PR 29-83 PART III
COMPILATION OF TRADE STUDIES, ENGINEERING ANALYSES AND OTHER REPORTS PREPARED DURING AAP MISSION 1A 60-DAY STUDY

Contract NAS 8-21004

20 September 1967

MARTIN MARIETTA CORPORATION
DENVER DIVISION

FOREWORD

This document, in three parts, consists of trade studies, engineering analyses, and other technical reports prepared during the AAP Early Applications Mission 1A 60-day study period. These reports are support data to the Final Report, PR 29-81.

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PR 29-83 PART III

PR-29-41

FINAL SYSTEMS SAFETY REPORT

MISSION 1A

Contract NAS 8-21004

25 August 1967

Prepared by R. Ritz
R. Ritz

Approved by J. T. Keeley
J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1.0 INTRODUCTION

1.1 Purpose - This report discusses the Systems and Crew Safety criteria and considerations applicable to AAP Mission 1A. It is intended to identify certain safety design parameters that are essential to the basic design approach. It will also define areas of concern that must be examined during the course of design maturation to assure survivability of the crew and mission success.

1.2 Objectives - The objective of the Systems/Crew safety effort is to assure that the carrier/experiment design and operations shall not create unnecessary hazards to the crew, launch area personnel, equipment and facilities.

2.0 SUMMARY

An analysis of the crew/systems safety aspects of the Mission 1A carrier has been completed. A conclusion has been reached that the mission can be successfully and safely accomplished by adhering to the established safety design criteria and performing the required safety analysis and audit activities during the program span.

3.0 DISCUSSION

3.1 Design Features - The manned portion of the experiment carrier as presently conceived for Mission 1A contains a conical pressure hull with a free volume of approximately 190 cubic feet. After docking with the CM, the carrier will be pressurized to 5 psia using the CSM O_2 supply. The major portion of the flight mission will be accomplished with the CM pressure-thermal hatch closed. Occasional IVA entry will be required to retrieve data or to operate experiments. Only equipment which requires crew manipulation has been located within the carrier pressure vessel, all other items are mounted externally on the external truss structure. Carrier airlocks will be qualified CM units available from the Apollo program wherever feasible. Hazards involved with the flight involve the following areas.

3.1.1 Fire - The carrier will be provided with a remote fire detection system with read-out indications on the D&C panel. Operation constraints may be imposed to include a requirement to power down experiments prior to crew entry into the carrier with this safe condition confirmed on the D&C.

3.1.2 Pressure - A means will be provided to assure pressure equalization across the CM pressure-thermal hatch prior to hatch opening. The carrier will also be provided with a remotely operated vent valve to bleed the pressure hull to vacuum prior to initiation of the CM/carrier pyro separation device. The Block II CM/LEM 4-way pressurization valve and CM hatch equalization valve is the baseline.

3.1.3 Temperature & Thermal Control - Carrier design will include provisions to determine and monitor atmosphere temperature in the carrier. The potential problem of condensation after the CM hatch is repeatedly opened will be studied.

The carrier active thermal control system is a cold plate and radiator system using Freon 21 as the fluid. Crew risk from fluid leakage is minimized by designing the entire liquid loop system external to the carrier pressure hull.

3.1.4 Lighting - Overall illumination will be specified at 20-30 foot candles intensity in the carrier. Local lighting may be necessary for performing work behind barriers or in confined areas. The need for portable emergency illumination equipment will be studied. All lighting equipment will be safe for use in a 5 psig O_2 atmosphere.

3.1.5 Pyrotechnics - At present there is no new pyrotechnic system requirement identified for the carrier. Should a requirement arise, the design will be reviewed to assure compliance with range safety requirements as specified in AFETR 127-1. The pyrotechnique SLA/ carrier separation will use LEM hardware identified to previous LEM flights.

3.1.6 Radiation - The 1A mission involves an earth orbit of 120/140 nm at an inclination of 50°. Preliminary studies indicate that human shielding will not be required. No EVA is planned for the mission. Possible shielding requirements for experiments and film is being studied.

3.1.7 Intra-Vehicular Activity (IVA) - IVA exercises will be accomplished with all crew members suited in the ILC-A7L suit. The carrier crewman's CM umbilical will provide oxygen and a communications link to the crewman in the carrier. A tether harness will be used at all task locations in the carrier. The carrier/experiment systems will be shut down and/or in a safe condition prior to crew entry. This condition will be verified on the Display and Control panel in the CM. The carrier will be free from protuberances and sharp edges.

3.1.8 Meteoroid Penetration - Penetration of the carrier pressure vessel will be minimized by material wall thickness selection and strategically located barriers on unprotected segments of the conical shell. Both are now under study.

3.2 Non-Metallic Materials Compatibility - The selection of non-metallic materials for use in the carrier is an important safety consideration as is the evaluation of GFP experiments for safe functioning in the O_2 environment. The approach to this area is contained in trade and evaluation study PR 29-9.

3.3 Manned Program Safety Implementation - Implementation of the Carrier Safety Program will be based upon a Systems Safety Engineering Plan, approved by NASA. The recommended program will contain both quantitative and qualitative hazard analysis, a close tie with failure mode effect and criticality analysis (FMECA) and a strong working relationship with the assigned mission crew to assure a high level of program safety awareness during design, build, test and flight operations.

PR 29-42

TRADE STUDY REPORT

THERMAL CONTROL SYSTEM

SYSTEM SELECTION STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

3 August 1967

Prepared by: J. Ashura

Approved by: E. Schumacher

MARTIN MARIETTA CORPORATION
DENVER DIVISION

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to document the data, methods, and results used in a study to select a thermal control system for the early experiments carrier.

1.2 Objectives - The objective of this report is to select the most favorable thermal control system from a group of five different configurations under consideration.

2. SUMMARY

Five parameters, namely schedule risk, weight, cost, reliability and flexibility have been used to evaluate five different thermal control system configurations. Evaluation points have been calculated and/or assigned to each system for each parameter. In addition weighting factors have been assigned to each of the five comparison factors. An overall figure of merit was arrived at by multiplying the evaluation points by the weighting factor. Configuration "C" shows the most merit and is being used as the baseline thermal control system for the early experiments carrier TCS. (See Figure 1.)

3. PARAMETERS

3.1 Schedule Risk - Assign a rating of 10 to the lowest total and assign the other systems lower ratings in proportion to their percentage over the lowest system.

A	9*	2	(10 - 4/5 x 10 = 2)
B	9	2	(10 - 4/5 x 10 = 2)
C	8	4	(10 - 3/5 x 10 = 4)
D	5	10	(10)
E	12	-4	(10 - 7/5 x 10 = -4)

*These totals were arrived at by multiplying the number of items requiring development by 2 and adding the result to the number of components requiring modification only. This was done to take into account the higher schedule risk of newly developed items.

3.1.1 Weight (301 Lbs. Allotted) - Assign a value of 10 to the lowest total and assign the other systems lower ratings in proportion to their percentage over the lowest system:

A	226	10	
B	237	9.5	(10 - 11/226 x 10 = 9.5)
C	299	6.8	(10 - 73/226 x 10 = 6.8)
D	935	-21.4	(10 - 709/226 x 10 = -21.4)
E	574	-5.4	(10 - 348/226 x 10 = 5.4)

3.1.2 Cost - Assign a value of 10 to the lowest total and assign the other systems lower ratings in proportion to their percentage over the lowest system:

A	$ 762,070	10	
B	$ 791,070	9.9	(10 - 9000/762070 x 10 = 9.9)
C	$ 805,500	9.4	(10 - 43430/762070 x 10 = 9.4)
D	$ 786,070	9.9	9.9
E	$1,399,570	1.6	(10 - 637500/762070 x 10 = 1.6)

3.1.3 Reliability (.9940 Allotted) - Assign a rating of 10 to the highest difference between predicted and allotted and assign other systems lower ratings in proportion to their percentage below the highest.

A	.9968	+.0028	5.3	(10 - 25/53 x 10 = 5.3)
B	.9975	+.0035	6.6	(10 - 18/53 x 10 = 6.6)
C	.9993	+.0053	10	
D	.9958	+.0018	3.3	(10 - 35/53 x 10 = 3.3)
E	.9953	+.0013	2.4	(10 - 40/53 x 10 = 2.4)

3.1.4 Flexibility - The following weight values are assigned to the respective configurations.

A	5
B	6
C	8
D	10
E	8

Of the five configurations, system "D" has the greatest capability to react to changes in system requirements. It can readily adapt to reduced heat loads without a freezing problem and has comparatively large capability for successful reaction to high, short term peaks. For these reasons it has been assigned the maximum evaluation points of 10. System "E" has been assigned the lower value of 8 since it will be somewhat

3.1.4 Flexibility (Continued)

less capable of reaction to changes in the lower load limits because of a possibility of radiator freezing. System "C" is considered to have approximately the same reaction capability as "E" since reaction to higher heat loads could be accomplished by starting a second pump while still maintaining a redundant status. Systems "A" and "B" are considered to have minimum capability of reaction since they would both have a possible freezing problem at loads less than system specification. Furthermore they would also have minimum capability of reaction to higher loads because of a lack of water evaporators for peaking loads. System "B" may have somewhat better possibilities for incorporation of changes to react to out of spec. loads than "A" since a double radiator loop would exist. This extra loop may be exploited for somewhat higher heat rejection than the single loop of configuration "A".

4. CONCLUSIONS AND RECOMMENDATIONS

When all parameters of design and program requirements are evaluated, Configuration "C" reflects the highest figure of merit and is recommended for selection as the thermal control system for the early experiments carrier.

TABLE 1
BUDGETARY PRICE CONFIGURATION "A"

Item Description	Basic Syst. Cost	Devel/Qual Test Cost	Total Hdwe. Quantity	Total Hdwe Cost	Delivery ARO
Radiator	$ 7,000	$183,000	(1) Fl., (3) Test	$ 28,000	10 mos
Pump Package	$43,000	$ 50,000	(1) Fl., (2) Test	$129,000	10 mos
Thermal Control Valve	$10,000	$ 43,000	(2) Fl., (4) Test	$ 30,000	8 mos
Freon Boiler	$ 3,000	Est. $ 15,000	(1) Fl., (3) Test	$ 12,000	10 mos
Cold Plates	Est. $ 8,250	Est. $ 75,000	Est. (11) Fl., (50) Test	Est. $ 45,570	10 mos
Quick Disconnects	$ 1,000	Est. $ 10,000	(1) Fl., (2) Test	$ 3,000	6 mos
Hand Valve 2 Units	$ 2,000	$ 8,000	(2) Fl., (5) Test	$ 7,000	8 mos
Orifices	Est. $ 3,000	-		Est. $ 9,000	Est. 5 mos
Solenoid 3 Way 2 Units	$ 2,000	$ 26,000	(2) Fl., (4) Test	$ 6,000	8 mos
Accumulator	$ 7,500	Est. $ 30,000	(1) Fl., (6) Test	$ 52,500	10 mos
Totals	$86,750	$440,000		$322,070	

Test Program Cost	$440,000
Total Hdwe Cost	322,070
	$762,070

Add approx 125K for Proj. Eng., Management, Etc.

$762,070
125,000
$887,070

TABLE 2
BUDGETARY PRICE CONFIGURATION "B"

Item Description	Basic Unit Cost	Devel/Qual Test Cost	Total Hdwe Quantity	Total Hdwe Cost	Delivery ARO
Radiator	Est. $10,000	Est. $200,000	(1) Fl., (3) Test	Est $ 40,000	10 mos
Pump Package	$43,000	$ 50,000	(1) Fl., (2) Test	$129,000	10 mos
Thermal Control Valve	$10,000	$ 43,000	(2) Fl., (4) Test	$ 30,000	8 mos
Freon Boiler	$ 3,000	Est. $ 15,000	(1) Fl., (3) Test	$ 12,000	10 mos
Cold Plates	Est. $ 8,250	Est. $ 75,000	Est. (11) Fl., (50) Test	Est. $ 45,570	10 mos
Quick Disconnect	$ 1,000	Est. $ 10,000	(1) Fl., (2) Test	$ 3,000	6 mos
Hand Valve 2 Units	$ 2,000	$ 8,000	(2) Fl., (5) Test	$ 7,000	8 mos
Orifice	Est. $ 3,000	-		Est. $ 9,000	Est. 5 mos
Solenoid 3 Way	$ 2,000	$ 26,000	(2) Fl., (4) Test	$ 6,000	8 mos
Accumulator	$ 7,500	Est. $ 30,000	(1) Fl., (6) Test	$ 52,500	10 mos
Totals	$89,750	$457,000		$334,070	

Test Program Cost	$457,000
Total Hdwe Cost	334,070
	$791,070

Add approx. 125K for Proj. Eng., Management, Etc.

$791,070
125,000

$916,070

TABLE 3

BUDGETARY PRICE CONFIGURATION "C"

Item Description	Basic Unit Cost	Devel/Qual Test Cost	Total Hdwe Quantity	Total Hdwe Cost	Delivery ARO
Radiator	Est. $10,000	Est. $200,000	(1) Fl., (3) Test	$ 40,000	10 mos
Pump Package	$43,000	$ 50,000	(1) Fl., (2) Test	$129,000	10 mos
Thermal Control Valve	$10,000	$ 43,000	(2) Fl., (4) Test	$ 30,000	8 mos
Freon Boiler	$ 3,000	Est. $ 15,000	(1) Fl., (3) Test	$ 12,000	10 mos
Cold Plates	Est. $11,000	Est. $100,000	Est. (11) Fl., (50) Test	Est. $ 61,000	10 mos
Quick Disconnects	$ 1,000	Est. $ 10,000	(1) Fl., (2) Test	$ 3,000	6 mos
Hand Valve	$ 4,000	$ 8,000	(4) Fl., (9) Test	$ 13,000	8 mos
Orifices	$ 6,000	-		Est. $ 9,000	Est. 5 mos
Accumulator	$ 7,500	$ 30,000	(1) Fl., (6) Test	$ 52,500	10 mos
Totals	$ 95,500	$456,000		$349,500	

Test Program Cost	$456,000
Total Hdwe. Cost	349,500
	$805,500

Add 125K for Proj. Engr., Management, Etc.

$805,500
125,000
$930,500

TABLE 4
BUDGETARY PRICE CONFIGURATION "D"

Item Description	Basic Syst. Cost	Devel/Qual Test Cost	Total Hdwe Quantity	Total Hdwe Cost	Delivery ARO
Pump Package	$ 43,000	-	(1) Fl., (2) Test	$129,000	6 mos
Water Evaporator	$122,000	-	(2) Fl., (3) Test	$305,000	6 mos
Cold Plates	$ 8,250	Est. $ 75,000	Est. (11) Fl., (50) Test	Est. $ 45,570	10 mos
Orifice	Est. $ 3,000	-		Est. $ 9,000	Est. 5 mos
Hand Valve	$ 6,000	$ 8,000	(6) Fl., (14) Test	$ 20,000	8 mos
Freon Boiler	$ 3,000	-	(1) Fl., (3) Test	$ 12,000	10 mos
Quick Disconnect	$ 1,000	-	(1) Fl., (2) Test	$ 3,000	6 mos
Water Tanks	Est. $ 32,000	Est. $ 99,500	(4) Fl., (6) Test	Est. $ 80,000	Est. 10 mos
Totals	$228,250	$182,500		$603,570	

Test Program Cost	$182,500
Total Hdwe. Cost	603,570
	$786,070

Add approx. 125K for Proj. Engr., Management, Etc.

$786,070
125,000
$911,070

TABLE 5

BUDGETARY PRICE CONFIGURATION "E"

Item Description	Basic Syst. Cost	Devel/Qual Test Cost	Total Hdwe Quantity	Total Hdwe Cost	Delivery ARO
Radiator	Est. $ 10,000	Est. $200,000	(1) Fl., (3) Test	$ 40,000	10 mos
Pump Package	$ 43,000	$ 50,000	(1) Fl., (2) Test	$129,000	10 mos
Thermal Control Valve	$ 10,000	$ 43,000	(2) Fl., (4) Test	$ 30,000	8 mos
Freon Boiler	$ 3,000	Est. $ 15,000	(1) Fl., (3) Test	$ 12,000	10 mos
Cold Plates	Est. $ 8,250	$ 75,000	(11) Fl., (50) Test	$ 45,570	10 mos
Quick Disconnect	$ 1,000	Est. $ 10,000	(1) Fl., (2) Test	$ 3,000	6 mos
Hand Valve	$ 6,000	$ 8,000	(6) Fl., (14) Test	$ 20,000	8 mos
Orifice	Est. $ 3,000			Est. $ 9,000	5 mos
Solenoid 3 Way	$ 2,000	$ 26,000	(2) Fl., (4) Test	$ 6,000	8 mos
Accumulator	$ 7,500	Est. $ 30,000	(1) Fl., (6) Test	$ 52,500	10 mos
Water Evaporator	$122,000	$ 50,000	(2) Fl., (4) Test	$366,000	8 mos
Water Tanks	$ 32,000	$ 99,500	(4) Fl., (6) Test	$ 80,000	10 mos
Totals	$247,750	$606,500		$793,070	

Test Program Cost	$ 606,500
Total Hdwe Cost	793,070
	$1,399,570

Add approx 125K for Proj. Engr., Management, Etc.

$1,399,570
125,000
$1,525,570

TABLE 6

WEIGHT STATEMENT *
"A"

Thermal Control System Special Carrier (Early Flight) Hardware, Fittings Lines and Fluid

			Lbs.
Radiator 24 sq. ft.	1 unit		36
Pump Package	1 unit		19
Thermal Control Valve	2 units		0.8
Freon Boiler	1 unit		0.7
Cold Plates		Est.	72.0
Quick Disconnects	1 unit		0.4
Hand Valve	2 units		0.4
Solenoid 3 Way valve	2 units		2.0
Orifices		Est.	1.0
Accumulator	1 unit		2.3
Lines & Fittings			10.
	Sub-Total		144.6 lbs.

Fluid

Freon-21		52 lbs.

Insulation

Total Wt.		29 lbs.
	Sub-Total	81 lbs.

Grand Total 225.6

Say 226 lbs.

*Detail component weights have been slightly modified and are reflected in the Mass Properties Report PR-29-36. Table 6 weights study did not include attachment hardware or contingency.

TABLE 7

WEIGHT STATEMENT*
"B"

Redundant Radiator Loop

Thermal Control System Special Carrier (Early Flight) Hardware, Fitting Lines and Fluid

			Lbs.
Radiator 24 sq. ft. 2 loops	1 units		45.0
Pump Package	1 unit		19
Thermal Control Valve	2 units		0.8
Freon Boiler	1 unit		0.7
Cold Plates		Est.	72.0
Quick Disconnects	1 unit		0.4
Hand Valve	2 units		0.4
Solenoid 3 Way Valve	2 units		2.0
Orifices		Est.	1.0
Accumulator	1 unit		2.3
Lines & Fittings			11.0
	Sub-Total		154.6 lbs.

Fluid

Freon-21		53.8 lbs.

Insulation

Total Wt.		29.0 lbs.
	Sub-Total	82.8 lbs.
	Grand Total	237.4
	Say 237 lbs.	

*Detail component weight have been slightly modified and are reflected in the Mass Properties Report PR-29-36. Table 7 weights study did not include attachment hardware or contingency.

TABLE 8

WEIGHT STATEMENT *
"C"

Thermal Control System Special Carrier (Early Flight) Hardware, Fittings Lines and Fluid

			Lbs.
Radiator 24 sq. ft. 2 loops	2 units		45.0
Pump Package	1 unit		19.0
Thermal Control Valve	2 units		0.8
Freon Boiler	1 unit		0.7
Cold Plates		Est.	72.0
Quick Disconnect	1 unit		0.4
Hand Valve	4 units		0.8
Orifices		Est.	2.0
Accumulator	2 units		9.2
Lines & Fittings			20.0
	Sub-Total		169.9 lbs.
Fluid			
Freon-21		Est.	100 lbs.
Insulation			
Total Wt.			29.0 lbs.
	Sub-Total		129.0
	Grand Total		298.9 lbs.
	Say 299 lbs.		

*Detail component weights have been slightly modified and are reflected in the Mass Properties Report PR-29-36. Table 8 weights study did not include attachment hardware or contingency.

TABLE 9

WEIGHT STATEMENT *
"D"

Thermal Control System Special Carrier (Early Flight) Hardware, Fittings Lines and Fluid

			Lbs.
Pump Package	1 unit		19.0
Water Boiler	2 units		32.0
Cold Plates		Est.	72.0
Orifices		Est.	1.0
Hand Valve	6 units		1.2
Freon Boiler	1 unit		0.7
Quick Disconnect	1 unit		.4
Water Tanks	4 units		120.0
	Sub-Total		246.3
Fluid			
Freon-21			52.0 lbs.
Water			508.0 lbs.
Insulation			
Total Wt.			29.0 lbs.
	Sub-Total		689.0
	Grand Total		935.3 lbs.
	Say 935 lbs.		

*Detail component weights have been slightly modified and are reflected in the Mass Properties Report PR-29-36. Table 9 weights study did not include attachment hardware or contingency.

TABLE 10

WEIGHT STATEMENT *
"E"

Thermal Control System Special Carrier (Early Flight) Hardware, Fittings Lines and Fluid

			Lbs.
Radiator 24 sq. ft. 2 loops	1 unit		45.0
Pump Package	1 unit		19.0
Thermal Control Valve	2 units		0.8
Freon Boiler	1 unit		0.7
Cold Plates		Est.	72.0
Quick Disconnects	1 unit		0.4
Hand Valves	6 units		1.2
Orifice		Est.	1.0
Solenoid 3 Way	2 units		2.0
Accumulator	1 unit		2.3
Water Boiler	2 units		32.0
Water Tanks	2 units		60.0
	Sub-Total		236.4
Fluid			
Freon-21			53.8
Water			255.0
Insulation			
Total Wt.			29.0
	Sub-Total		337.8
	Grand Total		574.2

Say 574 lbs.

*Detail component weight have been slight modified and are reflected in the Mass Properties Report PR-29-36. Table 10 weight study did not include attachment hardware or contingency.

PR-29-43

TRADE STUDY REPORT

POINTING AND STABILITY STUDIES

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

8 September 1967

Prepared By: W. Turner

Approved By: J. Josephson

MARTIN MARIETTA CORPORATION
DENVER DIVISION

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose - This report presents the results of a study on attitude control, pointing, and stabilization of the AAP/PIP Early Applications Vehicle.

1.2 Objectives - The objectives of the study were to investigate several alternative system mechanizations and to recommend a preferred configuration to meet the attitude control requirements of the mission.

2. SUMMARY

Techniques for pointing and control are investigated to satisfy requirements for controlled orientation experiments including local vertical, solar, and stellar pointing. These requirements must be met without exceeding the specified RCS propellant consumption allocated for attitude control. Further constraints are the minimum CSM modification and shelf hardware status required by the short schedule to flight.

The existing G & N system is recommended for local vertical control. A backup system, consisting of a carrier mounted horizon scanner-gyrocompass reference system driving a display for manual control by the astronaut, would provide assurance that the important earth resources experiments will be successfully oriented. The solar experiment should be manually controlled with the aid of a display driven by analog sun sensors. The recommended technique for stellar orientation is a coarse alignment with the G & N system and manual control for fine alignment. The study effort is continuing to further define these control methods and to investigate a carrier mounted local vertical system for the prime mode.

3. REQUIREMENTS

The experiments proposed for this mission present a variety of pointing requirements. Most of the instruments which sense incident radiation will be rigidly attached to the experiment carrier vehicle. Therefore, the sensitive axis of the experiment instrument is aligned to the desired target by pointing the vehicle with the appropriate orientation.

From the control system standpoint, the experiments may be subdivided into groups according to the type of target to which they must be aligned. The groups are earth resources, solar, stellar, manual navigation, and experiments requiring no

3. (Continued)

control. The earth resources experiments must be continuously aligned toward the instantaneous nadir and require "local vertical" orientation of the carrier. The solar experiment must be aligned with the sensitive axis toward the sun with an "inertial hold" vehicle orientation. The stellar experiments also require the vehicle to maintain an inertial hold but, in addition, require frequent reorientation to point the instruments at selected portions of the celestial sphere. The manual navigation experiments require vehicle reorientation to bring appropriate optical targets within the field of view of the spacecraft windows. The final group contains those experiments which do not impose any vehicle control constraints except, possibly, to initiate free drift by minimizing rates and disabling the Reaction Control System (RCS). These requirements and groups are summarized in Table III-1; the last group is omitted and will not be treated further in this report.

Reference to Table III-1 shows a sharp separation of attitude accuracy required in the local vertical group, one portion being 1.5 deg and the others ±5 to 10 deg. Some experiments, notably the metric camera, require a knowledge of the experiment line of sight to an accuracy of 0.5 deg or better. The metric camera is supported by a set of stellar cameras which will provide concurrent star field data to satisfy this requirement.

Experiments S017, S019 and S020 require fine pointing to 0.5 deg or better. As discussed in subsequent sections, these fine pointing requirements will be met by manual astronaut control of the vehicle with the aid of appropriate displays. S016 is not an earth resources experiment but does require an essentially local vertical orientation during passes through the South Atlantic Anomaly. In addition, the sensor must be rotated about an axis corresponding to the radius vector from earth's center in a manner that will maintain the experiment approximately normal to earth's magnetic field.

This maneuver could be performed under either computer or manual control. It is assumed that manual control will be used whenever this maneuver is required during a period when the computer is normally inactive.

All constraints placed on the maximum attitude rates are compatible with operation of the vehicle in a normal minimum impulse limit cycle mode.

TABLE III-1
ATTITUDE CONTROL REQUIREMENTS

EXPERIMENT		DESIRED ATTITUDE ACCURACY (DEGREES)	MAX. RATE (DEG/SEC)
Local Vertical Group (G & N System)			
S039	Day-Night Camera	10.	Normal Limit Cycle
S040	Dielectric Tape Camera	10.	Normal Limit Cycle
S043	IR Temperature Sounding	5.	Normal Limit Cycle
S048	UHF Sferics	5.	--
	Metric Camera	1.5	.05
	Multispectral Camera	1.5	.03
	Wide Range Imager	1.5	Normal Limit Cycle
	IR Radiometer	1.5	1.
	IR Spectrometer	1.5	1.
S044A	Scanned Microwave Radiometer	5.	Normal Limit Cycle
S016	Trapped Particle Assymmetry	2.	N/A
Solar Group			
S020	XUV Solar Photography	0.25	Minimize
Stellar Group			
S017	X-Ray Astronomy	0.5	0.05
S019	UV Stellar Astronomy	0.25	Minimize
Manual Navigation Group			
T002	Manual Navigation Sightings	5.	0.25
D009	Simple Navigation	5.	1.

4. LOCAL VERTICAL

4.1 General - A substantial portion of the AAP-1A mission is to be flown with experiment sensors oriented toward the nadir, that is, with the instrument sensitive axis viewing the ground track of the orbital vehicle. In addition, overall system trade studies have shown that it is preferable to align the vehicle longitudinal axis to the radius vector from earth's center.

A general approach was taken at the inception of the study and consisted of an evaluation of a wide range of reasonable control approaches to maintain the desired attitude. The range considered progressed from passive stabilization to manual control, use of present CSM systems and through increasingly complex supplementary systems. Specifically, the following approaches were considered:

a. Passive gravity gradient stabilization with manual RCS damping.

b. Manual with astronaut optical aids.

c. Manual with "Ordeal" system input to FDAI.

d. Automatic with Stabilization and Control System (SCS).

e. Automatic with Guidance and Navigation (G & N) System.

f. Carrier mounted Local Vertical System (LVS) correcting SCS gyros.

g. Carrier mounted LVS direct to RCS solenoids.

h. Carrier mounted LVS with independent propulsion.

i. Combinations of the above.

A first order trade study was conducted with principal emphasis on factors of cost, CSM modification, RCS propellant usage, power and weight. Quantitative reliability studies were not performed; these have been defined to be outside the scope of the study and sufficient data was not available.

The preliminary trade study results indicated the principal candidates to be the existing G & N system and the carrier mounted local vertical system driving the RCS thrusters.

4.1 (Continued)

The two principal candidates are discussed in the following sections. A brief analysis of orbital disturbance torques given in Paragraph 4.4 resulted in the elimination of passive gravity gradient stabilization as a candidate system. Other alternates were eliminated largely because of cost, CSM modifications and RCS propellant usage.

4.2 G & N Local Vertical Hold

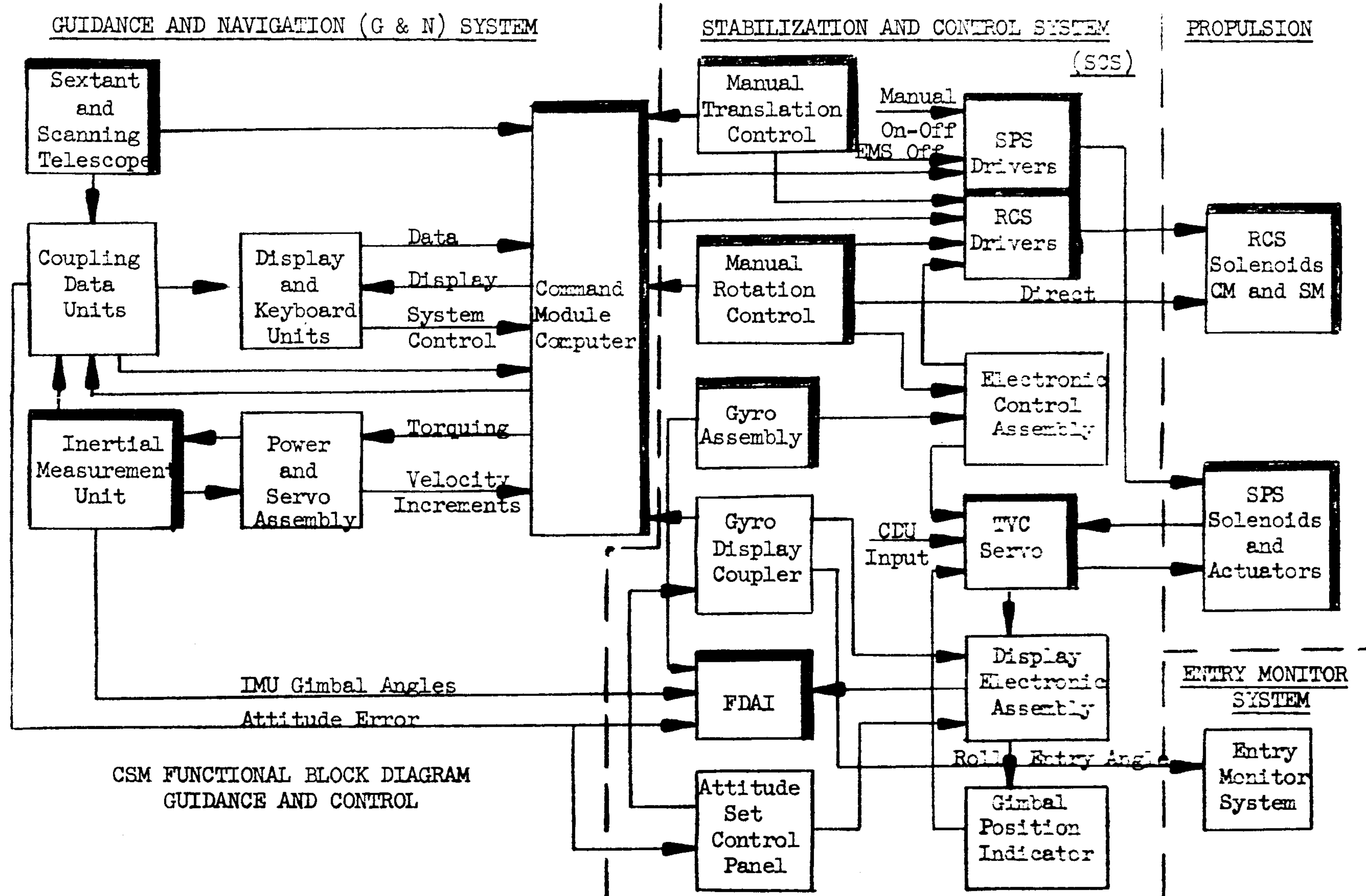
4.2.1 General - The CSM Guidance and Navigation (G & N) system has the basic capability to orient the vehicle along the local vertical. Figure 4.2-1 shows a block diagram of the CSM Guidance, Navigation and Control systems for reference. The major components of the G & N portion of this system are the Command Module Computer (CMC), Inertial Measurement Unit (IMU) and the Optical Subsystem (OSS) containing the sextant and scanning telescope.

Local vertical orientation with the G & N system may be provided by incorporating the appropriate routines in the CMC. In operation, the computer would combine the known orbital ephemeris with inertial coordinate data from the IMU to calculate the direction of the local vertical vector and align the vehicle to properly point the experiments. Additional constraints are imposed on the CMC program by the experiment angular offsets from the CSM Navigation Base on which the IMU is mounted and the limited angular freedom of the IMU middle gimbal. These constraints are discussed in Sections 4.2.2 and 4.2.3.

Over half of the experiments requiring controlled orientation and over half of the attitude controlled operating time of the mission requires local vertical control. The importance to the mission of local vertical control, as well as the reliability uncertainty of the G & N system for the planned operating time, requires that a backup system be recommended. Several backup system alternatives are discussed in Section 4.2.4.

4.2.2 Experiment Angular Alignment Errors

4.2.2.1 Definition - The CSM guidance and control coordinate systems are referenced to the Navigation Base (NB), as rigid member to which the IMU and OSS optical members are mounted. Differences in angular alignment between



CSM FUNCTIONAL BLOCK DIAGRAM
GUIDANCE AND CONTROL

Figure 4.2-1

4.2.2.1 (Continued)

the NB and experiments are a potential source of substantial pointing error. Errors accumlate from the NB to the CSM docking adapter, across the docking interface to the experiment carrier and through the carrier structure to the experiments. The largest error would lie between the NB and the carrier structure; investigation has shown that the following deviations must be expected after docking:

Azimuth:	10 deg max
Pitch or Roll:	5 deg max

where the axes of rotation are referred to the nose down orientation and defined as follows relative to the radius vector ($\bar{R}$) and velocity vector ($\bar{V}$):

Azimuth: $-\bar{R}$
Pitch: $\overline{(-\bar{R}) \times \bar{V}}$
Roll: $\bar{V}$

It is necessary, therefore, that the misalignment between the experiments and the NB be measured after docking and that the CMC program accept these measured values as keyboard data inputs. The CMC local vertical routine must incorporate the capability to correspondingly offset the orientation of the NB defined coordinates to compensate for experiment misalignment.

Several methods of determining experiment relative alignment have been considered. It was assumed that measurement errors which make a negligible contribution to a system error of 30 $\widehat{min}$ are sufficiently accurate. This would require that the measurements be accurate to 6 $\widehat{min}$ or better. Measurement methods are described in Sections 4.2.2.2 through 4.2.2.5. Section 4.2.2.2 is the recommended method.

4.2.2.2 Optical Star Alignment - A two axis optical sighting device may be located in the carrier and attached to a surface machined to constrain the base of the sighting device in three axes. The angular relationships between the sighting device base and the experiment mounting bases are measured and established prior to installation of the experiments. Using this device an astronaut can acquire a selected reference star. By sighting the same

4.2.2.2 (Continued)

star with the G & N OSS and reading the gimbal angles simultaneously a reference between the two optical systems is established. Repetition of this procedure with a second star would complete the necessary data acquisition to establish the experiment alignments relative to the NB.

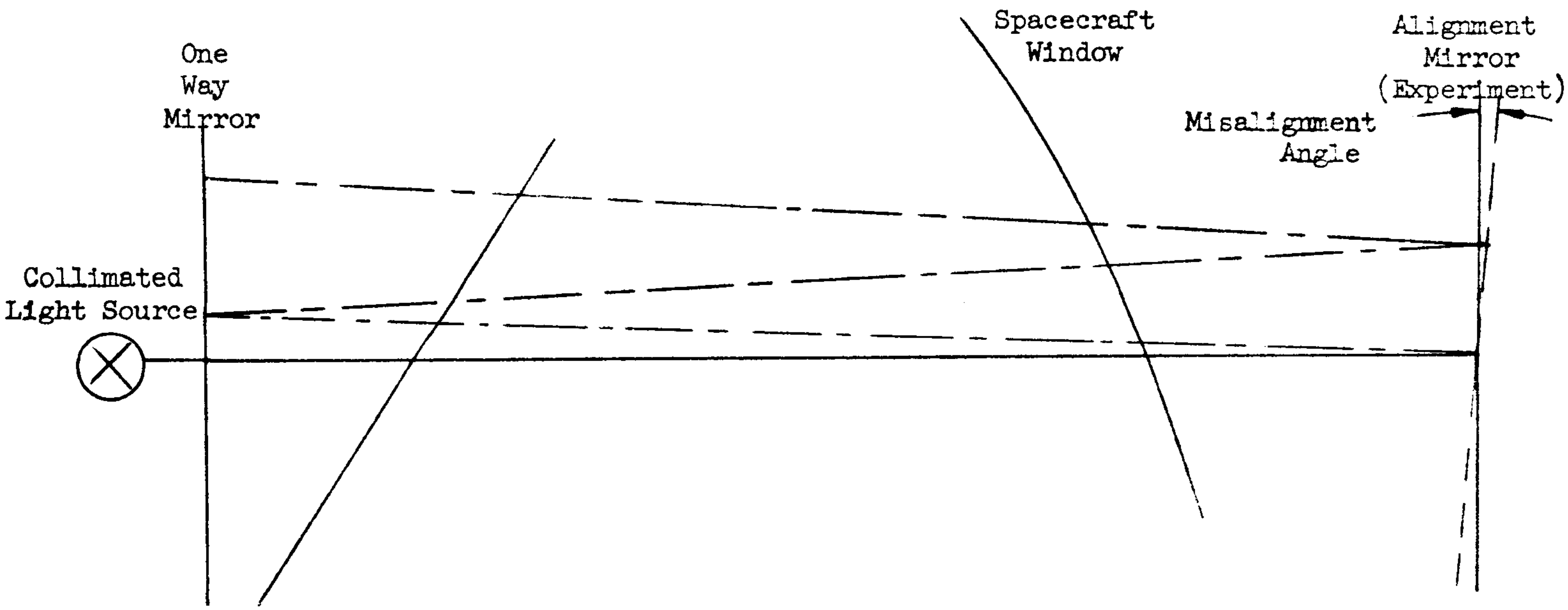
4.2.2.3 <u>Theodolite (Pitch and Roll Alignment)</u> - Since the existence of an alignment determination requirement will be known before launch, an optical surface (mirror) may be aligned to the required experiment axes to better than one $\widehat{\text{min}}$. The surface itself should be good to better than one $\widehat{\text{min}}$ and should be mounted in such a position that a collimated light beam may be shown through a spacecraft window onto the surface and returned through the same window.

With this arrangement a simplified standard two-axis theodolite with sufficient accuracy to meet approximately 5 $\widehat{\text{min}}$ mounted in the CSM window may now measure the relative alignment between the CSM theodolite axis and the carrier reference axis normal to the optical surface. The measurement of the alignment about the normal to the carrier reference mirror (CRM) is discussed later.

Under the circumstances of large misalignments and/or large separations between the theodolite and the CRM a rigidly mounted theodolite will place severe requirements on the size on the CRM. That is to say that for a 10 deg misalignment at 10 feet separation the mirror would require a 21-inch radius in order to have the theodolite capture a return beam. A theodolite translatable on a reasonably accurate rail will help resolve this problem but only about one axis if only one degree of translational freedom is made available. The docking accuracy about the pitch and roll axes should be significantly better than 5°, therefore the problem may not be as severe as implied.

4.2.2.4 <u>Dual Mirror (Pitch and Roll Alignment)</u> - Another technique may be suggested for determination of two axis alignment errors since accuracy requirements are not severe.

With this technique the requirement remains for the carrier reference mirror (CRM), the utilization of which remains the same. The difference here lies in the mechanization at a simplified two axis theodolite, a single axis of which is drawn schematically in Figure 4.2.2.4-1.



Single Axis Optical Schematic

Figure 4.2.2.4-1

4.2.2.4 (Continued)

The collimated light source, one way mirror, and semi-transparent material all are to be mounted on one assembly which is gimballed about two axes with anti-backlash worm gear drives and zeroable vernier readouts accurate to better than 3 min. The semi-transparent material acts as a viewing surface by presenting a dot for each beam striking it. A sequence of divergent dots will exist on this material as long as the one way mirror, which is laboratory aligned perpendicular to the collimated light beam, is not parallel to the CRM. As the two surfaces are brought closer to parallel the dots will become closer together. Finally, when the surfaces are parallel one dot should exist on the material. The angular deviation from initial alignment may be read off the vernier dials.

Since the diffraction of the windows may not be uniform and the separation of the surfaces may not be exactly known, a calibrated reticle would not be used on the semi-transparent material except to estimate alignment.

The same problem with respect to mirror size requirement exists with this technique as was discussed in Section 4.2.2.3.

4.2.2.5 Yaw Axis Alignment Determination - Yaw axis alignment may be determined by reading a vernier scale at the docking interface which is the method presently provided for in the CSM/LM. As an alternative, a polarized light source on the experiment carrier could be shown through a CSM window, through polarized optics and onto a photosensitive device. A vernier dial on the optics drive would be read out yielding the change in alignment about the roll axis from a previously calibrated point determined prior to launch.

4.2.3 Three-Gimbal IMU Gimbal Dynamics

4.2.3.1 General - The CSM G & N system utilizes a three-gimbal platform and the possibility of approaching gimbal lock conditions during vehicle pitch maneuvers under various initial IMU gimbal orientation must be considered. Should this region be approached, and depending upon the vehicle body rates, very high gimbal acceleration torques may be called for by the gyros in order that the stable

4.2.3.1 (Continued)

element be held fixed in inertial space. If these acceleration torques are not available or some gimbal freedoms are limited, the stabilization loops may saturate causing a platform "dump." This will cause a loss of the attitude reference previously held by this device. It is therefore necessary to know what regions have this potential so that they may be avoided.

4.2.3.2 System Definition - The gimbal axes will be designated as Outer, Middle, and Inner. These are aligned to null conditions along what are normally defined as the vehicle roll, yaw and pitch axes, respectively. Note that these are not the same as the axes referred to nose down orientation and defined in Section 4.2.2.1. The sense of the gimbal axes and rotations of the inner member about these axes are shown in Figure 4.2.3.2-1. Figure 4.2.3.2-2 is a schematic representation of the gimbal alignment at null. It may be seen that, with no previous maneuvers, pitch maneuvers are completely decoupled at the stable element by the inner gimbal. In a similar manner it may be seen that with a previous yaw rotation of 90 degrees the stable element has lost its degree of freedom about what is now the vehicle's pitch axis. Subsequent pitch maneuvers may therefore cause platform "dump" or loss of stability. The question to be resolved is what happens between these two extremes of zero yaw angle and 90 degrees yaw angle when the vehicle goes through a 360 degree pitch maneuver. To answer this question the gimbal dynamics were modeled under perturbing pitch motions. This model is discussed below.

4.2.3.3 Model - The model philosophy is to define the various rotational rates that may be made about all axes considered simultaneously and in the stable element coordinate system. Since the stable element must remain fixed in inertial space the vector sum of these rates must equal the zero vector. Mathematically this may be expressed as follows:

$$\overset{o}{\underline{B}}/_{SE} + \overset{o}{\underline{\alpha}}/_{SE} + \overset{o}{\underline{\beta}}/_{SE} + \overset{o}{\underline{\gamma}}/_{SE} = \underline{0}$$

where $\overset{o}{\underline{B}}/_{SE}$ = the vehicle body rate vector known in stable element coordinates

$\overset{o}{\alpha}$ = outer gimbal rate

$\overset{o}{\beta}$ = middle gimbal rate

$\overset{o}{\gamma}$ = inner gimbal rate

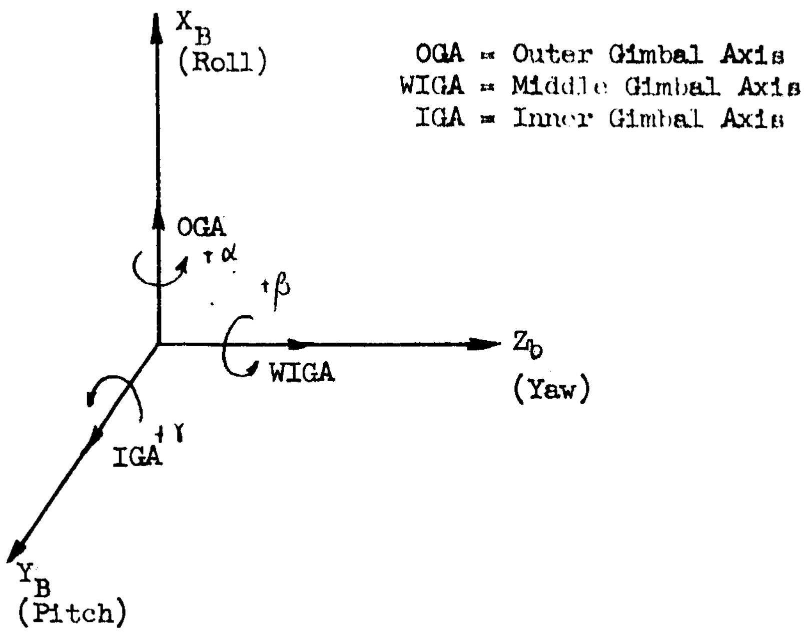


Figure 4.2.3.2-1

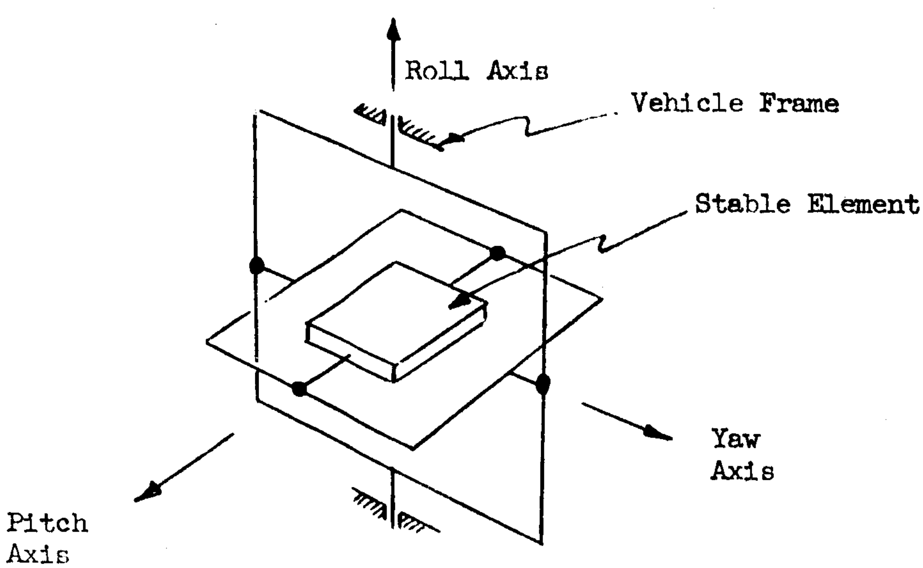


Figure 4.2.3.2-2

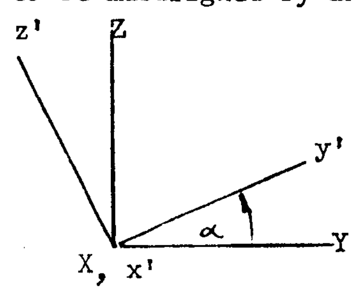
4.2.3.3 (Continued)

To clarify terminology a gimbal is defined as an axis of freedom, and a gimbal ring is the mechanical structure that interfaces with two gimbals. The outer gimbal ring interfaces with the outer and middle gimbal. The inner gimbal ring interfaces with the middle and inner gimbals.

