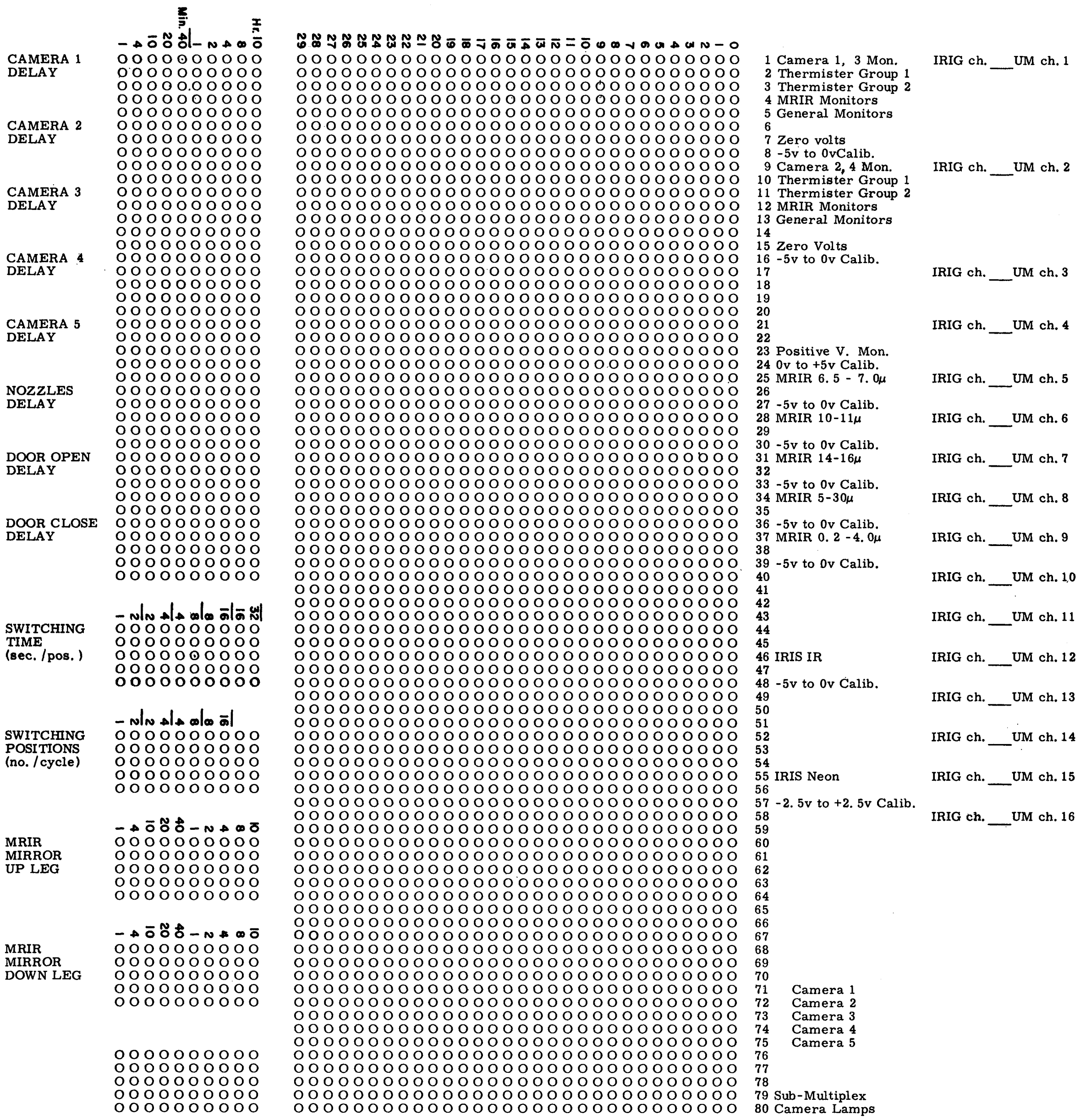

270°
180°
90°
0° REF.
UM IRIS LN2 SUPPLY
UM IRIS
UM IRIS CONTROL BOX
JET NITROGEN SUPPLY
JET
CAMERA CONTROL BOX (MAURER)
MISC. CONTROL BOX
MRIR MODULE
MRIR CONTROL BOX
GONDOLA PROGRAMMER
TELEMETRY CHASSIS
MAURER CAMERA (1) 75MM
MAURER CAMERA (2) 150MM
MAURER CAMERA (3) 38MM
MAURER CAMERA (4) 38MM
MAURER FILTERS
MRIR
HIGH ALTITUDE ENGINEERING LABORATORY
UNIVERSITY OF MICHIGAN
DEPARTMENT OF AERO. AND ASTRO. ENGINEERING
ANN ARBOR MICHIGAN
SCALE 1:4
PROJ. NO. 05863
DRAWN BY g.m.
DATE 1/12/67
NAME INSTR. LAYOUT ON UPPER SURFACE OF BASE PLATE
DRAWING NO. H5-5II14

Figure 1.

PROGRAM OF FUNCTIONS AND SIGNALS FOR BALLOON FLIGHT II



-2. 5v to +2. 5v Calib.		0v to +5v Calib.	-5v to 0v Calib.	General Monitors	MRIR Monitors	Pos. V. Monitors	Thermister Group 1	Thermistor Group 2
0	-2. 5v	0 0v	0 -5v	0 FAT Boom 1	0 Chop. Th. 1	0 Camera Bat.	0	0
1	-1. 5v	1 1v	1 -4v	1 FAT Boom 2	1 Chop. Th. 2	1 +10v Bat.	1	1
2	-0. 5v	2 2v	2 -3v	2 IRIS Door	2 Hsg. Th. 1	2 Photocell Bat.	2	2
3	+0. 5v	3 3v	3 -2v	3 Filter Wedge Door	3 Hsg. Th. 2	3	3	3
4	+1. 5v	4 4v	4 -1v	4 MRIR Mirror Pos.	4 Elect. Mod. Th.	4	4	4
5	+2. 5v	5 5v	5 0v	5 -10v Bat.	5 Th. Reg. PS	5	5	5
6	-2. 5v	6 0v	6 -5v	6 -20v Bat.	6 Chopper Mon.	6	6	6
7	-1. 5v	7 1v	7 -4v	7 -5. 4v Bat.	7 -10v PS	7	7	7
8	-0. 5v	8 2v	8 -3v	8	8 -24. 5v PS	8	8	8
9	+0. 5v	9 3v	9 -2v	9	9 Calib. PS 1-	9	9	9
10	+1. 5v	10 4v	10 -1v	10	10 Calib. PS 2 -	10	10	10
11	+2. 5v	11 5v	11 0v	11	11 Calib. PS 3 -	11	11	11
12		12 Calib. PS 1+	12	12	12 FAT Th PS	12	12 Th. Reg. PS	12 Th. Reg. PS. Bat.
13		13 Calib. PS 2+	13 FAT Th.___	13 FAT Th.___	13 FAT Th.PS	13	13 FAT Th.___	13 FAT Th.___
14		14	14 FAT Th.___	14 FAT Th.___	14 FAT Th. PS	14	14 FAT Th.___	14 FAT Th.___

Figure 2