The transformations required to bring the various rotational rates into stable element coordinates will now be developed.

Body to Outer Gimbal Ring Transformation:

Two coordinate sets are assumed to be fixed respectively in the Body and the Outer Gimbal Ring. These sets are known to be misaligned by an angle α as shown below.



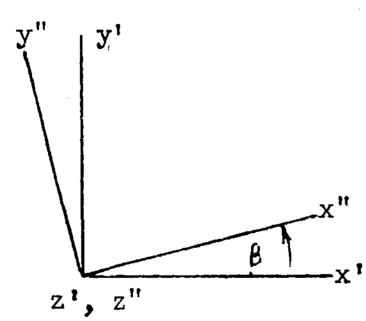
(X, Y, Z) —— Body (B)

(x', y', z') —— Outer Gimbal Ring (OGR)

Therefore, any vector in Body coordinates may be found in OGR coordinates by

$$\underline{A}/_{OGR} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix} \underline{A}_R = \left[C(\alpha)\right] \underline{A}_R$$

Similarly for OGR to Inner Gimbal Ring (IGR) coordinates:



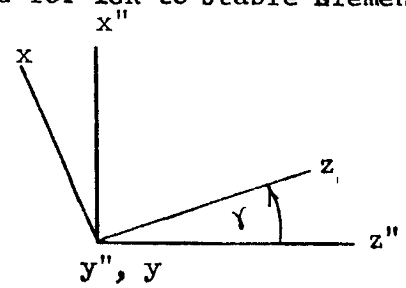
4.2.3.3 (Continued)

(x', y', z') —— OGR

(x", y", z") —— IGR

$$\underline{A}/_{IGR} = \begin{bmatrix} \text{Cos}\,\beta & \sin\beta & 0 \\ -\sin\beta & \text{Cos}\,\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \underline{A}_{OGR} = \left[C(\beta)\right] \underline{A}_{OGR}$$

And for IGR to Stable Element (SE) Coordinates:



(x", y", z") —— IGR

(x, y, z) —— SE

$$\underline{A}/_{SE} = \begin{bmatrix} \text{Cos}\,\gamma & 0 & -\sin\gamma \\ 0 & 1 & 0 \\ \sin\gamma & 0 & \text{Cos}\,\gamma \end{bmatrix} \underline{A}/_{IGR} = \left[C(\gamma)\right] \underline{A}/_{IGR}$$

Since $\underline{A}$ is a general vector, by substituting it is found that the rate equation becomes:

$$\left[C(\gamma)\ C(\beta)\ C(\alpha)\right] \overset{o}{\underline{B}}/_{B} + \left[C(\gamma)\ C(\beta)\right] \overset{o}{\underline{\alpha}}/_{OGR} +$$
$$\left[C(\gamma)\right] \overset{o}{\underline{\beta}}/_{IGR} + \overset{o}{\underline{\gamma}}/_{SE} = \underline{0}$$

By substituting and carrying out the matrix multiplication:

$$\left[C(\gamma)\ C(\beta)\right] = \begin{bmatrix} \text{Cos}\,\gamma\ \text{Cos}\,\beta & \text{Cos}\,\gamma\ \sin\beta & -\sin\gamma \\ -\sin\beta & \text{Cos}\,\beta & 0 \\ \sin\gamma\ \text{Cos}\,\beta & \sin\gamma\ \sin\beta & \text{Cos}\,\gamma \end{bmatrix}$$

4.2.3.3 (Continued)

and

$$\left[C(\gamma)\ C(\beta)\ C(\alpha)\right] = \begin{bmatrix} (\cos\gamma \cos\beta) & (\cos\alpha \cos\gamma \sin\beta + \sin\gamma \sin\alpha) & (\sin\alpha \cos\gamma \sin\beta - \sin\gamma \cos\alpha) \\ (-\sin\beta) & (\cos\beta \cos\alpha) & (\sin\alpha \cos\beta) \\ (\sin\gamma \cos\beta) & (\cos\alpha \sin\gamma \sin\beta - \cos\gamma \sin\alpha) & (\sin\alpha \sin\gamma \sin\beta + \cos\gamma \cos\alpha) \end{bmatrix}$$

Since the vectors $\underline{\dot{\alpha}}$, $\underline{\dot{\beta}}$, and $\underline{\dot{\gamma}}$ are vectors constrained to one axis within their respective coordinate systems they have the following values:

$$\underline{\dot{\alpha}}/_{OGR} = \begin{bmatrix} \dot{\alpha} \\ 0 \\ 0 \end{bmatrix}, \quad \underline{\dot{\beta}}/_{IGR} = \begin{bmatrix} 0 \\ 0 \\ \dot{\beta} \end{bmatrix}, \quad \text{and} \quad \underline{\dot{\gamma}}/_{SE} = \begin{bmatrix} 0 \\ \dot{\gamma} \\ 0 \end{bmatrix}$$

For this problem the specific case of pitch motion only was defined. Therefore

$$\underline{\dot{B}}/_{B} = \begin{bmatrix} 0 \\ \dot{B} \\ 0 \end{bmatrix}$$

Carrying out the matrix multiplication on these simple vectors yields the following set of coupled nonlinear nonhomogenous differential equations.

$$\dot{B}\,(\cos\alpha \cos\gamma \sin\beta + \sin\gamma \sin\alpha) + (\cos\gamma \cos\beta)\,\dot{\alpha} - (\sin\gamma)\,\dot{\beta} = 0$$

$$\dot{B}\,(\cos\beta \cos\alpha) - (\sin\beta)\,\dot{\alpha} + \dot{\gamma} = 0$$

$$\dot{B}\,(\cos\alpha \sin\gamma \sin\beta + \cos\gamma \sin\alpha) + (\sin\gamma \cos\beta)\,\dot{\alpha} + (\cos\gamma)\,\dot{\beta} = 0$$

A closed form solution for virtually any driving function is difficult or impossible; therefore a digital simulation was chosen as a method of solution.

Solving simultaneously for the gimbal rates as a function of the pitch body rate it is found that:

4.2.3.3 (Continued)

$$\dot{\alpha} = -\dot{B}\left[\frac{\sin\gamma}{\cos\beta} \cdot (\cos\alpha\sin\beta(\cos\gamma + \sin\gamma) + \sin\alpha(\sin\gamma - \cos\gamma))\right] = -\dot{B}\left|F\right|$$

$$\dot{\ } = -\dot{B}\left[\frac{\cos\alpha\sin\gamma\sin\beta}{\cos\gamma} - \frac{\sin\alpha - \sin\gamma\cos\beta}{\cos\gamma}(F)\right]$$

$$= -\dot{B}\left[G\right]$$

$$\dot{\ } = -\dot{B}\left[\cos\beta\cos\alpha + \sin\beta(F)\right] = -\dot{B}\left[H\right]$$

For this problem a fourth equation exists:

$\dot{B} = C$ (a constant)

An approximate recursive solution may be found in the following way:

$$\frac{\Delta\alpha}{\Delta T} = -\frac{\Delta B}{\Delta T} F(\alpha, \beta, \gamma)$$, α, β, γ are past total values

Therefore

$$\Delta\alpha = -\Delta B\ F(\alpha, \beta, \gamma)$$

Where

$B = C\Delta T$, C = constant

Similarly

$$\Delta\beta = -\Delta B\ G(\alpha, \beta, \gamma)$$

and

$$\Delta\gamma = -\Delta B\ H(\alpha, \beta, \gamma)$$

4.2.3.3 (Continued)

The new total values of α, β, γ, and B are given by:

$$B_L = B_o + \Delta B$$

$$\alpha_L = \alpha_o + \Delta\alpha$$

$$\beta_L = \beta_o + \Delta\beta$$

$$\gamma_L = \gamma_o + \Delta\gamma$$

Where subscript L represents the new value and o represents the back value. Initial conditions at the starting time are the back value.

4.2.3.4 Results and Conclusions - The results of the simulation show that constant pitch rates following initial yaw displacements of greater than 10 degrees can yield a potential problem by approaching gimbal lock conditions and consequent high gimbal rate requirements. Conditions other than these produce either constant or periodic gimbal rates that do not greatly exceed the body rate driving function. Therefore, the CMC IMU alignment routine must provide that the vehicle null yaw orientations lie in or near the orbit plane. Also, maneuvers about the vehicle yaw axis must be restricted during local vertical periods.

The data in Table 4.2.3.4-1 was derived from a computer mechanization as outlined above. The gimbal angles, alpha, beta, and gamma are respectively the outer, middle and inner gimbals. The body rotational rate was assumed to be 1° per unit time totally about pitch. The output from the program is a print of the three gimbal angles, each ten (10) units of time until the body has rotated through 360°. The maximum change of a gimbal angle for all print intervals over the 360° of body rotation is given, along with the gimbal initial conditions. Since the print interval is uniform the maximum angular change over all print intervals is a measure of the maximum gimbal angle rate required to hold the stable element fixed in inertial space.

The conclusion that may be drawn is that the region of initial conditions reflected in cases 5 through 13 should be avoided. In fact, some subsequent runs have shown that gimbal rate requirements are excessively high if initial

4.2.3.4 (Continued)

Case	Initial Conditions (Degrees)			Maximum Angular Change Per 10 Unit Time Intervals (Degrees)		
	Alpha	Beta	Gamma	Alpha	Beta	Gamma
1	0	0	0	0	0	10
2	30	0	0	6	5	11
3	60	0	0	16	9	19
4	90	0	0	0	10	0
5	0	30	0	80	170	90
6	30	30	0	*	80	*
7	60	30	0	70	10	71
8	90	30	0	0	10	0
9	0	60	0	40	14	40
10	30	60	0	11	60	8
11	60	60	0	*	26	*
12	90	60	0	0	10	0
13	30	30	30	6	43	9
14	60	60	60	22	38	20

*Implies that the angle was too large to consider reasonable, probably due to the model approaching a singular point corresponding to "gimbal lock" conditions.

TABLE 4.2.3.4-1

4.2.3.4 (Continued)

conditions on Beta are in excess of 10 to 15 degrees. Cases with intial conditions in this range should be studied in more detail.

Although the results appear reasonably conclusive, the program is not as general as possible. In further studies a more general solution would be mechanized and areas where high gimbal rates occur investigated in more detail.

4.2.4 Backup Systems

4.2.4.1 General - A number of backup systems have been considered in conjunction with operation of the G & N system as the prime mode for local vertical orientation. Such a system could be considered as either a backup, or as an alternate which would enable more versatility in mission planning by alternating with the G & N system for local vertical maintenance and permitting more extensive use of the CMC in other modes and applications.

The backup systems considered are all based on man-in-the-loop operation and would provide a display to the astronaut from which the astronaut would command vehicle attitude using the hand controller. The systems which were evaluated are:

a. Optical local vertical control using an instrument which would image sectors of the horizon and operate in conjunction with a drift meter device.

b. Use of G & N optical system to provide periodic local vertical realignment.

c. Horizon scanner and gyrocompass mechanization driving astronaut display.

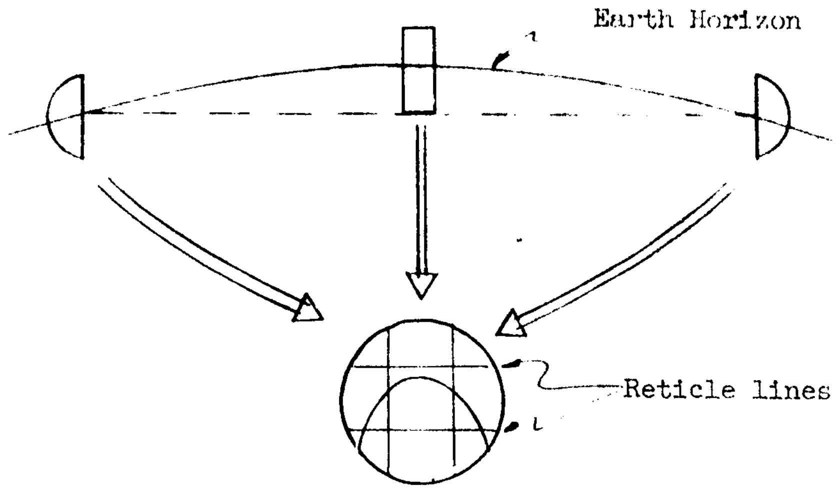
The last of these is the recommended alternative. These three approaches are discussed in Sections 4.2.4.2 through 4.2.4.4. Factors determining selection are discussed in Section 4.2.4.5.

4.2.4.2 Optical Local Vertical Control

a. Horizon Sector Imager - This approach to backup local vertical control requires an instrument which would provide the astronaut an image combining sectors of the horizon visible simultaneously from one or more of the spacecraft windows. The instrument would be rigidly attached inside the CSM and the image would be such that a specific pattern appeared with the spacecraft oriented to the local horizontal plane. For accurate orientations it is probable that development of a new instrument would be required. However, a stadimeter, as available from the Kollsman Instrument Corp., furnishes the basic imaging capability. This instrument is being developed for manual determination of altitude from a spacecraft. This is accomplished by measuring an angle obtained from three equally spaced points on the horizon. However, the resulting visual horizon display also satisfies the requirement to orient the vehicle to the local horizontal. Figure 4.2.4.2-1 illustrates the horizon points and horizon imaging. This type of instrument will enable orientation to the local horizontal plane but does not provide information as to azimuth error (angle from the velocity vector within the plane). This is discussed in the next Section.

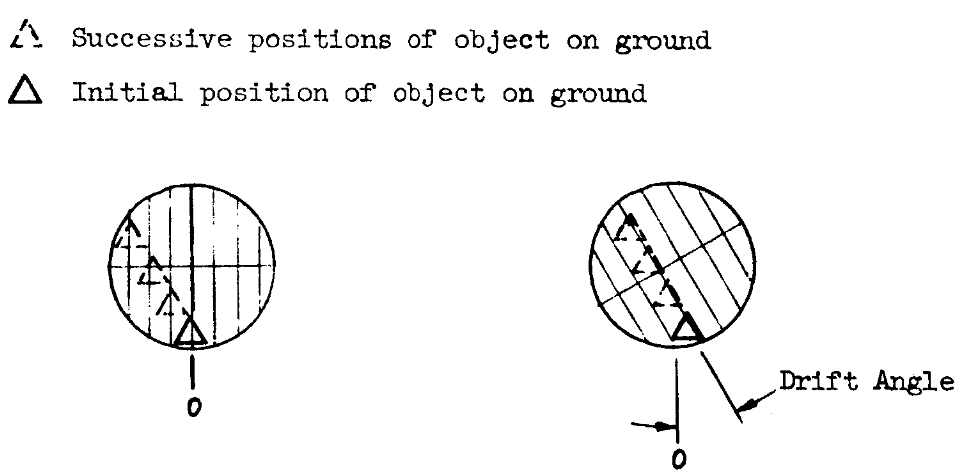
b. Drift Meter - This is a device which was developed to provide an optical system to look along the ground track of an airplane. Through the use of a rotatable reticle an observer can determine the angle between the carrier vehicle heading vector and the velocity vector by rotating the optics such that an object on the ground follows along a line on the reticle. Figure 4.2.4.2-2 illustrates the principle of this instrument. An angular accuracy of 0.5 deg is considered reasonable for operation in an aircraft but cannot be considered applicable to spacecraft.

Two drift meter problem areas appear applicable to spacecraft usage. If the field of view (FOV) is narrow an object may pass through the FOV too rapidly for alignment to be made. Also, pitch or roll motions cause the instrument line of sight to shift with a resulting displacement of the objects in the FOV. The latter problem is eliminated if the instrument has gyro stabilized optics.



Split Image Visual Display

Figure 4.2.4.2-1



Optics held fixed

Optics Aligned

Figure 4.2.4.2-2

4.2.4.2 b. (Continued)

Considering the first problem, it is noted that an object on the ground will have an apparent speed of approximately 4.6 mi/sec. This means that with a FOV of 1.8 deg, corresponding to the on-board sextant, an object will pass through the FOV in approximately one second. The on-board scanning telescope has a FOV of 60 deg and for this case a given object would be available for about 27 sec; this is considered to be sufficient.

A worst case roll rate may be calculated by assuming a two jet completely unsymmetric minimum impulse limit cycle without cross coupling. For this case the vehicle roll rate is given by:

$$\dot{\phi} = \frac{2L(F\ t)_{min}}{I}$$

where: $L = 6.4$ ft

$(F\ t)_{min} = 0.5$ lb-sec

$I = 16{,}000$ ft-lb-sec^2

$\dot{\phi} = 4 \times 10^{-4}$ rad/sec or 0.023 deg/sec

The resulting apparent transverse rate of an object on the ground would be 0.05 mi/sec.

If the roll rate is assumed to be identically zero, the transverse rate of a ground object due to an angular displacement between vehicle heading and the velocity vector would be:

$$v_T = /V/ \sin X$$

where $/V/ = 4.6$ mi/sec

From which, the transverse rate due to heading error would be less than the rate due to roll limit cycles for values of heading error less than 0.6 deg and this would seriously degrade the achievable azimuth alignment accuracy.

4.2.4.3 G & N Optical Realignment - For the purpose of this procedure it is assumed that the astronaut has at his disposal the following information and equipment.

a. The vehicle's orbital parameters and its position in terms of its longitude, latitude and altitude.

b. Time

c. Ephemeris information

d. CSM G & N optical system sextant (2LOS) but not the IMU and CMC.

e. Manual attitude control through the hand controller.

It is well known that fixes on two stars, not on the same LOS, determines a unique attitude since rotating about either star LOS will remove the other LOS from the second star. Using this fact and the two-LOS sextant mounted on the navigation base, an astronaut may align an axis of the vehicle closely to the local geographic vertical (within 12 $\widehat{\text{min}}$), as well as define a unique heading.

With the knowledge of local longitude, latitude and time possibly through voice communication with tracking stations, the astronaut may convert ephemeris information on various stars (at least two) to azimuth and elevation angles in and from the local horizontal plane for a spherical earth. By setting the appropriate angles for these stars in the sextant and bringing the vehicle around until the stars are sighted along the appropriate LOS the vehicle will be aligned near the local vertical at the specified longitude and latitude. Since the acquisition at the reference stars takes time and the local vertical moves at orbital rate (approximately 4 degrees/minute), the astronaut would anticipate passing over the required longitude and latitude point by having acquired the required stars with the sextant in advance. When the vehicle reached its required point it could be taken from visual control of the astronaut and the orbital rate introduced into the pitch axis in order to hold local vertical.

4.2.4.3 (Continued)

Depending upon the current shape of the earth being used, the true local vertical may deviate from the vertical determined by the above technique by as much as 12 min. This is probably acceptable; however, if not, varied degrees of hand correction could be made depending upon the level of accuracy required. Correction philosophies range from simply adding a correction term to the geocentric latitude that is a periodic function of that latitude, to that of using extensive tabular data.

Control subsequent to this realignment procedure assumes the use of the SCS. Two modes would be available. In one, the pitch gyro would be torqued at the orbital rate and control maintained automatically. Alternatively, the FDAI may be precessed at the orbital rate and the astronaut would manually introduce the rate necessary to maintain the displayed pitch error at null.

4.2.4.4 Horizon Sensor and Gyrocompass Display for Manual Control -

Horizon sensors present a proven method of determining the attitude of a vehicle relative to the local horizontal plane. Further, by gyrocompassing techniques which appropriately combine horizon sensor and gyro data the vehicle azimuth error may be determined. The system proposed here includes the sensor hardware and gyrocompass signal processing discussed in detail in Section 4.3. However, the sensor system output, consisting of three-axis error signals, would be the input to an astronaut display. In addition, a rate gyro package would be mounted on the experiment carrier and the three-axis rate information combined with the attitude error display. Figure 4.2.4.4-1 shows the system block diagram.

4.2.4.5 Backup System Trade-off Factors

4.2.4.5.1 Cost - From the standpoint of cost the three alternatives discussed would have the following ranking with the cost items identified:

a. G & N Optical Realignment - No cost, existing CSM system.

b. Optical Local Vertical Control - Development and qualification of at least one, probably two, optical instruments.

c. Horizon Sensor and Gyrocompass - System development effort, re-qualification of existing hardware.

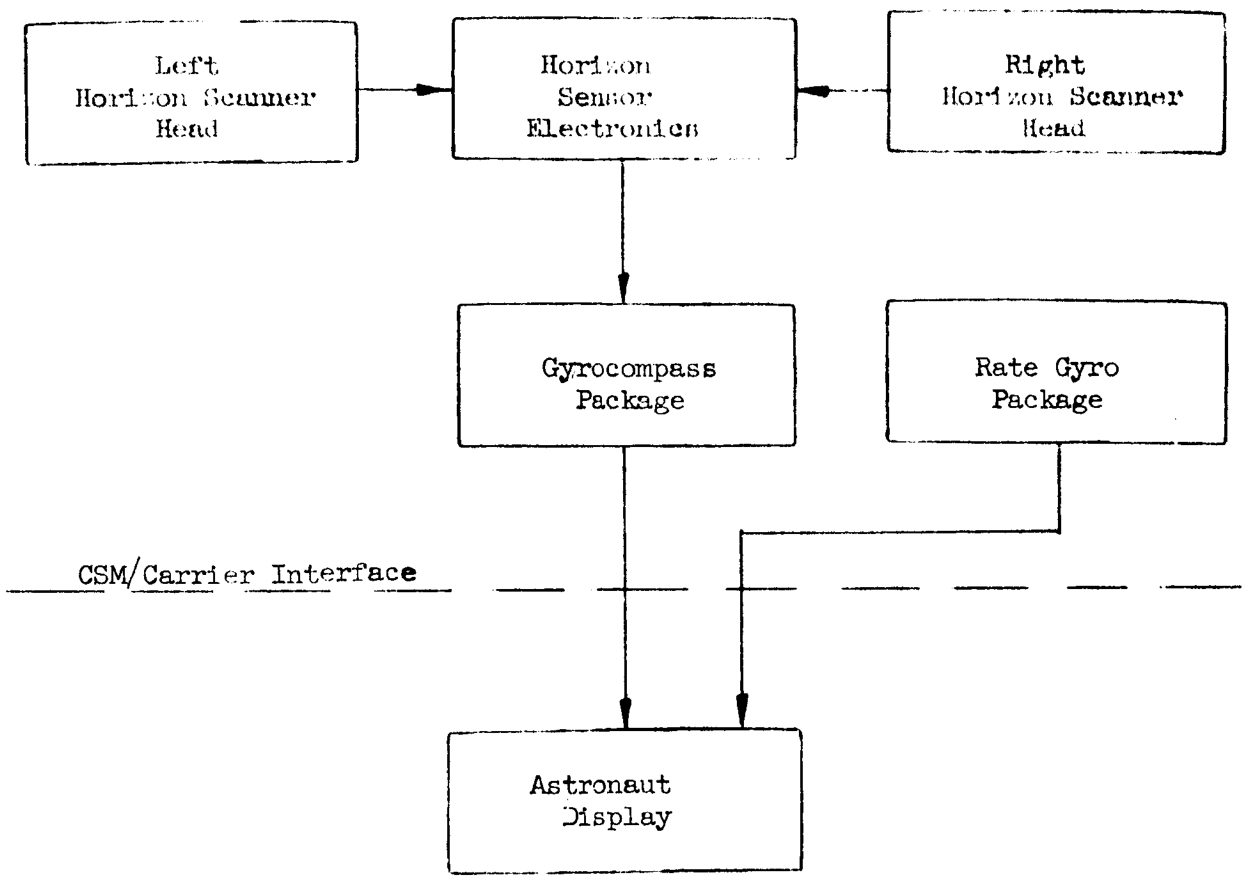


Figure 4.2.4.4-1

4.2.4.5.1 (Continued)

The relatively higher cost of the last alternative results largely from the qualification of hardware to Apollo specifications. If it is anticipated that the horizon sensor system will satisfy requirements which will arise on other AAP flights the cost contrast is significantly reduced.

4.2.4.5.2 Power - The three alternatives are ranked as follows:

a. Optical Local Vertical Control - Power for illumination only.

b. Horizon Sensor and Gyrocompass - Average power of approximately 50 watts from experiment carrier.

c. G & N Optical Realignment - Requires the SCS as well as the optical system, average power in excess of 500 watts from CSM fuel cells.

4.2.4.5.3 RCS Propellant - The three alternatives are ranked as follows:

a. Horizon Sensor and Gyrocompass - Simulation required for quantitative data.

b. G & N Optical Realignment - Approximately 2.9 lb/hr for SCS attitude hold under Mission 1A conditions.

c. Optical Local Vertical Control - Not less than 3 lb/hr.

This trade-off factor is considered to be highly significant. The SCS attitude hold propellant usage rate is obtained from SID66-1501-A, Vol. 3, Performance Data Supplement (MMDB), 15 March 1967.

Simulations have demonstrated that propellant usage of 3 lb/hr may be expected for alignment to a target with an optical instrument and errors maintained at about 0.25 deg. However, this simulation requires observation of just a single image, control about only two axes, and was for periods of one-half hour or less. Although it is not anticipated that 0.25 deg accuracy will be required for the local vertical hold, the optical local vertical controlmode would require simultaneous control about three axes using two optical instruments for extended periods of time. It is not reasonable to expect more efficient propellant utilization under these conditions.

4.2.4.5.3 (Continued)

A significant difference is inherent with the Horizon Sensor and Gyrocompass alternative. The outputs are electrical, not visual, and hence may be displayed in conjunction with vehicle angular rate data. The combination of attitude and rate on an appropriate display, combined with crew training, would make it possible to approach optimum limit cycle operation with a resultant significant decrease in RCS propellant usage rates.

4.2.4.5.4 Accuracy - The alternatives are ranked as follows:

a. Horizon Scanner and Gyrocompass - Obtainable accuracy should be better than 1 deg but would be limited more by propellant conservation than system errors.

b. Optical Local Vertical Control - Accuracy is estimated to be better than 5 deg. Azimuth error could probably not be reduced below 2 deg at best.

c. G & N Optical Realignment - Error over an orbit is estimated to exceed 5 deg due primarily to gyro drift, accumulative error in open loop orbital rate torquing and cross coupling effect.

4.2.4.5.5 Crew Factors - This is another significant factor favoring selection of the Horizon Sensor and Gyrocompass. With this alternative direct manual control may be exercised from an unrestrained position aided by a display which would minimize fatigue. Either of the other alternatives appear to impose relatively severe requirements on the crew.

4.3 Carrier Mounted Local Vertical System - Serious consideration was given to a carrier mounted local vertical system. It would be comprised of a three-axis reference system and control logic mounted in the carrier and would interface with the SCS at the output of the RCS drivers. A horizon scanner-strapdown gyrocompass combination will probably provide a sufficiently accurate three-axis reference. The system would result in an approximate 25 KWH saving of CSM fuel cell energy (power to the G & N system) at the expense of a 5 KWH carrier battery requirement. This system would allow more margin for use of the G & N system for other experiments and would decrease the alignment problem by location of the sensors in the carrier. Except for the electronics, all necessary hardware, i.e., horizon sensors and gyros, is flight qualified.

4.3 (Continued)

The concept met with resistance because of the additional wires required across the docking interface and because of the required cable modifications to interface with the RCS driver outputs. The carrier mounted system was therefore not recommended for the prime local vertical control. However, a sizable effort was initiated to investigate the feasibility of the strapdown gyrocompass approach and some of the preliminary results are discussed in the following paragraphs.

4.3.1 Preliminary Gyrocompass Considerations - The yaw sensing and control of an earth pointing satellite where pitch and roll information is available from a horizon sensor is considered. (In this context, and for small angular deviations from an orbit reference coordinate frame, roll is a rotation about an axis pointing in direction of velocity, yaw is a rotation about an earth pointing axis, pitch is a rotation about the normal to orbit plane.)

Various methods of yaw sensing are described in the literature (Table 4.3.1-1); they include in the approximate order of decreasing accuracy:

a. Stable gimballed platform

b. Stable analytic platform

c. Body mounted two-degree-of-freedom gyro

d. Body mounted single-degree-of-freedom gyro(s)

Selection of a specific method for AAP/PIP Mission 1A is influenced to a large extent by the following factors:

a. Simplicity of design and minimal computational requirements

b. Availability of flight proven hardware

In this context method a. is not considered because of its unavailability as flight proven hardware; method b is not desired because of either the complexity of its analog realization or the computational requirements for its digital implementation.

4.3.1 (Continued)

The choice of methods c. and d. is the subject of current investigations; method d. concerns primarily the possibility of treating the complete vehicle as a stabilized platform. Certain operating conditions appear favorable to that concept, i.e.,

a. Vehicle principal axes of inertia are advantageously oriented with respect to gravity gradient

b. Orbit is nominally circular

c. Deviation and rates of deviation (limit cycle rates) from nominal reference orientation are small

Problems under consideration include the following areas:

a. Effective orientation of gyro(s)

b. Influence of sensor noise on accuracy of heading information

c. Influence of sensor dynamics on stability

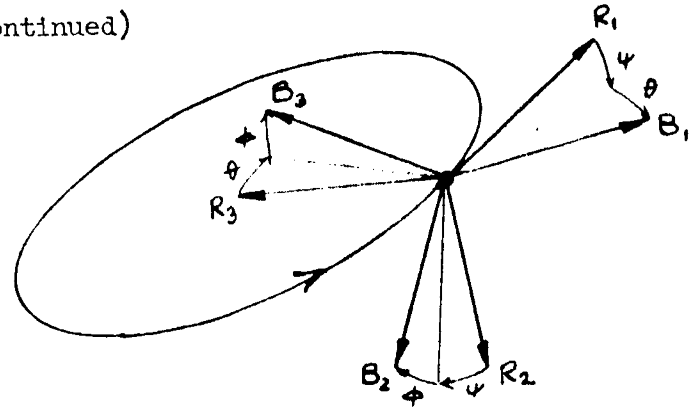
d. Effects of environmental disturbances

e. Selection of a compatible control system.

To illustrate the concept of treating the vehicle as a stabilized platform, the following simplified equations are developed:

Sketch 1 illustrates the orientation of the orbit reference coordinate system R and the body reference system B. Frame B differs from frame R by the small euler angles $\Delta\phi$, $\Delta\theta$, $\Delta\psi$. The sequence of rotation from R into B is ψ about R_3, θ about displaced R_2 ($=R_2'$), ϕ about twice displaced R_1 ($=R_1'' = B_1$).

4.3.1 (Continued)



Sketch 1

R_1 — in direction of velocity

R_2 — normal to orbit plane

R_3 — towards center of earth

The transformation of the unit vectors (e) is given by:

$$e^B = T_{BR}\, e^R$$

where for small angles

$$T_{BR} \approx \begin{bmatrix} 1 & \Delta\psi & -\Delta\theta \\ -\Delta\psi & 1 & \Delta\phi \\ \Delta\theta & -\Delta\phi & 1 \end{bmatrix}$$

thence the description of orbital rate (ω_{RI}):

$$\omega_{RI} = -\Omega_o e_2^R = \begin{Bmatrix} 0 \\ -\Omega_o \\ 0 \end{Bmatrix}^R \approx \begin{Bmatrix} -\Delta\psi\,\Omega_o \\ -\Omega_o \\ +\Delta\phi\,\Omega_o \end{Bmatrix}^B$$

(Note: Superscript is used for frame of reference, subscript designates component)

Rate of rotation of body relative to frame R:

$$\omega_{BR} = (p, q, r)^T$$

thence the inertial rate

$$\omega_{BI} = \omega_{BR} + \omega_{RI} = (\hat{p}, \hat{q}, \hat{r})^T = \begin{bmatrix} p - \Delta\psi\,\Omega_o \\ q - \Omega_o \\ r + \Delta\phi\,\Omega_o \end{bmatrix}^B$$

4.3.1 (Continued)

Again for small angles, the transformation of euler rates into relative body rates according to the established sequence is as follows:

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} \cong \begin{bmatrix} 1 & 0 & -\Delta\theta \\ 0 & 1 & \Delta\phi \\ 0 & -\Delta\phi & 1 \end{bmatrix} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

thence the following are equivalent rate expressions in the coordinates of B:

$$\begin{bmatrix} \hat{p} \\ \hat{q} \\ \hat{r} \end{bmatrix}^B \propto \begin{bmatrix} p - \Delta\psi\Omega_o \\ q - \Omega_o \\ r + \Delta\phi\Omega_o \end{bmatrix}^B = \begin{bmatrix} \dot{\phi} - \Delta\psi\Omega_o & -\Delta\theta\dot{\psi} \\ \dot{\theta} - \Omega_o & +\Delta\phi\dot{\psi} \\ \dot{\psi} + \Delta\phi\Omega_o & -\Delta\phi\dot{\theta} \end{bmatrix}^B$$

As a first approximation, it is assumed that the B_1 and B_3 terms are presented good enough by

$$\hat{p} \approx \dot{\phi} - \Delta\psi\Omega_o$$
$$\hat{r} \approx \dot{\psi} + \Delta\phi\Omega_o$$

it follows that with the proper biasing of integrating gyros mounted on these axes, secondary roll and yaw information is obtained.

The above reasoning provides a basis for the diagram and analysis presented in the next section.

4.3.2 <u>Strapdown Gyrocompass Analysis and Simulations</u> - The systems shown in Figures 4.3.2-1 and 4.3.2-2 are presently examined by simulation and analysis as possible candidates for a strapdown gyro compassing scheme, i.e., strapdown without electronic gimballing.

Basically the two systems are quite similar, that is, the purpose of the feedback paths containing gains K_3 and K_4 (second order system), and K_5 and K_6 (third order system) is to reduce the cross coupling inputs seen by the roll and yaw gyro respectively. In both systems the error signal developed by taking the difference between the horizon scanner output and the roll gyro feedback is used to torque the yaw gyro - the purpose is to decrease the response time of the gyro compass loop. The difference between the two systems shown is in the path of this error signal to the yaw torque generator, i.e., the third order system divides the signal in this path and provides an integration in one of the paths. R. L. Gordon (Ref. (3), Table 4.3.2-2 has shown

4.3.2 (Continued)

that this configuration is such that the steady state errors caused by horizon scanner bias, roll gyro offset, and yaw gyro drift are zero.

The respective transfer functions and steady state errors of the two systems as a function of gain are shown in Table 4.3.2-1.

A simulation of each of these systems has been initiated, the first phase of this simulation is to indicate feasibility; for this reason it was not felt that a one-to-one simulation was required. A block diagram of the simulation is shown in Figure 4.3.2-3. This system is being simulated on the digital computer (CDC 6400) with a program called MIMIC. The program MIMIC allows the user to program as he would on analog computer without the trouble of time or amplitude scaling. Useful results from this simulation are expected in the near future.

Another system under consideration has been derived from a spacial-rate gyrocompassing scheme previously used to align inertial platforms. The system comprises two or three body mounted single degree of freedom attitude gyros torqued electronically by the output of a two-axis horizon sensor. The outputs of the attitude gyros drive the attitude control system forcing the body dynamics. The body dynamics in turn force both the gyros and the horizon sensor dynamics. A functional block diagram of this scheme is shown in Figure 4.3.2-4. The Roll-Yaw Coupling block of this Figure serves a dual function. Since the vehicle roll error is a function of the yaw misalignment, the yaw axis is torqued by the roll horizon sensor output in order that the yaw error may be driven to null. The block also serves as a point of stability compensation.

Figure 4.3.2-5 is a simplified system error block diagram showing more details of the element's dynamics. At this point it is possible with some assumptions about the unlisted dynamics to perform a steady state analysis in order to determine the final values of the significant variables in the environment of the disturbances shown.

A cursory steady state analysis was made under the following assumptions:

a. The system is linear

4.3.2 (Continued)

b. The gyro's output axis dynamics are that of a proportional gyro, i.e.,

$$\frac{Kpo}{JS^2 + BS + K} \approx \frac{Kpo}{BS}$$

c. The attitude controllers and the roll-yaw coupling are pure gains in the steady state

e. The disturbances are steps at time zero

The results were as follows:

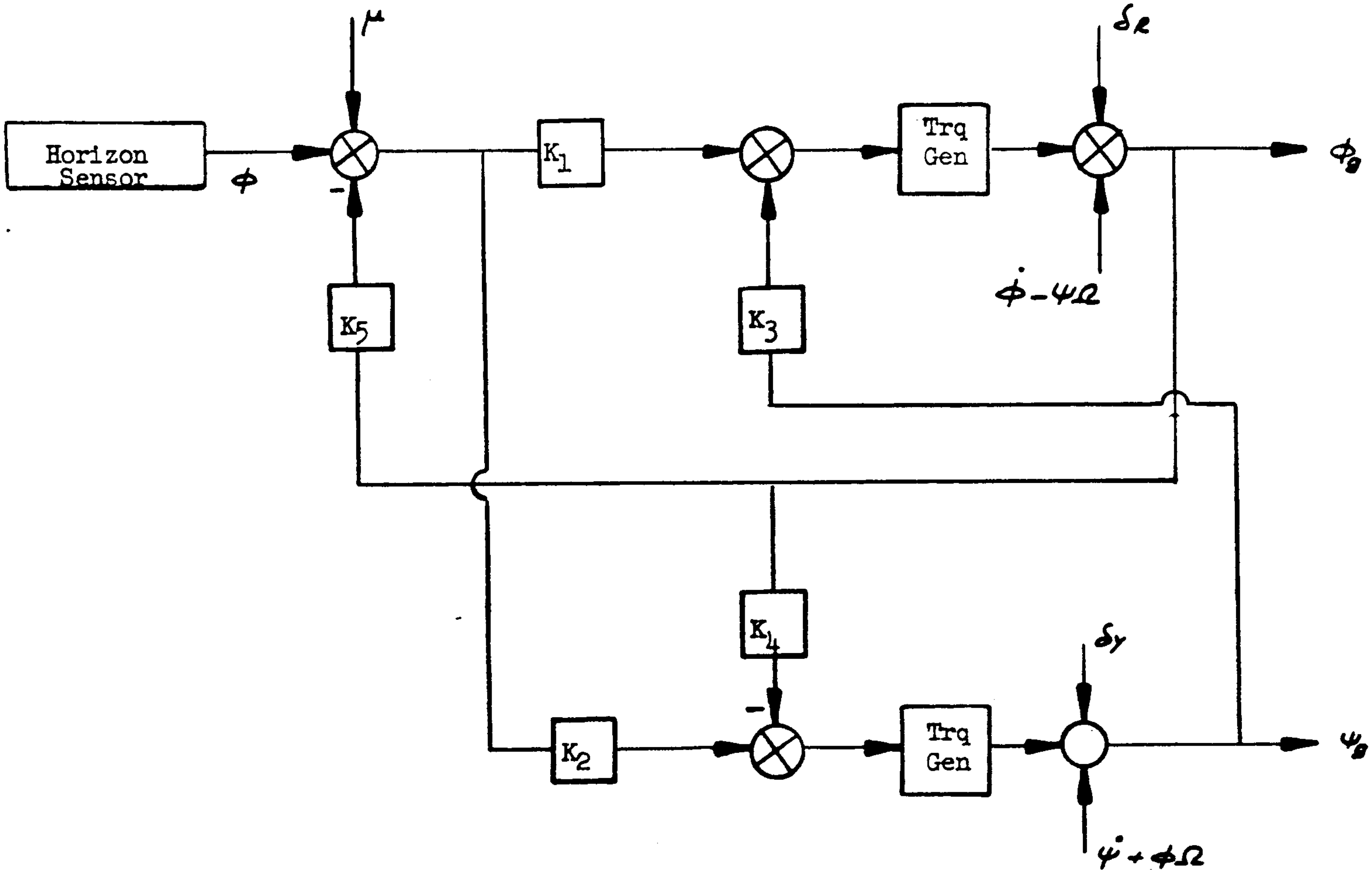
$$Y = K_1 E_R + K_2 b_R$$

$$R = K_3 E_y + K_4 b_R$$

$$P = K_5 E_p + K_6 b_p$$

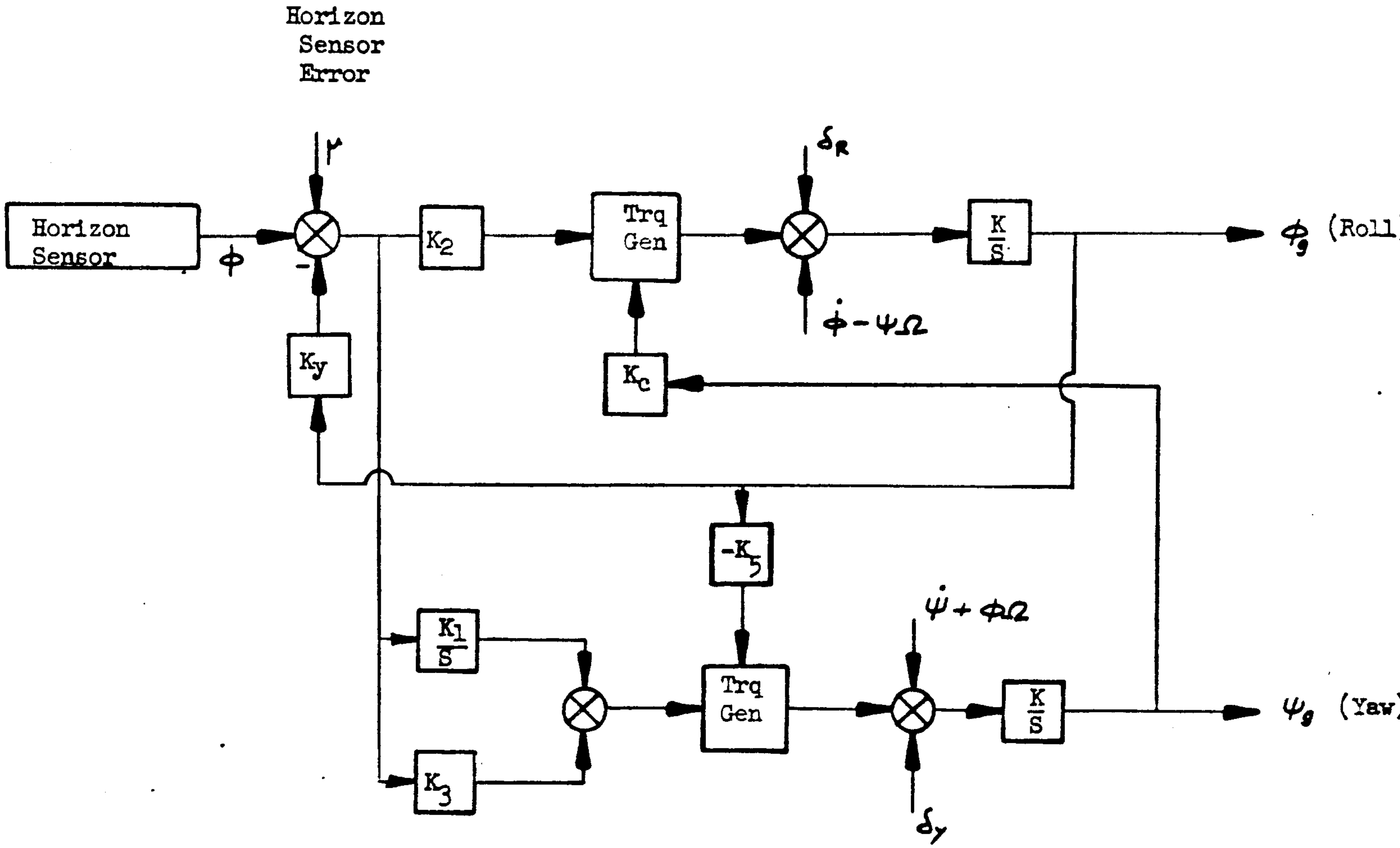
Where K_i, $i = 1 - 6$, are the ratio of products of various system gains and therefore may be considered design parameters.

The stability and transient analysis is not complete and therefore is not discussed here; however, this effort is being actively pursued. Consideration will be given in further study to nonlinearities in at least the attitude controllers and consideration will be given to the elimination of the pitch gyro by driving the pitch attitude controller directly.



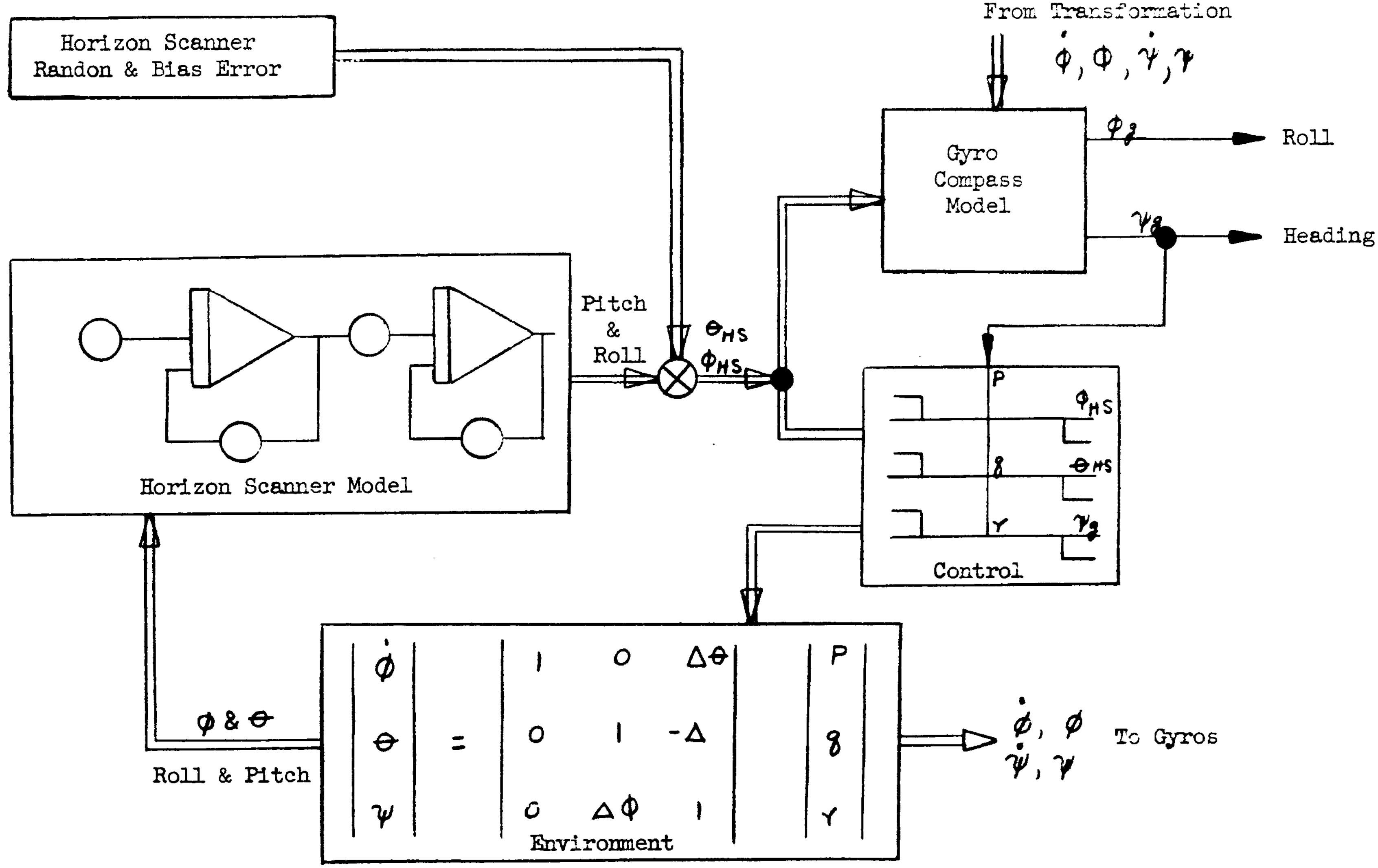
Strap-Down Orbital Gyro Compass, Second Order

Figure 4.3.2-1



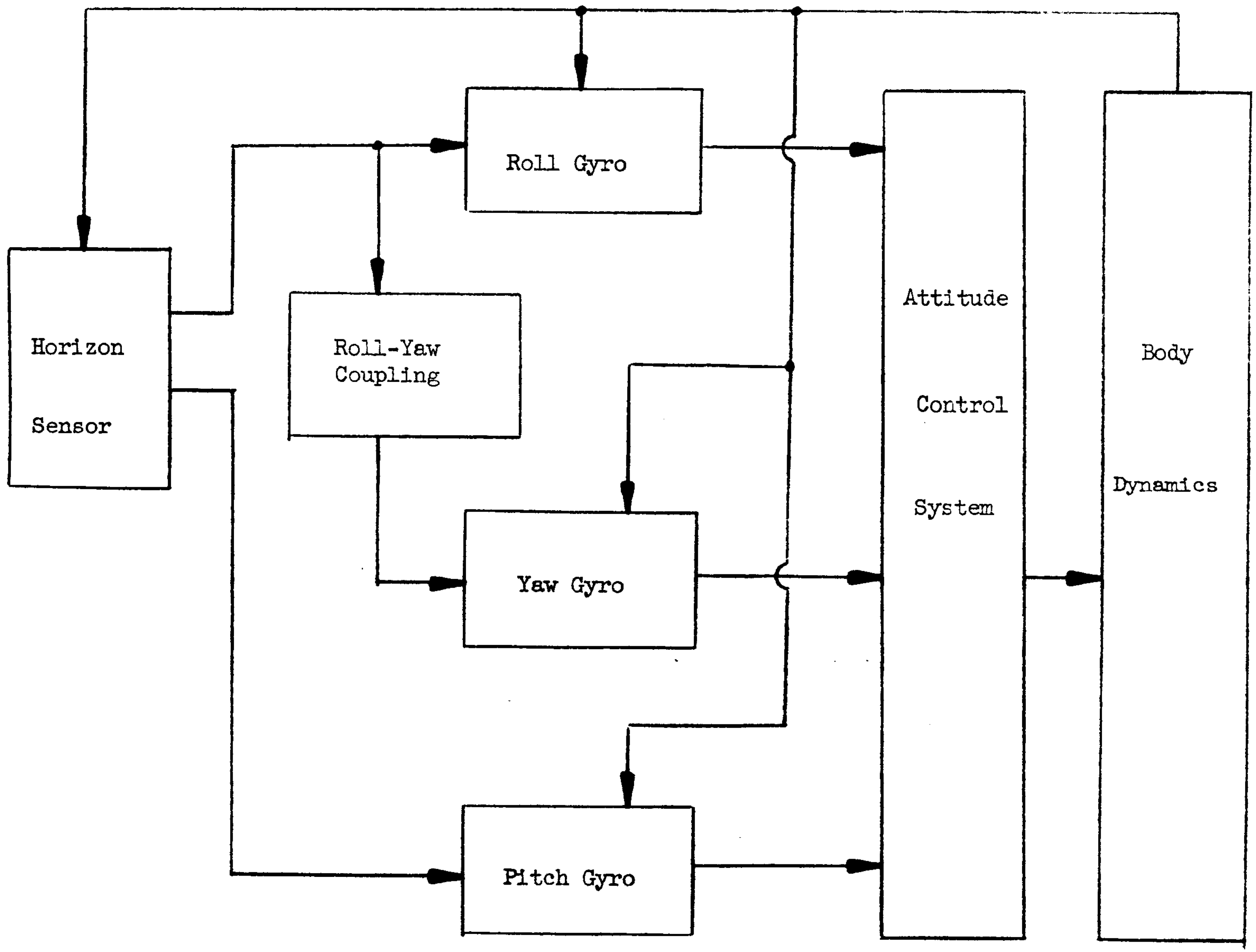
Strap-Down Orbital Gyrocompass, Third Order

Figure 4.3.2-2



Simulation Block Diagram

Figure 4.3.2-3

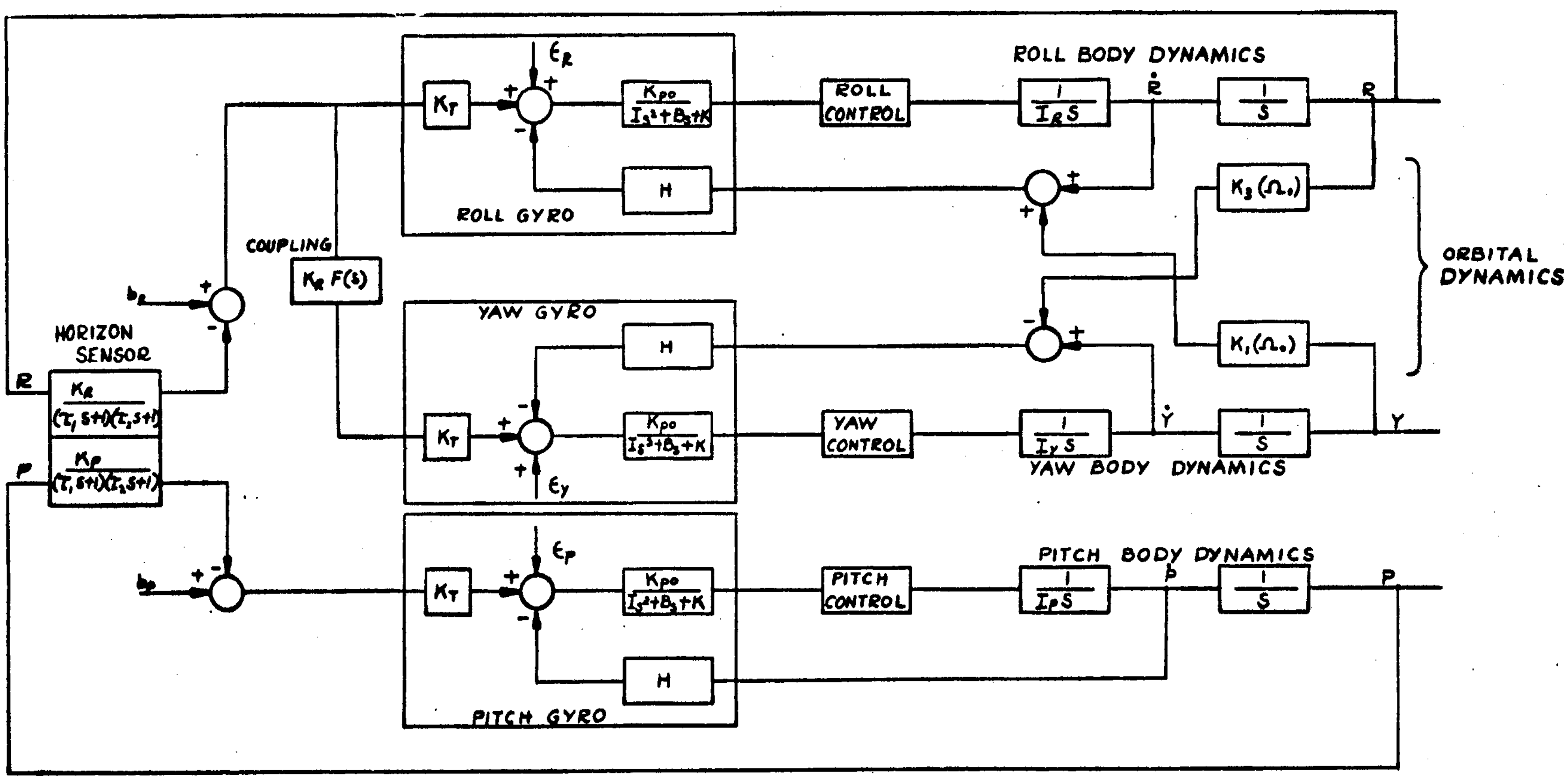


Automatic Orbital Alignment Functional Block Diagram

Figure 4.3.2-4

	TRANSFER FUNCTIONS		STEADY STATE ERRORS	
	2nd ORDER SYSTEM	3rd ORDER SYSTEM	2nd ORDER SYSTEM	3rd ORDER SYSTEM
HORIZON SCANNER BIAS	$\frac{\psi_e}{\mu} = \frac{KK_2(S-KK_1K4/K_2)}{S^2+KK_1K_5S+K^2K_3(K_2K_5+K_4)}$	$\frac{\psi_e}{\mu} = \frac{KK_3\left[S^2+S(K_1-KK_2K_5)/K_3\right]}{S^3+KK_2K_4S^2+(K^2K_5K_6+K^2K_3K_4K_6)S+K^2K_1K_4K_6}$	$\frac{-K_1K_4}{K_3(K_2K_5+K_4)}$	0.
YAW GYRO DRIFT	$\frac{\psi_e}{\delta_y} = \frac{K(S+KK_1K_5)}{S^2+KK_1K_5S+K^2K_3(K_2K_5+K_4)}$	$\frac{\psi_e}{\delta_y} = \frac{Ks(S+KK_2K_4)}{S^3+KK_2K_4S^2+(K^2K_5K_6+K^2K_3K_4K_6)S+K^2K_1K_4K_6}$	$\frac{K_1K_5}{K_3(K_2K_5+K_4)}$	0.
ROLL GYRO DRIFT	$\frac{\psi_e}{\delta_R} = \frac{-K^2(K_2K_5+K_4)}{S^2+KK_1K_5S+K^2K_3(K_2K_5+K_4)}$	$\frac{\psi_e}{\delta_R} = \frac{-K^2\left[K_5+K_3K_4\right]\left[S+K_1K_4/(K_5+K_3K_4)\right]}{S^3+KK_2K_4S^2+(K^2K_5K_6+K^2K_3K_4K_6)S+K^2K_1K_4K_6}$	$\frac{1}{K_3}$	$-\frac{1}{K_6}$
ROLL ANGLE	$\frac{\psi_e}{\phi} = \frac{\left[K(K_2+\Omega)-K^2(K_2K_5+K_4)\right]\left[S+\frac{K^2K_1K_5\Omega-K^2K_4K_1}{K(K_2+\Omega)-K^2(K_2K_5+K_4)}\right]}{S^2+KK_1K_5S+K^2K_3(K_2K_5+K_4)}$	$\frac{\psi_e}{\phi} = \frac{K\left[\Omega+K_3-K(K_5+K_3K_4)\right]\left[S^2+S\left(\frac{K_1+KK_2K_4\Omega-KK_2K_5-KK_1K_4}{\Omega+K_3-K(K_5+K_3K_4)}\right)\right]}{S^3+KK_2K_4S^2+(K^2K_5K_6+K^2K_3K_4K_6)S+K^2K_1K_4K_6}$	$\frac{K_1(\Omega K_5-K_4)}{K_3(K_2K_5+K_4)}$	0.
YAW ANGLE	$\frac{\psi_e}{\psi} = \frac{K\left[S^2+KK_1K_5S+\Omega K(K_2K_5+K_4)\right]}{S^2+KK_1K_5S+K^2K_3(K_2K_5+K_4)}$	$\frac{\psi_e}{\psi} = \frac{K\left[S^3+KK_2K_4S^2-\Omega K(K_5+K_3K_4)S-\Omega KK_1K_4\right]}{S^3+KK_2K_4S^2+(K^2K_5K_6+K^2K_3K_4K_6)S+K^2K_1K_4K_6}$	$\frac{\Omega}{K_3}$	$\frac{\Omega}{K_6}$

TABLE 4.3.2-1 TRANSFER FUNCTION AND STEADY STATE ERRORS FOR THE SECOND AND THIRD ORDER GYRO-COMPASS SCHEMES SHOWN IN FIGURES 1 AND 2



AUTOMATIC ORBITAL ALIGNMENT ERROR BLOCK DIAGRAM
FIGURE 4.3.2-5

TABLE 4.3.2-2

GYROCOMPASS REFERENCES

(1) Autonetics Division of North American Aviation
Report CG-33a/3061
Application of Gyrocompassing to Space Missions
(Feb 66)

(2) R. L. Gordon
An Orbital Gyrocompass Heading Reference for Satellite Vehicles
J. Spacecraft V2 #6 Nov-Dec 65

(3) Third-Order Orbital Gyrocompass Heading Reference
J. Spacecraft V3 #6 June 66

(4) F. J. Moran
The Use of a Two-Degree-Of-Freedom Gyroscope as a Satellite Yaw Sensor
NASA TN-D-2134 (Feb 64)

(5) V. K. Merrick
Some Control Problems Associated with Earth-Oriented Satellites
NASA TN D-1771 (June 63)

(6) Inertial Guidance
G. R. Pitman, Jr. Editor
John Wiley & Sons, Inc. New York

4.4 Passive Stabilization - Orientation of the CSM and experiment carrier with the longitudinal axis parallel to the radius vector corresponds to the attitude the vehicle would tend to assume under the influence of gravity gradient torques. This would appear to be a particularly attractive approach since RCS propellant and electrical power consumption would be at a minimum. Also, the presence of the crew would eliminate the problems of initial orientation and damping of oscillations that are inherent to this type of stabilization. However, the calculations which follow demonstrate that at the mission orbital altitude, aerodynamic torques will exceed the gravity gradient torques. Although a mass could be deployed from the vehicle to enhance the inertia ratios and hence the stabilizing torques, the resulting mechanical and dynamic complications were considered to make this approach impractical.

The following data was assumed:

$$I_{11} = 1.6 \times 10^4 \text{ slug - ft}^2$$

$$I_{22} = I_{33} = 8.3 \times 10^4 \text{ slug - ft}^2$$

$$X_{cg} - X_{cp} = 41.5 \text{ in.}$$

Figure 4.4.1-1 depicts a distributed rigid mass, M, in the earth gravitational field.

The gravitational force acting on the mass M assuming the earth's gravitational field to be radially symmetric is:

(a) $\bar{F}_G = -KM\,\bar{r}/r^3$ where K = gravitational constant for the earth.

The gravity gradient torque on the mass M is then:

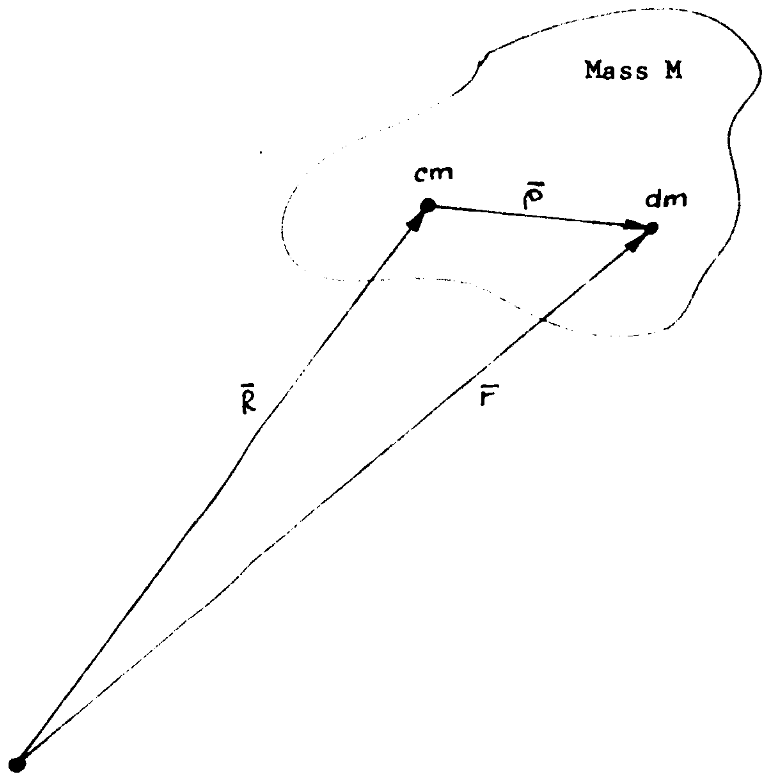
(b) $\bar{T}_G = \int_M \bar{\rho} \times d\bar{F}_G$ where X denotes the cross product.

(c) $\bar{T}_G = -k\int_M \bar{\rho} \times \bar{r}\, dm / r^3$

From Figure 1 $\bar{r} = \bar{\rho} + \bar{R}$

Also $r^2 = \bar{r} \cdot \bar{r}$ where $\cdot$ denotes the dot product.

$$r^2 = (\bar{\rho} + \bar{R}) \cdot (\bar{\rho} + \bar{R})$$
$$= R^2 + \rho^2 + 2\bar{R} \cdot \bar{\rho}$$
$$= R^2 \left(1 + (\rho^2 + 2\bar{R} \cdot \bar{\rho}) / R^2 \right)$$



Earth Center

$\bar{R}$ - vector from geocenter to the center of mass of Mass M. (CM)

$\bar{\rho}$ - vector from the CM to an elemental mass

$\bar{r}$ - vector from the geocenter to dm

Figure 4.4.1-1

$$r^{-3} = (r^2)^{-3/2}$$
$$= R^{-3}\left(1 + (\rho^2 + 2\bar{R}\cdot\bar{\rho})/R^2\right)^{-3/2}$$

By the binomial expansion and retaining terms to (ρ/R)

$$\bar{T}_G \simeq -K\int_M \bar{\rho}\times\left(\bar{\rho}+\bar{R} - 3\bar{R}\cdot\bar{\rho}/R^2\,(\bar{\rho}+\bar{R})\right)dm/R^3$$

and $\int_M \bar{\rho}\,dm = 0$ since the torques are taken about the CM, therefore

$$\bar{T}_G \simeq -3KR^{-5}\ \bar{R}\times\int_M \bar{\rho}\bar{\rho}\,dm\cdot\bar{R}$$

$$\bar{T}_G \simeq 3KR^{-5}\ \bar{R}\times\int_M(\bar{\rho}\cdot\bar{\rho}\,\Psi - \bar{\rho}\bar{\rho})\,dm\cdot\bar{R}$$

where Ψ is a unit dyadic

using Φ (or the inertia diadic of the body:

$$\bar{T}_G \simeq 3KR^{-3}\ \hat{R}\times\Phi\cdot\hat{R}$$

where $\hat{R}$ denotes a unit vector in the R direction $\left(\hat{R} = \frac{\bar{R}}{|R|}\right)$.

Assume a right handed body fixed coordinate system with origin at the CM and axes X_1, X_2, X_3 with unit vectors $\hat{X}_1$, $\hat{X}_2$ and $\hat{X}_3$.

Assume a second right handed orbiting reference frame with origin at the CM and the E_3 axis pointing outward from the geocenter along the R vector with the E_2 axis perpendicular to the orbit plane, and the E_1 axis along the orbital velocity fector. The corresponding unit vectors are E_1, E_2, and E_3 where the E_3 = R. Let the two systems be related by the direction cosine matrix A

$$\begin{bmatrix} \hat{X}_1 \\ \hat{X}_2 \\ \hat{X}_3 \end{bmatrix} = A \begin{bmatrix} E_1 \\ E_2 \\ E_3 \end{bmatrix}$$

$$\text{Where } A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{12} & a_{22} & a_{23} \\ a_{13} & a_{23} & a_{33} \end{bmatrix}$$

$\hat{E}_3$ is written in terms of $\hat{X}_1$, $\hat{X}_2$, $\hat{X}_3$, and A

$$\hat{E}_3 = a_{13}\hat{X}_1 + a_{23}\hat{X}_2 + a_{33}\hat{X}_3$$

The inertia dyadic with respect to the X coordinate system is

$$\Phi = \lfloor \hat{X}_1, \hat{X}_2, \hat{X}_3 \rfloor \begin{bmatrix} I_{11} & I_{12} & I_{13} \\ I_{21} & I_{22} & I_{23} \\ I_{31} & I_{32} & I_{33} \end{bmatrix} \begin{bmatrix} \hat{X}_1 \\ \hat{X}_2 \\ \hat{X}_3 \end{bmatrix}$$

The equation for $\bar{T}_G$ written in the X frame becomes

$$\bar{T}_G \cong \frac{3K}{R^3} \begin{bmatrix} 0 & -a_{33} & a_{23} \\ a_{33} & 0 & -a_{13} \\ -a_{23} & a_{13} & 0 \end{bmatrix} \begin{bmatrix} I_{11} & I_{12} & I_{13} \\ I_{21} & I_{22} & I_{23} \\ I_{31} & I_{32} & I_{33} \end{bmatrix} \begin{bmatrix} a_{13} \\ a_{23} \\ a_{33} \end{bmatrix}$$

If now the reference system X is chosen to be the principal axis

$$T_{G1} \simeq (3K/R^3)\,(I_{33} - I_{22})\,a_{23}\,a_{33}$$
$$T_{G2} \simeq (3K/R^3)\,(I_{11} - I_{33})\,a_{13}\,a_{33}$$
$$T_{G3} \simeq (3K/R^3)\,(I_{22} - I_{11})\,a_{13}\,a_{23}$$

Now define A by the following

$$\begin{bmatrix} C\theta_3 & S\theta_3 & 0 \\ -S\theta_3 & C\theta_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C\theta_2 & 0 & S\theta_2 \\ 0 & 1 & 0 \\ S\theta_2 & 0 & C\theta_2 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & C\theta_1 & S\theta_1 \\ 0 & S\theta_1 & C\theta_1 \end{bmatrix}$$

Where S and C denote sine and cosine respectively; assume θ_3 and θ_2 to be small then $a_{13} = 0$, $a_{23} = S\theta_1$, $a_{33} = C\theta_1$

then

$$T_{G1} \cong (3K/2R^3)\,(I_{33} - I_{22}) \sin 2\theta_1$$

for a circular orbit $(K/R^3) = \omega_o^2$, hence

$$T_{G1} \cong (3/2)\omega_o^2\,(I_{33} - I_{22}) \sin 2\theta_1$$

Also, the aerodynamic disturbance torque is given by:

$$T_A = C_D A (1/2) \rho V^2 (x_{CG} - x_{CP})$$

where ρ = density of air

V = velocity with respect to wind

A = reference area

C_D = drag coefficient

The numerical results are:

$$T_{G1} = 0.137 \sin 2\theta \quad \text{ft-lb}$$
$$T_A = 0.202 \cos \theta \quad \text{ft-lb}$$

and, therefore, within the region of interest the aerodynamic torque exceeds the gravity gradient torque and passive gravity gradient stabilization cannot be achieved at the desired attitude.

5. SOLAR ORIENTATION

5.1 General - One experiment proposed for AAP Flight 1-A requires orientation toward the sun. This is S020, X-Ray/UV Solar Photography, which is designed to acquire data on the Sun's radiant energy in the indicated portions of the spectrum and requires that the center of the sun be maintained within ± 0.25 deg. of the center of the instrument FOV. Accurate orientation is required in only two axes, the orientation about the experiment-sun line is not critical. As designed, an astronaut display which would provide the pointing reference for manual control is a part of the experiment. Two approaches for vehicle control during the operation of this experiment have been considered: Use of the experiment display and control of the vehicle from a remote display.

5.2 Control to Experiment Display - Manual control using the experiment display is a simple and accurate method from the control system standpoint. The display presents an image of the sun which is to be held in a square reticle, by moving the vehicle, to satisfy the accuracy requirements. The only modification required would be to provide a longer cable with one hand controller so that the unit could be carried into the experiment carrier. However, objections arise both to a control station in the experiment carrier and to a cable through the docking tunnel and across the CSM/Carrier interface. The alternative discussed in the next section is not subject to these objections.

5.3 Control with Remote Display - The experiment's sensitive axis may be properly pointed, within the desired accuracy, through normal manual control from a position in the CSM if an adequate display is provided to the astronaut. A sun sensor system, such as produced by Ball Bros. Research, offers this capability. The sun sensor would be rigidly attached to the carrier structure and aligned to the experiment mounting surfaces in the appropriate airlock module. The sensor system's electrical output would be routed to the experiment Display and Control Console to drive an appropriate two-axis display which could be as simple as two voltmeters. Pointing accuracy would be predominantly limited by RCS propellant usage. Alignment between the sensor and airlock adapter could be less than one minute of arc, null accuracy of a representative sensor system is two minutes of arc, and assuming that

5.3 (Continued)

the angular misalignment between the experiment and air-lock does not exceed one arc minute the overall error in the display would be compatible with achieving 0.25 deg. pointing accuracy.

6. STELLAR ORIENTATION

Two experiments, S017 and S019, require orientation to stellar targets. The pointing requirements of these experiments are markedly similar to S020, discussed in the preceding section, in that an inertial hold is required, fine pointing is achieved by manual control and the experiment design provides an astronaut display. Current mission planning provides that the vehicle will be maneuvered with the G&N system to point the experiments at a region of interest. Fine pointing and attitude hold will then be provided by an astronaut using the hand controller. As with S020, one of the hand controllers could be taken forward to the experiment carrier but the same objections cited in Section 5.1 would again be applicable.

The display for experiment S017 consists of a set of lights and, since the input to the display consists of electrical signals, is compatible with remote mounting for use at a control station in the CSM. Experiment S019, however, provides a telescope for the astronaut pointing reference. Manual control from a station in the CSM for this experiment will require use of the G&N Optical System Scanning Telescope (SCT) which must be aligned to the experiment LOS and can then be used as the pointing reference for astronaut manual control. The alignment established by the techniques described in para. 4.2.2.2 should be adequate. However, if dimensional changes have occurred, possibly due to boost launch environment, the "boresight" method described in the next paragraph will be applied.

Alignment may be accomplished by maneuvering the spacecraft until the experiment mounted telescope has a selected star centered in the reticle. Alignment is achieved by adjusting the SCT LOS to simultaneously center the same star in the SCT optics. The required maneuver involves two crew members, one at the experiment orally directing the spacecraft motion and the second at the navigation station to respond to directions with the hand controller and after star acquisition, to adjust the SCT LOS.

7. RCS PROPELLANT

The Block II CSM provides 1285 lb. of usable RCS propellant - 281 lb. has been allocated for on-orbit operations after deducting the quantities required for transposition and docking, SPS thrusting, and de-orbit backup. Table 8.1-1 gives the estimated propellant budget by experiment. The Table is based on the recommended configuration discussed in Section 8 and the mission plan developed in PR-29-46, Mission Timelines. Propellant values given result from usage rates which are discussed below. The rates are considered to be conservative but do not represent a 3-sigma worst case. Also, Table 8.1-1 does not include a reserve for contingencies such as venting disturbances or a one quad out failure condition. Provision for such contingencies would require a reduction in the experiment schedule. This reduction could be made on an arbitrary percentage basis in advance or become part of a flight contingency plan to reduce the remaining experiment activity schedule in the event of a failure or other in-flight contingency.

Propellant required for maneuvers and attitude hold is given in Vol. 3 of SID 66-1501-A, Mission Modular Data Book (MMDB), revised 15 March 1967. A conservative value for maneuver propellant results if a simultaneous three-axis 50 deg. SCS manual maneuver is assumed. Curves in the MMDB give a 0.98 lb. propellant requirement for this assumption and a 34,000 lb. vehicle which approximates the Mission 1A configuration. As a check, propellant was calculated on the assumption of a sequential three-axis maneuver with approximately 30 percent system overshoot and no cross coupling. The basic equation is:

$$W_p = \frac{2KI}{LI_{sp}}$$

where
W_p = propellant consumed
K = overshoot and damping factor
I = moment of inertia
L = thruster moment arm
I_{sp} = steady state specific impulse
= maneuver rate (0.2 deg/sec)

there results:

$$W_p = 0.96 \text{ lb.}$$

ESTIMATED RCS PROPELLANT BUDGET

Experiment		RCS Propellant
T002	Manual Navigation Sightings	20 lb.
D009	Simple Navigation	36
S016	Trapped Particle Asymmetry	76
S017	X-Ray Astronomy	45
S019	UV Stellar Astronomy	33
S020	XUV Solar Photography	16
Standard Application		44
	Sub Total	270
Rate Damping During Drift Periods		11
	Total	281 lb.

Table 8.1-1

7. (Continued)

This value is in good agreement with the MMDB and was rounded off to 1.0 lb/maneuver in Table 8.1-1.

Propellant required for attitude hold is dependent on the control mode, orbital altitude and vehicle orientation. The MMDB curves result in a value of 0.5 lb/hr for fine deadband (0.5 deg) G&N mode attitude hold. To achieve this performance would require some optimization of the limit cycle characteristics in the presence of disturbance torques but as the CMC has this capability the 0.5 lb/hr value was accepted as realistic.

Propellant consumption for manual attitude hold can best be determined by a simulation study. An applicable study was performed for experiments S019 and S020, the results are given in MSC Note No. 67-EG-13, Results of a CSM Attitude Control Task Simulation for Experiments S-19 and S-20, 3 April 1967. The results show propellant consumption of approximately 3 lb/hr to maintain an attitude hold with a maximum deviation of 0.25 deg. from the experiment reference. This may be compared to an SCS automatic fine mode hold shown by the MMDB to require 2.9 lb/hr. These values are significantly higher than could be achieved with more nearly optimum control. In Table 8.1-1 propellant consumption of 3.0 lb/hr was used for manual control, this is considered to result in a conservative estimate as attitude hold accuracy of 0.25 deg. is not required throughout all manual control periods.

8. CONCLUSIONS

It is the conclusion of this study that the proposed Mission 1A pointing and stabilization requirements can be met by the existing CSM systems. Provision of a backup system for local vertical orientation is recommended and a supplementary sensor and display is recommended for solar orientation. Use of the CSM systems result in a minimum cost, minimum modification method of providing experiment pointing and stabilization. A potential for greater mission flexibility and extended time in orbit could be available by provision of an automatic carrier mounted local vertical system. Although this system is not recommended under the ground rules of the present study, the potential justifies continuing effort.

The recommended configuration and control methods are summarized below for each experiment group:

8. (Continued)

. Earth Resources

Local Vertical hold with the CSM G&N attitude hold mode. Backup system utilizing horizon scanners and a gyrocompass system to provide a crew display in the CSM.

. Solar Orientation

Manual control to a crew display in the CSM. Input signals to the display furnished by a sun sensor system mounted in the experiment carrier.

. Stellar Orientation

Coarse acquisition with the CSM G&N maneuver mode. Fine pointing by manual control to a crew display in the CSM or to a star field using the optical system SCT as required.

The estimated electrical energy required for pointing and stabilization is 47 KWH to be furnished by the CSM Electrical Power System (EPS). A contingent requirement of 4 KWH is imposed on the experiment carrier EPS for the local vertical backup system.

The estimated weight of the local vertical backup system to be added to the experiment carrier is 46 lb.

PR 29-44

TRADE STUDY REPORT

PCM ENCODER REVIEW

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS 8-21004

1 September 1967

Prepared By: M. J. Costello

Approved By: [signature]

Martin Marietta Corporation
Denver Division

1. INTRODUCTION

1.1 Purpose - This trade study was conducted to ascertain the availability of a PCM encoder capable of fullfilling the changing data requirements imposed on the Data Management System by the experiments and subsystems of the 1A carrier and the limitations existing in the associated data recorders/RF transmitters needed to fully complete the data Management System.

1.2 Objectives - The primary objective of the study was to determine the existence, at the present time, of a PCM unit capable of accomodating the known data requirements on the 1-A carrier. The availability as well as qualification status, ground station status and flexibility of the units were equally prime factors considered in this study.

2. SUMMARY

This report will delineate the various PCM units (encoders or encoding systems) considered for use on the 1-A carrier. Also listed will be the various formats, capacity, bit rates, compatibility with existing ground equipment, availability, qualification status, weight and power requirements and past or existing use of the subject equipment.

A base line for data requirements was not utilized in this review due to the assumption that the unit selected will be capable, channel and sample wise, of meeting the changing requirements present on the 1-A carrier.

3. DISCUSSION

The units under consideration for this study were manufactured by Radiation Inc (1.6 and 51.2 KBPS) and Electro-Magnetic Research (EMR) (5.12 KBPS).

All units considered utilized an 8 Bit word format, with frame synchronization and identification different for each system investigated. This difference in no way affected the ability of these units to be utilized on the 1-A carrier.

3. (Continued)

All units considered are, at the present time, components of existing systems utilizing ground equipment available and in use. The 1.6-51.2 KBPS units are used on the Apollo - CSM and the 5.12 KBPS unit was used on the Gemini project and is presently being considered as part of the Data Management System (DMS) on the air lock Module of the AAP Program.

3.1 System Description

3.1.1 1.6 KBPS System - This system is capable of accepting high level (0-5V) and low level (0-40 mv) (with addition of low level amplifier and low level analog multiplexer) analog signals and both serial and parallel digital signals. These signals are time multiplexed into a serial PCM Non-Return to Zero (NRZ) output pulse train at a 1.6 KBPS rate. The unit described is the low bit rate portion of the succeeding 51.2 KBPS system, also described.

3.1.2 Capability - The number of signals to be processed at 1.6 KBPS are 100 high level analog inputs, 288 parallel digital (1 Bit) and one 40 Bit serial digital input word. A 32 Bit synchronization/identification (ID) word and an 8-Bit format ID word are generated inside the PCM.

3.1.3 Format - At the rate of 1.6 KBPS, there is one frame per second, containing 200 8-Bit words (1600 Bits) the first four 8-Bit words are used for synchronization and identification.

3.1.4 Synchronization - The PCM output data and control signals are synchronized by timing signals generated by an external clock. With the external source being 512KHZ, various time intervals are available and are logically combined in the programmer to provide the timing format and program sequencing commands.

3.1.5 Operation - The operation of the encoder is not part of this trade study.

3.1.6 Output - The output of the encoder is adaptable to VHF or USBE Transmitters or magnetic tape for delayed transmission.

3.1.7 Encoder Configuration

QUANTITY	SAMPLES PER SEC.	WORDS PER SEC.	BITS PER WORD	BITS PER SEC.	REMARKS
Analog Data 100	1	100	8	800	0 to 5 VFS
Digital Data					
1	10	10	8	80	BIT Parallel
1	1	1	32	32	Binary "one" (+ 3.5 to 10V)
31	1	31	8	248	Binary "zero" (0 ± .5V)
1	10	10	40	400 (1)	Bit Serial requires start stop & digital serial Bit sync pulses.
1	1	1	32	32	sync word
1	1	1	8	8	Format ID 8 Bits of ID
TOTALS A = 100 D = 36		144		1600	

(1) The 1 channel of digital serial data is not considered usable for the anticipated 1-A carrier data requirements.

3.1.8 Weight and Power - This unit is considered questionable from a weight and power standpoint, for use on the 1A carrier.

Power - 115/200 V, 3 pluse, 400 CPS (21 watts)
11 VDC (2.2 watts)

Weight - 44 pounds (13.3 W, 7.0" H, 14.2" D)

These values apply to the system described in Section 3.2 of this review.

3.2 51.2 KBPS System - This system is the high bit rate portion of the system described as the 1.6 KBPS system. Inputs may be high (0-5V), or low (0-40 mv) level analog, and both serial and parallel digital signals. The resultant serial time multiplexed data train is at a rate of 51.2 KBPS.

3.2.1 Capability - The number of signals to be processed is determined by a preset format and controlled by the programmer. The input capacity is 365 high level analog, 304 parallel digital (1 BIT) and one 40 BIT digital word. Synchronization/identification (ID/word requires 32 BITS and a 8 BIT format 10 word. Both are generated within the encoder. Sample rates of 200 per second are available.

3.2.2 Format - The normal format is a 51.2 KBPS NRZ serial bit stream using the first four 8-BIT words in each frame for synchronization/identification. There are 128 - 8 BIT words (1024 BITS) in each prime frame and a total of 50 prime frame per second for a total of 51.2 KBPS.

3.2.3 Synchronization - The PCM output data and control signals are synchronized by timing signals generated by an external clock. With the source being 512 KHZ, various time intervals are available and are logically combined in the programmer to provide the timing format and program sequencing commands.

3.2.4 Operation - The operation of the encoder is not part of this trade study.

3.2.5 Output - The serial data train resulting from the various inputs is adaptable to any of the RF systems considered for use on the 1-A carrier. However, the bit rate is to high for application to the DSE.

3.2.6 Encoder Configuration

QUANTITY	SAMPLES PER SEC.	WORD PER SEC.	BITS PER WORD	BITS PER SEC.	REMARKS
Analog					
4	200	800	8	6400	HL (0-5V F.S)

3.2.6 (Continued)

	QUANTITY	SAMPLES PER SEC.	WORD PER SEC.	BITS PER WORD	BITS PER SEC.	REMARKS
	16	100	1600	8	12800	
	15	50	750	8	6000	(1)
	165	10	1650	8	13200	
	150	1	150	8	1200	
TOTAL	350		4950		39600	
	Digital Data					
	1	200	200	16	3200	Bit Parallel
	1	50	50	8	400	Binary "one" = + 3.5 to + 10 volts
	1	10	10	32	320	Binary "zero" = 0 ± .5V
	1	10	10	16	160	
	44	10	440	8	3520	
	1	50	50	40	2000	Bit Serial Requires start, stop, and digital serial bit sync. pulses.
	1	50	50	32	1600	Sync word (32 bits or fixed sync code
	1	50	50	8	400	Format ID 8 Bits
TOTAL	51		860		11600	

3.2.6 (Continued)

QUANTITY	SAMPLES PER SEC.	WORD PER SEC.	BITS PER WORD	BITS PER SEC.	REMARKS
(1) Low Level (0-40 MV) when used replaces one 0-5V F.S. Channel at 50 SPS					
50	1	50	8	400	

3.2.7 Weight & Power - See information in Section 3.1.8

3.3 5.12 KBPS System - This system is capable of accepting high level (0-5V) and low level (0-40 mv) analog signals and both serial and parallel digital signals. The resultant serial time multiplexed data train is at a rate of 5.12 KBPS. This output is for application to a magnetic tape recorder or for real time transmission. This system also has the capability to provide a high bit rate output (51.2 KBPS) that includes all the low bit rate channels as well as additional channels. These additional channels are sampled at a much higher rate than the channels assigned to the lower bit rate section of the encoder.

3.3.1 Capability - The number of signals to be processed is determined by a preset format and controlled by the programmer. The input capacity is 108 high level analog, 96 low level analog, 88 bi-level, 32 bi-level pulse, and 24 digital in the configuration anticipated for use on the 1A carrier. Synchronization/identification (ID) word requires 24 bits and a 24 bit frame identification word. Both are generated within the encoder. Sample rates of 40 per second are available in the lower rate while 640 is available if the high rate was used.

3.3.2 Format - The normal format is a 51.2 KBPS NRZ serial bit stream, while the portion planned for use on the 1A carrier is a 5.12 RZ serial bit train. There are 64-8 bit words (512 bits) in each sub frame and a total of 10 frames per word for a total of 5.12 KBPS.

3.3.3 Synchronization - As used on the Gemini program this unit was controlled by an external clock. The incorporation of an internal clock for use on the 1A carrier is going to be accomplished.

3.3.4 Output - The serial data train (51.2 & 5.12 KHZ) provided by this unit is adaptable to any of the RF system (Direct input) being considered for the 1A carrier. However only the 5.12 KHZ signal is adaptable to the DSE considered for carrier use.

3.3.5 Encoder Configuration - The system under consideration is comprised of 3 low level multiplexers and 2 high level multiplexers. With this configuration the following capabilities exist.

QUANTITY	SAMPLES PER SEC.	WORD PER SEC.	BITS PER WORD	BITS PER SEC.	REMARKS
Analog					
3	40	120	8	960	Hi-Level
3	20	60	8	480	Hi-Level
6	10	60	8	480	Hi-Level
96	1.25	120	8	960	Hi-Level
24	1.25	30	8	240	Lo-Level
72	0.416	--	8		Lo-Level
Digital					
88	10		8	7040	Bi-Level
32	10		8		Bi-Level Pulse
24	0.416		8		Digital-Parallel

Hi-Level = 0 - 5VOC
Lo-Level = 0-- 20MV
Bi-Level = 0 = 5V
1 = 15V
Digital = N.A.

3.3.6 Weight and Power - This system has good weight and power values.

Weight (3 Low level and a high level multiplexers)
34.7 pounds

Power 28 VDC, 10 watts

4. CONCLUSION AND RECOMMENDATIONS

The results of this study clearly reflects the availability of various PCM systems that can be utilized on the 1A carrier. The controlling feature in selection of the system for the carrier will be the completed measurements list and a PCM system with sufficient channel and sampling capacity. In addition, the data compression required for this carrier will impact this selection also.

It was also evident from the review that the availability of other PCM system, in particular, a 10 bit system is poor.

The recommendation, from the review results, is that the EMR 5.12 KBPS system be utilized and the higher bit rate portion be utilized, if necessary, for real time data transmission only.

PR 29-45

TRADE STUDY REPORT

TAPE RECORDER TRADE STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

September 1967

Prepared By [signature]

Approved By [signature]

MARTIN MARIETTA CORPORATION
Denver Division

1. INTRODUCTION

1.1 Purpose - This study was undertaken so that a competent decision could be made when data recoding/playback requirements imposed on the Data Management System are finalized.

1.2 Objectives - The objectives for this study were as follows:

1.2.1 Insure the availability of a recorder system technically and environmentally qualified for for use on the 1A carrier.

1.2.2 Evaluate the capability of the recorder to satisfy the record/playback times inherent in the concept of the 1A carrier's mission.

1.2.3 Pursue the possibility of modifying a recorder system to satisfy the particular data requirements of the 1A carrier.

1.2.4 Investigate the possibility of utilizing experiment data systems either as is or modifying to satisfy additional data requirements.

1.2.5 Verify the ability of the recorder to satisfy either or both the following input requirements;

1.2.5.1 5.12 IBPS PCM & 6-8 channel FM Multiplexed signal.

1.2.5.2 Experiment PCM Data Train (Approx. 23 KBPS).

1.2.6 Insure the playback speed, with the necessary RF bandwidth consistent with data input, is within the capabilities of the transmitters selected as well as the MSFN.

2. SUMMARY

This report will delineate the various systems or methods considered for use on the carrier. Manufacturer of the particular units will be referenced only for identification purposes. Model or type will be presented to clarify the investigation.

2. SUMMARY (Continued)

Record/playback time required will not be specified for each unit because the conditions could vary. Below are listed the record/playback times used as a baseline during evaluation.

2.1 System 1 - record minimum of 4 hours with maximum dump time of 12 minutes.

2.2 System 2 - record minimum of 36 minutes with maximum dump time of 9 minutes.

To satisfy these requirements, consideration was given to modify an experiment data system as well as existing recorder systems.

3. DISCUSSIONS

The units under consideration are products of RCA and Leach. Various models or types from each manufacturer were reviewed and the presentation will delineate the ones considered possible for the 1A carrier. All units considered have usage in a space application prior to 1A flight. Because of this, the environmental capabilities of each unit will be considered adequate and this review will not pursue this requirement.

Also, because of the usage, these units are considered available for use on the 1A carrier.

3.1 System Description

3.1.1 RCA Model SL-100 - This unit was used in conjunction with the Electro-Magnetic Research (EMR) 51.2/5.12 KBPS PCM Encoder on the Gemini Program. The recorder/encoder combination fulfills the requirement for the long data storage capabilities (4 hours) of the 1A carrier.

The extremely high compression capabilities (22:1) also makes this unit acceptable for use on the 1A carrier (record at 1-1/8 ips, playback at 41.25 ips).

3.1.1 (Continued)

The application on the carrier would be identical to that used on the Gemini Program. The encoder would be the same type making the record capabilities the same.

Data requirements on the 1A carrier precludes the use of only a PCM system. The need exists for several channels of FM data (Multiplexed). For this reason, the following is being proposed, as a modification, on the RCA recorder.

The need exists for approximately 8 channels of this time multiplexed data (FM), with the maximum response such that the aforementioned recorder tape speed (1-7/8 ips) would be adequate. The plan would be to use an additional track (the recorder has a capacity of 7 tracks, with either digital and/or analog input) to record this data and the subsequent playback frequency would be within the capabilities of the anticipated VHF transmitter. All standard IRIG sub-carriers are planned, therefore the system would be standard throughout proposed record/playback use.

3.1.2 Leach Series 3200 - This unit, at present, is the type proposed for use as the DSE in the Data Management System of the Apollo Command Module.

The units capabilities are such that the unmodified version exceeds the carrier requirements in several categories, while not satisfying these requirements in others.

3.1.2.1 The particular categories are as follows:

Sufficient

- Total number of channels 14 - the effective recording capabilities are really 11 because the high bit rate PCM is shifted from serial to

3.1.2.1 (Continued)

parallel and uses 4 tracks for recording. The additional tracks are used for analog - 9 tracks, and timing - 1 track.

- Analog channels capable of 25 KHZ signal input.
- Tape speeds of 3.75 and 15 ips for record and 15 and 120 for playback.
- PCM bit rate of 51.2 KBPS can be recorded.

<u>Insufficient</u>

- Playback compression ratio imposes a subsequent VHF RF bandwidth exceeding system limits.
- Record time at 15 ips is only 30 minutes. The 3.75 ips record speed provides a longer time for recording, but the subsequent 120 ips playback speed puts the system in the condition described in preceding paragraph.
- Data requirements on the carrier are such that additional data storage capabilities are needed. The data requirements for real time and delayed data transmissions precludes utilization of 1 tape system for all data during the 1A mission.

3.1.3 <u>Leach Series 2000</u> - This unit has seen frequent usage in space applications. Its availability is good and the introduction of modifications will not produce excessive delays. The power/weight requirements are also acceptable.

The proposed application of this unit on the carrier would be to complement the recorder being used for the 5.12 KBPS PCM. The usage would be in such a way that all peculiar

3.1.3 (Continued)

data requirements; i.e., experiment data at 23 KBPS, would be applied to this recorder and later, when over a suitable ground station, playback through the RF system. The utilization of this recorder as a prime data storage system would impose a problem in adapting the recorder to the anticipated 5.12 KBPS PCM encoder. The previously described system (RCA) is engineered to adequately accept the PCM data.

The capacity of this series recorder is more than adequate for the 1A carrier data requirements, but mission requirements are such that record time vs. playback time over ground stations, makes it mandatory to have more than one recorder.

The playback ratios available in this series recorder are such that this item poses no problem in determining its usefulness on the carrier.

3.1.4 Experiment Recorder/Data Handling System - Inherent in the design of two (2) experiments proposed for use on the 1A carrier is a data handling system with capabilities that could be adapted for other experiments. The data time line is such that the utilization of this data system would not interfere with its original intent.

The data handling system has a capability that exceeds the carrier's requirements but the simultaneous utilization of the subsystem within this data handling system is not practical. The system is composed of a PCM system, an FM multiplex system and a tape recorder. The tape recorder is utilized for redundant recording on its two (2) tracks. The recorder is a Leach MTR 2110. The experiments associated with this system are:

1. Frog otolith function (T004)
2. X-ray astronomy (S017)

3.1.4 (Continued)

The recorder has at the present time the ability to record for a minimum of 32 minutes and playback at a 4:1 ratio.

The proposed modification to this system is to expand the input capability so that non-experiment data (T004 & S017) can be introduced to the tape recorder. This change would be in the input side only. In addition, the ability to record digital data would be added. This addition would be external to the data system as a black box.

All other aspects of the data system would remain unchanged.

The output of the recorder (playback mode) would be time shared on a VHF link with another recorder's data.

4. CONCLUSIONS AND RECOMMENDATIONS

This study clearly points out the necessity for a recorder system with dual complex capabilities. The solution would be a 2 recorder system or 1 system capable of recording high bit rates along with low bit rates, each from a different source and also being able to record analog data, all with long recording times and very short playback times. The 2 recorder scheme appears most advantageous because each recorder can satisfy a specific experiment's data requirements and playback the data at a ratio that is consistent with the RF system and the accompanying MSFN ground station. The resultant RF system (VHF) transmitter bandwidth would remain tolerable and the task imposed on the MSFN would be within acceptable limits.

The recommendations resulting from this study is to utilize the identical system employed on the Gemini Program with the addition of the recorder channel and its necessary electronics for recording the FM multiplex data.

In addition, it is recommended that using the experiment data handling system's tape recorder with the external modifications mentioned would be the most expeditious method of satisfying the remaining data requirements problem. At

4. (Continued)

present, this recorder would be utilized for recording only one (1) PCM serial data train associated with one (1) experiment. The bit rate would be approximately 23 KBPS.

PR 29-46

TRADE STUDY REPORT

MISSION TIMELINES

AAP/PIP EARLY APPLICATIONS

Contract NAS8-21004

14 September 1967

Prepared by: W. D. Carmean
W. D. Carmean

Approved by: J. T. Keeley
J. T. Keeley

MARTIN MARIETTA CORPORATION
DENVER DIVISION

TABLE OF CONTENTS

1. INTRODUCTION

To determine the feasibility of satisfying the baseline experiment requirements without overloading the crew capability a total mission experiment timeline was prepared. A representative day was then chosen for detailed analysis to determine total experiment operational time, experiment support requirements, MSFN data dump capability, and crew availability for experiment operation and support functions.

2. SUMMARY

This report defines the experiment operational requirements and the extent to which these requirements have been satisfied based on a total mission timeline analysis. Experiment operational utilization is categorized by on-time, preparation and support time provisioning. The rationale leading to the scheduling of experiments and allocation of time is presented. Ground track constraints such as MSFN contact, Zone of Interior over flights, Southern Atlantic Anomaly crossings and day/night cycles are discussed.

The time allocation desired for crew maintenance functions are denoted and the deviations to these requirements, resulting from the timeline analysis, are presented. Areas to which special emphasis should be given in future study are identified.

Figures 1 and 2 contain the total mission (14 day) experiment timeline and the 24 hour (April 5) timeline. The 24 hour profile is considered representative of an experiment day to which the Applications Experiments have been assigned.

3. EXPERIMENT CRITERIA

In the foregoing discussion of the experiment time requirements, scheduling rationale and considerations, frequent reference is made to an experiment by its designated number. Table 1 has been included to provide the reader a reference for identifying the titles and the classification of the baseline experiments.

Table 1 AAP Mission 1A Baseline Experiments

Number	Title
Applications "A" Experiments	
S039	Day-Night Camera
S040	Dielectric Tape Camera
S043	IR Temperature Sounder
S044A	Elec Scanned Microwave Radiometer
S048	UHF Sferics Detection
Astronomy Experiments	
S017	X-Ray Astronomy
S019	UV Stellar Astronomy
S020	UV X-Ray Solar Photography
Bio-Science/Technological Experiments	
D017	CO_2 Reduction
S015	Zero-G Single Human Cell
T003	Inflight Nephelometer
T004	Frog Otolith Function
Earth Resources Experiments	
E06-1	Metric Camera
E06-4	(S042) Multispectral Camera
E06-7	IR Imager
E06-9	IR Radiometer/Spectrometer
E06-11	Multifrequency Microwave Radiometer
Uncategorized Experiments	
D008	Radiation
D009	Simple Navigation
S016	Trapped Particle Asymmetry
S018	Micrometeorite Collection
T002	Manual Navigation Sighting

3.1 Experiment Operation Utilization - This section discusses the time allocations for each experiment. The allocations are divided into on-time, prep time and support time.

3.1.1 Experiment On-Time - In setting forth a schedule of specified duration for the operation of the aforementioned experiments, compromises have been made in an attempt to satisfy to the extent possible the data collection requirements for all the experiments. Table 2 presents a summary of the experiment requirements as specified by the NASA MSC and the percentage of the extent to which these requirements are satisfied by the timeline developed by MMC. The detailed requirements for each experiment are set forth in PR 29-51, Experiment Requirements.

3.1.2 Experiment Prep-Time - Preparation time as referenced herein includes: warmup, calibration, checkout, mode control selection, camera selection, sensor deployment, and target acquisition. The 24-hour timeline (April 5), presented in Section 6. of this report includes the preparation time for each experiment or experiment grouping. Preparation times are not included for all experiments on the 14 day schedule. Consideration has been given, however, to prep-time for the standard applications grouping. The fourth 24-hour period was selected as a representative standard applications day and the allocation of experiment preparation time for this day has been considered in the scheduling of activities for April 3, 4, 8, and 9.

Several of the short duration, "single-shot" experiments, such as D017 and D009 do include prep-time and are so noted on the 14-day timeline. The passive experiments for which no prep-time other than equipment installation or attitude orientation is required are S016, S018, and D017.

3.1.3 Experiment Support Time - IMU alignment, equipment unstowage and placement, experiment data logging, recording, voice annotation, film change, boresighting, and workstation transfer (crew) are classified as experiment support functions. The 14-day timeline allocates time for boresighting the S019 sextant with the G&N sextant, standard applications film retrieval and replacement, equipment (S016, S018, S019, and S020) installation and removal from the airlocks, T002 and D009 component transfer from the carrier to the CM, D009 retrieval from temporary storage in the CM, S019 prism change, and crew transfer between the CM and carrier.

Table 3 presents the time and frequency requirements for selected support functions. These data have been incorporated in the applicable functions on both the 14-day and 24-hour (April 5) timeline.

Table 2 Experiment Operation Utilization

Experiment	Operating Time: Requested	Operating Time: % Sched
S039	Automatic mode	
	(a) Continuous during applications day	50%*
	(b) Manual mode - 4 hrs	100%
S040	Continuous during applications day daylight	20%*
S043	50 targets of opportunity	100%
S044A	Continuous during applications day	100%
S048	Automatic mode	
	(a) Continuous for 11 days	17%
	(b) Manual mode - 4 hrs, dark only	100%
S017	20 sightings/20 min ea	100%
S019	135 exposures	66%
S020	10 sightings, light only	75%
D017	6 hours	100%
S015	Feed every 12 hours, photo every 6 hours (except during sleep)	100%
T003	Every 4 hours of work period	100%
T004	Continuously for 72 hrs after launch	100%
E06-1	900 frames	100%
E06-4	540 frames/camera	100%
E06-7	11 hrs (100 ft film)	100%
E06-9	30 targets/7 min ea	100%
E06-11	30 targets - U.S. and coastal waters	100%
D008	3 passes in SAA and 3 out	100%
D009	6 night passes and 3 day passes	100%
S016	80% of SAA passes	92%
S018	40 hours exposure	100%
T002	56 - 20 to 30 min observations on night pass	15%

* Data dump restriction

Table 3 Experiment Support Requirements

Function	Est Time Required	Frequency	Notes
IMU Alignment			
Initial	35 min	Once per experiment day	Night pass only
Realignment	20 min	Every second orbit during experiment day	Night pass only
Film Reload (6 cassettes)	50 min	Every 1½ to 2 standard apps days	
Airlock Operation			
Prepare dome A/L, install & deploy S016*	25 min	1 time	
Retract & remove S016**	9 min	1 time	
Prepare wall A/L and install S020*	17½ min	1 time	
Remove S020**	10½ min	1 time	
Install S019*	16 min	1 time	
Remove S019**	7 min	1 time	
Install & deploy S018*	20 min	1 time	
Retract & remove S018**	10 min	1 time	
Retrieval of carrier stowed experiments for A/L insertion	10 min	4 times	
Crew transfer from CM center couch to experiment truss in carrier	10 min	9 to 11 times	Includes carrier light activation; crewman carrying equipment.
Crew transfer from carrier experiment truss to CM center couch	12 min	9 to 11 times	Includes carrier light deactivation; crewman carrying equipment.
Forward hatch opening	3 min	8 times	
Forward hatch unstowage and closure	4 min	8 times	
Boresight S019 with G&N sextant	35 min	1 time	Night pass
S019 prism change	30 min	1 time	Includes time for removal and insertion in A/L

Table 3 Experiment Support Requirements (continued)

Function	Est Time Required	Frequency	Notes
Remove carrier dust cover and stow, retrieve exp D&C panel, perform electrical connection, and close circuit breakers.	35 min	1 time	Assumes crewman in soft suit.
Remove probe and drogue assys and stow in CM.	5 min	1 time	
Maneuver spacecraft from starfield pointing to LV.	7 to 12 min.	As required.	Assumes single sensor; 90° to 180° pitch or yaw maneuver.

*Excludes unstowage and checkout of component to be installed.
**Excludes stowage of component.

3.2 <u>Experiment Scheduling Rationale</u> - Experiment scheduling was dependent on the following major factors:

ZI (U.S. and coastal water) overflights - frequency, duration and time of day
Southern Atlantic Anomaly passes - duration and time of day
Experiment operational requirements
Experiment life cycle
Experiment priority
Film change requirements (E06-4)
Minimization of carrier entries
Crew constraints

The first group of experiments scheduled were the Standard Applications experiments. April 3, 4, 5 were chosen because the ZI overpasses commenced at a time commensurate with the initiation of the crew's duty cycle. April 2 and 6 were not selected because of the priority rating applied to S019 and S020 and the desire to accomplish experiments considered more difficult as early in the mission as possible. April 7 was arbitrarily selected as the crew "rest" day. Consequently, the final two standard applications days were assigned to April 8 and 9 to utilize as much of the ZI overpass periods as possible.

3.2 (continued)

S016 was the second experiment assigned - the intent being to provide local vertical orientation of the spacecraft during a maximum of SAA passes. To minimize carrier entries and provide maximum S016 sensor exposure the S016 unit was assigned to the dome airlock. Airlock insertion was scheduled on the first day during the first actual carrier entry when the experiment D&C panel is retrieved.

S020 was scheduled on April 2. Prior to crew exit following the termination of S020 operations, S019 is installed in the wall airlock after removal of S020. S019 operation was scheduled for April 6 to avoid successive days of carrier operation. In addition, April 3 provides a greater number of ZI passes for the Standard Apps group.

Upon completion of S019 activities at the wall airlock, the experiment is removed and replaced by S018. Because S018 is a passive experiment and only requires periodic spacecraft orientation for S018 exposure to deep space, this experiment was scheduled through April 7, the day of rest.

S017 considered next in priority and order of operational difficulty was assigned to April 10 and 11. T002 followed on April 12 and D009 on April 13. April 14, reserved for equipment and data transfer between the vehicles, was considered off limits for any major or sustained experiment operation. S015 requires attention for periods from 2 to 5 minutes, four times daily. S016 was scheduled also on April 14 during two SAA crossings to increase the compliance with data collection requirements.

T004 (Frog Otolith) requires collection of all data within a 72-hour period commencing as soon after lift off as the schedule permits. Because of the crew constraints (i.e., sleep cycles, etc.) control of T004 is shared with the ground control network. Periodic experiment checks varying from ½ to 2½ hours are scheduled for 62 of the 72 hour cycle. These data collection periods are indicated on the 14 day timeline by vertical hatch marks. Experiment operation is initiated 7½ hours into the mission after retrieval of the D&C panel from the carrier.

T003, S015, D008, and D017 were then assigned in accordance with experiment requirements and crew constraints.

3.2 (continued)

It should be noted that compliance with a simultaneous sleep cycle was considered until an analysis of the S016 requirements dictated a deviation. As shown on the 14 Day Timeline, Figure 1, 8 sleep periods are staggered. The maximum offset is two hours and during all of these periods only one crewman is required to stay on duty. The sleep cycles are discussed in more detail in Section 4, Crew Criteria.

Table 4 provides a quantitative reference of each SAA contact period for the baselined 140 n mi, 50 degree orbit. Mr. Steve Mansur, NASA/MSC/S&AD, the technical monitor for the S016 experiment provided MMC with an estimated definition of the SAA envelope geometry.

Table 4 SAA Contact Periods

Date (CST)	Initial Contact Time CST	Initial Contact Time GMT	Duration	Date (CST)	Initial Contact Time CST	Initial Contact Time GMT	Duration
April 1	1541 hr	2141 hr	6 min	April 8	0023 hr	0623 hr	6 min
	1712	2312	8		1319	1919	8
	1846	0046	7		1451	2051	8
	2018	0218	6		1625	2225	7
	2331	0531	8		2109	0309	10
April 2	0103	0703	12		2240	0440	12
	0237	0837	7	April 9	1140	1740	3
	1534	2134	7		1311	1911	7
	1707	2307	8		1443	2043	8
	1840	0040	7		1617	2217	6
	2014	0214	4		2100	0300	12
	2324	0524	9		2233	0433	11
April 3	0057	0657	12	April 10	1132	1732	4
	1527	2127	8		1302	1902	8
	1700	2300	8		1434	2034	8
	1833	0033	7		1609	2209	6
	2009	0209	3		2051	0251	12
	2317	0517	12		2225	0425	10
April 4	0047	0647	12	April 11	1122	1722	6
	1350	1950	3		1254	1854	8
	1521	2121	8		1424	2024	8
	1653	2253	8		1602	2202	4
	1827	0027	5		1911	0111	7
	2311	0511	12		2043	0243	12
April 5	0043	0643	11		2214	0414	8
	1343	1943	5	April 12	1111	1711	7
	1513	2113	8		1244	1844	8
	1644	2244	8		1418	2018	7
	1820	0020	6		1553	2153	3
	2132	0332	8		1903	0103	8
	2303	0503	12		2033	0233	13
April 6	0036	0636	10		2209	0409	6
	1335	1935	6	April 13	1103	1703	7
	1507	2107	8		1235	1835	8
	1639	2239	6		1409	2009	6
	1815	0015	4		1544	2144	2
	2125	0325	8		1853	0053	10
	2256	0456	12		2025	0225	12
April 7	0030	0630	8	April 14	0924	1524	3
	1327	1927	7		1054	1654	7
	1458	2058	9		1225	1825	8
	1632	2232	7		1400	2000	7
	1807	0007	3		1844	0044	10
	2116	0316	9		2014	0214	12
	2249	0449	12	April 15	0913	1513	4
					1044	1644	8

The day/night cycles, ZI passes and MSFN station contact times are denoted in PR 29-19, Revised Ground Track, MSFN and Truth Site Data.

4. CREW CRITERIA

This section identifies the required time allocation for the Apollo system and crew maintenance and housekeeping functions. Timeline provisions which deviate from these requirements are discussed in Section 4.2.

4.1 Crew Scheduling Requirements - The crew constraints to which consideration was given in the development of the mission timelines are presented in Table 5.

Table 5 Crew Scheduling Requirements

Function	Time Allocation/Day
Sleep	*8 hours/crewman
Eat	*3-1 hour periods/crewman
Exercise	3-10 min periods/crewman
Crew Housekeeping	1½ hours/crewman
Systems Housekeeping	*2 hours/crewman
Suit Donning	**12 min unassisted
Suit Doffing	** 9 min unassisted

*Simultaneous participation by all three crewmen preferred.
**Sequential participation recommended.

It is desirable to schedule the systems housekeeping functions in three periods with one early in the day, one near midday and the latter in the evening. Personal hygiene, waste management, flight plan updating, and crew housekeeping are not scheduled items. Open periods in the mission plan will be occupied primarily by the performance of these functions. Collectively from 3½ to 4½ hours per day will be devoted to these activities by each crewman.

Eat periods are scheduled with all three crewmen participating simultaneously, although the hot water supply cycle may constrain this to some degree. The third eat period should provide the last major activity of the day and normally would follow the systems housekeeping functions.

Each function noted in Table 5 includes time allocation for crew transfer from one position to another within the CM.

4.2 Crew Scheduling Provisions - To incorporate all of the baseline experiments in the total mission timeline and to provide minimum reduction of experiment data collection activity, deviations to crew scheduling requirements were necessary. The exact extent of deviation will not be known until each day of the mission is analyzed in detail, therefore the results of the 24 hour timeline performed for April 5 (Ref. Fig. 2) will be used as a representative basis for discussion. A summary of the crew activities is included in Table 7, 24 Hour Timeline Summary Analysis.

Because the waste management facilities in the CM accommodate but one crewman, the initial eat period is staggered by 10 minutes for each crewman. Although this does not appear to provide earlier initiation of experiment activity, it may provide a demand rate for hot water more compatible with the system makeup cycle. The second and third eat periods are scheduled for simultaneous participation which, of course would contradict the noted advantage derived from a staggered cycle.

The first systems housekeeping (SH) cycle provides 40 minutes of elapsed time, however this does not include total crew participation. The Pilot is not available for SH until 10 minutes after the Command Pilot. To minimize the staggered sequence the Pilot's activity was terminated 5 minutes after the CP and SP had completed the activity. The CP and SP were scheduled for 35 minutes rather than 40 to allow a 10 minute open period prior to the IMU coarse and fine mode alignment sequence. The second SH period allows simultaneous participation for two crewmen for 30 minutes. The scheduling of S015 and S016 activities during this period, followed by an IMU realignment sequence, required within the night pass compound the conflict of activity. With a ZI pass just preceding this period it was not possible to initiate the SH function earlier. Forty minutes of simultaneous SH activity was assigned for the third period. This period could be extended to compensate for the abbreviated periods.

The April 5 sleep cycle is one of eight (Ref. Fig. 1) requiring one crewman to stay on watch during a SAA crossing for S016 data collection. This 12 minute crossing is terminated at 2315. The SP, who was designated as experiment operator for night S016 operation on this day, then retires at 2400.

Crew responsibility for night S016 operation (LV vehicle orientation) has been rotated over the eight days to minimize crew fatigue. In several cases, to allow initiation of experiment activity during an advantageous ground track position, the crewman retiring after an extended duty cycle is provided a 7½ hour sleep period.

5. TOTAL MISSION (14 DAY) EXPERIMENT TIMELINE

The enclosed timeline (Figure 1) represents the initial effort at integration of the baseline experiments into a total mission schedule. Additional iterations will be necessary before each experimental and supporting incremental task activity may be plotted against time. It is MMC's intent in the presentation of this data to ascertain the feasibility of the baseline experiment grouping relative to environmental operational requirements, power and data constraints, and crew and environmental limitations.

Table 5 presents a summary analysis of the critical mission and system parameters considered in the development of the 14 day timeline.

Table 5 Total Mission Timeline Summary Analysis

Mission Parameter	Scheduled or Elapsed Time
Launch Time	0900 CST April 1
Elliptical Injection	0910
Time allocated for:	
CSM/SLA separation	27 min
Transposition	
Docking	
SIVB Jettison	
Initial hatch opening for SLA circuit connection	1000 CST April 1
Circular Injection	1251 CST April 1
Second hatch opening for:	1530 CST April 1
Probe and drogue removal	
D&C retrieval	
S016 installation	
D&C Panel On	1624 CST April 1
Third hatch opening for S020 operation	0900 CST April 2
Fourth hatch opening for film change	1650 CST April 4
Fifth hatch opening for S019 operation	1012 CST April 5
Sixth hatch opening for:	0835 CST April 8
Film change	
T002 and D009 retrieval	
Seventh hatch opening for final equipment transfer and stowage	0900 CST April 14
Preparation for carrier jettison	0615 CST April 15
Jettison carrier	0830 CST April 15
Splash down	1020 CST April 15

6. 24 HOUR (APRIL 5) TIMELINE

A detailed analysis of a 24 hour period considered to be representative of an Applications Experiments day was conducted. April 5, the fourth 24 hour period of the baseline 1A mission, was selected. Figure 2 presents this timeline incorporating the Applications "A", Earth resources, selected Bio-Science and the trapped Particle Asymmetry (S016) experiments.

As on the 14 Day Timeline, both CST and GMT are shown. The crew work/rest schedule is referenced to the local Houston (CST) cycle.

A summary analysis of major crew and system events is presented in Table 6.

Table 6 Summary Analysis - 24 Hour Timeline

Event	Time Allocation
Eating	3-1 hour cycles; First cycle staggered Second and third simultaneous
Systems Housekeeping	First period - three crewmen - 100 min combined total, 35 min elapsed Second period - two crewmen 60 min combined total, 30 min elapsed Third period - three crewmen 120 min combined total, 40 min elapsed
IMU Alignment	
Initial	35 min elapsed
Realignment	Two periods (every second night pass after initial alignment) -20 min elapsed each period.
Local Vertical Orientation after IMU alignment	Three cycles - 5 min/cycle
All experiments - Total data collection time	8 hr 9 min elapsed
Passive Experiment (S039, Grp 2) - Total data collection time	7 hr 30 min elapsed
Active Experiments - Total data collection time	2 hr 9 min elapsed

7. CONCLUSIONS AND RECOMMENDATIONS

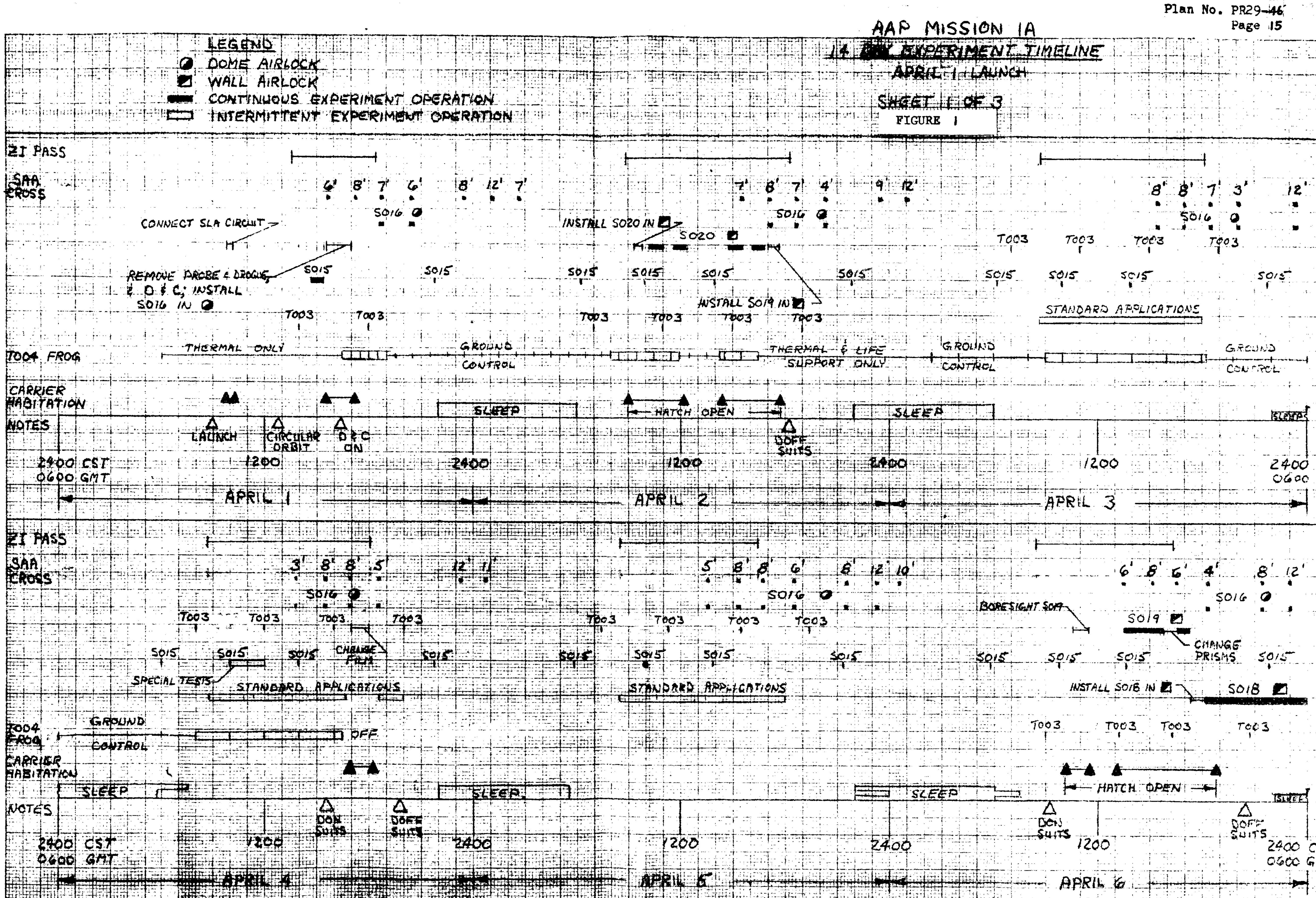
Additional analysis is necessary to determine if experiment requirements exceed crew work load capability. With the exception of S015, S016, and T003, all of the experiments included in the baseline grouping may be scheduled within a nominal 8 hour duty period. A simultaneous sleep cycle is considered attainable if the requirements for S016 were relaxed to permit deletion of data collection after 1900 hours. Experiments S015 and T003 must be further evaluated to determine the extent of crew input and time required for the incremental task activity.

Because of the inherent complexity in the operation and calibration requirements of S019 and S020 time requirements can be determined accurately only after each task has been simulated. Both the carrier and CM worksite activities must be evaluated for scheduling of sequential and simultaneous tasks.

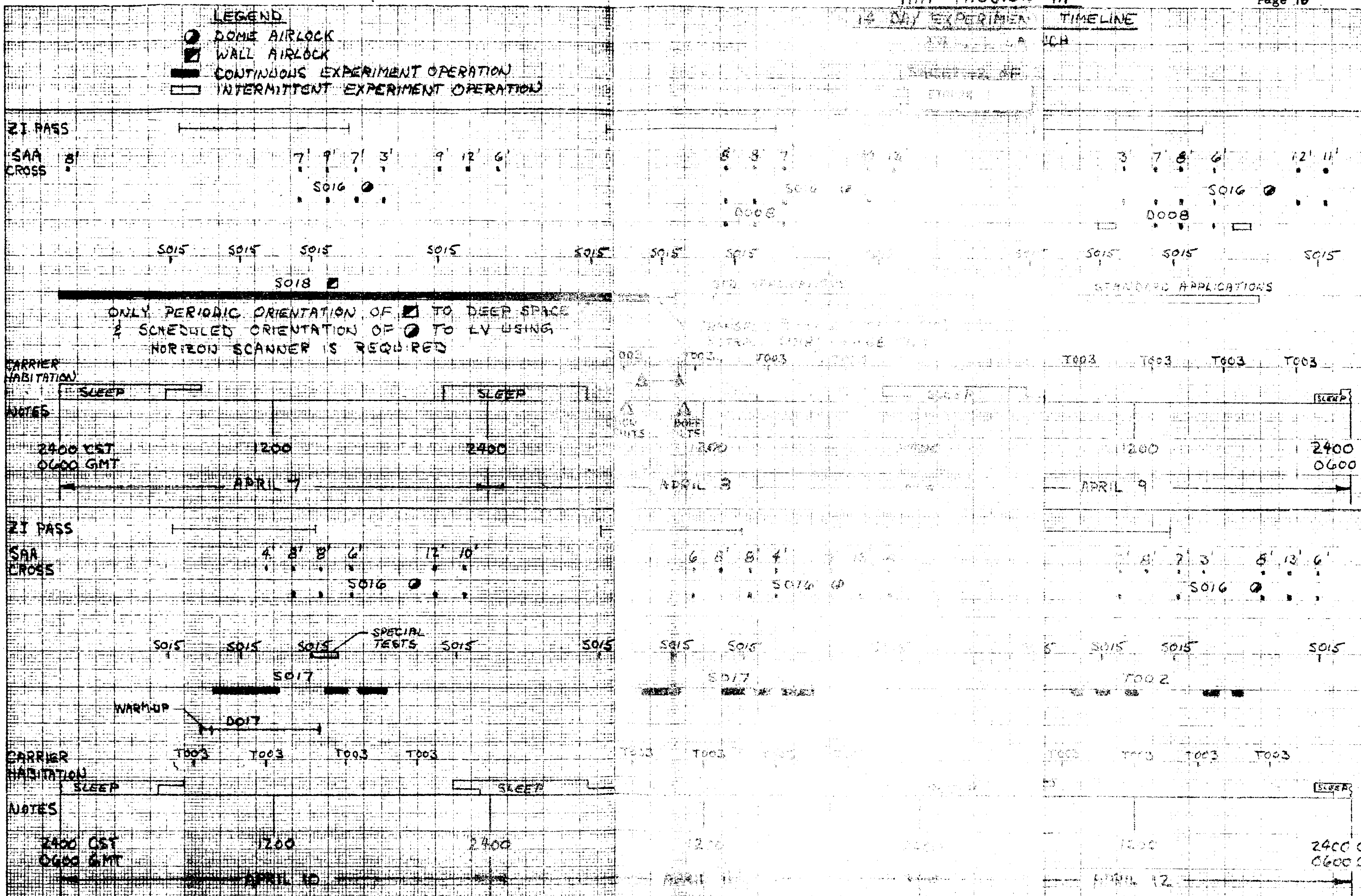
All activities requiring usage of the carrier mounted airlocks have been estimated relative to elapsed time based on operational requirements set forth in Apollo Scientific Experiments Airlock Information Guide, a NASA MSC document. Operations involving the ablative plug were deleted in lieu of Block II hatch design modifications.

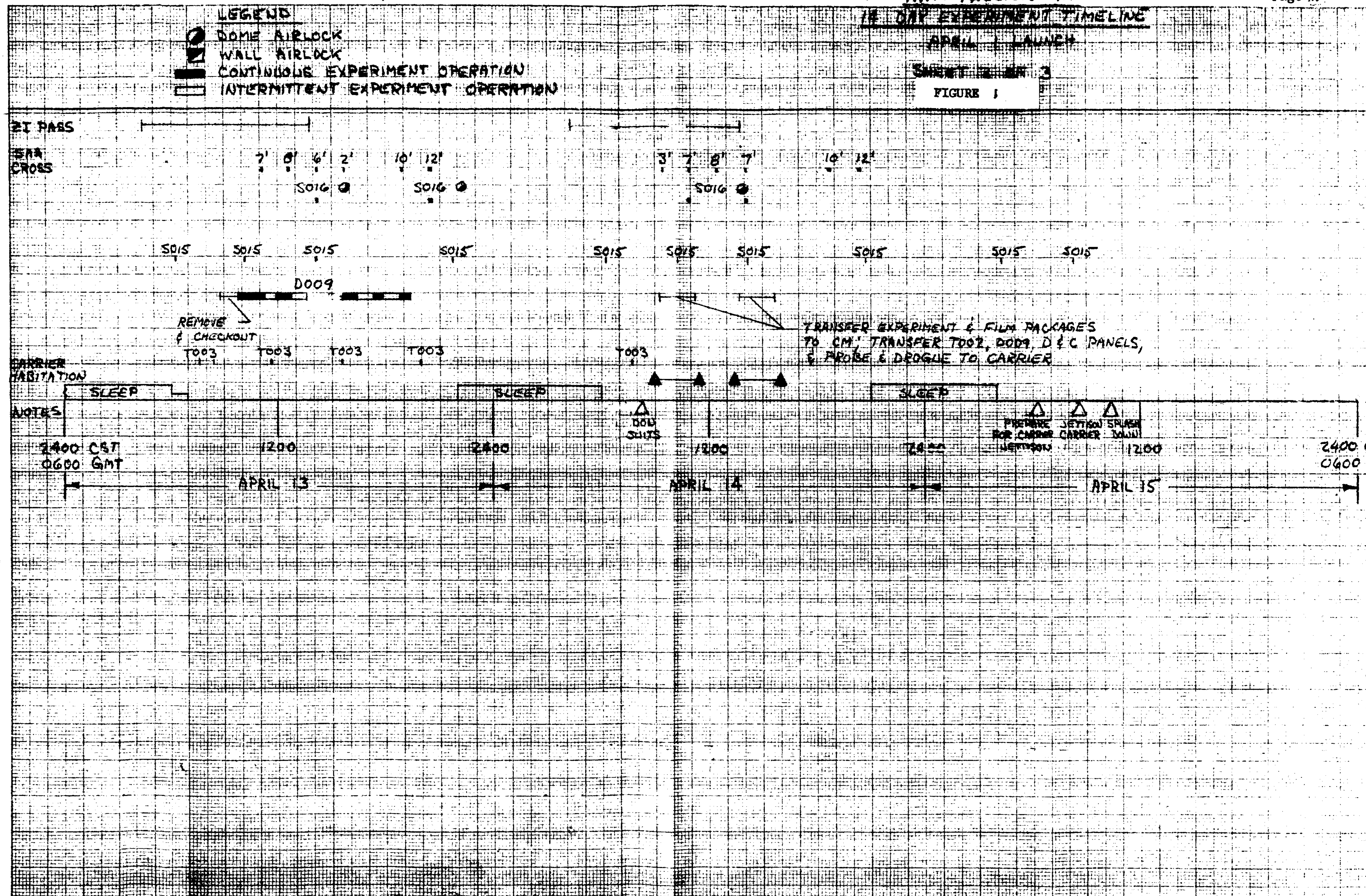
Considerable study is required to determine the capability of the MSFN for data dump and to ascertain the compatibility of existing experiment utilization with the MSFN capability. The April 5-24 hour timeline has been analyzed in detail with respect to the data constraints and adjustments were made to the experiment operating time to eliminate overloading of the ground station net. Additional adjustments will be necessary after a detailed analysis of the experiment periods has been completed.

The experiment support activities including the E06-4 film change, component retrieval from carrier stowage (D&C, T002 and D009), S019 prism change, and general crew mobility and translation within the carrier must be evaluated further to ascertain time requirements. In addition, a comprehensive stowage management study is required to establish the sequence of component transfer, both temporary and permanent stowage locations for experimental and Apollo mainline equipment, and time allocation for these operations.


AAP MISSION IA
14 DAY EXPERIMENT TIMELINE
APRIL 1 LAUNCH
SHEET 1 OF 3
FIGURE 1
LEGEND
DOME AIRLOCK
WALL AIRLOCK
CONTINUOUS EXPERIMENT OPERATION
INTERMITTENT EXPERIMENT OPERATION
ZI PASS
SAA CROSS
T004 FROG
CARRIER HABITATION
NOTES
CONNECT SLA CIRCUIT
REMOVE PROBE & DROGUE, E, D & C; INSTALL S016 IN
INSTALL S020 IN
S020
INSTALL S019 IN
S016
S015
T003
THERMAL ONLY
GROUND CONTROL
THERMAL & LIFE SUPPORT ONLY
STANDARD APPLICATIONS
SLEEP
HATCH OPEN
LAUNCH
CIRCULAR ORBIT
D & C ON
DOFF SUITS
DON SUITS
2400 CST
0600 GMT
1200
2400
APRIL 1
APRIL 2
APRIL 3
SPECIAL TESTS
CHANGE FILM
BORESIGHT S019
S019
CHANGE PRISMS
INSTALL S018 IN
S018
OFF
APRIL 4
APRIL 5
APRIL 6

AAP MISSION 1A
14 DAY EXPERIMENT TIMELINE




AAP MISSION 1A
14 DAY EXPERIMENT TIMELINE
APRIL 1 LAUNCH
SHEET 2 OF 3
FIGURE 1
LEGEND
DOME AIRLOCK
WALL AIRLOCK
CONTINUOUS EXPERIMENT OPERATION
INTERMITTENT EXPERIMENT OPERATION
ZI PASS
SAA CROSS
7' 8' 6' 2' 10' 12'
3' 7' 8' 7' 10' 12'
S016
S015
D009
REMOVE & CHECKOUT
T003
TRANSFER EXPERIMENT & FILM PACKAGES TO CM; TRANSFER T002, D009, D & C PANELS, & PROBE & DROGUE TO CARRIER
CARRIER HABITATION
SLEEP
NOTES
DON SUITS
PREPARE FOR CARRIER JETTISON
JETTISON CARRIER
SPLASH DOWN
2400 CST
0600 GMT
1200
2400
APRIL 13
APRIL 14
APRIL 15

AAP MISSION IA
STANDARD APPLICATIONS
DAY 5 TIMELINE

SHEET 1 OF 2

FIGURE 2

9-8-67 W. CARMEAN

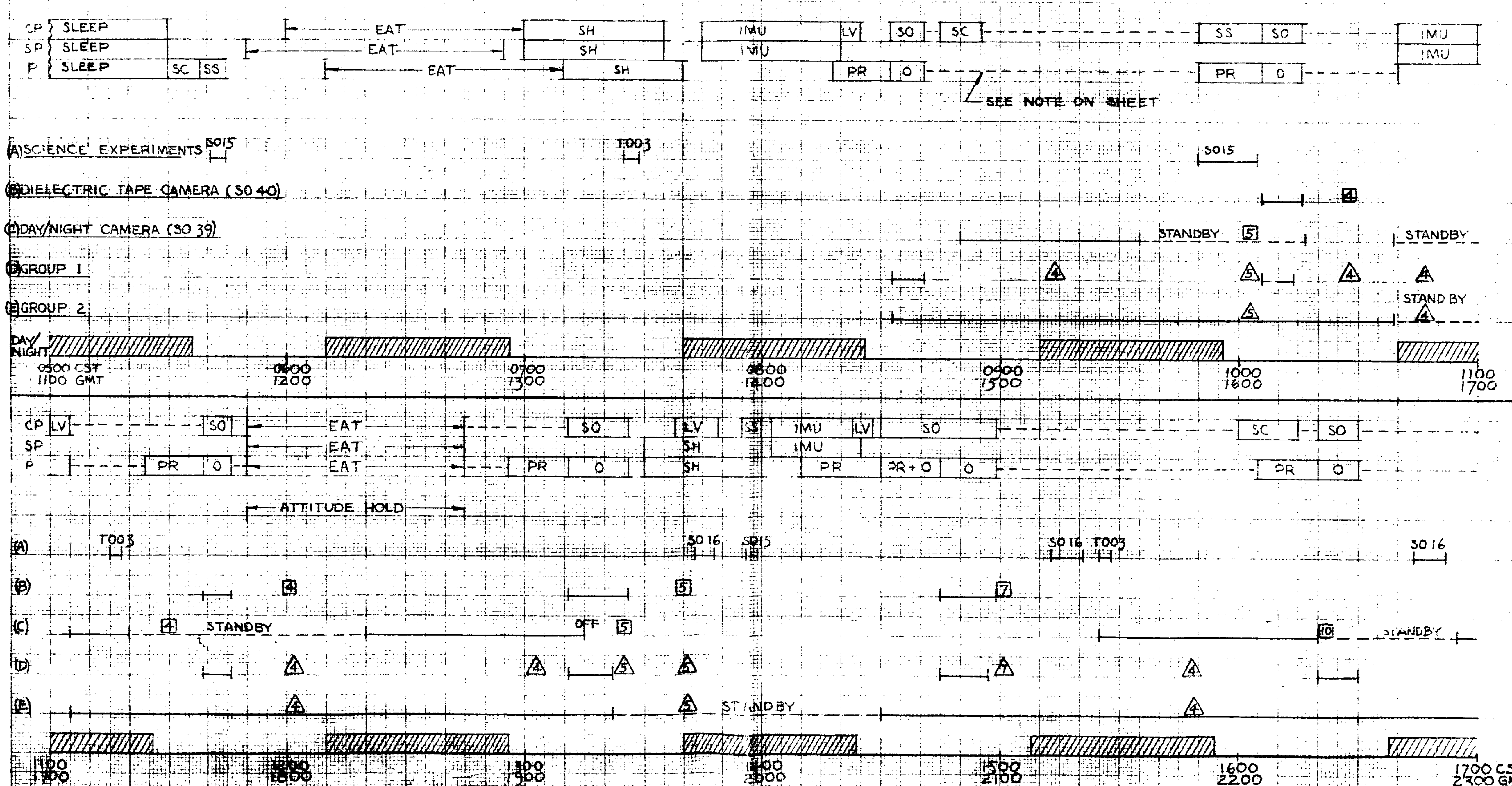
CODE	
SS	SUPPORT S015
SH	SYSTEMS HOUSEKEEPING
IMU	IMU ALIGNMENT
LV	LOCAL VERTICAL ORIENTATION
PR	PREP EXPERIMENT
O	OPERATE EXPERIMENT
SO	SUPPORT EXPERIMENT OPERATION
△	DATA DUMP VHF (MINUTES)
□	DATA DUMP S-BAND (MINUTES)

(D) EXPERIMENT GROUP 1

- E06-1 METRIC CAMERA
- E06-4 MULTISPECTRAL CAMERA
- E06-7 IR IMAGER
- E06-9A IR RADIOMETER
- E06-9B IR SPECTROMETER
- E06-11 PASSIVE M.W. RADIOMETER

(E) EXPERIMENT GROUP 2

- S043 IR TEMPERATURE SOUNDER (TARGETS OF OPPORTUNITY)
- S044A ELECTRICALLY SCANNED MICROWAVE RADIOMETER
- S048 UHF SFERICS



MARTIN MARIETTA CORPORATION
DENVER DIVISION

FOLDOUT FRAME 1 FOLDOUT FRAME FOLDOUT FRAME 2

AAP MISSION IA
STANDARD APPLICATIONS
DAY 5 TIMELINE

SHEET 2 OF 2

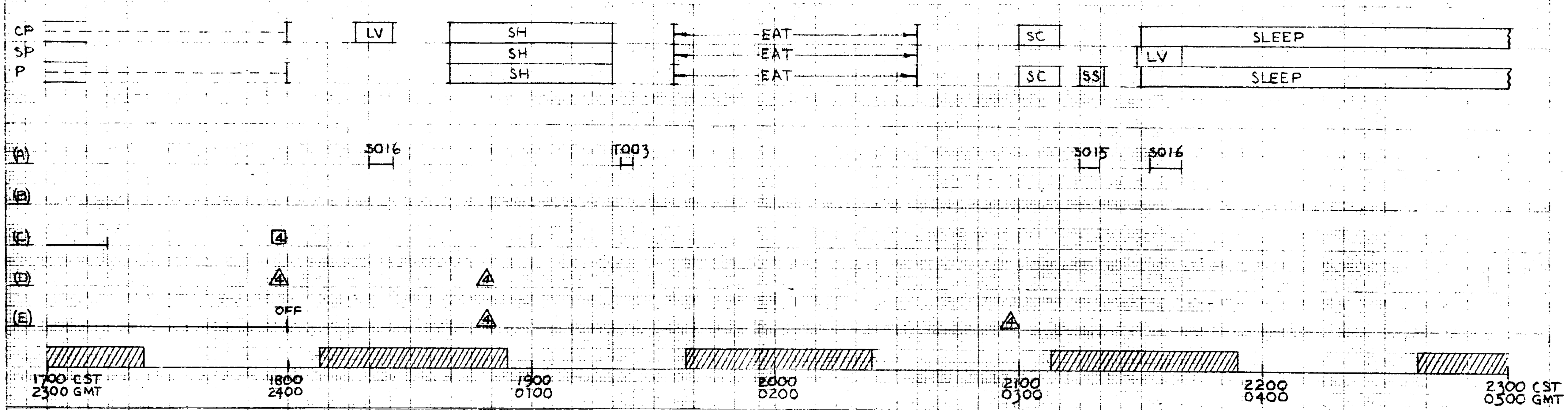
FIGURE 2

9-8-67

W. CARMEAN

CODE	
SS	SUPPORT S015
SH	SYSTEMS HOUSEKEEPING
IMU	IMU ALIGNMENT
LV	LOCAL VERTICAL ORIENTATION
PR	PREP EXPERIMENTS
O	OPERATE EXPERIMENT
SO	SUPPORT EXPERIMENT OPERATION
△	DATA DUMP VHF (MINUTES)
□	DATA DUMP S-BAND (MINUTES)

(A) SCIENCE EXPERIMENTS
(B) DIELECTRIC TAPE CAMERA (S040)
(C) DAY/NIGHT CAMERA (S039)
(D) GROUP 1 (SEE SHEET 1)
(E) GROUP 2 (SEE SHEET 1)



NOTE: ALL THREE CREWMEN MAY ROTATE RESPONSIBILITY FOR CONTROLLING VEHICLE + MONITORING DAY/NIGHT CAMERA + GROUP 2 EXPERIMENTS DURING EXTENDED PERIODS OF OPERATION. THESE PERIODS ARE INDICATED BY |- - - - - - - -|

PR 29-47

TRADE STUDY REPORT

DATA BANDWIDTH UTILIZATION

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

September 5, 1967

Prepared by: W E Smull

Approved by: [illegible signature]

Martin Marietta Corporation
Denver Division

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose - Two experiments under consideration for Mission IA are the Day-Night Camera (S039) and the Dielectric Tape Camera (S040). These experiments produce data with bandwidths much too large to be accommodated by normal multiplexing systems. This study was undertaken to examine means for transmitting data from these two experiments on an S-band telemetry link.

1.2 Objectives

1.2.1 To determine the spectrum occupied by an RF carrier when frequency modulated by the signal from experiment S040.

1.2.2 To study the feasibility of multiplexing other signals on the same carrier; e.g., the signal from experiment S039 and the 1.024 MHz PCM subcarrier.

1.2.3 To define operating parameters of the transmitter and ground station required for acquisition of the data.

2.0 SUMMARY

This study explores the problems involved in transmitting wideband data over an S-band telemetry link. An analytical technique is developed using a group of sinusoidal signals to represent the complex wideband signal. Sideband amplitudes and rf spectrum envelopes are calculated for a low-pass-filtered signal with two values of carrier deviation, and for a band-limited signal. The feasibility of frequency multiplexing other data is evaluated, and transmitter power requirements are calculated.

It is concluded that transmission of such a signal is feasible, and that multiplexing of PCM data on the same carrier is possible. Recommended operating parameters are given for the transmitter and ground station.

3.0 ANALYSIS

3.1 Signal Characteristics - The data signal is described in reference 1 as extending from 10 Hz to 680 kHz. No information is given on the spectral distribution of signal components over the frequency range. It is known that the signal consists of video-type data.

It will be assumed that the signal has a uniform power spectral density over the stated frequency range. Since the spectral content of the signal above 680 kHz is unknown, two approaches will be explored: first, the signal will be assumed to be continuous above 680 kHz, but a low-pass filter will be used to roll off high frequency components; second, the signal will be assumed to be band-limited, with zero energy above 680 kHz.

Although a linear phase filter would probably be desirable in the actual application, the analysis to follow is not significantly affected if a mathematically-simpler filter is assumed. For a maximally flat amplitude (Butterworth) low-pass filter, the amplitude response is

$$\left(\frac{V_p}{V}\right)^2 = 1 + \left(f/f_{co}\right)^{2m} \qquad (1)$$

where V_p = peak output voltage in the pass band,

V = output voltage at frequency f,

f_{co} = frequency at which output is 3 db down, and

m = number of poles.

The rate of attenuation outside the passband is determined by the number of poles in the Butterworth function. The number of poles should be chosen to describe a filter which is within the realm of realizability. A conservative value for m is 3; this specifies an ultimate attenuation slope of 18 db per octave. A cutoff frequency of 680 kHz will be used.

3.2 Analytical Approach - A method for calculation of the spectrum of a transmitter which is frequency modulated by a complex wideband signal is not known. However, techniques are available for determining sideband amplitudes produced by one or more sinusoidal modulating signals (ref. 2). Such a technique can be applied if the 10 Hz-680 kHz signal can be reasonably represented by a group of sinusoidal signals, or tones.

Let V_M equal the rms value of the complex modulating signal produced by the linear mixing of a group of n tones. Since the tones are sinusoidal,

$$V_M = \left[\sum_{i=1}^{n} (V_i)^2\right]^{1/2} \qquad (2)$$

and $V_{ip} = \sqrt{2}\, V_i$ (3)

where V_i = rms voltage of the i^{th} tone,

and V_{ip} = peak voltage of the i^{th} tone.

If d is the deviation sensitivity of the transmitter in MHz per volt, the rms carrier deviation is $dV_M = \Delta f$ MHz. The peak carrier deviation is $\Delta f_p = \sum_{i=1}^{n} dV_{ip}$. This value has a vanishingly small probability of occurrence. An assumption which is true for considerably more than 99% of the time is that $\Delta f_p = 4\Delta f$. (Ref. 3).

If we define A_i to be the relative rms amplitude of the i^{th} tone which is V/V_p from equation (1), and $kA_i = V_i$ where k = a constant, it can be seen that

$$k\left[\sum_{i=1}^{n} A_i^2\right]^{1/2} = \left[\sum_{i=1}^{n} V_i^2\right]^{1/2} = V_M = \frac{\Delta f}{d}. \qquad (4)$$

If Δf_{ip} is the peak carrier deviation due to the i^{th} tone,

$$\Delta f_{ip} = dV_{ip} = \sqrt{2}\, d\, V_i = \sqrt{2}\, d\, k\, A_i, \text{ and}$$

substituting $k = \dfrac{\Delta f}{d\left[\sum_{i=1}^{n} A_i^2\right]^{1/2}}$ from (4) into the above equation, the resultant equation becomes

$$\Delta f_{ip} = \frac{\sqrt{2}\,\Delta f}{\left[\sum_{i=1}^{n} A_i^2\right]^{1/2}} A_i. \qquad (5)$$

The modulation index for the i^{th} tone is, by definition, the peak carrier deviation due to this tone divided by the frequency of the tone:

$$M_i = \frac{\Delta f_{ip}}{f_i}. \qquad (6)$$

To provide a suitable approximation of the complex wideband signal, the n tones should be uniformly spaced over the frequency range of interest. Those tones higher in frequency than the 3 db frequency of the low-pass filter will contribute less spectrum energy than the lower-frequency tones, but a small number of high frequency tones is required to define the spectrum envelope. To insure that none of the sidebands from a tone will coincide with the fundamental frequency of any tone, the frequencies should be chosen so that none is an integral multiple of any other.

Nine tones satisfying these criteria for a representation of the low-pass-filtered signal are listed in Table 1. For each frequency, the relative amplitude was calculated using equation (1). When an overall carrier deviation has been selected, the individual deviations and modulation indexes for the tones can be calculated using equations (5) and (6).

The Apollo television system has a nominal video bandwidth of 500 kHz; frequencies above 500 kHz are attenuated by a 20 db per octave filter. Signal voltage is adjusted to produce a peak carrier deviation of 1.00 MHz (ref. 5). The overall modulation index (peak carrier deviation divided by video filter cutoff frequency) is thus 2. Two choices for peak carrier deviation are thus presented: 1.00 MHz (the value presently used for television) and 1.36 MHz (2 times 680 kHz). Calculations were made to determine the peak sideband amplitudes for these two cases with the filtered signal. Values more than 40 db below unmodulated carrier were discarded. Sideband amplitudes were calculated using the expression

$$V = J_p(M_i) \qquad (7)$$

where J_p = Bessel function of the first kind, $p^{\underline{th}}$ order

and M_i is as defined in equation (6). This expression gives the peak amplitude of the sidebands located $\pm$ p times the tone frequency from the carrier center frequency. Standard tables of the Bessel functions were used to obtain most of the values. For values of M_i less than 0.1, the following approximations from ref. 4 were used:

$$J_1(M_i) \approx \frac{M_i}{2} \; ; \; J_2(M_i) = J_3(M_i) = J_4(M_i) = 0$$

Experience gained from calculations on the filtered signal indicated that a larger number of tones would better define the envelope of sidebands. Also, the effect of distributing signal energy lower in the spectrum needed investigation. Accordingly, for the band-limited case, eleven equal-amplitude tones were chosen. Each of the tones, shown in Table 2, has a frequency about 1.5 times that of the next lower tone. The tones cover a range from 12 - 680 kHz.

Calculations on the filtered signal showed that spectrum width was not strongly affected by carrier deviation; therefore, calculations of sideband amplitudes for the band-limited signal were carried out for only one value of peak carrier deviation, 1.56 MHz.

3.5 Discussion of Results - Calculated sideband amplitudes are listed in Tables 3, 4 and 5. Spectrum envelopes are plotted in Figures 1, 2 and 3; only half the spectrum is actually shown, since the sidebands are duplicated on the opposite side of the carrier.

It was found in each case that the envelope is defined by the first sideband of each tone. The lower frequency tones, having relatively high modulation indexes, produce a large number of significant sidebands; however, the high-order sidebands are always of lower amplitude than the first sidebands of tones in the same frequency region.

When a carrier is frequency modulated, energy is removed from the carrier and is distributed in the sidebands. For a single modulating frequency, it is shown in ref. 4 that

$$\left[J_o(M)\right]^2 + 2\left[J_1(M)\right]^2 + 2\left[J_2(M)\right]^2 + \ldots = 1 \qquad (8)$$

With equation (8), the number of sidebands which encompass an arbitrary percentage of the total energy for a given value of M can be determined. A few calculations were made for the 99% level. The results below show the maximum sideband order needed to include 99% energy for selected modulation index values.

M	Sideband Order
0.2	0
0.5	1
1.0	2
2.0	3
3.0	4
4.0	5

This shows that, for a modulation index of 0.2 or less, more than 99% of the energy remains in the carrier; for M = 0.5, 99% of the energy is in the carrier and first order sidebands, etc. It can be seen in Tables 3, 4 and 5 that even the first order sidebands of the higher tones, because of the very low modulation indexes, contain insignificant amounts of energy.

The sideband envelopes, in all three cases, peak at about -5 db at around 0.1 MHz from center frequency. Also, in every case, the envelope is approximately 30 db down at

1.0 MHz. It would appear that other signals having no significant sidebands below 1.0 MHz could be multiplexed by using one or more suitably-located subcarriers.

3.4 Subcarrier Evaluation - Let us consider the use of a subcarrier for the S039 data signal, which extends from 140 kHz to 240 kHz. To provide adequate separation from the S040 baseband spectrum, and to permit a reasonable subcarrier deviation ratio, the center frequency should be no lower than about 1.5 MHz. A deviation ratio of 2, a predetection bandwidth of 5 MHz, and a post-detection bandwidth of 240 kHz will be assumed for a sample calculation. If a predetection signal-to-noise ratio of 12 db and a post-detection signal-to-noise ratio of 30 db are specified, the required carrier deviation for this subcarrier can be calculated by equation (6) of ref. 3. The calculation shows that a peak carrier deviation of 1.97 MHz would have to be assigned to the subcarrier.

The rms deviation would be 1.39 MHz. When this value is compared with the 0.34 MHz rms deviation used for the baseband signal, it can be seen that the subcarrier uses the majority of the transmitter power to transmit a relatively narrow data bandwidth.

On the other hand, the 1.024 MHz subcarrier, phase modulated by 51.2 KBPS NRZ PCM data, occupies a narrow bandwidth and would require much less carrier deviation.

3.5 Transmitter Power Requirement - An estimate of the transmitter power required for this link is needed so that a tentative hardware selection can be made. Values for most of the link parameters were obtained from ref. 6; others were either calculated or estimated.

An orbit altitude of 140 nautical miles and a minimum receiving antenna elevation of 5° are assumed. These values give a maximum slant range of 736 nautical miles and a path loss of 162.2 db at 2272 MHz. The omnidirectional transmitting antenna system has a gain of at least -3 db over 80% of the radiation sphere. The experiment carrier will have a controlled attitude and the antenna locations can be chosen to give a favorable pattern with this attitude, and the transmitting antenna gain is therefore estimated to be 0 db. Two values for receiving antenna gain will be considered: 44 db and 52 db, for 30 foot and 85 foot antennas.

A predetection bandwidth of 10 MHz is normally used for FM reception by the MSFN stations. However, it appears that a bandwidth of 3.3 MHz (normal for the PM mode) might be feasible for this special case. The receiving system noise figure is 2.0 db; the calculated receiver noise powers are -106.3 and -111.1 dbm for bandwidths of 10 MHz and 3.3 MHz, respectively.

Threshold signal-to-noise ratio for the ground station is 10 db. Miscellaneous airborne and ground circuit losses total 7.5 db. Transmitter power required to provide a link margin of 6 db will be calculated. Parameter values are summarized as follows:

Slant range:	736 nm
Path loss:	162.2 db
Transmitting antenna gain	0 db
Receiving antenna gain	44 db and 52 db
Predetection bandwidth:	10 MHz and 3.3 MHz
Receiver noise power:	-106.3 dbm and -111.1 dbm
Predetection S/N:	10 db
Miscellaneous losses:	7.5 db
Margin:	6 db

Two values each for receiving antenna gain and predetection bandwidth produce four possible values for transmitter power. The results of the calculations are shown in the following table.

Receiving Antenna	Bandwidth	Required Xmtr Power
30 ft.	10 MHz	3.46 watts
30 ft.	3.3 MHz	1.15 watts
85 ft.	10 MHz	0.55 watts
85 ft.	3.3 MHz	0.18 watts

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

a. An ensemble of sinusoidal signals appears to be a reasonable model of a wideband signal.
b. The sideband envelopes are similar for the three cases studied.
c. For the models assumed, a premodulation low pass filter has little effect on the results.

d. Less than 1% of the signal energy is contributed by sideband components located more than twice the rms deviation from the carrier center frequency.
e. It is feasible to multiplex the 1.024 MHz PCM subcarrier.
f. It is <u>not</u> feasible to multiplex the S039 data on a subcarrier.
g. The LM S-band transmitter, with a power output of 0.75 watt, would be adequate for transmitting data to MSFN stations which are equipped with 85-foot antennas.

4.2 Recommendations

a. A peak carrier deviation of 1.36 MHz should be allocated to the S040 signal.
b. If the S040 signal contains significant frequency components above 680 kHz, or if the high frequency region is undefined, a premodulation low-pass filter should be used.
c. The ground station used for acquisition of the transmitted S040 data should have a predetection bandwidth of at least 3.0 MHz and a postdetection bandwidth of 680 kHz.
d. The feasibility of the basic approach, and of any contemplated multiplexing scheme, should be verified experimentally.

REFERENCES

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5. Apollo Training Manual, Telecommunication Subsystem, Apollo Block II, North American Aviation, Downey, California

6. Command and Service Module - Manned Space Flight Network Signal Performance and Interface Specification, Block II; Document No. SID 64-1613, North American Aviation, 22 February 1965.

TABLE I. TONES USED TO REPRESENT FILTERED SIGNAL

Tone Number	1	2	3	4	5	6	7	8	9
f_i, kHz	51	121	211	300	410	540	680	880	1100
Relative Amplitude	1.00	1.00	1.00	1.00	0.98	0.89	0.71	0.42	0.25
Peak Carrier Deviation = 1.00 MHz									
Δf_{ip}, kHz	139	139	139	139	136	124	99	58	35
M_i	2.73	1.15	0.66	0.46	0.33	0.23	1.15	0.066	0.032
Peak Carrier Deviation = 1.36 MHz									
Δf_{ip}, kHz	189	189	189	189	187	168	134	79	47
M_i	3.70	1.56	0.90	0.63	0.46	0.31	0.20	0.090	0.043

TABLE 2. TONES USED TO REPRESENT BAND-LIMITED SIGNAL

Tone Number	1	2	3	4	5	6	7	8	9	10	11
f_i, kHz	12	18	26	40	60	89	134	201	302	453	680

Peak Carrier Deviation = 1.36 MC

Δf_{ip}, kHz	145	145	145	145	145	145	145	145	145	145	145
M_i	12.1	8.1	5.6	3.6	2.4	1.6	1.08	0.72	0.48	0.32	0.21

TABLE 3.
SIDEBAND AMPLITUDES,
FILTERED SIGNAL, PEAK DEVIATION 1.00 MHz

LOCATION	FREQUENCY	EXPRESSION	AMPLITUDE*
$f_c \pm f_1$	$f_c \pm 51$ kHz	J_1 (2.73)	-7.5 db
$2f_1$	102	J_2 (2.73)	-6.5
$3f_1$	153	J_3 (2.73)	-11.5
$4f_1$	204	J_4 (2.73)	-20.0
$5f_1$	255	J_5 (2.73)	-29.5
f_2	$\pm$ 121	J_1 (1.15)	-6.5
$2f_2$	242	J_2(1.15)	-17.0
$3f_2$	363	J_3 (1.15)	-30.5
f_3	$\pm$ 211	J_1(0.66)	-10.0
$2f_3$	422	J_2 (0.66)	-26.0
f_4	$\pm$ 300	J_1 (0.46)	-12.5
$2f_4$	600	J_2 (0.46)	-32.0
f_5	$\pm$ 410	J_1(0.33)	-15.5
$2f_5$	820	J_2(0.33)	-37.0
f_6	$\pm$ 540	J_1 (0.23)	-19.0
f_7	$\pm$ 680	J_1 (0.15)	-22.5
f_8	$\pm$ 880	J_1 (0.066)	-29.5
f_9	$\pm$ 1100	J_1 (0.032)	-36.0

*db relative to unmodulated carrier

TABLE 4.
SIDEBAND AMPLITUDES,
FILTERED SIGNAL, PEAK DEVIATION 1.36 MHz

LOCATION	FREQUENCY	EXPRESSION	AMPLITUDE*
$f_c \pm f_1$	$f_c \pm 51$ kHz	J_1 (3.7)	-25.4 db
$2f_1$	102	J_2 (3.7)	-7.5
$3f_1$	153	J_3 (3.7)	-8.0
$4f_1$	204	J_4 (3.7)	-12.5
$5f_1$	255	J_5 (3.7)	-20.5
$6f_1$	306	J_6 (3.7)	-29.0
$7f_1$	357	J_7 (3.7)	-40.0
f_2	$\pm$ 121	J_1(1.56)	-5.0
$2f_2$	242	J_2(1.56)	-12.0
$3f_2$	363	J_3(1.56)	-23.5
$4f_2$	484	J_4 (1.56)	-37.5
f_3	$\pm$ 211	J_1 (.9)	-8.0
$2f_3$	422	J_2 (.9)	-20.5
$3f_3$	633	J_3 (.9)	-36.5
f_4	$\pm$ 300	J_1(.63)	-10.5
$2f_4$	600	J_2 (.63)	-27.0
f_5	$\pm$ 410	J_1(.46)	-12.5
$2f_5$	820	J_2(.46)	-32.0
f_6	$\pm$ 540	J_1(.31)	-16.0
f_7	$\pm$ 680	J_1(.2)	-20.0
f_8	$\pm$ 880	J_1(.09)	-26.5
f_9	$\pm$ 1100	J_1(.043)	-33.0

*db relative to unmodulated carrier

TABLE 5.
SIDEBAND AMPLITUDES,
BAND-LIMITED SIGNAL, PEAK DEVIATION
1.36 MHz

LOCATION	FREQUENCY, kHz	EXPRESSION	AMPLITUDE*
$f_c \pm f_1$	$f_c \pm 12$	J_1 (12.1)	-13.3
$\pm 2f_1$	± 24	J_2 (12.1)	-20.3
$\pm 3f_1$	± 36	J_3 (12.1)	-15.1
$\pm 4f_1$	± 48	J_4 (12.1)	-14.9
$\pm 5f_1$	± 60	J_5 (12.1)	-25.5
$\pm 6f_1$	± 72	J_6 (12.1)	-12.7
$\pm 7f_1$	± 84	J_7 (12.1)	-15.0
$\pm 8f_1$	± 96	J_8 (12.1)	-31.5
$\pm 9f_1$	± 108	J_9 (12.1)	-13.4
$\pm 10f_1$	± 120	J_{10} (12.1)	-10.6
$\pm 11f_1$	± 132	J_{11} (12.1)	-11.3
$\pm 12f_1$	± 144	J_{12} (12.1)	-13.9
$\pm 13f_1$	± 156	J_{13} (12.1)	-17.9
$\pm 14f_1$	± 168	J_{14} (12.1)	-23.0
$\pm 15f_1$	± 180	J_{15}(12.1)	-29.1
$\pm 16f_1$	± 192	J_{16} (12.1)	-36.0
$f_c \pm f_2$	± 18	J_1 (8.1)	-12.1
$\pm 2f_2$	± 36	J_2 (8.1)	-21.4
$\pm 3f_2$	± 54	J_3 (8.1)	-11.0
$\pm 4f_2$	± 72	J_4 (8.1)	-18.3
$\pm 5f_2$	± 90	j_5 (8.1)	-15.6
$\pm 6f_2$	± 108	J_6 (8.1)	-9.8
$\pm 7f_2$	± 126	J_7 (8.1)	-9.9
$\pm 8f_2$	± 144	J_8 (8.1)	-12.7
$\pm 9f_2$	± 162	J_9 (8.1)	-17.4
$\pm 10f_2$	± 180	J_{10} (8.1)	-23.5

*db relative to unmodulated carrier

TABLE 5.
SIDEBAND AMPLITUDES,
BAND-LIMITED SIGNAL, PEAK DEVIATION
1.36 MHz

(continued)

LOCATION	FREQUENCY, kHz	EXPRESSION	AMPLITUDE*
$f_c \pm 11f_2$	$f_c \pm 198$	J_{11} (8.1)	-30.7
$\pm 12f_2$	± 216	J_{12} (8.1)	-38.9
$\pm f_3$	± 26	J_1(5.6)	-9.5
$\pm 2f_3$	± 52	J_2(5.6)	-17.9
$\pm 3f_3$	± 78	J_3 (5.6)	-13.4
$\pm 4f_3$	± 104	J_4 (5.6)	-8.6
$\pm 5f_3$	± 130	J_5 (5.6)	-9.9
$\pm 6f_3$	± 156	J_6 (5.6)	-14.0
$\pm 7f_3$	± 182	J_7 (5.6)	-20.1
$\pm 8f_3$	± 208	J_8 (5.6)	-27.7
$\pm 9f_3$	± 234	J_9 (5.6)	-36.5
$f_c \pm f_4$	± 40	J_1 (3.6)	-20.4
$\pm 2f_4$	± 80	J_2 (3.6)	-7.0
$\pm 3f_4$	± 120	J_3 (3.6)	-8.0
$\pm 4f_4$	± 160	J_4 (3.6)	-13.2
$\pm 5f_4$	± 200	J_5 (3.6)	-20.3
$\pm 6f_4$	± 240	J_6 (3.6)	-29.4
$\pm 7f_4$	± 280	J_7 (3.6)	-39.9
$f_c \pm f_5$	± 60	J_1 (2.4)	-5.7
$\pm 2f_5$	± 120	J_2 (2.4)	-7.3
$\pm 3f_5$	± 180	J_3 (2.4)	-14.1
$\pm 4f_5$	± 240	J_4 (2.4)	-23.8
$\pm 5f_5$	± 300	J_5 (2.4)	-33.4

*db relative to unmodulated carrier

TABLE 5.
SIDEBAND AMPLITUDES,
BAND-LIMITED SIGNAL, PEAK DEVIATION
1.36 MHz
(continued)

LOCATION	FREQUENCY, kHz	EXPRESSION	AMPLITUDE*
$f_c \pm f_6$	$f_c \pm 89$	J_1 (1.6)	-4.9
$\pm 2f_6$	± 178	J_2 (1.6)	-11.8
$\pm 3f_6$	± 267	J_3 (1.6)	-22.8
$\pm 4f_6$	± 356	J_4 (1.6)	-36.5
$f_c \pm f_7$	± 134	J_1 (1.1)	-6.5
$\pm 2f_7$	± 268	J_2 (1.1)	-17.3
$\pm 3f_7$	± 402	J_3 (1.1)	-31.8
$f_c \pm f_8$	± 201	J_1 (.72)	-9.5
$\pm 2f_8$	± 402	J_2 (.72)	-22.0
$f_c \pm f_9$	± 302	J_1 (.48)	-12.5
$\pm 2f_9$	± 604	J_2 (.48)	-31.0
$f_c \pm f_{10}$	± 453	J_1 (.32)	-16.0
$\pm 2f_{10}$	± 906	J_2 (.32)	-37.5
$f_c \pm f_{11}$	± 680	J_1 (.21)	-19.5

*db relative to unmodulated carrier

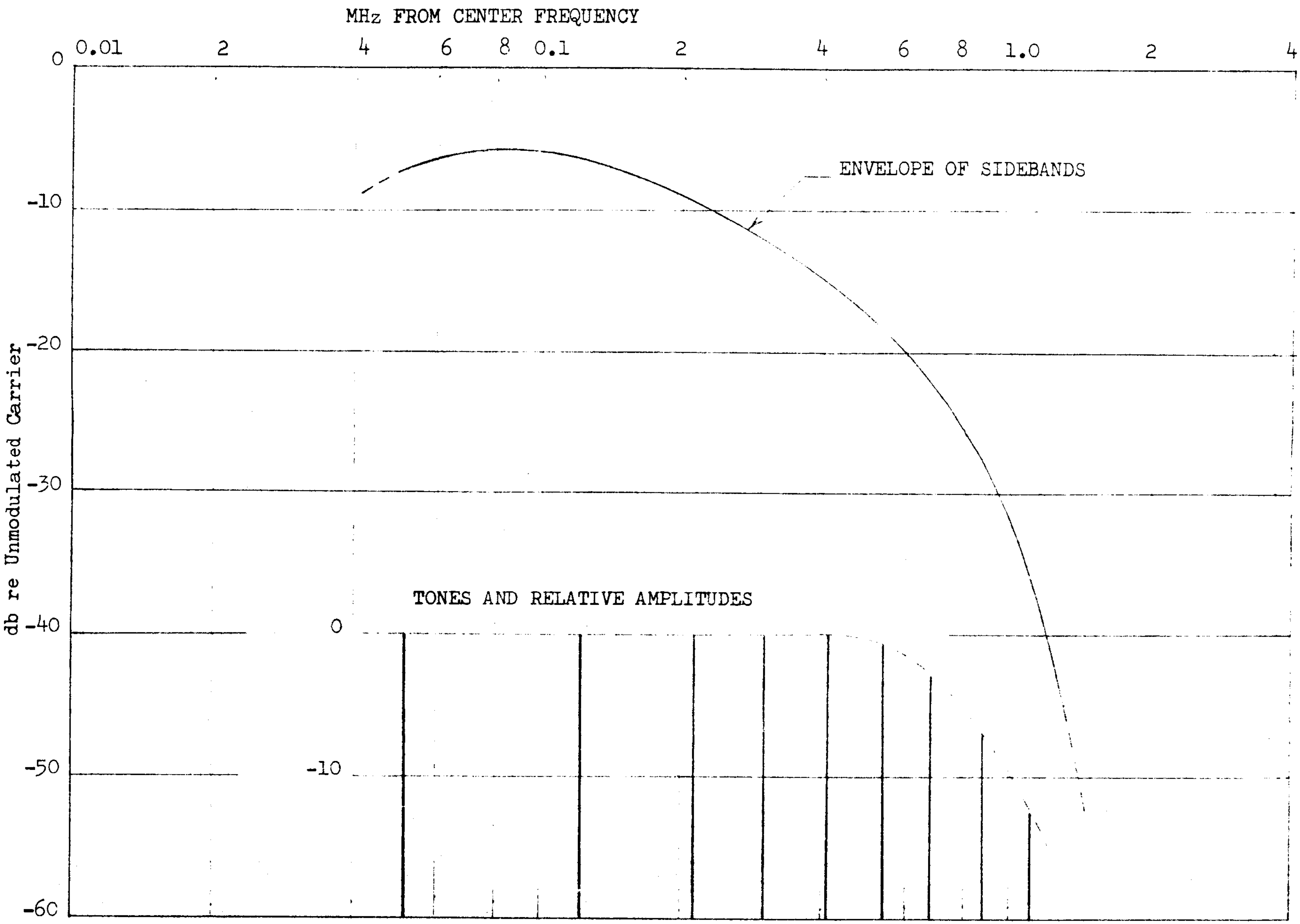


FIG. 1 - RF SPECTRUM OF FILTERED SIGNAL, PEAK DEVIATION 1.00 MHz

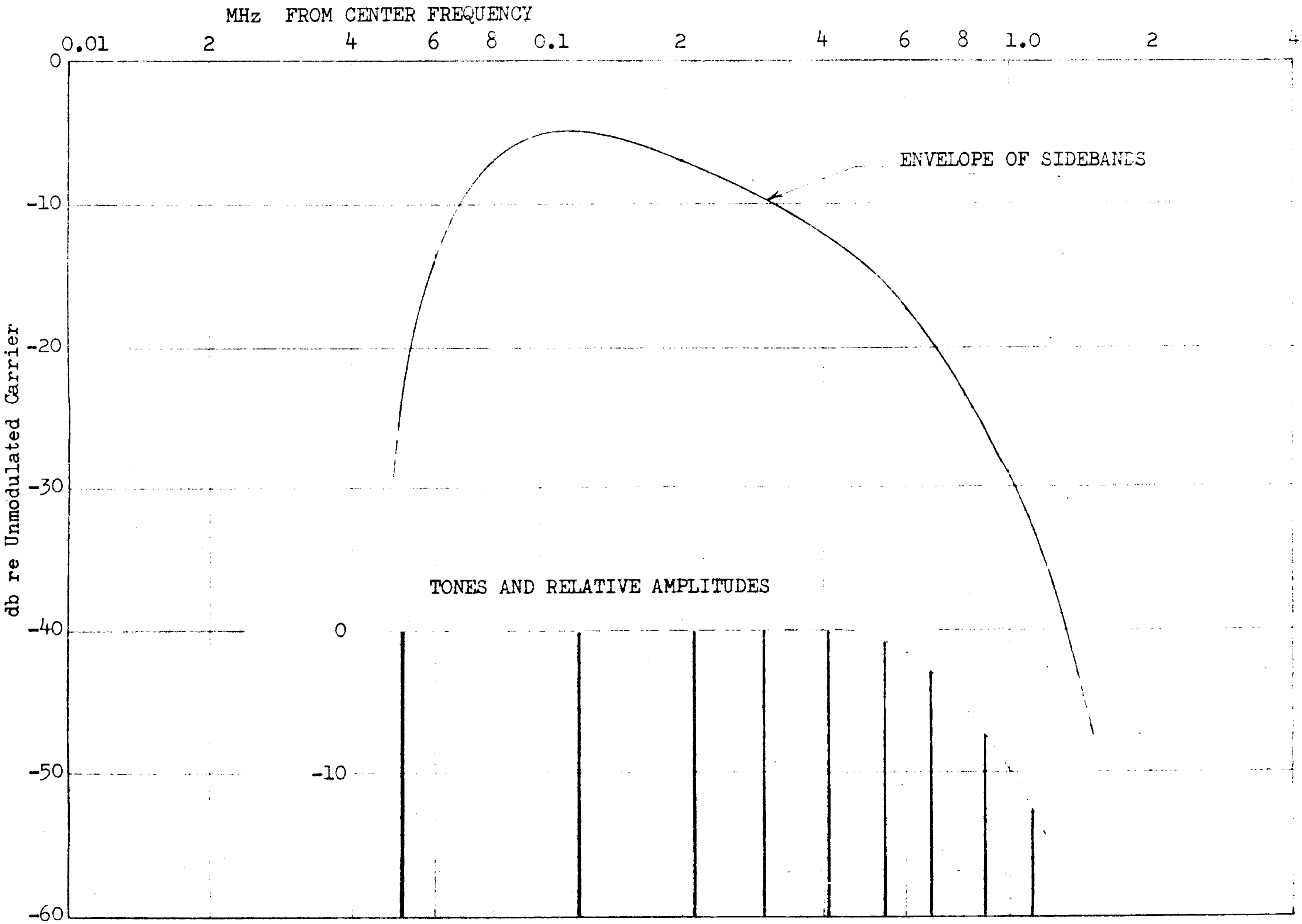


FIG. 2 - RF SPECTRUM OF FILTERED SIGNAL, PEAK DEVIATION 1.36 MHz

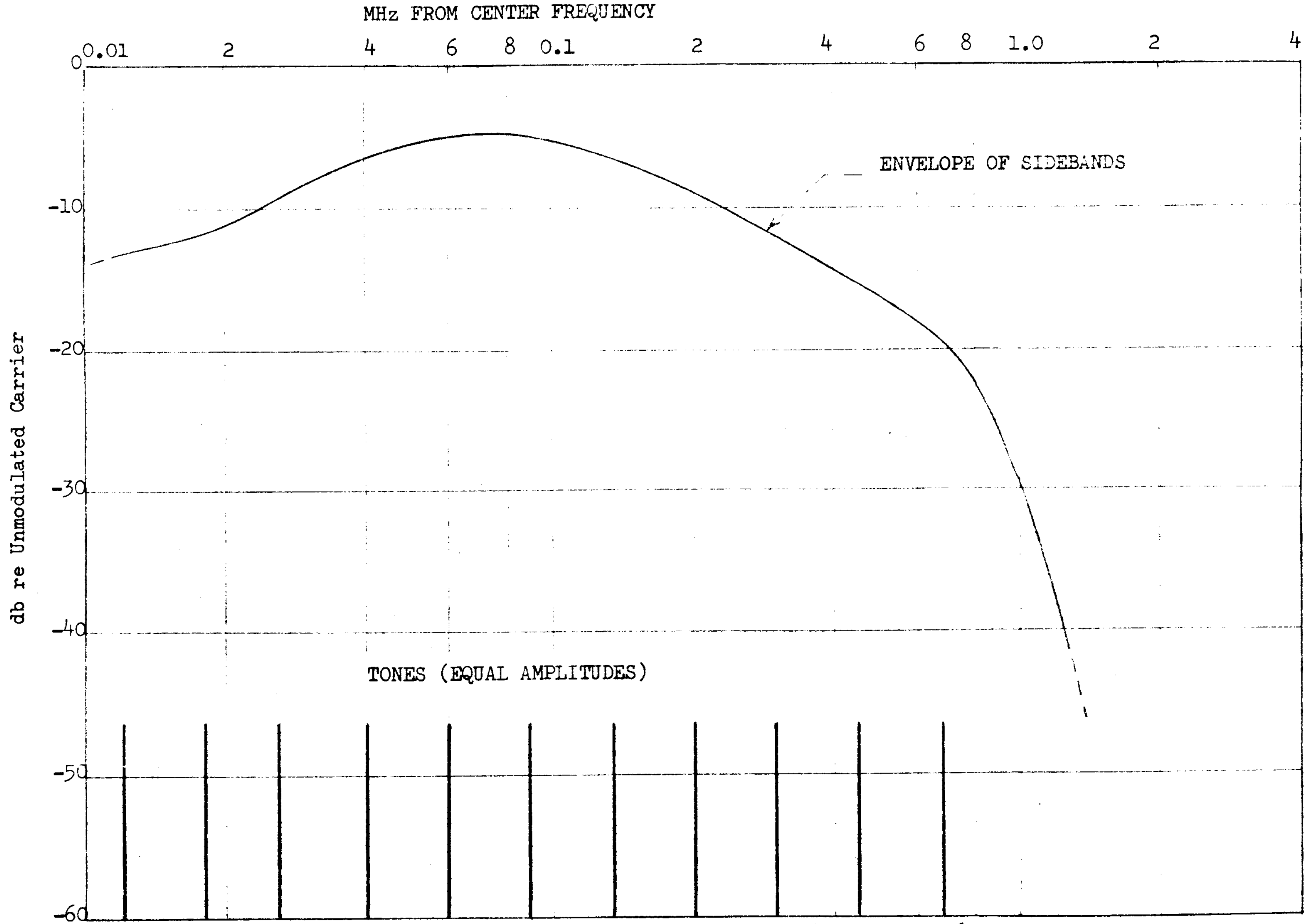


FIG. 3 - RF SPECTRUM OF BAND-LIMITED SIGNAL, PEAK DEVIATION 1.36 MHz

PR-29-48

TRADE STUDY REPORT

TCS PUMP SELECTION STUDY

AAP/PIP EARLY APPLICATIONS

Contract NAS 8-21004

8 September 1967

Prepared by: J. Ashura

Approved by: E. Schumacher

MARTIN MARIETTA CORPORATION

Denver Division

1. INTRODUCTION

1.1 Purpose - The purpose of this report is to document the data, methods and results of preliminary TCS pump selection study.

1.2 Objective - The objectives of this report was to determine the best pump package available for use in the Early Applications Vehicle Thermal Control System.

2. SUMMARY

Five parameters, namely, schedule risk, cost, weight, power requirements and growth potential have been used to evaluate pump packages that are available and have been used on the Apollo or LM programs. Evaluation points have been calculated and/or assigned to each of the comparison factors. In addition weighting factors have been assigned to each of the five comparison factors. An overall figure of merit has been arrived at by multiplying the evaluation points by the weighting factor. The LM pump package has been selected from this study and is being used in the baseline TCS.

3. DISCUSSION

3.1 Three pump packages have been compared, two of which have been proposed by Garrett Corporation and one by Hamilton Standard. The first Garrett pump (see Item 1, Figure 1) is basically an Apollo Block II unit with a modification that replaces the AC pump motors with a brushless D.C. motor, a modification to the accumulators, and a change of "O" ring materials. The second Garrett pump package is an AAP unit with a change to the diffusor outlet diameter (from an .060 to an .080 drill) and a change to "O" ring materials (see Item 2, Figure 1). Garrett has not built or tested a unit in the first configuration with freon 21. They have run 500 hours with freon 21 on the second unit. They have also run 3000 hours with freon 21 with a boilerplate unit driven with a brushless D.C. motor. The Hamilton Standard unit (see Item 3, Figure 1) manufactured by Hydro Aire, includes a change of "O" ring material as the only modification. It has been run for 3000 hours on freon 21.

3.2 The following indicates methods used in arriving at the figure of merit numbers.

3.2.1 Schedule Risk - Assign a rating of 10 to the lowest total of required modifications and assign other units lower ratings in proportions to their percentage over the lowest unit.

Unit No.	No. of Mods.	Evaluation	Calculation
1	3	-10	$10-\left[\frac{3-1}{1} \times 10\right]$
2	2	0	$10-\left[\frac{2-1}{1} \times 10\right]$
3	1	+10	

3.2.2 Cost - Assign a value of 10 to the lowest cost unit and assign the other units lower ratings in proportion to their percentage over the lowest unit.

Unit No.	Cost	Evaluation	Calculation
1	257,000	-7.4	$10-\left[\frac{163,000}{94,000} \times 10\right]$
2	94,000	10	
3	132,000	6.0	$10-\left[\frac{38,000}{94,000} \times 10\right]$

3.2.3 Weight - Assign a value of 10 to the lowest weight unit and assign other units lower ratings in proportion to their percentage over the lowest unit.

Unit No.	Weight	Evaluation	Calculation
1	14.6	-.3	$10-\left[\frac{7.4}{7.2} \times 10\right]$
2	14.6	-.3	$10-\left[\frac{7.4}{7.2} \times 10\right]$
3	7.2	10	

3.2.4 Power - Assign a value of 10 to the unit requiring the least power and assign the other units lower ratings in proportion to their percentage over the lowest unit.

Unit No.	Power Required	Evaluation	Calculation
1	20.0 Watts DC	10	
2	45.5 Watts DC	-2.8	$10-\left[\frac{45.5-20}{20} \times 10\right]$
3	26.6 Watts DC	6.7	$10-\left[\frac{26.6-20}{20} \times 10\right]$

3.2.5 Growth Potential - Inspection of pump performance data reveals the following:

(a) The Hamilton Standard pump (Unit #3) cannot exceed 478 #/hr flow without modification that would require a speed change and perhaps bearing changes. For this reason it has been assigned a value of 3 for its lack of growth potential.

(b) The Garrett Unit No. 1 will lose approximately 3 psi in pressure rise for an increase of 100 #/hr of flow and the Garrett Unit No. 2 will loose approximately 6 psi in pressure rise for an increase of 100 #/hr of flow.

It would probably therefore be practical to grow to a considerably higher flow requirement with the basic Garrett packages. For this reason they have been assigned the higher evaluation points of 10 and 8.

4. CONCLUSIONS AND RECOMMENDATIONS

Figures of merit for Units 1, 2 and 3 respectively are 9.2, 38.8 and 136. The LM unit obviously appears far superior for purposes of this program. The overriding influence on the figure of merit for this unit are the schedule risk and weight. In view of the schedule requirements of the program this unit is recommended for use and is included in the baseline configuration.

Figure 1

TCS Pump Selection

Figure of Merit Matrix

(W) Weighting Factor	5			2					4			4			2		
	Schedule Risk			Cost					Weight			Power			Growth Potential		
Unit	No. of Mods	Eval.	Eval. x w	Per Unit	Non Recurring	Total	Eval.	Eval. x w	Actual	Eval.	Eval. x w	Actual D.C. Watts	Eval.	Eval. x w	Eval.	Eval. x w	Total Figure of Merit
1 - Garrett Block II pump package modified	3	-10	-50	$33,000. or $132,000. per vehicle	$125,000.	$257,000.	-7.4	-14.8	18.5* -3.9 14.6	3.5	14	20	10	40	10	20	9.2
2 - Garrett AAP pump package modified	2	0	0	$16,000. or $64,000. per vehicle	$30,000.	$94,000.	10	20	18.5* -3.9 14.6	3.5	14	35 AC or 45.5 DC	-2.8	-11.2	8	16	38.8
3 - LM Pump package modified	1	10	+50	$30,000. or $120,000. per vehicle	$12,000.	$132,000.	6.0	12	7.2	10	40	26.6	6.7	28	3	6	136

* 3.9 lbs has been subtracted from the Garrett pump packages for comparison purposes since these packages contain accumulators and the LM package does not.

PR-29-50

TRADE STUDY REPORT

CARRIER TIMING TECHNIQUES

AAP/PIP EARLY APPLICATIONS

CONTRACT NAS 8-21004

8 September 1967

Prepared By: ______________________
E. Phillips

Approved By: ______________________
A. B. Huff

MARTIN MARIETTA CORPORATION

DENVER DIVISION

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose - The purpose of this trade study is to examine various methods of providing the timing signals required and make a recommendation as to the solution.

1.2 Objective - The objective of this trade study is to determine the most feasible method of providing required experiment and subsystem timing for the 1A mission.

2.0 SUMMARY

This study report explores four different approaches that could be taken to provide time-of-day signals in the carrier. These approaches are: (1) Use the Apollo CTE, (2) Obtain timing from the Apollo 51.2 KHZ PCM signal, (3) Use a carrier CTE, and (4) Design and develop a timing unit.

It is concluded that a CTE should be used in the carrier.

3.0 DISCUSSION

3.1 Timing Requirements

3.1.1 Carrier Subsystems

3.1.1.1 Carrier PCM Encoder - The carrier PCM encoder requires a parallel 24-bit time-of-day signal. The "1" bit must be at least 15 volts in amplitude and the "0" bit must have a range of 0-5 volts. Also required is a 51.2 KHZ clock rate for backup control of the PCM encoder.

3.1.1.2 Carrier FM Tape Recorder - The FM tape recorder requires a serial time-of-day signal.

3.1.2 Experiments

3.1.2.1 X-Ray Astronomy (S017) - This experiment requires the Apollo 51.2 KHZ PCM clock, G and N word, and G and N start pulse. These signals will be obtained from the Command Module.

3.1.2.2 Day-Night Camera (S039) - The day-night camera requires a time-of-day signal, and time correlation of housekeeping data.

3.1.2.3 Dielectric-Tape Camera (S040) - The dielectric-tape camera requires a time-of-day signal, and time correlation of housekeeping data.

3.1.2.4 Metric Camera (E06-1) - The metric camera requires a time-of-day signal and time correlation of housekeeping data.

3.1.2.5 Multispectral Camera (E06-4) The multispectral camera requires a time-of-day signal.

3.1.2.6 IR Radiometer (E06-9a) - The IR radiometer requires a time-of-day signal and time correlation of housekeeping data.

3.1.2.7 IR Spectrometer (E06-9b) - The IR spectrometer requires a time-of-day signal and time correlation of housekeeping data.

3.1.2.8 The following experiments will have time correlation of the data in the carrier PCM encoder and/or FM tape recorder.

a. IR Temperature Sounding (S043)
b. Microwave Radiometer (S044A)
c. UHF Sferics (S048)
d. UV X-ray Solar Photography (S020)
e. CO_2 Reduction (D017)
f. IR Imager (E06-7)
g. Multifrequency Microwave Radiometer (E06-11)
h. Manual Navigation Sighting (T002)

3.1.2.9 A 2400 HZ sync signal (multiple or submultiple) must be provided for the following experiments.

a. Microwave Radiometer (S044A)
b. Multifrequency Microwave Radiometer (E06-11)

3.1.2.10 A 800 HZ sync signal must be provided for the IR Temperature Sounding (S043).

3.2 Design Approaches - The approaches that can be taken to satisfy the timing requirements of the experiments and carrier subsystems are (1) Use the Apollo Central Timing equipment (CTE), (2) obtain timing from the Apollo 51.2 PCM signal, (3) use an Apollo CTE in carrier, and (4) design and develop carrier timing unit. These approaches are described below.

3.2.1 Use Apollo CTE - The most direct method of obtaining the required timing signals is to pass the 512 KHZ clock signal, 26 bit parallel time-of-day signal, and the modified IRIG B serial time-of-day signal across the carrier/CM interface. This method assures that correlation of carrier and command module data can be made accurately. Any up-dating of the time-of-day signal would be reflected into the carrier timing. The required sync signals would be submultiples of the basic 512 KHZ clock signals. These signals would be formed by circuits located in the signal conditioning unit.

The disadvantage of this method is the number of pins required across the carrier/CM interface. This interface would require 28 pins for the parallel and serial time-of-day signals, and a coax for the 512 KHZ clock signal. This interface would require a wiring modification to the command module so that these signals could be obtained.

3.2.2 Timing from the Apollo 51.2 KHZ PCM Signal - Since the X-ray Astronomy Experiment (S017) requires the Apollo 51.2 KHZ PCM signal, the G and N start pulse, and the PCM 51.2 KHZ clock signal in the carrier, it is possible to obtain time-of-day from the PCM signal. The time-of-day signal is incorporated into the PCM signal at a rate of 10 times per second. With the use of the 51.2 KHZ PCM clock signal, a 1 PPS PCM sub-frame rate signal, and a 50 PPS PCM prime frame start signal extracting the

3.2.2 (continued)

time-of-day signal could be accomplished with the use of a decoding device (see Figure 1). Only two additional interface pins between the carrier and CM would be required to obtain the 1 PPS subframe rate and the 50 PPS prime frame start from the Apollo PCm encoder. This method would also provide accurate correlation of data between the spacecraft and carrier. Required sync signals would be formed by circuits in the signal conditioning unit from the 51.2 KHZ clock signal.

3.2.3 Carrier CTE - A carrier CTE would provide the required time-of-day directly; however, to retain close correlation of data, up-date provisions would be required. Two approaches to the up-date requirement are available, namely (1) Use the existing Apollo capability and interface as required, or (2) incorporate an up-data link capability into the carrier S-Band system.

Using the Apollo up-data link for up-dating the carrier time-of-day signal would require five carrier/CM interface pins. The functions on these pins would be in parallel with the Apollo CTE.

Incorporating an up-data link into the carrier S-Band system would require an S-Band receiver, 70 KHZ discriminator, and decoding electronics. Additional provisions would be required in the ground equipment to provide the carrier up-data link signals.

Sync signals would be formed by circuits in the signal conditioning unit from the 512 KHZ clock signal.

3.2.4 Build and Develop a Timing Unit - Developing a new timing unit for the carrier would provide the capability of forming the sync and time-of-day signals required by the experiments and carrier subsystems. To maintain data correlation, up-data link provisions would be

3.2.4 (continued)

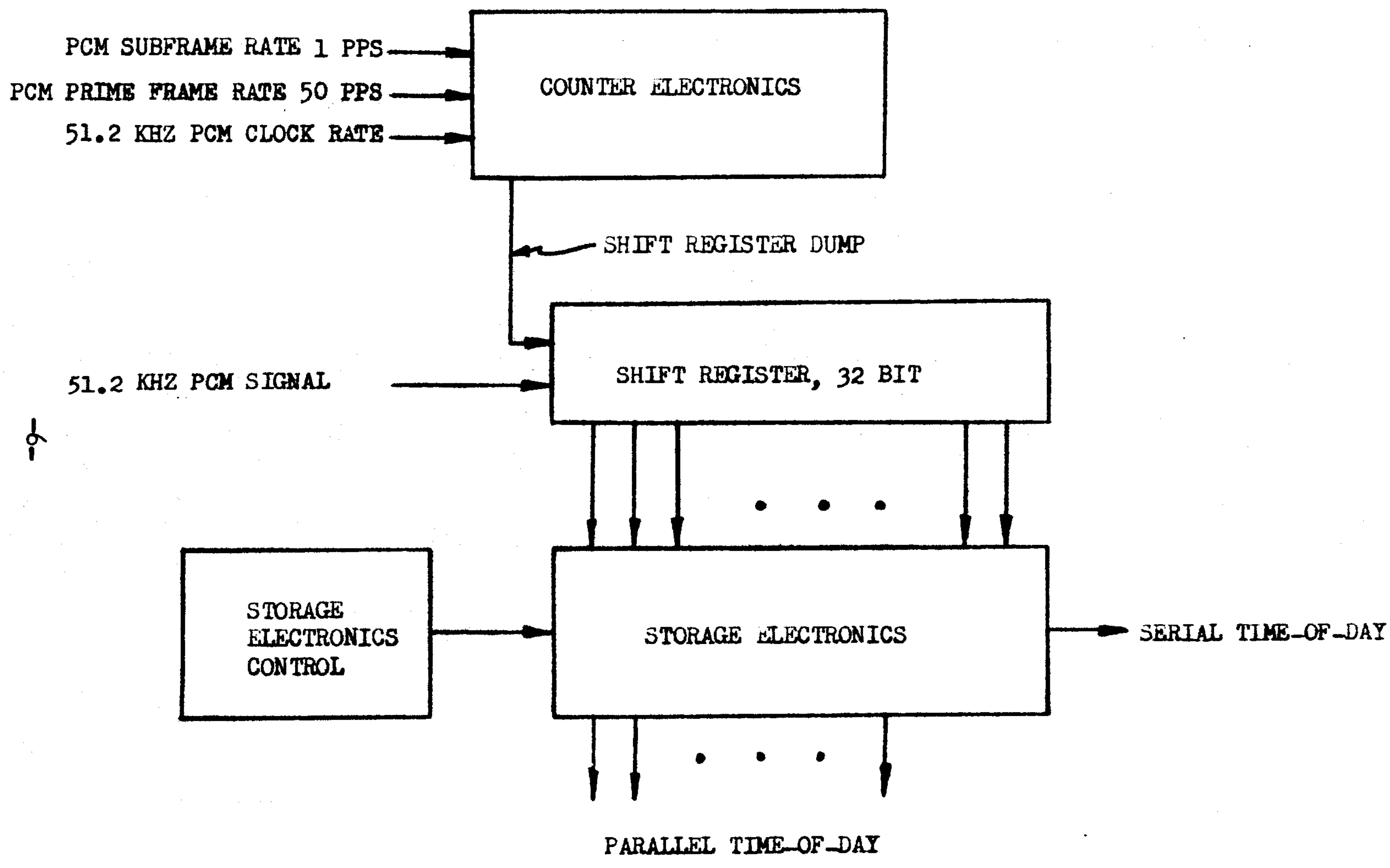
required. This could be provided in two ways as described in paragraph 3.2.3. This method would be feasible except that with the severe schedule restriction imposed on the 1A mission, a reliable and accurate timing unit could not be produced in time.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Of the four approaches available, only two approaches can be given serious consideration, namely (1) Carrier CTE, and (2) Timing from the Apollo 51.2 KHZ PCM signal. Use of the Apollo CTE approach is not recommended because of the severe pin limitation now imposed on the Carrier/CM interface. The Build and Develop Timing Unit approach is not recommended because the lack of development time for a qualified unit, and the qualified Apollo CTE can provide the time-of-day signals now required.

It is recommended that a separate CTE be provided in the carrier. This unit can give both serial and parallel time-of-day signals as required. Unless precise data correlation is needed, the up-date capability is not recommended. Using ground station techniques, the time-of-day delta between the carrier and CM can be determined. If up-date capability becomes a requirement, it is recommended that this provision be provided through the interface from the CM.

The only drawback of the PCM signal approach is the development needed for the decoding device. This approach does have an advantage in that up-date capability is already provided. Both approaches require that sync signals be formed in the carrier.



TIMING DECODER - BLOCK DIAGRAM

FIGURE 1

PR 29-51

TRADE STUDY REPORT

EXPERIMENT REQUIREMENTS

AAP/PIP EARLY APPLICATIONS

KCW

Contract NAS 8-21004

August 27, 1967

Prepared by: Roy Applegate
R. Applegate

Arth C. Cunningham
A. Cunningham

Kent O'Kelly
K. O'Kelly

William Q Nobles
W. Nobles

Approved by: D. Procter-Gregg
D. Procter-Gregg

MARTIN MARIETTA CORPORATION
DENVER DIVISION

INTRODUCTION

This report contains the experiment data packages which summarize the experiment requirements used for carrier design and crew operations analysis. The data contained herein represents a combination of information received from NASA/MSC and from Experiment Contractors. Experiment requirements are presented for experiments listed in the index below.

INDEX

Experiment Physical Characteristics

Ref. Desig.	Major Components	Ascent (in/lb) Dim.	Vol.	Wt.	Re-Entry (in/lb) Dim.	Vol.	Wt.
S039	Camera	21.2x7x7.5	1113	30.1			
	Electronics	8.5x7.5x11.5	733	14.9	N/A	N/A	N/A
	Recorder	15.1x14.2x7.5	1608	16			
S040	Camera	15x7.5x24	2700	64	N/A	N/A	N/A
	Electronics	13x6x6	468	19			
S043	Radiometer	13x9.5x10.5	1297	25	N/A	N/A	N/A
	Electronics	8x12x19	1824	20			
S044A	Antenna	6x18x18	1944	15			
	Electronics	8x6x13	624	4.5	N/A	N/A	N/A
	Cup Antenna	1.5x1.5 dia	2.65	0.5			
S048	Antenna	10.8x43.2 dia	15,969	15			
	Amplifier	9x6x10	540	10	N/A	N/A	N/A
	Data System	6x6x12	432	6			
E06-1	Camera Unit	24x15x21	7540	200	12x12x10	1440	20
E06-4	Camera Set						
	(6 Hasselblads)	10x12x14	1680	33.3	18 Cassettes at 4x4x4	1152	23.4
	12 Cassettes	16x12x4	768	15.6			
	Control Box	2x2x3	12	5.0			
E06-7	Scanner	16x32.625x10.875	5680	110	9x9x3	243	5
	Supply Cassette	9x9x3	243	5			
	Take-Up Cassette	9x9x3	243	5			
E06-9A	Radiometer	23x11x7	1771	30	N/A	N/A	N/A
E06-9B	Spectrometer	30x20x8	4800	50	N/A	N/A	N/A
E06-11	Antenna/Electronics	24x48 dia	44,208	50	N/A	N/A	N/A

Experiment Physical Characteristics (Continued)

Ref. Desig.	Major Components	Ascent (in/lb) Dim.	Vol.	Wt.	Re-Entry (in/lb) Dim.	Vol.	Wt.
T002	Sextant Acessories	8.28x6.28x7.59 7x6x1	395 42	6.5 0.8	8.28x6.28x7.59 7x6x1.	395 42	6.5 0.8
T003	Nephelometer	3.75x7.5x5.5	155	5.5	3.75x7.5x5.5	155	5.5
T004	Life Support System	18.62x18.75 dia	4710	86	N/A	N/A	N/A
D008	Electronics/Active Dosimeter 5 Passive Dosimeters	8x4x3.18 4.5x3x6 (1.5x1.5 x 6 ea)	102 80 (13.5 ea)	2.5 2.5	8x4x3.8 4.5x3x6	102 80	2.5 2.5
D009	Sextant Stadimeter Accessories	6.9x5.56x5.85 7.375x6.375x5.06 7.0x6.0x1.0	216 235 42	5.8 4.4 0.8	N/A N/A 7x6x1	N/A N/A 42	N/A N/A 0.8
D017	Electrolytic Cell Electronics	18.5x6.5x7.5 10.5x5.82x14	902 856	17 15	N/A	N/A	N/A
S015	Cam/Micro.Pack/ Bio-Packs	15.5x6.5x8.06	812	22	15.5x6.5x8.06	812	22
S016	Nuc. Emul Background Emulsion	5 dia x 3.5 1x1x1	68 1	8 0.25	5 dia x 3.5 1x1x1	68 1	8 0.25
S017	X-Ray Sensor Electronics Data System Cont. & Disp. Panel	30x20x15 17x15x11 26x18x11 7x11x16.25	4500 2805 3850 1251	176 46 70 26	N/A	N/A	N/A
S018	Collector Box	5.125 sq. x 3.75	98.5	5.5	5.125 dia x 3.75	98.5	5.5
S019	Spec. Cam.Sys/Film	8x8x16.75	1060	43	8x8x16.75	1060	43
S020	Spec.Unit/Film	6.5x5.75x16	600	24.69	6.5x5.75x16	600	24.69

NOTE: No stowage, (and with few exceptions) no mounting provisions included in these dimensions and weights.

Date: 23 Aug. 1967

EXPERIMENT NUMBER

S039

TITLE

DAY-NIGHT CAMERA SYSTEM

MSC CONTACT	R. Hergert	MSC-Houston	HU3-4621
PI	Tom Cooney	GSFC	
CONTRACTOR	Hazeltine Corp.	Little Neck, N.Y.	212-321 [redacted]-2300
GSE CONTACT	N. Ortiz[redacted]	Little Neck, N.Y.	212-321 [redacted]-2300
MMC ANALYST	Bill Nobles		X3584

Hardware Status	Delivery of:	~~Prototype~~	Integration [redacted] Unit	Flight Unit
Hardware designed for Nimbus, Application (GFE)		[redacted]	7/30/68	*12/30 [redacted] 68 *Refurbished qualification unit.

9/1/7
8/25/7
A.02

Exp. No. S039

Title Day-Night Camera System

II PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Camera	30.1	0	~~1092~~ 1113	0	7.5X7.0X21.2	0
2. Electronics	14.9	0	734	0	8.5X7.5X11.5	0
3. Tape Recorder	16.0	0	1608	0	7.5X14.2X15.1	0
	61.0	0	2455			

F.O.V.	Aperature	Window Matl	Min/max between Components	C.G.
120°	7X7.5	None Permissible	Not Critical	

Boost Orientation Constraints	Flight Orientation Constraints
Launch vector cannot be collinear with Image Orthicon X-axis (21.2" dimension)	21/2" dimension along nadir

Mounting Provisions

Hard mounted

Removal Envelope of Data Cassette

Not applicable

8/25/7

A.03

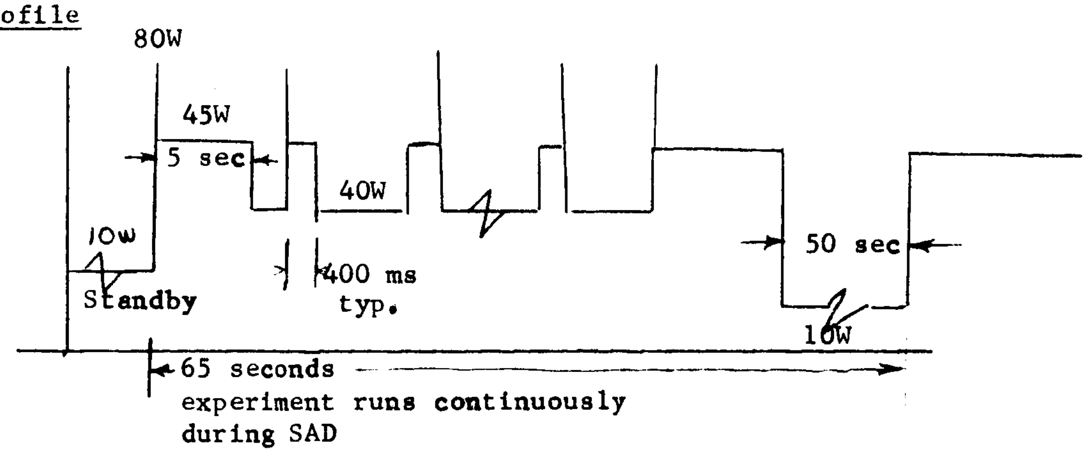
Exp. No. S039

Title Day-Night Camera System

III(a) POWER REQUIREMENTS

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1. Camera					
2. Electronics	10	43	45	-24.5 v.d.c.	
3. Tape Recorder					

Power Profile



III(b) THERMAL CONTROL

Component	Temp Range Operate	Survive	Temp Stability	Temp Gradient
1. Camera	+5 to +45°C	-5 to +55°C	Not Critical	Not Critical
2. Electronics				
3. Tape Recorder				

Environment

Component	Press Req. Stowed	Operate	Type Atmosphere	Press Interfaces
1. Camera	Unpress Req'd.		None	None
2. Electronics				
3. Tape Recorder				

8/25/7
A.04

Exp. No. S039

Title Day-Night Camera System

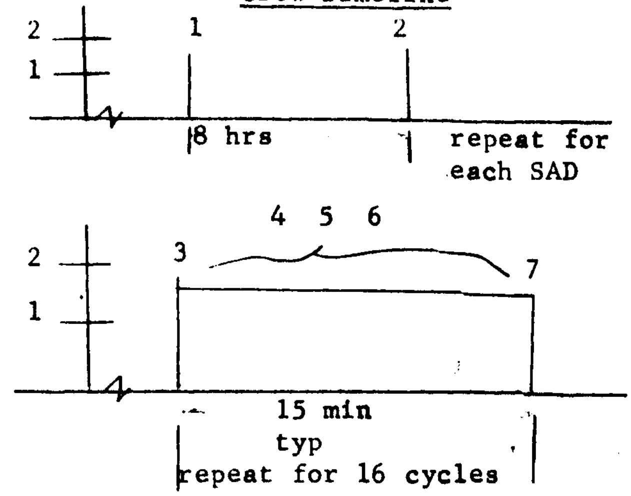
IV CREW REQUIREMENTS

Crew Task

During SAD automatic mode
1. Switch to operate
2. Switch to off

During SAD manual mode (10% of total operate time)
3. Switch to operate
4. Mount or scope
5. Adjust exposure
6. Select filters (4)
7. Switch to off

Crew Timeline



No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
16 manual operation modes	4.0	40	None

Controls

1. Off-standby-operate
2. Mode selection (manual, automatic)
3. Spectral selection (four position switch)
4. Exposure Control (potentiometer)

Displays

1. Indicator lamps (6)
2. Meter (film remaining)
3. CRT (video monitor)

V(a) ALIGNMENT

Component	To Carrier	To Other Expt (specify)	Alignment Mechanism
1. Camera	± 3°	None	Mounting pads
2. Electronics	any	None	pads--
3. Tape Recorder	any	None	----

V(b) POINTING AND STABILIZATION

Types	Limit Cycle Amplitude ~~Accuracy~~	Hold Time	Max Permissible Rates
Local Vertical ± 10°	± 0.5° ~~of commanded attitude~~	Continuous during SAD	Dead Band Mode Rates

8/25/7
A.05

Exp. No. S039

Title Day-Night Camera System

Maneuver Requirement

Calibrate	Target Track
None	None

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/ Bit Rate
Expt.	2	Video	--	(1) 140-240 KCPS (2) 50 KCPS
H.K.	25	Digital (8 bit)	1 sps	8 BPS

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: 1) Experiment Test Set; 2) Flight Source; 3) Film & film processing equipment
2. Simulator supplied with experiment? Yes X No ____
3. Humidity limits: Operating: 100% Survival: 100%
4. Cryogenic Servicing: Commodity: None
   Quantity: Temperature: Pressure:
5. Vacuum Servicing Requirements: None
6. Ground Calibration: Black body temperature: None
   Temperature Tolerance:
7. Checkout and Malfunction Isolation Test Connectors:
   Will special connectors paralleling operational connectors be supplied? YES
8. Input and Output Signal Characteristics: None req'd.
9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals?
   0-50 feet X
10. Power Requirements for Experiment GSE:
    Voltage: 115 V a.c. Current: 15 amps Frequency: 60 cps
    Ground Checkout Requirements for functional sensor protective devices (lens covers, aperture covers, etc): Check lens cover operation via remote command from CM.
11. Launch Pad Operations Requirements (include equipment needed):
    Checkout: None
    Alignment: None
    Adjustment: None
    Calibration: None

8/25/7
A.06

Exp. No. S039

Title Day-Night Camera System

VII GSE REQUIREMENTS (continued)

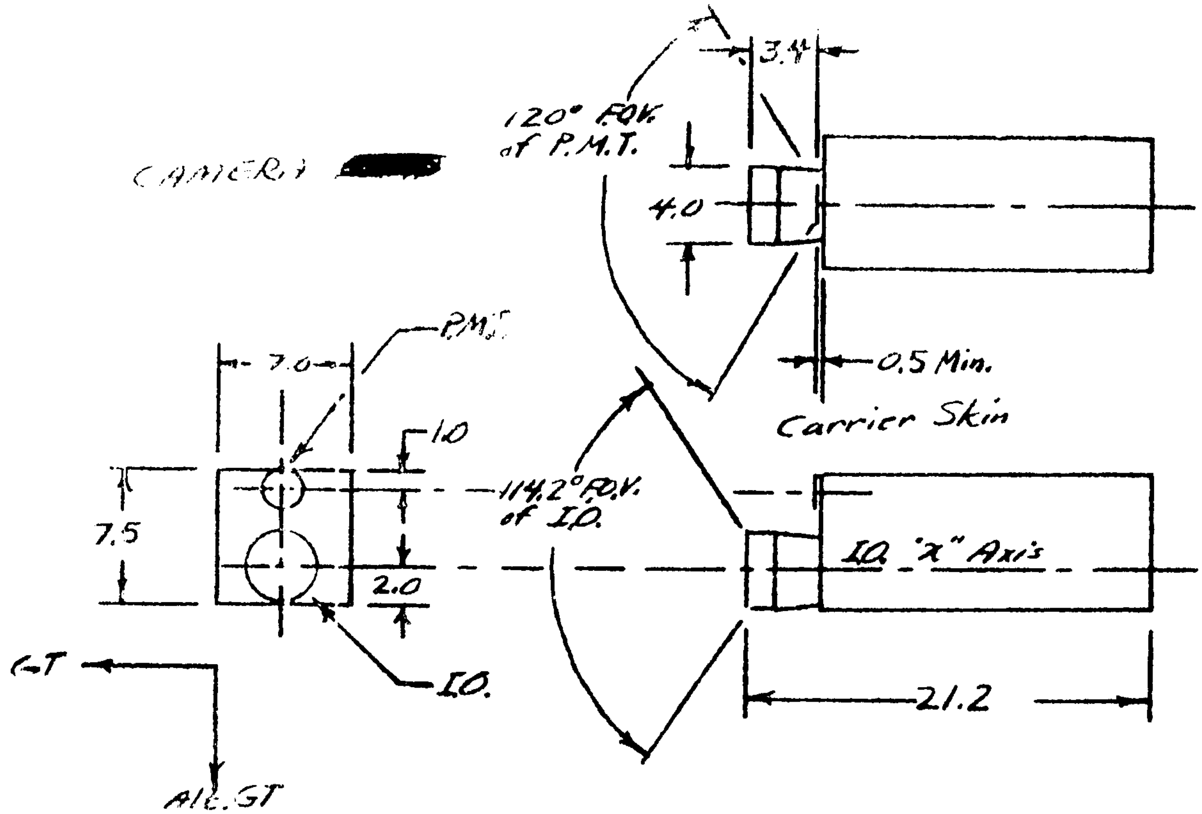
12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours): Activate experiment-monitor housekeeping via TM.

13. Experiment Shipment: Will reusable shipping container be supplied? YES.
Is there any problem associated with shipment of this experiment as an integral part of the carrier? NO

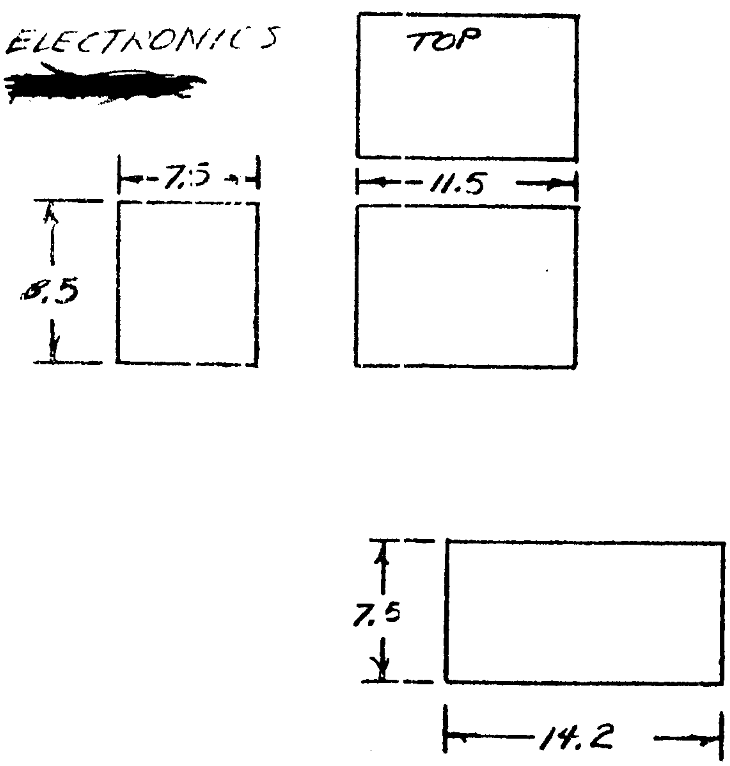
14. Special handling requirements during installation on carrier: None

8/25/7
A.07

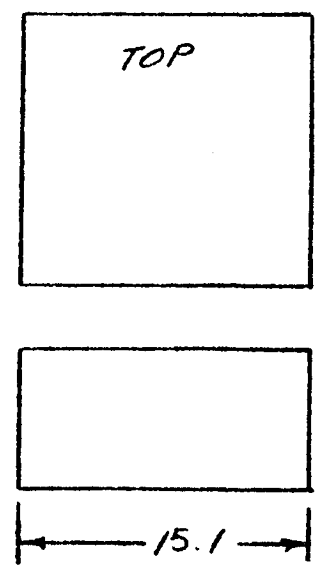
CAMERA [redacted]



ELECTRONICS [redacted]



[redacted] RECORDER



5039 DAY-NIGHT CAMERA

9/1/7
A.07.01

Date: 23 Aug. 1967

EXPERIMENT NUMBER

S040

TITLE

DIELECTRIC TAPE CAMERA

MSC CONTACT	R. Hergent		713 HU3-4621
PI			
CONTRACTOR	RCA	Princeton, N.J.	
GSE CONTACT			
MMC ANALYST	Bill Nobles		X3584

Hardware Status	Delivery of:	[redacted]	Integration [redacted] Unit	Flight Unit
Hardware designed for Nimbus Application (GFE)		[redacted]	7/30/68	* 12/30/68

*Refurbished qualification unit

8/25/7
A.08

Exp. No. S040

Title Dielectric Tape Camera

II PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Camera	64.0	0	2700	0	24"X15"X7.5"	0
2. Electronics	19.0	0	468	0	6X6X13	0
	83.0	0	3168	0		

F.O.V.	Aperture	Window Matl	Min/max between Components	C.G.
98.1° X 8° (98.1° is crosstrack)	12" X 4"	None	Not Critical	

Boost Orientation Constraints	Flight Orientation Constraints
None	15" dimension along nadir 7.5" dimension along ground track

Mounting Provisions

Hard mounted on external rack

Removal Envelope of Data Cassette

Not applicable

III(a) POWER REQUIREMENTS

Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1. Camera	6	27	80	-24.5 v.d.c.	
2. Electronics					

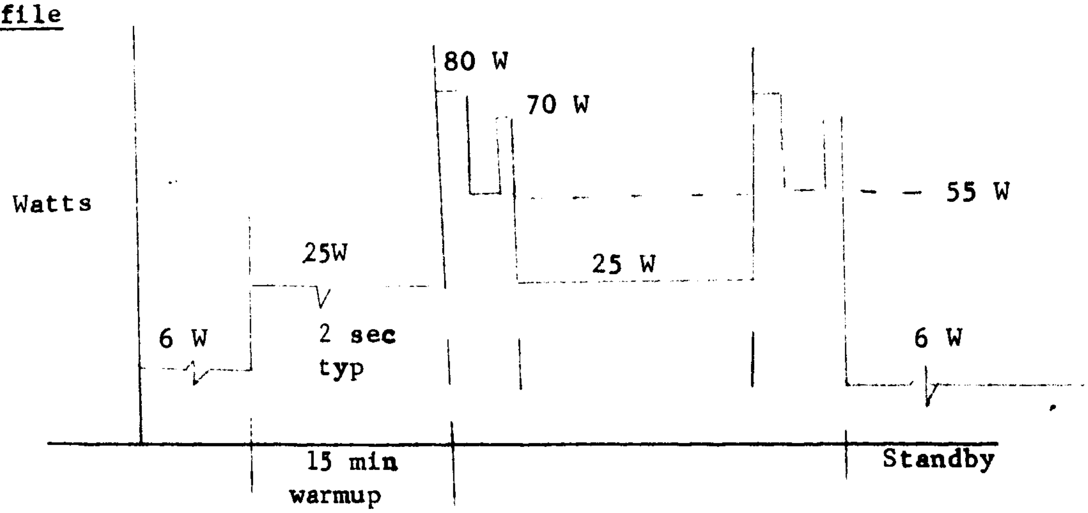
8/25/7
A.09

Exp. No. S040

Title Dielectric Tape Camera

III(a) POWER REQUIREMENTS (continued)

Power Profile



III(b) THERMAL CONTROL

Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1. Camera	+5 to +45°C	-5 to +55°C	Not Critical	Not Critical
2. Electronics	+5 to +45°C	-5 to +55°C	Not Critical	Not Critical

Environment

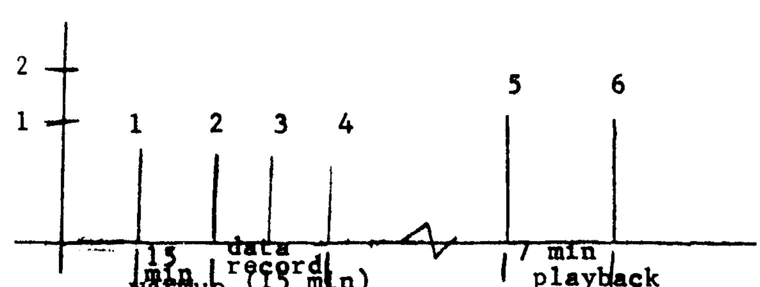
Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1. Camera	Unpress	Req'd	None	None
2. Electronics	Any		--	--

IV CREW REQUIREMENTS

Crew Task

1. Switch to On
2. Switch to Record
3. Describe Target
4. Switch to Standby
5. Switch to Playback
6. Switch to Off

Crew Timeline



Data record sequence only during daylight pass over North American Continent. Repeat 30 times total for 15 minutes (typ) per pass.)

8/25/7

A.10

Exp. No. S040

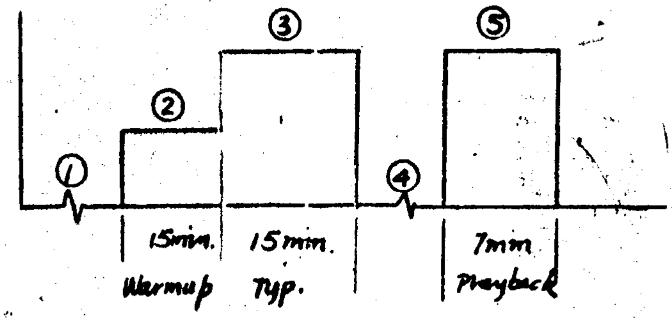
Title Dielectric Tape Camera

IV CREW REQUIREMENTS (continued)

Exp Function

1. Off
2. On
3. Record
4. Standby
5. Playback

Exp Timeline



No. Performances	Total Operate Time M Hr	Exp. Hr	Operation Constraints, Target Light, dark, sun angle, etc.
30	1.0	7.5	Operate only during daylight pass over North American Continent

Controls	Displays
1. Off/On/Record/ playback 4 position switch	1 Status lamp (go/no go)

V(a) ALIGNMENT

Component	To Carrier	To Other Expt (specify)	Alignment Mechanism
1. Camera	± 0.5°	None	Optical
2. Electronics	---	--	Surface ---

V(b) POINTING AND STABILIZATION

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local Vertical ±10°	± 10°	15 min per for 30 targets total	Dead Band Mode Rates

Maneuver Requirement

Calibrate	Target Track
None	None

8/25/7

A.11

Exp. No. S040

Title Dielectric Tape Camera

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Feq Response/Bit Rate
Expt	1	Video	---	* 680 KCPS
H.K.	35	Analog (0-5V)	1.0 sps	---

Remarks

*Record signal is 680 KCPS video
1% accuracy required

VII m GSE REQUIREMENTS

1. GSE normally provided with experiment: A) 1 Rack electronics checkout gear (3'X3"X5'); B) Vacuum system
2. Simulator supplied with experiment? NO
3. Humidity limits: Operating: 100% Survival: 100%
4. Cryogenic Servicing: Commodity: None
   Quantity: --- Temperature: --- Pressure: ---
5. Vacuum Servicing Requirements: Vacuum System provided to evacuate experiment during checkout operation.
6. Ground Calibration: Black body temperature: None
   Temperature Tolerance: None
7. Checkout and Malfunction Isolation Test Connectors:
   Will special connectors paralleling operational connectors be supplied? YES
8. Input and Output Signal Characteristics: None required.
9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals?
   0-50 Feet
10. Power Requirements for Experiment GSE:
    Voltage: 115 V a.c. Current: 15 amps Frequency: 60 cps
    Ground Checkout Requirements for functional sensor protective devices (lens covers, aperature covers, etc): Check aperture cover operation on command signal from CM.

8/25/7
A.12

Exp. No. S040

Title Dielectric Tape Camera

VII GSE REQUIREMENTS (continued)

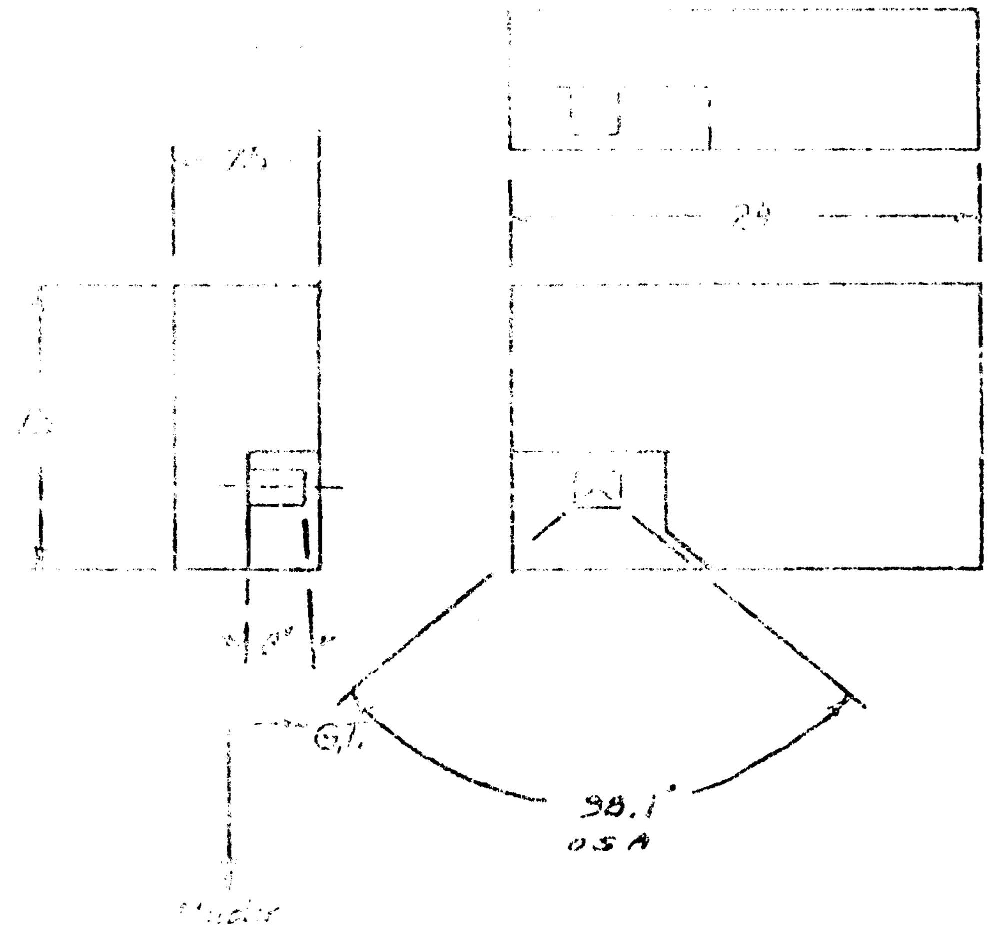
11. Launch Pad Operations Requirements (including equipment needed):
Checkout: Vacuum pump to evacuate experiment
Alignment: None
Adjustment: None
Calibration: None

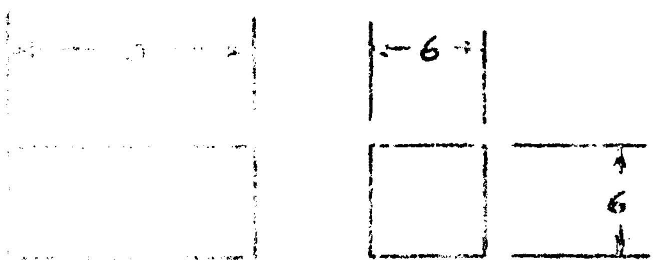
12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours): Activate experiment and monitor housekeeping parameters via TM.

13. Experiment Shipment: Will reusable shipping container be supplied: YES
Is there any problem associated with shipment of this experiment as an integral part of the carrier? NO

14. Special handling reequirements during installation on carrier: NONE

8/25/7
A.13





[illegible] [redacted]

[illegible] TAPE CAMERA

9/1/7

A.13.01

EXPERIMENT NUMBER

S043

TITLE

IR TEMPERATURE SOUNDING

MSC Contact	Bill Hensley	Houston, Texas	
PI	Dr. John Shaw	Columbus, Ohio	(614) CY3-7968
Contractor	JPL(Dan LaPorte)	Pasadena, Calif.	
GSE Contact	JPL(Dan LaPorte)	Pasadena, Calif.	
MMC Analyst	Art Cunningham		Ext. 4167

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Balloon version exists, has been flown successfully space design exists		8 mo.	12 mo. [redacted].

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A.14

Exp. No. S043

Title IR Temperature Sounding

II Physical Parameters

	Component	Weight Ascent	Weight Return	Volume (in³) Ascent	Volume (in³) Return	Dimensions Ascent	Dimensions Return
1.	Radiometer	25	0	1297	0	9.5x10.5x13	0
2.	Electronics	20	0	~~1948~~ 1824	0	8x[redacted] 12.0x19	0
		45	0	3121	0		

F.O.V.	Aperture	Window Matl	Min/Max between Components	C.G.
12°	2"x3"	None permissible	not critical	

Boost Orientation Constraints

None

Flight Orientation Constraints

Radiometer point to nadir

Connector Type and Locations

Electronics has 5 connectors
Radiometer has 3 connectors

Mounting Provisions

Hardmount both units with thermal isolation mouhts on radiometer for thermal control

Removal Envelope of Data Cassette

None

III(a) Power Requirements

	Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1.	Radiometer	5	35	70	28vd.c.	20 to 40
2.	Electronics	50	50	50	28 vd.c	20 to 40

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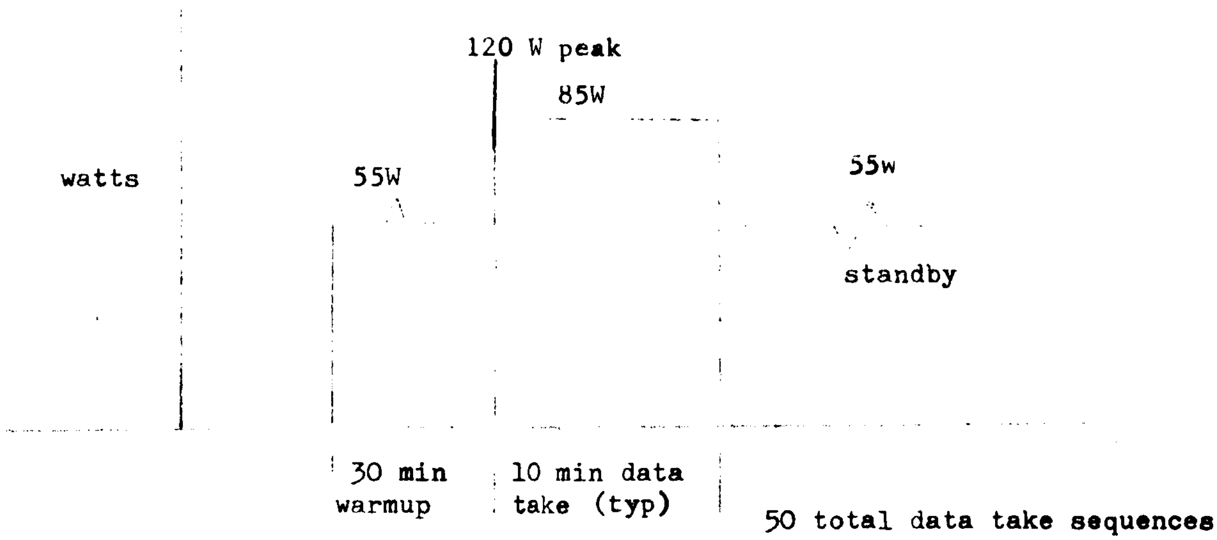
A.15

Exp. No. S043

Title IR Temperature Sounding

Power Profile

Experiment can be turned off; but must allow 30 minute warmup.



III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1.	Radiometer	-30 to +40°C	-65° to +85°C	Prefer 0°C ± 5°C	10°C/foot
2.	Electronics	-60 to +30 °C	-65° to +85°C	any	any

Heat Source

Pre-amplifier bank (35 pre-amplifier) using 35 [redacted] watts average located near entrance slit (front end of radiometer head) Maintain at 0°C as closely as possible

Critical Control Points

blade plate - 265°k ± 0.1°k
chopper - 240°k ± 3°k
Temp monitor to 0.08°k provided by experiment
Thermal control can be maintained internally if front end dissipates [redacted]w nominal ([redacted]) to carrier
35

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1.	Radiometer	Unpress	Req'd	None	None
2.	Electronics	None		None	None

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A,16

Exp. No. S043

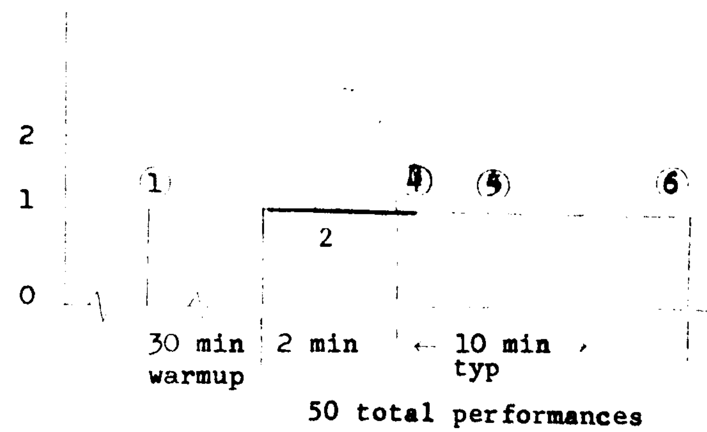
Title IR Temperature Sounding

IV. Crew Requirements

Crew Task

1. Switch to standby
2. Identify desired target
3. Switch to operate as target enters f.o.v.
4. Describe target
5. Switch to standby or off

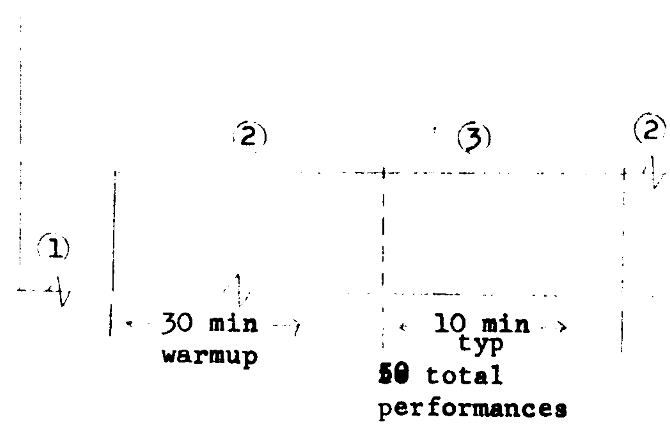
Crew Timeline



Exp Function

1. Off
2. Standby (warmup)
3. Data take

Exp Timeline



No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
50	10 (12 min for each of 50 targets)	33.3 (40 min for each of 50 targets' includes warmup of 30 min per target)	all combinations of day-night/ land-sea/high inclination-equator desired

Controls

(1) Off-standby-operate 3 position switch

2 Mode switch
(a) Calibrate
(b) Long period
2 position switch

Displays

(1) Status lamp (standby-operate)

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A.17

Exp. No. S043

Title IR Temperature Sounding

V(a) Alignment

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1.	Radiometer	± 0.5°	± 0.5° to support camera	Optical surface provided
2.	Electronics	-	-	

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude ~~Accuracy~~	Hold Time	Max Permissible Rates
Local vertical ~~and offaxis~~ ±5° but known to 1° 3σ	±5°	Ten minutes per target for 50 targets	Dead Band Mode Rates

Maneuver Requirement

Calibrate	Target Track
One per day for 2.5 minutes observation of clear space	

VI. Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	1	Digital (10 bit serial)	10 sps	100 BPS
H.K.	1	Digital (8 bit serial)	10 sps	80 BPS

Remarks

Expt data - 41 parameters, 10 bit words sampled 10 sps experiment commutates parameters to one serial train - includes 35 detector output. During 9 sec. exposure all channels integrate radiance simultaneously and store on storage capacitors.

H.K. data - 19 parameters, 8 bit words, sampled 10 sps. Experiment commutates parameters to one serial train.

Note: Carrier must control multiplexer with timing and sample commands.

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A.18

Exp. No. S043

Title IR Temperature Sounding

VII GSE Requirements

1. GSE normally provided with experiment 3 electronics racks (3'x4'x2' total envelope), 1 vacuum system, 1 light source, handling equipment.

2. Simulator supplied with experiment? Yes X No_____

3. Humidity limits: Operating Radiometer - 0% Electronics - 50% Survival Radiometer - 0% Electronics - 50%

4. Cryogenic Servicing: Commodity None

5. Vacuum Servicing Requirements - None - Pump provided with GSE by EC.

6. Ground Calibration: Black body temperature None

7. Checkout and Malfunction Isolation Test Connectors:

   Will special connectors paralleling operational connectors be supplied? Yes

8. Input and Output Signal Characteristics: None

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals?

   0-50 feet ______ 50-100 feet ______ 100-200 feet X

10. Power Requirements for Experiment GSE:

Voltage 110 v.a.c. Current 3-4 15 amp circuits Frequency 60 cps

Ground Checkout Requirements for functional sensor protective devices (less covers, aperture covers, etc) aperture cover req'd on radiometer-check operation from CM command signal.

11. Launch Pad Operations Requirements (include equipment needed):

    Checkout None

    Alignment None

    Adjustment None

    Calibration None

12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours) activate experiment and monitor TM data.

13. Experiment Shipment: Will reusable shipping container be supplied? Yes

    Is there any problem associated with shipment of this experiment as an integral part of the carrier? Yes - Radiometer must have N_2 purge and be sealed at entrance aperture, and pressurized with dry nitrogen.

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Exp No. S043
Title IR Temperature Sounding

14. Special handling requirements during installation on carrier: Radiometer must be sealed at entrance aperture, and pressurized with dry nitrogen.

15. Manufacturer's understanding of Acceptance Testing Requirements at his facility: EC to perform acceptance testing with MMC cognizance.

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility: Bench checkout and calibration.

17. Other GSE requirements: None

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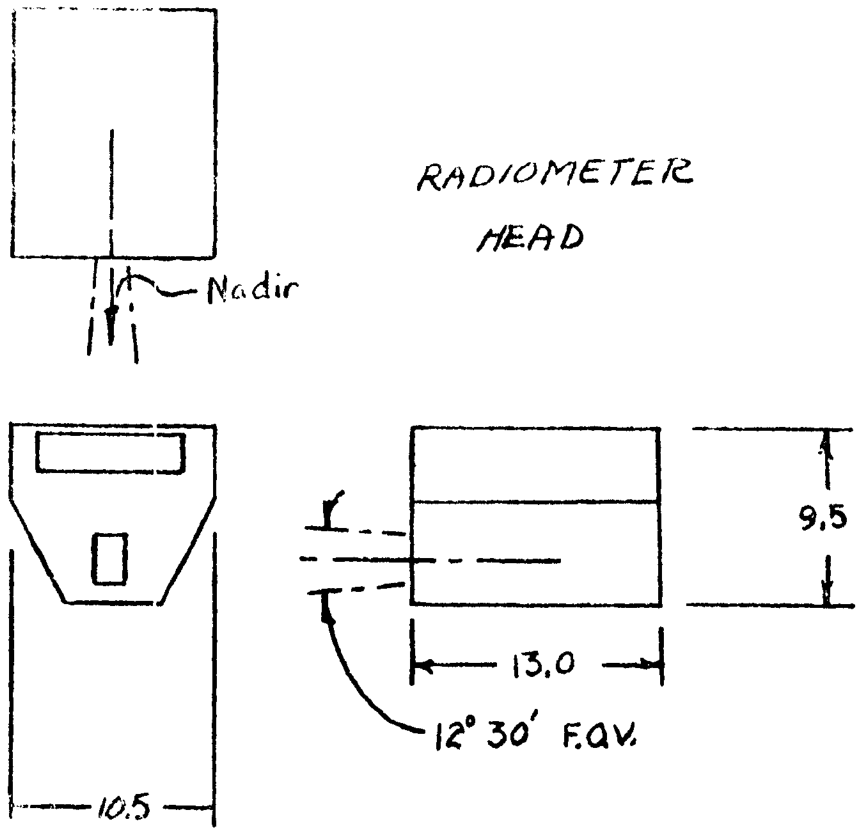
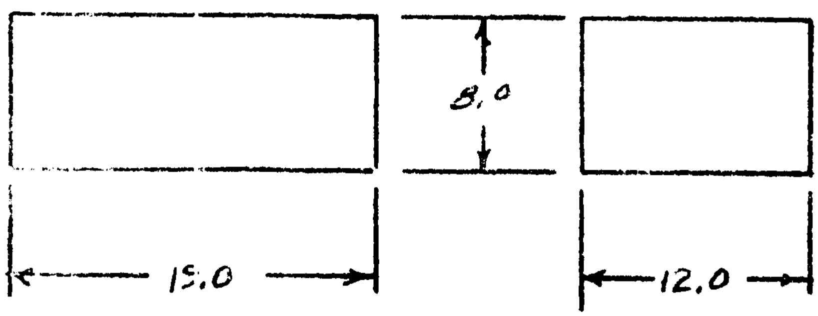
A.20



ELECTRONICS PACKAGE



SO43 IR TEMPERATURE SOUNDER

9/1/7

A.20.01

Date: 8/16/67

Experiment Number

S044A

Title

Electrically Scanned Microwave Radiometer

MSC Contact	Name	Address	Telephone
PI	Dr. Thaddeus		
CONTRACTOR	Space General Attn: George Oister	El Monte, Calif.	213-443-4271
GSE CONTACT	Same	Same	213-443-4271
MMC ANALYST	Kent O'Kelly		X3584

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Aircraft model has been flown space design exists.	[redacted]	9 mos.	[redacted] 12 mo.

8/25/67
A.21

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

I FUNCTIONAL DESCRIPTION

The electrically scanned microwave radiometer is a small radio telescope designed to make precise measurements of the intensity of thermal radiation at a wavelength of 1.55 cm (19.35 GHz frequency). The beam of the phased-array antenna, whose width is 2.7°, is scanned electrically in one dimension through an angle of ±50°, across the ground track. The antenna scans continuously, so that the radiometer builds up an image of the earth as the spacecraft advances. Brightness temperature of the earth will be mapped on a global scale and meteorological measurements made.

The antenna is a phased array of slotted waveguides which is scanned electrically. This avoids the mechanical scanning required of a paraboloid which poses several disadvantages for an attitude stabilized satellite. A small cup antenna is also used, oriented to space as a cold reference. Microwave energy is received and integrated at each antenna scan position for 198 milliseconds; then set to the next scan position in 1.2 milliseconds. By continuously scanning the antenna in this fashion, a thermal image of the earth is formed.

Data from each scan position is read serially on a single data channel, recorded on tape, and dumped during overflight of a receiving station.

II PHYSICAL PARAMETERS

	Component	Weight Ascent	Weight Return	Volume (in³) Ascent	Volume (in³) Return	Dimensions Ascent	Dimensions Return
*1.	Antenna	115	0	1944	0	6X18X18	0
2.	Electronics	4 [redacted]	0	624	0	8X6X13	0
3.	Cup Antenna	0.5	0	3	0	1.5 x 1.5 dia	0
		200		2571			

F.O.V.	Aperture	Window Matl	Min/Max Between Components
(a) 100° crosstrack 2.5° ground track	18"X18"	None permissible	Antennas to electronics maximum two foot separation
(b) Cup Antenna 15° F.O.V. to space	2½" dia		

Boost Orientation Constraints	Flight Orientation Constraints
None	Scanning antenna points to nadir (100°X2.7° F.O.V.) Cup antenna points to space (30° F.O.V.)

9.2577
9.22

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

Mounting Provisions

Hard mounted, with cable between antennas and electronics as short as possible, and less than one foot maximum.

Removal Envelope of Data Cassettes

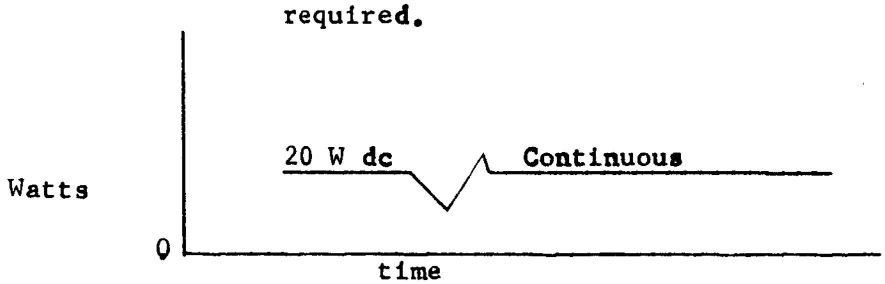
None

III(a) POWER REQUIREMENTS

	Power (watts)			Voltage	
Component	Standby	Operate	Peak	Nominal	Tolerance
1. Antenna	0	0	0	0	
2. Electronics	20	20	28	28 VDC	± 5V

Power Profile

Note: Can turn experiment off, no warning time required.



Noise and Ripple Tolerance	Transient Tolerance	Feedback to Bus (0.1 ohm)
2% (0.5V) up to 100 KC		0.2 to 0.3 amp current changes in 3 millisec observed on aircraft

Electromagnetic Interference (EMI):

Requirements: Susceptible to 19.35 GHz EMC ± 200 MHz
Problem areas receiver front end rejection and power supply voltage conversion.

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A.23

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

III(b) THERMAL CONTROL

Component	Temp Range (°C) Operate	Survive	Temp Stability	Temp Gradients
1. Antenna	-60 to +85	-65 to +85	not critical	5°/foot max.
2. Electronics	-10 to 65°C	-65 to +85	not critical	any

Heat Source

Electronics (20W continuous) internal conduction paths to experiment case provided.

Critical Control Points

Antenna temp gradients to be minimized (5°/foot max.)

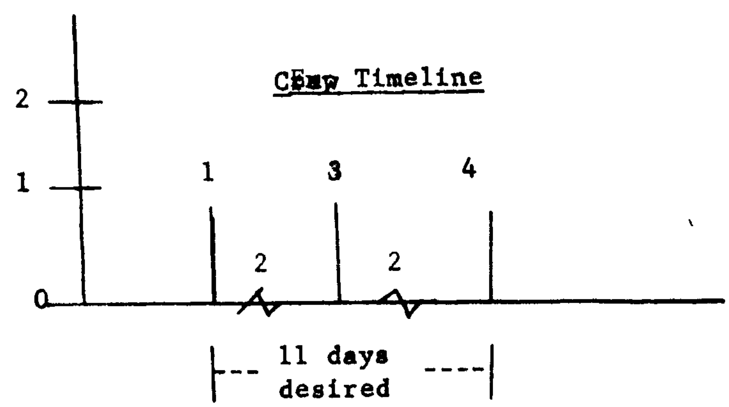
Environment

Component	Press Req Stowed	Operate	Type Atmosphere	Press Interfaces
1. Antenna	Unpress	Req.	none	none
2. Electronics	none	none	none	none

IV CREW REQUIREMENTS

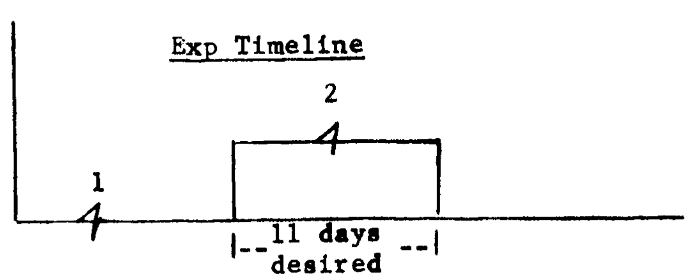
Crew Task

1. Turn on (switch)
2. Periodic status monitor
3. If malfunction, switch to fail safe mode
4. Turn off (only to conserve power, data)



Exp. Function

1. Off
2. On
3. Fail Safe (only if malfunction occurs in antenna scan circuits).



No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, Dark, Sun, Angle, Etc.
Continuous prefered	0.5	Continuous prefered	None

8/25/7
A.Z.

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

Controls	Displays
1. On/Off Switch	1. Status lamp go/no go
2. Fail Safe Command Switch	

V(a) ALIGNMENT

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1. Antenna	±0.5°	± 0.5° to multifrequency microwave radiometer	Optical surface provided
2. Electronics			

V(b) POINTING AND STABILIZATION

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local vertical ±5° but Known to 1° 3σ	~~±5°~~ ±5°	Continuous	Dead Band Mode Rates

Maneuver Requirements

Calibrate	Target Track
None Req'd. (if 1 to 2 360° rolls per day are permissible, cup antenna is not necessary)	Look at moon briefly (once during mission) Look at sun briefly (once during mission)

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/ Bit Rate
Expt.	1	digital (10 bit serial)	5 SPS	50 BPS
H.K.	1	Analog (0-5V)	5 SPS	Only on command 8 bit accuracy

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A.25

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

Remarks

Data Channel:

16 sec.
- Cold Ref 10 bits in 200 msec
- 39 data words at 10 bits/200 msec
- Multiplex A etc
- 39 data words
- Cold Ref.
- 39 data words
- Multiplex B
- etc for 4 multiplex parameters

Multiplex Parameters
- (A) Antenna Temperature
- (B) Hotest Point in Electronics
- (C) Power Supply Voltage
- (D) Spare

H.K. Channel (only on command)

Consists of analog signals internally multiplexed. Must be encoded by MMC with 8 bits/sample, 5 SPS

Synch signal (2400 cps, multiple, or sub-multiple) should be available to experiment.

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: (a) 1 rack electronics (5'X4'X3') (provides prime power to expt., receives digital output, timing signals to expt., paper, printer, AGC monitor, VTVM); (b) 1 cryo flask for calibration (LHe or LN2); (c) antenna hat; (d) handling curt; (e) installation sling.
2. Simulator supplied with experiment: Yes
3. Humidity limits: Operating: Not critical Survival Not critical
4. Cryogenic Servicing: Commodity: LHe or LN_2 Quantity: 2 ft^3 Temperature: 4° K or 77° K Pressure: Ambient
5. Vacuum Servicing Requirements: None
6. Ground Calibration: Black body temperature: 4° K or 77° K Temperature Tolerance: None
7. Checkout and Malfunction Isolation Test Connectors: Will special connectors paralleling operational connectors be supplied? No
8. Input and Output Signal Characteristics: None
9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals: 0-50 feet

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A.26

Exp. No. S044A

Title Electrically Scanned Microwave Radiometer

10. Power Requirements for Experiment GSE:

    Voltage: 115 VAC   Current: 15 amps   Frequency: 60 cps

    Ground Checkout Requirements for functional sensor protective devices (less covers, aperture covers, etc): None

11. Launch Pad Operations Requirements (include equipment needed):

    Checkout: None
    Alignment: None
    Adjustment: None
    Calibration: Activate experiment to view paste reflectors in F.O.V. inside SLA-monitor TM data

12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours): None, except calibration as above.

13. Experiment Shipment: Will reusable shipping container be supplied: Yes
    Is there any problem associated with shipment of this experiment as an integral part of the carrier? No

14. Special handling requirements during installation on carrier: None

15. Manufacturer's understanding of Acceptance Testing Requirements at his facility: EC will perform Acceptance Testing with MMC cognizance.

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility: Calibration and bench checkout with GSE electronics.

17. Other GSE Requirements: None

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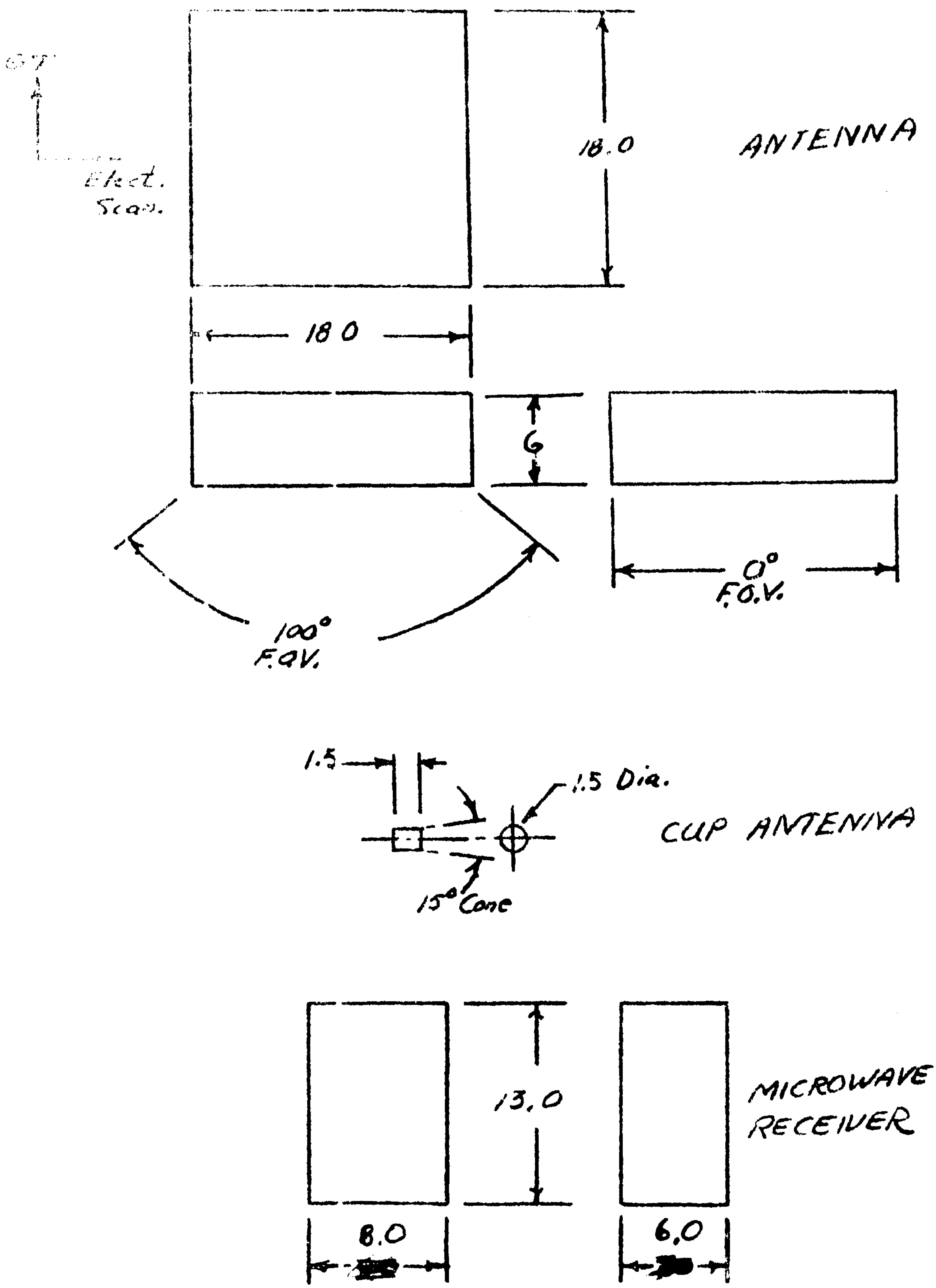
A.27



S014A ELECTRICALLY SCANNED MICROWAVE RADIOMETER

9/1/7

A.27.01

Date: 8/15/67

Exp No.

Experiment Number

[redacted]
SO 48

Title

UHF Sferics Detection

MSC Contact	Name	Address	Telephone
PI	Dr. Stig Rossby	NCAR, Boulder, Colo.	
CONTRACTOR	Space General Attn: John Cernius	El Monte, Calif.	213-443-4271
GSE CONTACT	John Cernius	El Monte, Calif.	213-443-4271
MMC ANALYST	A. Cunningham		x 4167

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Aircraft model exists Space design complete	[redacted]	8 mo	12 mos

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A.28

Exp No. S048

[redacted]

Title UHF Sferics

[redacted]

I FUNCTIONAL DESCRIPTION

Experiment objectives are:

(1) Map the global distribution of thunderstorm activity
(2) Identify weather features difficult to interpret with photography
(3) Test the theory that thunderstorms maintain the Earth-Ionosphere potential difference
(4) Determine if cloud UHF emissions contribute substantially to the total earth UHF emission

The instrument utilizes the relatively quiet 610 MH_z radio astronomy band to detect electrical disturbances associated with thunderstorm buildup and activity. Quiet clouds yield single, scattered, 1 μ sec pulses. Active clouds (thunderforms) yield a series of pulses of 20-40 μ sec total duration.

Experiment data yields, each 50 milliseconds, the highest peak (amplitude), whether it was a single or group pulse, and whether it was narrow or wide. In addition, each 100 milliseconds, the total number of narrow and wide pulses is determined.

Operation is in two modes:
(1) Using 72° 1(3 db) beam width during continuous mode
(2) Using 32° (3 db) beam width during manual astronaut observation mode. In this mode, astronaut observes lighting flashes, and marks each with a marker button.

Support photography and astronaut notes yield the type of cloud activity observed during the mission.

II PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Antenna	15	0	15969 [redacted]	0	10.8 x 43.2 dia	0
2. Amplifier	10	0	540	0	9 x 10 x 6	0
3. Data System	6	0	432	0	6 x 6 x 12	0
[redacted]	[redacted] 31	[redacted] 0	16,941			

F.O.V.	Aperture	Window Matl	Min/Max Between Components [redacted]
126°	43.2 dia	none permissable	Antenna - amplifier, 2 ft max

Boost Orientation Constraints	Flight Orientation Constraints
none	Antenna points to nadir

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A.29
[redacted]

Exp No. S048

Title OHF Sferics

Mounting Provisions

Hardmounted - amplifier and data system preferred mounted behind antenna, as close as possible between components

Removal envelope of data cassettes

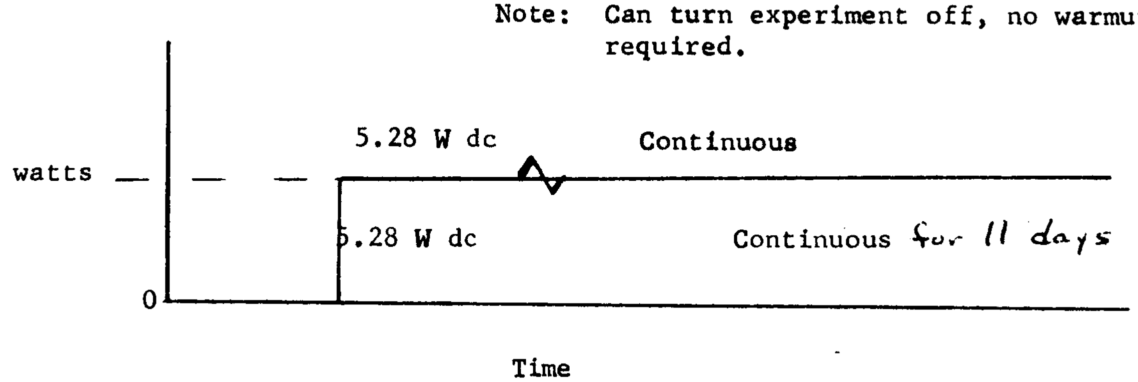
None

III(a) POWER REQUIREMENTS

Component	Power (watts) standby	operate	peak	Voltage nominal	tolerance
1. Antenna					
2. Amplifier	5.28	5.28	5.28	28vdc	± 1 preferred ± 5 ok
3. Data System					

Power Profile

Note: Can turn experiment off, no warmup time required.



Noise & Ripple
Electromagnetic Interference (EMI):
Requirements ________
Requirements: Susceptible to EMC at 610 mc ± 1 mc

III (b) THERMAL CONTROL

Component	Temperature Range Operate	Survive	
1. Antenna	-60 to 60	-60 to 100	± 15°C
2. Amplifier	0 to 60° [redacted]	0 to 60	± [redacted] 5°C
3. Data System	-20 to 60°C	-20 to 60°C	± 15°C

Critical Control Points:
Amplifier - hold ± 5°C from preferred 25°C during operation

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A.30

Exp No. S048

Title UHF Sferics

Environment

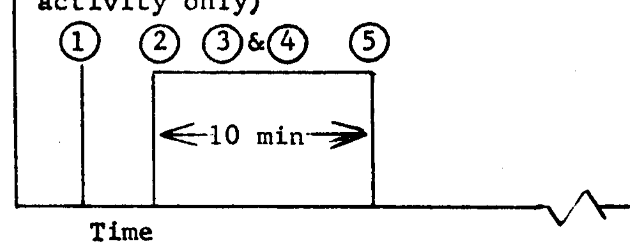
Component	Stowed Operate	Type Atmos	Press Interfaces
1. Antenna	required unpress	none	none
2. Amplifier	none	none	none
3. Data System	none	none	none

[redacted]

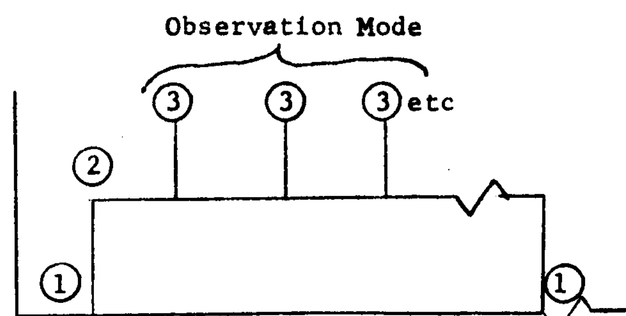
IV CREW REQUIREMENTS

Crew Task	Crew Timeline
1. Turn on (switch)	2
2. Select beamwidth (switch)	1
3. Observe cloud formations	
4. Press [redacted] lightning marker button (switch)	1
5. Select beamwidth (switch)	

Note: observation mode - repeat ~ 24 [redacted] times (during thunderstorm activity only)



Experiment Function	Experiment Timeline
1. Off	
2. On	continuous for 11 days
3. Lightning marker	



Experiment prefers to run continuously
Turn off only to conserve power, data

No. Performances	Total Operate Time M Hrs	Total Operate Time Exp Hr	Operation Constraints
Approx 24 [redacted] observation modes Experiment runs continuously	[redacted] 4.c	continuous preferred	Observation mode [redacted] in dark only

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A.31

Exp No. S048

Title UHF Sferics

Controls	Displays
1. On-off switch	1. Status lamp
2. Beam width selector switch (2 position)	
3. Marker button	

V(a) ALIGNMENT

	Component	To Carrier	To Other Experiment	Alignment Mechanism
1.	C			
1.	Antenna	$\pm .5^\circ$	$\pm$ 0.5° to support camera	optical surface provided
2.	Amplifier	any	any	-
3.	Data System	any	any	-

V(b) POINTING & STABILIZATION

Type	Limit Cycle Amplitude [redacted]	Hold Time	Max permissible rates
local vertical ±5° but known to 2° 3T	$\pm$ 5° [redacted]	Continuous	any

Maneuver Requirement

Calibrate	Target Track
None	None Once during mission, roll S/C to look at galactic center for 5 minutes. [redacted]

VI DATA REQUIREMENTS

Function	Channels	Format	Sample Rate	Freq Response/ Bit Rate
Expt	2	Digital (8 bit serial)	20 sps	160 bps per channel
H.K.	8	Analog 0-5 V $\pm$ 1% accuracy	0.1 sps	--

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A.32

Exp No. S048

Title UHF Sferics

Remarks

1. Incorporate marker button signal into data. Put ;marker signal into separate channel or into timing channel. Do not place in experiment data channels noted above.

2. Experiment data channel # 1 - 6 bits for pulse amplitude, 1 bit for group or pulse, 1 bit for wide or narrow pulse

   Experiment data channel # 2 - 2a - 8 bits - number of narrow pulses/100 ms
   2b - 8 bits - number of [redacted] wide pulses/100 ms

3. Housekeeping channels

   2 temp indicators, one on amplifier, one on data system

   3 power supply voltages

   1 RMS noise

   2 spares

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: Yes - a. (1) VHF signal generator HP Model 612A [redacted] b. (4) attenuators, (2) HP 355C, (2) HP 355D c. (1) Power meter HP 8900B d. (2) pulse generators data pulse 109 e. (1) power supply HP 6266A f. (2) RF modulators General Radio 1000 P7 g. (1) dc volt meter 40412A h. (1) oscilloscopic TEK RM35A i. (2) Preamplifiers, 1 TEK Type CA, 1 TEK Type L, j. (1) recorder HP 63A k. Antenna hat

2. Simulator supplied with experiment? No.

3. Humidity Limits: Operating 100% Survival 100%

4. Cryogenic Servicing: Commodity - none

5. Vacuum Servicing Requirements - none

6. Ground Calibration: None

7. Checkout and Malfunction Isolation Test Connectors:
   Will special connectors paralleling operational connectors be supplied? Yes.
   Remarks - Special connector used to obtain internal experiment voltages.

8. Input and Output Signal Characteristics: None

8/25/7

Exp No. S048

Title UHF Sferics

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals:

0-50 Feet ___x___

Note: Cable length as short as possible 6" from antenna hat to attenuator during calibration only

10. Power Requirements for Experiment GSE:

Voltage ___115V AC___ Current ______15 A___ Frequency __________

10. Power Requirements for Experiment GSE:

Voltage ___115V AC___ Current ___15 A______ Frequency ___60 cps___

11. Launch pad operations requirements (include equipment needed):

Checkout: go-no go test cable required from GSE to experiment
Alignment: none
Adjustment: none
Calibration: none

12. Status monitoring requirements between launch pad evacuation and launch ___none___

13. Experiment shipment: will reusable shipping container be supplied? Yes

Is there any problem associated with shipment of this experiment as an integral part of the carrier? No

14. Special handling requirements during installation on carrier ___none___

15. Manufacturer's understanding of Acceptance Testing Requirements at his facility: Acceptance test at EC facility with MMC cognizance

16. Manufacturer's recommendations for receiving and compliance testing requirements at integrator's facility: Check calibration, beam pattern

17. Other GSE requirements: Antenna hat required during all calibrations for input signal to antenna. Coax length from power meter/directional coupler/attenuator to antenna hat should be 6 inch length or less.

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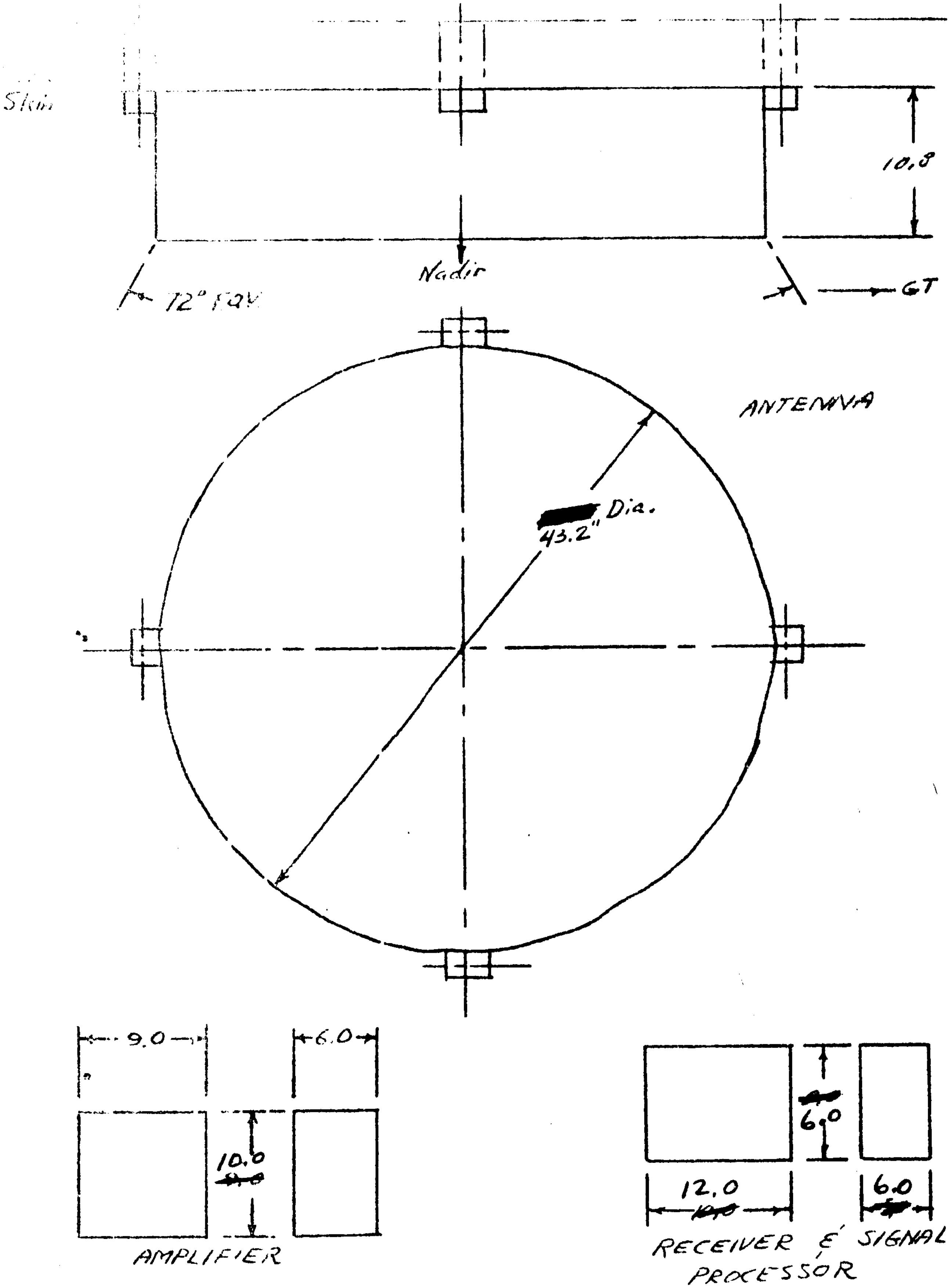

S048 UHF SFERICS DETECTION

9/1/7

A.34.01

EXPERIMENT NUMBER

S017

TITLE

X-Ray Astronomy

MSC Contact	Steve Mansur	MSC-Houston	483-5046
PI	R. Giaconni	AS&E	617/868-1600
Contractor	American Sci. & Eng.	Cambridge, Mass.	617/868-1600
GSE Contact			
MMC Analyst			

Hardware Status Presently Available	Delivery of:	[redacted]	Integration [redacted] Unit	Flight Unit

8/25/7

A.35

Exp. No. S017

Title X-Ray Astronomy

I Functional Description

The primary objective of this experiment is to study the location of presently known x-ray sources and to refine their positions to a few minutes of arc.

The x-ray sources must be located and correlated to a celestial coordinate system. The measurements will all be made by the equipment provided, and only maintenance of pointing and drift rate will require astronaut assistance. The primary celestial reference system will be the Apollo Command Module G&N system with its inertial measurement unit (IMU); therefore accurate alignment of the experiment sensor package with reference to carrier structure and CM star tracker is required.

The S017 experiment consists of four (4) major systems: A sensor unit, an electronic unit, a data unit and a control unit (C&D).

Experiment S017 and T004 use a common data system (supplied as part of S017) which is independent of spacecraft systems.

The experiment data system required the wiring of three G&N signals to the carrier: G&N PCM word, G&N 'start', and 51.2 kc clock.

Approximately 20 sources are to be observed for about 30 minutes each.

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A.36

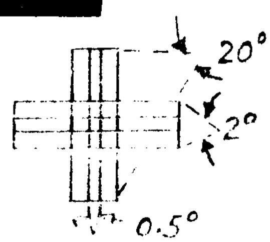
Exp. No. S017

Title X-Ray Astronomy

II Physical Parameters (Ref Dwg MH01-12058-117)

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Dimensions Ascent
1 X-Ray Sensor Pkg	176	0	4500	30 x 30 x 20(triangle) x 15
2 C & D Panel	26	0	1251	16.25 x 11 x 7
3 Electronics Pkg	46	0	[redacted] 2805	17 x 15 x [redacted] 11
4 Data Pkg	70	0	3850	26 x 18 x 20 x 16(trapezoid [redacted])x

F.O.V	Aperture	Window Matl	Min/Max between Components	C.G.
Star Sensor: [redacted] 3° Full Cone; Counters: .5° x .5°, 2° x 2°, 20° x 20°		N/A		



Boost Orientation Constraints

N/A

Flight Orientation Constraints

Do not point X-ray Sensor at sun, remain 2 to 3° away from sun.

Connector Type and Locations

Ref. NAA ICD MH01-12052-216 Sheets 1, 2, 3
D & C Panel - 3 connectors X-ray Electronics - 9 connectors
Data Handling System - 7 connectors X-ray Sensor - 3 connectors

Mounting Provisions

Removal Envelope of Data Cassette

N/A

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A.37

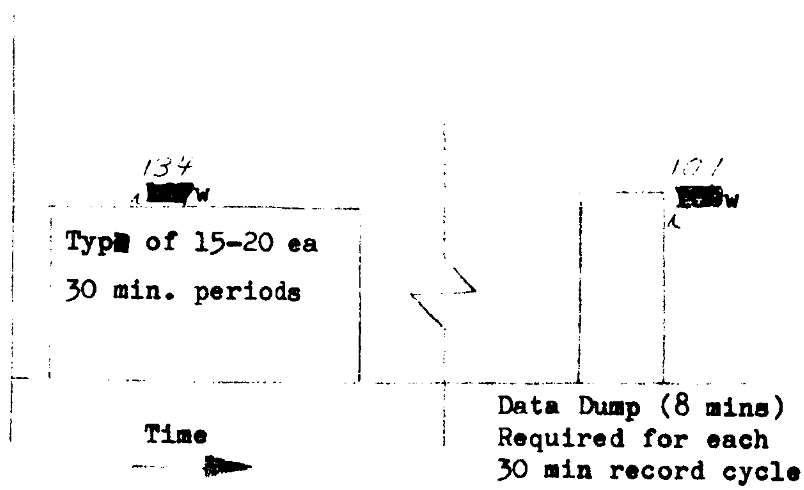
Exp. No. S017

Title X-Ray Astronomy

III(a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1 Sensor		2w		27.5 VDC	± 2.5
2 Electronics		28w			
3 Data System		104w (record)			
4 D & C		77w (data dump)			

Power Profile



Note: Since the electronics and data systems are used in support of experiment T004 (Frog Otolith), the power associated with T004 operation must be added to those outlined above to complete power profile.

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Base (0.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg Not Available - TBS

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A.38

Title X-Ray Astronomy

III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	X-Ray Sensor	0-150°F	0-150°F		

Heat Source

Critical Control Points

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1	X-Ray Sensor	Unpress.	Req'd	Vacuum	Electrical cordage thru carrier bulkhead
2	Electronics		"	"	
3	Data System		"	"	"
4	C & D Panel	Press	Pref.	Compatible with 100% O_2	None

Note: Sensor, electronics and data system to be mounted on carrier outside pressurized can. C & D panel to be located in carrier A/L during boost, extended to CM during use and stowed in carrier prior to re-entry.

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Exp. No. S017

Title X-Ray Astronomy

IV Crew Requirements

Crew Task

1 Extend control unit to CM, Apply X-Ray Power

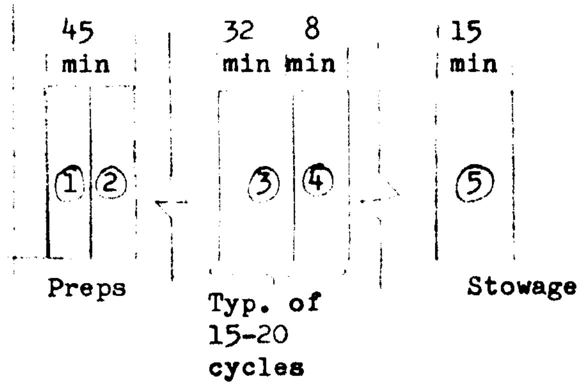
2 Perform Equipment C/O

3 Acquire X-ray Source(s) and record (3-5 sources per data period.)

4 Perform data dump

5 Remove Power Replace Control unit in carrier

Crew Timeline



Exp Function

Exp Timeline

Note: Experiment function/timeline is identical to crew requirements.

[redacted]

Item	No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
1	1	15 MINS		Restrict RCS, waste dump and venting during sensor operation.
2	1	30 MINS		
3	15 - 20	7½ - 10 HRS		
4	15 - 20	2 - 2.7 HRS		
5	1	15 MINS		

Controls	Displays
- Self Contained	C&D Unit -

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A.40

Exp. No. S017

Title X-Ray Astronomy

V(a) Alignment

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1	X-Ray Sensor Unit	See Note [redacted]	CM star tracking telescope [redacted]	Mounting Provisions

Note: The field-of-view of the sensor package must remain within the field-of-view of the G&N star tracker telescope when all docking tolerances, mechanical and electrical deformations are considered.

V(b) Pointing and Stabilization

Types	Limit Cycle Dead Band [redacted]	Hold Time	Max Permissible Rates
X-Ray Sources *Acquire source to ±0.5°*	± 0.5° [redacted] (S/C fine mode dead band about all axis)	30 min. or less 15-20 repetitions	0.1 to 0.05°/sec

Maneuver Requirement

Calibrate   Target Track

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Exp. No. S017

Title X-Ray Astronomy

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	(Self Contained)			
H.K.	See Remarks			

Remarks

1. Housekeeping Data

   A. G & N Data

      1) G & N PCM word at bit rate of 51.2 kc

      2) 51.2 kc S/C clock

      3) G & N "Start"

   B. Time

   C. S/C Attitude
      1 readout/sec.(min)

   } Req'd for each exposure period

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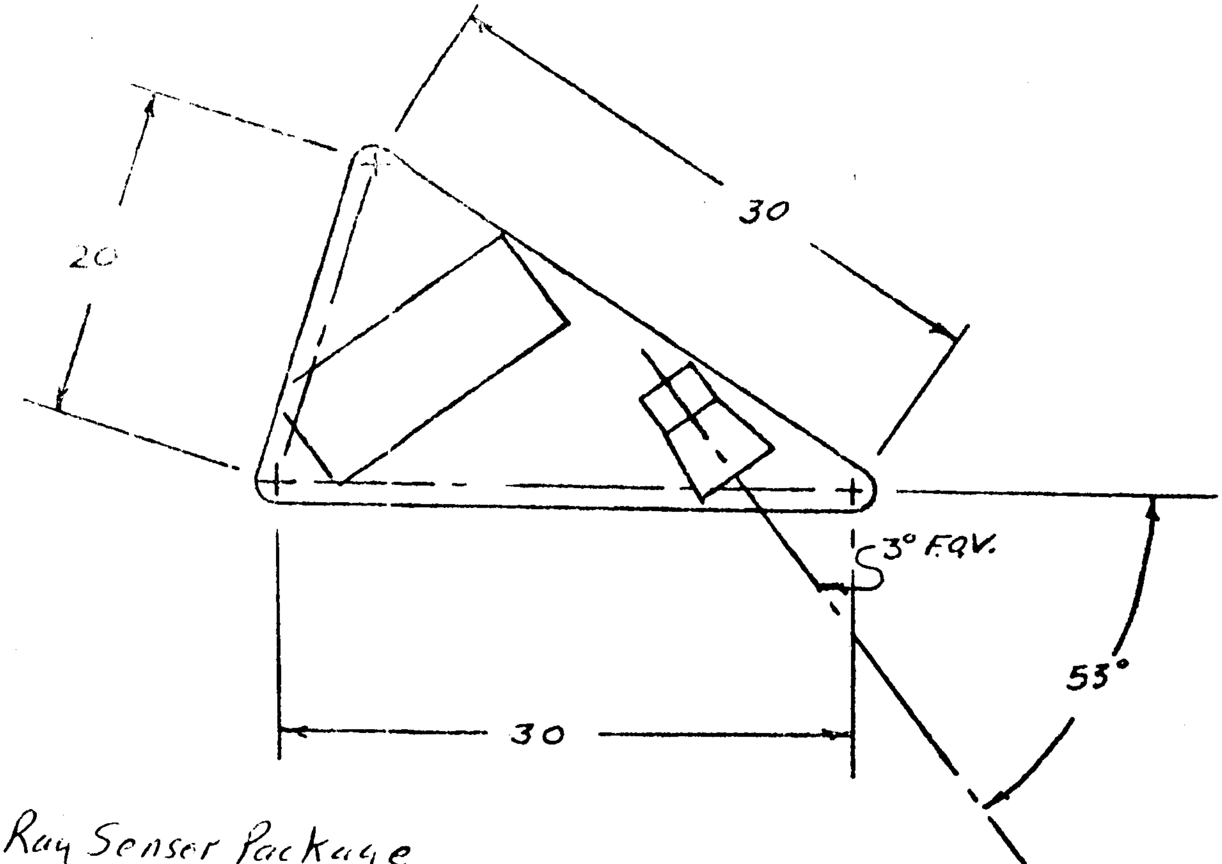
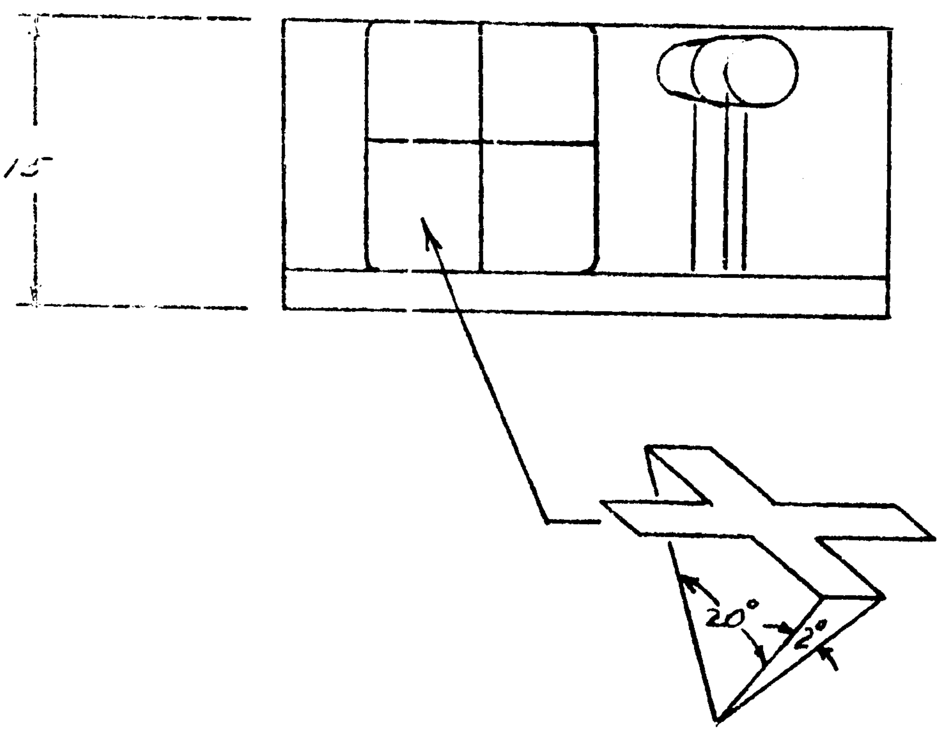
NO ______ ______ NO 260-C SHIELD COTE SHIELD COTE



X-Ray Senser Package



S017 X-RAY ASTRONOMY

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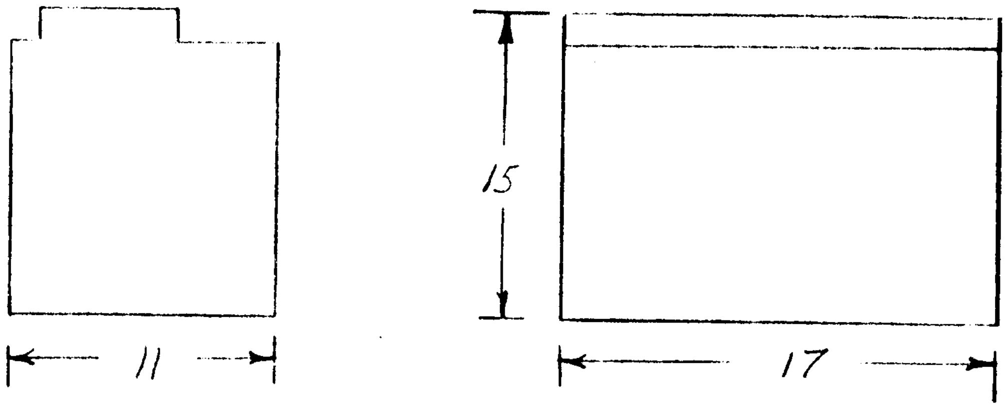
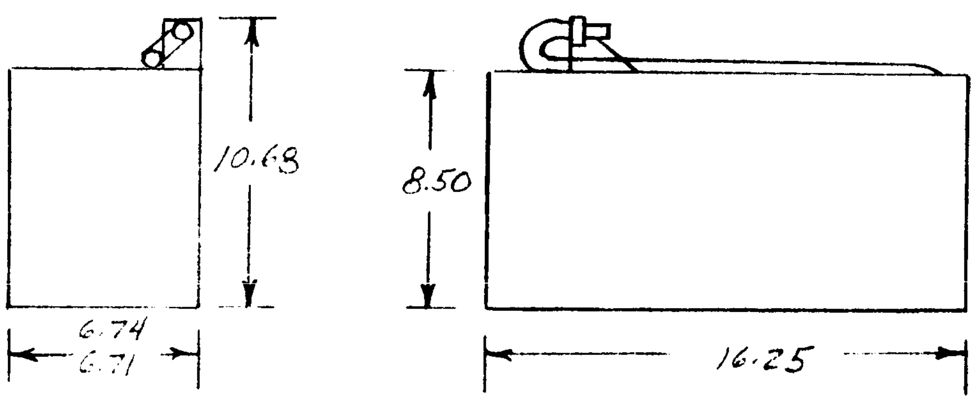
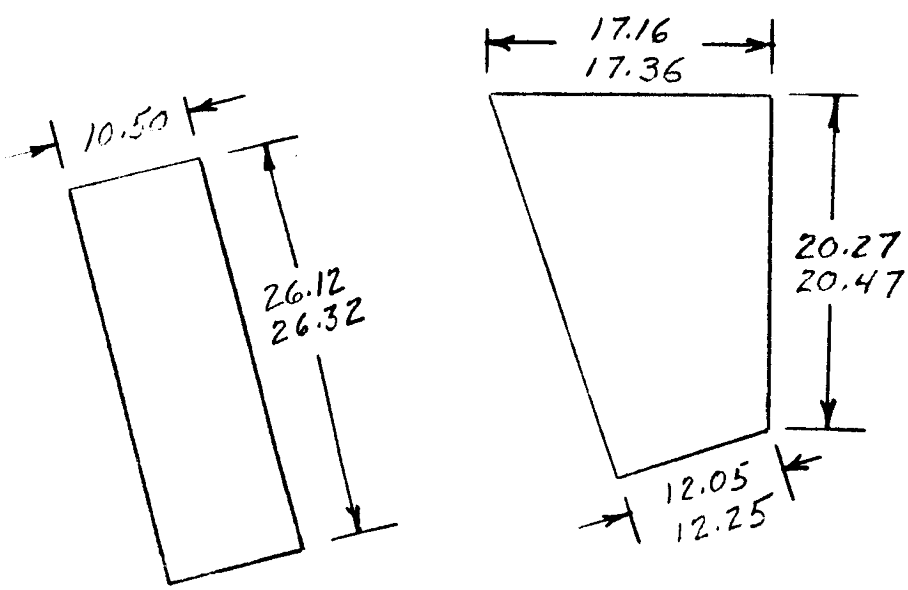
A.42.01



Electronics Package



Control & Display Unit



Data Handling System

EXPERIMENT NUMBER

S019

TITLE

UV Stellar Astronomy

MSC Contact	Mark Lee	MSC - Houston	483-5046
PI	Karl G. Henize	Northwestern Univ.	
Contractor	Cook Electric		
GSE Contact			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	*Integration* [redacted] Unit	Flight Unit
June '68			

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9.43

Exp. No. S019

Title: UV - Stellar Astronomy

I Functional Description

Primary components of this experiment are a special design spectrograph camera, film cassette, a finding/guiding telescope, and a focusing microscope; all housed in a single unit. The unit provides a lever operated film transport system and a focus control mechanism.

The spectrograph unit is designed to be operated in the scientific airlock and a pressure seal is formed between the spectrograph and an airlock adapter (provided as part of the airlock system).

The film must never be exposed to cabin atmosphere, therefore a special hatch is designed to seal it apart from the objective cannister. In stowage the film cannister is evacuated, the film cannister hatch is opened after the spectrograph is mounted in the airlock and exposed to space.

A maximum of three closely grouped star fields can be recorded per night pass. Five photographs/field are required (two at 20 seconds duration, two at 60 seconds duration and one at 150 seconds). A total of 150 slides are available (including 15 calibration and background slides).

A crew control station is required in the carrier to control initial target acquisition, [redacted] and to permit operation of the manual controls on the experiment and scientific airlock.

II Physical Parameters (Ref Dwg: See DEP Figure 1)

	Component	Weight Ascent	Weight Return	Volme (in^3) Ascent	Volme (in^3) Return	Dimensions Ascent	Dimensions Return
1	Spectrograph/Film Unit w/bracket	43	43	1060 [redacted]	1060 [redacted]	8 x 8 x 16-3/4 (approx)	✓

NOTE: Sizes and weights do not include stowage provisions.

		F.O.V.	Aperture	Window Mat'l	Min/Max between Components	C.G.
1	Spectrograph	4.^{o}1 x 5.^{o}0	6"	N/A		
2	Finding/Guiding telescope (7X)	unk	1"			
3	Focusing Microscope	unk	-x-			

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A.44

Exp. No. S019

Title: UV-Stellar Astronomy

II Physical Parameters (Continued)

Boost Orientation Constraints	Flight Orientation Constraints
None	Direction of motion (free drift) must be within 45° of the left-right direction of the guiding reticle. (Reticle gives non-inverted image)

Connector Type and Locations

None

Mounting Provisions

Mounts φin A/L using special A/L adapter plate

Removal Envelope of Data Cassette

Removal of film cassette not presently possible; study underway to solve this problem.

III(a) Power Requirements

(Self Contained Battery)
2.7 volt Gulton
(Not replaaeable in flight)

Power Profile

N/A

III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Spectrograph/Film	50 - 80°F	100°F (max) (film constraint)		

Heat Source

Insignificant

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A, 45

BLACK STAIN-O-GRAPH #33

Exp. No. S019

Title: UV - Stellar Astronomy

III(b) Thermal Control (Continued)

Environment

Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1 Spectrograph/Film	Press. Pref	Unpress Req'd	Compatible with 100% O_2	Spectrograph face plate interface with A/L adapter

NOTE: Film cassette must be maintained in vacuum. Spectrograph optics to be exposed to vacuum during operation, and pressurized to cabin environment during stowage.

IV Crew Requirements

Ref: Appendix B of 9 DEP for details

(1 Crew Task

(1 Prepare A/L

(2 Mount Exp. in A/L

(3 Perform Checkout of Eqpt

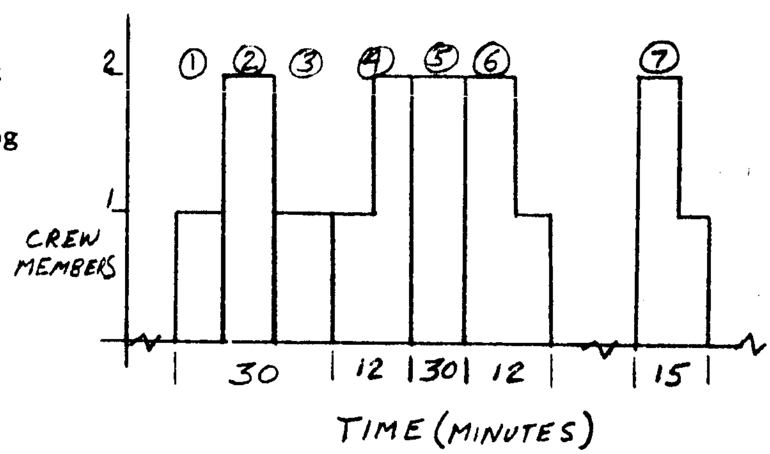
(4 Acquire Star, Expose, Log data

(5 Remove Exp from A/L and change Optic wedge

(6 Install Exp. in A/L and repeat 3 & 4

(7 Remove Exp. from A/L and stow

Crew Timeline



Exp. Function

Exp. Timeline

(Experiment timeline is identical to crew requirements)

Crew Task	No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
1,2,3	1	.5	One 10-hr work period	1 Disable RCS thruster over airlock quad to avoid contamination of experiment optics
4[redacted]	6 to 8	[redacted]5 5.5		
5[redacted]	1	[redacted]5 .5		
6	//	3.5		2 Perform during dark side of orbit
7	/	.25		

Controls

Displays

Self Contained

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A, 46

BLACK STAIN-O-GRAPH #33

Exp. No. S019

Title UV-Stellar Astronomy

V(A) ALIGNMENT N/A

V(B) POINTING AND STABILIZATION

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Star(s) (Pre-determined) ± 2°	[redacted] Fine mode G&N hold for 20 second exposures	Up to 150 sec max. (See note below.)	Damp out drifts and rates as well as possible prior to start of exposure. After start of exposure, let S,C drift. [redacted]

Note: Film exposure times are set as follows:
Five photos per field (27 fields desired)

1 field { 2 at 20 sec
2 at 60 sec
1 at 150 sec

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/ Bit Rate
Expt	None			
H.K.	See Remarks			

Remarks

Housekeeping Data
1. Voice recording
   a. Name of field being photographed
   b. Time of beginning of first exposure of each field to ± 30 sec.
   c. Verbal "mark" at beginning and end of each exposure.
   d. Description of problems or anomolys during exp. conducting.
2. Crew log
3. S/C orientation, rates

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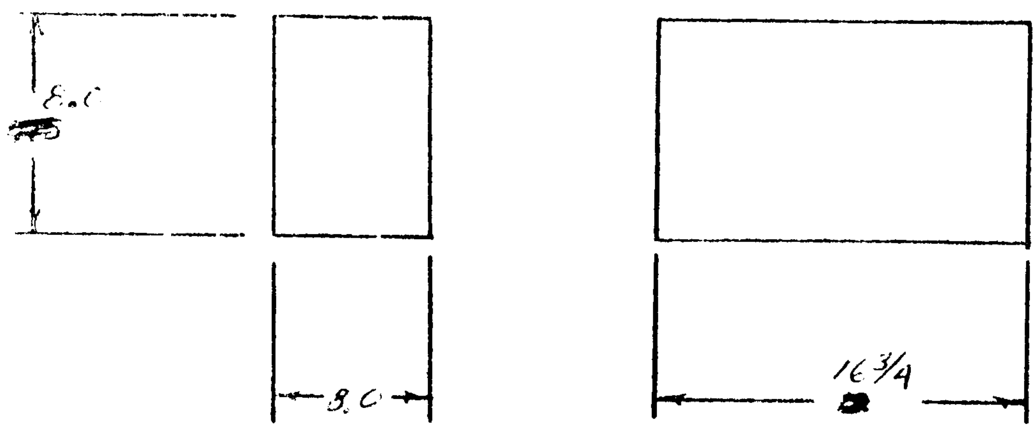
A.47



S019 UV STELLAR ASTRONOMY

9/1/7

A.47.01

EXPERIMENT NUMBER

S020

TITLE

X-RAY/UV SOLAR PHOTOGRAPHY

MSC Contact	Mark Lee	MSC - Houston	483-5046
PI	Dr. R. Tousey	NRL	
Contractor	NRL	Washington, D. C.	
GSE Contact			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently Available			

8/25/7

A.48

Exp. No. S020

Title: X-Ray/UV Solar Photography

I Functional Description

The experiment objective is to photograph the XUV and X-ray spectrum of the sun in the wavelength region from 100 to 10 Å. Exposures of up to one hour duration with a spectrograph of fine spectral resolution will extend magnitude of lines in this spectral region.

The instrument will be placed in the carrier scientific airlock and spacecraft oriented to point the instrument at the sun.

Ten sightings with exposure periods varying from five minutes to one hour will be performed during one work period (8-10 passes). The one hour exposure (2 ea.) may be divided into two one-half hour exposures on different orbits.

Timeline details include two exposures at one hour, two at one-half hour, two at 15 minutes, two at eight minutes and two at five minutes. Sightings during solar activity would greatly enhance data.

The spectrograph will be located in the carrier for boost, operated in the carrier scientific airlock, and stowed in the CM prior to re-entry. The film cannister is not separable in the present design configuration necessitating need to return entire unit. A crew control station [redacted] is required in the carrier to permit [redacted] target acquisition [redacted] and experiment operation. Power is required for reticle illumination, film advance and status outputs. Three channels of T/M data are required.

II Physical Parameters (Ref Dwg ____________________)

	~~Component~~ Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1	Spectrometer/Film	[redacted] 24.69	[redacted] 24.69	✓ 600 [redacted]	✓ 600	6½ x 5¾ x 16 [redacted]	

Note: stowage provisions not included.

F.O.V.	Aperture	Window Mat'l	Min/Max between Components	C.G.
>1° Spectrograph >14° Boresighter >3½° Fine point boresighter		N/A		

Boost Orientation Constraints	Flight Orientation Constraints
N/A	Mounted in A/L

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A.49

Exp. No. XS020

Title: X-Ray/UV Solar Photography

II Physical Parameters (Continued)

Connector Type and Locations

Deutsch #346T-10-19S) Deutsch #DSN127T-27-30P)	Cable Assembly part of experiment
Deutsch #340T-10-19P	Connector on spectrograph

Mounting Provisions

Mounts in A.L. "O" ring seal on front plate of spectrograph. Mates with quick release device on A/L adapter plate.

Removal Envelope of Data Cassette

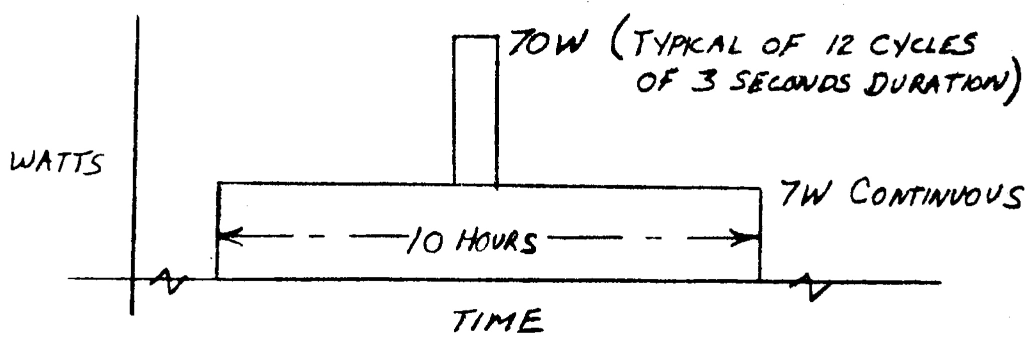
Not currently separable; study underway

III(a) Power Requirements

	Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1	Spectrograph	7 W	7 W	70 W (3 sec) (12 cycles)	27.5	±2.5

Total Power ~ .0287 KWH

Power Profile



Wiring Diagram - Ref Dwg: See DEP Fig. 10

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A.50

Exp. No. S020

Title: X-Ray/UV Solar Photography

III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Spectrograph	32-122°F (ambient)	100°F Max (Film Constraint)	--	--

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1	Spectrograph	Press Pref	Unpress Req'd	Vacuum (see note)	1. Front Plate of Spectrograph and A/L adapter 2. Internal to Spectrograph to expose film magazine to space.

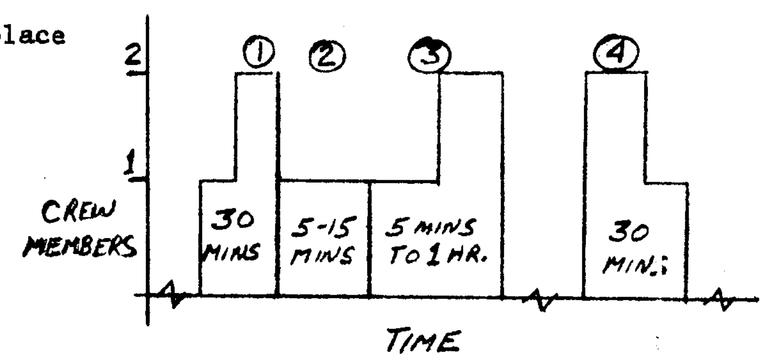
NOTE: Film must be continuously in vacuum. This is accomplished by special control on spectrograph. The spectrograph optics may be exposed to cabin pressure (during stowage) or vacuum (during operation).

IV Crew Requirements

Crew Task

1. Remove from stowage and place in A/L
2. Orient vehicle to point spectrograph at sun
3. Perform exposure and log data
4. Remove from A/L and stow

Crew Timeline



NOTE: See functional description for programmed exposure times.

Exp Function | **Exp Timeline**

(Same as crew requirements)

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A.51

Exp. No. S020

Title: X-Ray/UV Solar Photography

IV Crew Requirements (Continued)

Crew Task	No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
1	1	.75	One ten	Daytime passes
2 & 3	10	6	hr work	
4	1	.75	cycle	

Controls	Displays
Self contained	

V(a) Alignment - N/A

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Sun	Pitch $\pm\frac{1}{4}^{\circ}$ Yaw $\pm\frac{1}{4}^{\circ}$ Roll--N/A	5 min to 1 hour	Rates will be damped out as well as possible and the vehicle allowed to drift. Manual control will be exercised when drift exceeds $\pm\frac{1}{4}^{\circ}$ as indicated on experiment display.

NOTE: Coarse acquisition by G & N, fine acquistion and hold accomplished by manual control. [redacted]

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	3	Bi-level	1 sps	
H.K.	(See remarks)			

Remarks

Housekeeping Data:

1. S/C Attitude, altitude and position relative to earth-sun line.
2. Experiment local ambient temp.
3. Crew logbook

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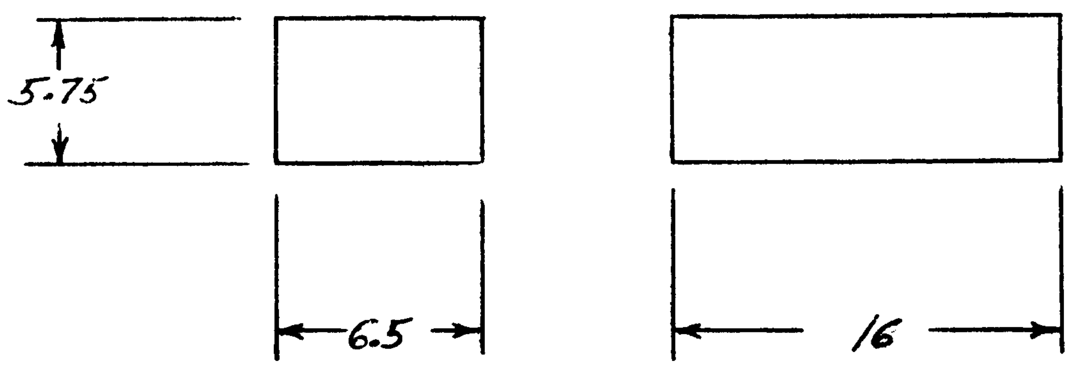
A.52



S020- UV X-RAY SOLAR PHOTOGRAPHY

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A.52.01

Date: 8/22/67

EXPERIMENT NUMBER

D017[redacted]

TITLE

Solid Electrolyte Carbon Dioxide Reduction

MSC Contact	Capt. Donahue	AFSCFO	
PI	Richard E. Bennett	Wright Patterson - Ohio	483-3542
Contractor	Bio-Med Lab Wright Pat AFB	Wright Patterson - Ohio	
GSE Contact			
MMC Analyst			
Hardware Status Delivery of:	[redacted]e	Integration [redacted] Unit	Flight Unit
January '68			

8/25/7
A.53

Exp. No. D017[redacted]

Title: Solid Electrolyte Carbon Dioxide Reduction

I. Functional Description

The experiment consists of two packages, an electronics package and an electrolytic cell. The function of the experiment is to evaluate the process of reclaiming oxygen from CO_2 during extended periods of weightlessness.

The experiment procedure will be simply to activate the system by switching power on. Due to the elevated temperatures required for operation of the electrolytic cell and the requirement to expell the gaseous products of operation, the experiment will be located on the carrier, outside of the pressure vessel.

A warm-up period of approximately 1/2 hour is required followed by a continuous operation period of about four hours. Total weight of the experiment is [redacted] 32 lbs. excluding mounting provisions.

The following parameters will be measured during the course of the experiment from activation to deactivation.

a) Electrolysis Voltage
b) Electrolysis Current
c) Electrolytic Cell Temperature
d) Oxygen Temperature
e) Carbon Dioxide/Carbon Monoxide Temperature
f) Oxygen Pressure
g) Carbon Dioxide/Carbon Monoxide Pressure

Retrieval of the electrolytic cell is desirable but not essential.

8/25/7
A.54

Exp. No. D017[illegible]

Title: Solid Electrolyte Carbon Dioxide Reduction

II. Physical Parameters (Ref Dwg. MH01-12103-136 Sheets 1 & 2)

	Component	Weight Ascent	Weight Return	Volume (in3) Ascent	Volume (in3) Return	Dimensions Ascent
1	Electrolytic [redacted] Cell	17	0	902	0	$6\frac{1}{2} \times 18\frac{1}{2} \times 7\frac{1}{2}$ (Approx.)
2	Electronics	15	0	85[illegible]	0	$10\frac{1}{2} \times 5.82 \times 14$ (Approx.)
3						
4						

*Note: Mounting provisions for fuel cell and electronics not included in these figures.

F.O.V.	Aperture	Window Matl	Min/max between Components	C.G.
N/A				

Boost Orientation Constraints	Flight Orientation Constraints
N/A	N/A

Connector Type and Locations

ME414-0096-0053 (DTK07-14-19P) Deutsch equivalent
Ref. Dwg. MH01-12118-236

Mounting Provisions

Mounting provisions not part of experiment physical parameters identified above. Fuel cell and electronics to be mounted external to pressure vessel due to thermal considerations and venting requirements of experiment.

Removal Envelope of Data Cassette

N/A

8/25/7
A.55

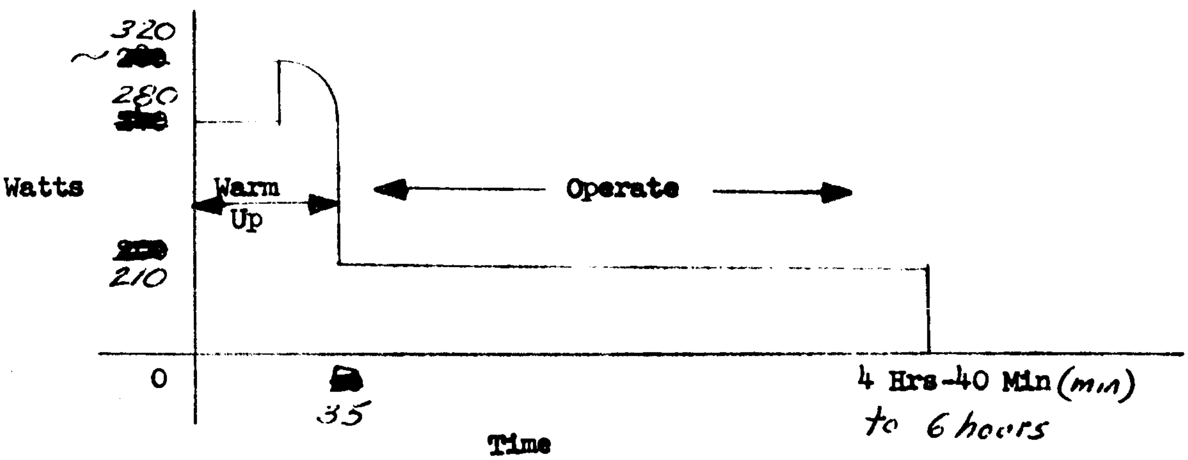
Exp No. D017

Title: Solid Electrolyte Carbon Dioxide Reduction

III (a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1 Electrolytic Cell	0	280 W (35 Mins)	320 W	28 VDC	± 2
2 Electronics					
3		210 W (Continuous 6 hours Hours)			
4					

Power Profile



Noise & Ripple Tolerance

Transient Tolerance

Feedback to Buss (0.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer Ref: Qual test plan LB-6-25-66, June 1966

Wiring Diagram - Ref Dwg ________________.

8/25/7
A.56

Exp. No. D017[redacted]

Title: Solid Electrolyte Carbon Dioxide Reduction

III (b) Thermal Control

		Temp Range			
	Component	Operate	Survive	Temp Stability	Temp Gradients
1	Electrolytic Cell	920 to 1000°C	0-1300°C	Internally Controlled	
2					
3					
4					

Heat Source	Critical Control Points
Electrolytic Cell	The outer surface of insulation surrounding the cell shall not radiate more than 40 BTU/Hr.

Environment

		Press Req		Type	Press
	Component	Stowed	Operate	Atmosphere	Interfaces
1	Electrolytic Cell	Unpress.	Req'd.	Vacuum	Cabling through pressure vessel bulkhead.
2	Electronics	Unpress.	Req'd.	Vacuum	
3					
4					

8/25/7

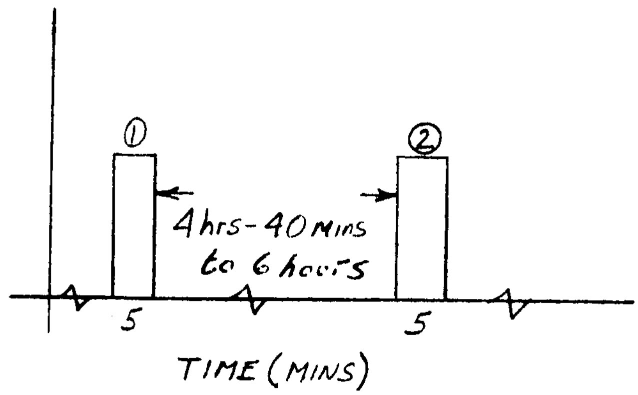
A.57

Exp. No. D017

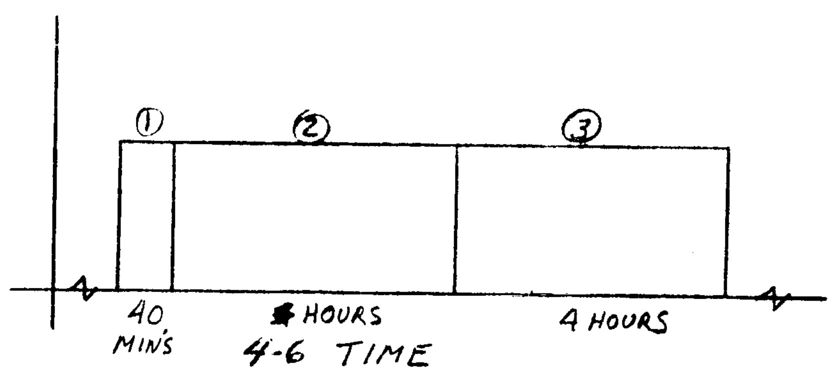
Title: Solid Electrolyte Carbon Dioxide Reduction

IV. Crew Requirements

Crew Task	Crew Timeline
1. Initiate power application	
2. Remove power	
3	
4	
5	
6	
7	



Exp Function	Exp Timeline
1. Warm-up	
2. Operate	
3. Cool-down	
4	
5	
6	



No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
1	10 Min.	4 Hrs-40 Min. to 6 hours	None

Controls	Displays
Power Switch On/Off	Power Indicator Lamp

8/25/7

A,58

Exp No. D017

Title: Solid Electrolyte Carbon Dioxide Reduction

V. (a) Alignment

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1				
2				
3	N/A			
4				
5				

V. (b) Pointing and Stabilization

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max. Permissible Rates
N/A			

Maneuver Requirement

Calibrate	Target Track

8/25/7

Exp No. D017

Title: Solid Electrolyte Carbon Dioxide Reduction

VI. Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	7	0-5 VDC	1sps	
H.K.	(See remarks)			

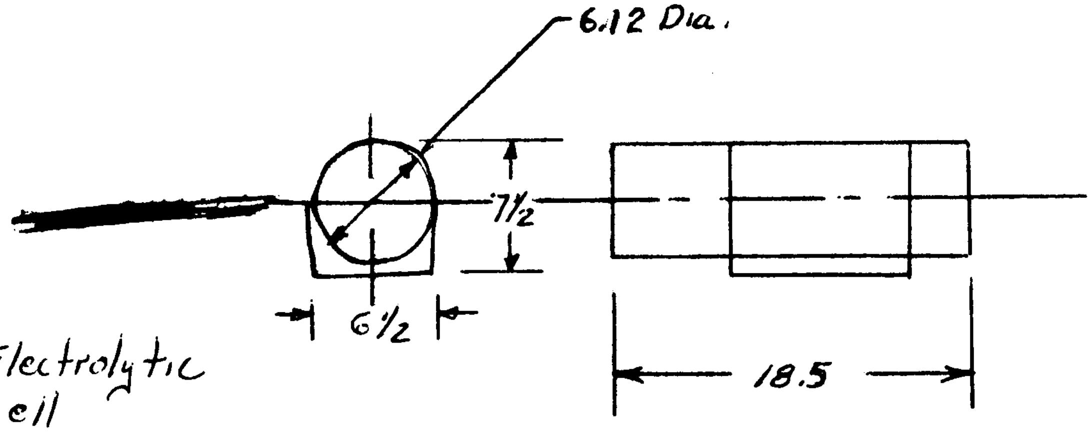
Note: All signals pre-conditioned by the experiment to the 0-5VDC range.

Remarks

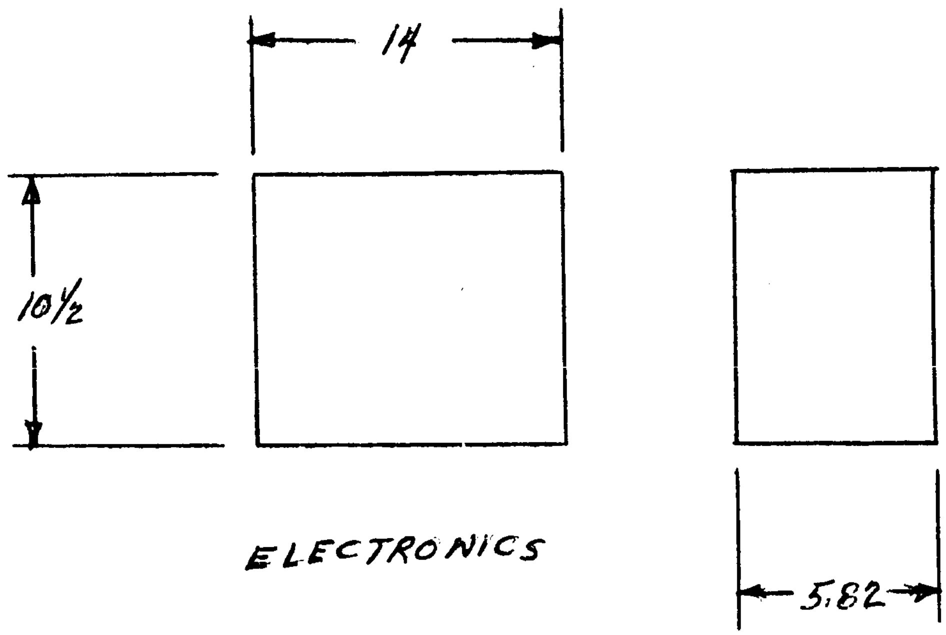
Housekeeping Data

1) Temperature provile ambient to experiment during operation
2) Pressure profile ambient to experiment during operation
3) Pressure profile ambient to dump lines (2) during operation
4) Gravity profile during experiment operation
5) Voltage profile to fuel cell during experiment operation

8/25/7
A.60



Electrolytic Cell



ELECTRONICS

D017 CO_2 REDUCTION

EXPERIMENT NUMBER

S015

TITLE

Influence of Zero-G On Human Cells

MSC Contact	Roy D. Berkley	MSC-Houston	713/483-5046
PI	P. O'B Montgomery	Woodlawn Hospital Dallas, Texas	
Contractor	V. E. Cook	Woodlawn Hospital Dallas, Texas	
GSE Contact			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently Available			

8/25/7

A.61

Exp. No. S015

Title Influence of Zero-G On Human Cells

I Functional Description

As the title suggests, the objective of this experiment is to determine the affects of prolonged zero gravity on single human cells. The experiment hardware consists of two basic subsystem mounted in a single enclosure. One subsystem, the microscope/camera subsystem will photograph the reaction of the cells to the Zero-G environment at specific intervals. The second subsystem, a bio-pack subsystem consists of two bio-pack units containing 26 bio-packs. The bio-pack subsystem cell cultures are maintained at body temperature by an internal thermal control system, and the bio-packs are hermetically sealed so that one atmosphere pressure can be maintained.

Since "tender loving care" must be exercised, and since the repetition of tests are demanding, the experiment will remain in the CM throughout the mission.

The experiment will be installed in the CM about 6 hours prior to liftoff, and power must be provided from installation until recovery in order to maintain thermal control.

A feed cycle is required each 12 hours following liftoff, and photo cycles are required every 6 hours.

It is not known if the presently designed stowage location in the CM will be available for Mission 1A.

The experiment container mounts all controls and indicators required for operation of the experiment. Only voice recording and crew log notations will be required to satisfy data requirements.

Review of the 14-day timeline and the experiment requirements indicate a conflict exists between the 6-hour film cycles required by the experiment and the concurrent crew sleep cycle. A possible compromise would be to perform the film cycles at 8-hour intervals. Further discussion with experiment contractors is required to verify acceptability of this approach.

8/25/7

A.62

Exp. No. S015

Title Influence of Zero-G On Human Cells

II Physical Parameters (Ref Dwg 103050A (Univ. of Texas))

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
					✓	✓
1 Camera/Microscope Bio-Packs	22	22	812	812	15½ x 6½ x 8.06	

Note: Sizes and weights do not include stowage provisions.

F.O.V.	Aperture	Window Matl	Min/Max between Components	C.G.
N/A				Ref: Drawing 103050A (Univ. of Texas)

Boost Orientation Constraints	Flight Orientation Constraints
Requires Special Shock Mtg. (C/M req't)	N/A

Connector Type and Locations

1 Deutsch 346-10-19S } Jumper Cable stowed in Experiment Stowage Container
2 Deutsch 346-8-7PX }

Mounting Provisions

A new mounting bracket is required for the experiment in the operation position to replace the velcro tape presently provided.

Removal Envelope of Data Cassette

N/A

8/25/7

Exp. No. S015

Title Influence of Zero-G On Human Cells

III(a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1 Camera/Microscope Pack, Bio-Pack	See Note			27.5	± 2.5

Note: Peak Stowed - 19.8w
Peak Operate - 26.0 (4 sec) reducing to 22.8w
Average (14 days) 7.5w Total - 2.5 kwh

Power Profile

Ref: S-15 power profile dated 20 September 1966

Requires heater power prior to liftoff at installation and continuing through splashdown.

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Base (0.1 ohm)

Electromagnetic Interference (EMI): Ref MSC Qual. Test

Requirements

Tests Run By Manufacturer

Wiring Diagram - Ref Dwg 569700 (Texas Instruments Inc.)

8/25-7

A.64

NO. 290-C SHIELD COTE NO. 290-C SHIELD COTE

Exp. No. S015

Title Influence of Zero-G On Human Cells

III(b) Thermal Control

Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1 Bio-Pack	60-90°F (ambient)	100°F (ambient)		

Temperature internally controlled at 94 to 99°F

Heat Source	Critical Control Points
Heater	

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1		Press - Req'd		Compatible with 100% O_2	None

8/25/7

A.65

Exp. No. S015

Title Influence of Zero-G On Human Cells

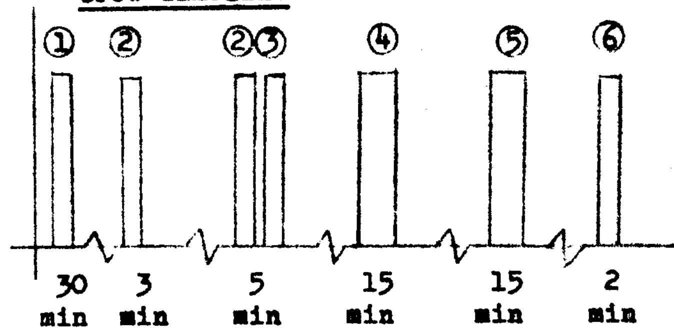
IV Crew Requirements

Crew Task

Refer to D.E.P. for detailed Operation Plan

1. Unstow and prepare for operation
2. Each 6 hrs following L/O activate photo cycle
3. Each 12 hrs following L/O activate feed cycle
4. At day 4 fix & label cycle for Bio-Pack #1
5. At day 10 fix & label cycle for Bio-Pack #2
6. Continue feed cycles for Bio-Pack #2

Crew Timeline



Exp Function

Exp Timeline

Experiment cycle is continuous from the time of installation (6 hours prior to liftoff) until experiment recovery.

Task	No. Performances	Total Operate Time M Hour	Total Operate Time Exp Hour	Operation Constraints, Target light, dark, sun angle, etc.
1	1	30 min	14 days	None
2	64	192 min		
3	28	56 min		
4	1	2 hrs		
5	1	1½ hrs		
6	6	12 min		

Controls **Displays**

- Self Contained -

8/25/7
A.66

Exp. No. S015

Title Influence of Zero-G On Human Cells

V(a) Alignment None

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism

V(b) Pointing and Stabilization N/A

Types	~~[illegible]~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates

Maneuver Requirement N/A

Calibrate	Target Track

8/25/7

A.67

Exp. No. S015

Title Influence of Zero-G On Human Cells

VI Data Requirements

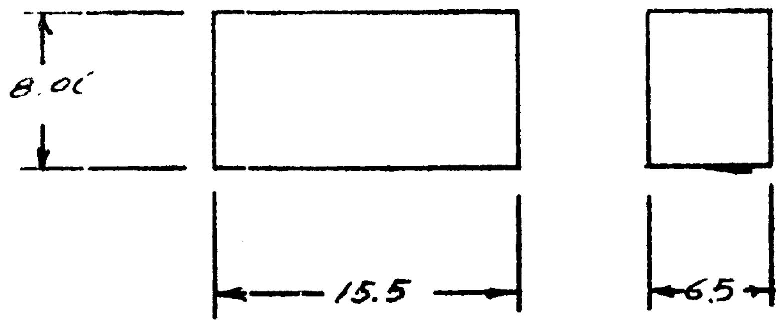
Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	None-All self contained			
H.K.	See Remarks			

Remarks

1 Crew logbook

2 Voice Recording

8/25/7



5015 ZERO-G SINGLE HUMAN CELL

9/1/7

A.68.01

EXPERIMENT NUMBER

T003

TITLE

Aerosol Particle Analyzer

(Inflight Nephelometer)

MSC Contact	Mark Lee	MSC-Houston	713/483-5046
PI	Dr. William Z. Leavitt	NASA Research Center Camb., Mass	617/491-1500
Contractor	NASA Electronics Research Center	Camb., Mass.	
GSE Contact			
MMC Analyst			

Hardware Status Delivery of: [redacted] Integration [redacted] Unit Flight Unit

Presently Available

8/25/7

A.69

Exp. No. T003

Title Aerosol Particle Analyzer

I Functional Description

The Aerosol particle analyzer is a hand-held, self contained, battery operated device used to determine size, quantity and distribution of aerosols in the space cabin.

The device will permit 100 sampling periods of approximately 110 seconds each.

First sample period ASAP after insertion, then every 4 hours. Special samples required before and after Lithium hydroxide changes, suitings, and at ECS inlet-outlet. The analyzer shall remain in the CM for ascent, use and re-entry. The analyzer must be returned for evaluation since the data is continued on the filter elements internal to the device.

The analyzer is automatic in operation once initiated. Approximately 2 minutes per sample period is required for equipment operation, with 1 minute required to manually log the results.

No readings are to be taken if cabin temperature exceeds 90°F, if humidity exceeds 85% RH, or if visible fogging exists.

Exp. No. T003

Title Aerosol Particle Analyzer

II Physical Parameters (Ref Dwg MH01-12070-116)

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
			✓	✓	✓	✓
1 Nephelometer	5.5	5.5	[redacted] 153		3.75 x 7.50 x 5.50	

Note: Stowage provisions in the CM must be provided for ascent and re-entry. A mounting bracket must be provided to mount the unit between sample periods.

F.O.V.	Aperture	Window Matl	Min/max between Components	C.G.
N/A				Within ½" of geometric center

Boost Orientation Constraints

N/A

Flight Orientation Constraints

See Functional Description

Connector Type and Locations

N/A

Mounting Provisions

TBD Velcro no longer permissible. Special clamp required in C/M.

Removal Envelope of Data Cassette

8/25/7
A.71

Exp. No. T003

Title Aerosol Particle Analyzer

III(a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
(Self Contained Battery) 3 hrs min life					

Battery pack consists of four (4) Yardney PM-1 cells (6 v). Batteries are not replaceable in flight.

Power Profile

N/A

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Base (0.1 ohm)
N/A	-	-

Electromagnetic Interference (EMI): Ref MSC Qual. Test

Requirements

Tests Run By Manufacturer

Wiring Diagram - Ref Dwg 80415800010 (Kollsman Instr. Co.)

9/1/7
8/25/7
A. 72

Exp. No. T003

Title Aerosol Particle Analyzer

III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Nephelometer	40-80°F	0-120°F		

Heat Source	Critical Control Points
N/A	

Environment

	Component	Press Req Stowed ✓	Press Req Operate ✓	Type Atmosphere	Press Interfaces
1	Nephelometer	Press - Pref		Compatible with 100% O_2	None

8/25/7

Exp. No. [illegible]

Title Aerosol Particle Analyzer

IV Crew Requirements

Crew Task

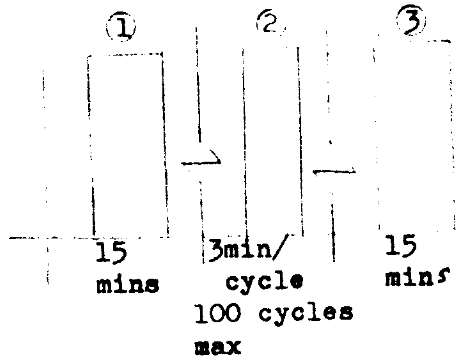
Ref. DEP Pg 19-20 for details

1 Remove From Stowage

2 Sample & Record

3 Stow

Crew Timeline



Exp Function

Exp Timeline

Task	No. Performances	Total Operate Time M Hr	Exp Hr
1	1	15 mins	
2	100 (max)	3 min/cycle	
3	1	15 mins	

Operation Constraints, Target Light, dark, sun angle, etc.

Ref: Functional description for special measurements required.

Controls **Displays**

Self Contained

8/25/7

A.74

Exp. No. T003

Title Aerosol Particle Analyzer

V(a) Alignment N/A

Component	To Carrier	To Other Expt (Specify)	Alighment Mechanism

V(b) Pointing and Stabilization N/A

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates

Maneuver Requirement N/A

Calibrate	Target Track

9/25/7

A.75

Exp. No. T003

Title Aerosol Particle Analyzer

VI Data Requirements Self Contained

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	Self Contained			
H.K.	(See Remarks)			

Remarks

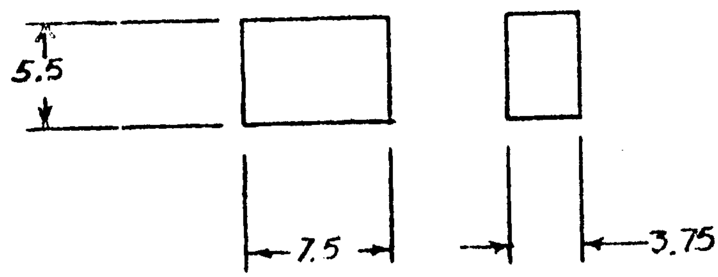
Housekeeping Data

1. Crew log
2. Voice recording

8/25/7

A.76

NO 260-C SHIELD COLE



Aerosol Particle Analyzer

TOC 3 (INFLIGHT NEPHELOMETER)

9/1/7

A.76.01

EXPERIMENT NUMBER

T004

TITLE

FROG OTOLITH FUNCTION

Contact	Name	Address	Telephone
MSC	L. H. Ballinger	MSC - Houston	483-5046
PI	Dr. T. Gualtierotti	Ames Research Center	
Contractor	Applied Physics Lab.	Johns Hopkins Univ.	
GSE			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently available			

8/25/7
A.77

Experiment No. T004

Title: Frog Otolith Function

I Functional Description

The experiment biopackage is designed to record directly the changes in activity of the otolith system of two bullfrogs which might occur during a period of prolonged weightlessness.

Microelectrodes implanted in the vestibular nerves of the two bullfrogs measure bioelectric action potential during weightlessness and repeated simulated gravity stimulus obtained by astronaut activation of the self-contained frog centrifuge.

Additional measurements are required to record contrifugal acceleration profile at the head of each animal, EKG of each animal as an index of animal welfare and water temperature.

Secondary measurements of acceleration of spacecraft in all three axis and "housekeeping" data for postflight evaluation are also required.

The data requirements of this experiment will be met using the data system supplied as part of experiment S017. The control/display requirements of T004 must be tied into an "up-link" system to permit experiment cycling during sleep cycles.

Power for life support is required from the time of experiment installation (approx 2 hours prior to L/O) until completion of experiment.

Three days of data is desired (minimum) with data cycles of eight minutes each half hour during the first 3 hours after insertion. The cycles will continue at a rate of 1 hour between test for 21 hours, then no cycles for 10 hours, and cycles scheduled every 2-3 hours for remainder of 72 hours.

The initial timeline analysis together with review of available ground control station locations and capabilities indicate a problem area exists during the first sleep cycle. Inadequate S-band coverage during this sleep cycle presents problems with capability to initiate test cycles and data cycles at the required intervals. Further analysis will be required to resolve this problem.

8/25/7

A,78

Title: Frog Otolith Function

II Physical Parameters (Ref Dwg MH01-12056-117)

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Frog Life Support	86	0	4710	0	18.75 Dia X 18.62	0
2.						
3.						
4.						

F.O.V.	Aperture	Window Matl	Min/Max between Components	C. G.
N/A				

Boost Orientation Constraints	Flight Orientation Constraints
N/A	N/A

Connector Type and Locations

Signal Receptacle - (NA) ME414-0560-0003 (346-10-195)
Power Receptacle - (includes centrifuge Cmd) (NA) ME414-0560-0001 (47004-8-7PP)
Test Receptacle - (TBD)
Ref: MH01-12052-216

Mounting Provisions

Requires special shock mount on experiment truss

½" approx insulation envelope required over portion of container

Removal Envelope of Data Cassette

N/A

8/25/7
A.79

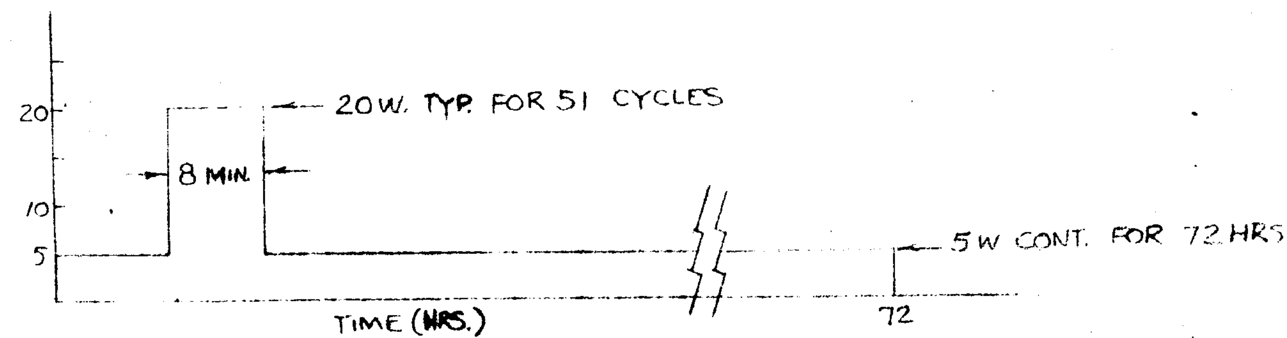
Title: Frog Otolith Function

III(a) Power Requirements

Component	Power (Watts) Standby	Power (Watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1. Frog Life Support System	5w (Continuous beginning at installation and ending after 72 hrs of test)	20w (during 8 min spin cycles)		28 vdc	

NOTE: Approx [redacted] 51 spin cycles of 8 minutes each will be required during 3 earth days which is life of this experiment.

Power Profile



Note: Power required for 5017/7004 (joint) data system not shown. Requires 51 record cycles of 8 min. each at 104 w and 102 min. of data dump at 77 w.

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (0.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg ____________________

9/1/7
8/25/7
A.80

Experiment No. T004

Title: Frog Otolith Function

III(b) Thermal Control

	Temp Range			
Component	Operate	Survive	Temp Stability	Temp Gradients
1 Frog Life Support System	*65 ± 5°F Ambient environment will be space vacuum No active thermal control is required			
2				
3				
4				

*Experiment contains its own thermal control system to maintain these limits.

Heat Source	Critical Control Points

Environment

	Press Req		Type	Press
Component	Stowed	Operate	Atmosphere	Interfaces
1. Frog Life Support	Unpress.	Pref	Vacuum Ambient	1. Internal for life support environment 2. Carrier bulkhead for electrical penetration
2.				
3.				
4.				

NOTE: Frog life support system shall be mounted on the carrier outside of the pressure vessel. The system is not returned.

8/25/7
A,81

Experiment No. 1004

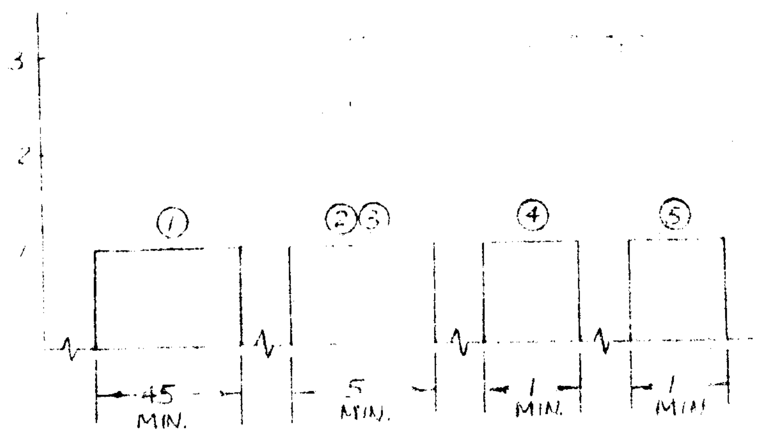
Title: Frog Otolith Function

IV Crew Requirements

<u>Crew Task</u>

1. Retrieve Control Box and locate in CM
2. Apply exp. power, turn on recorder
3. Make voice annotation Initiate test cycle
4. Initiate Data Dump
5. Terminate Experiment
6.
7.

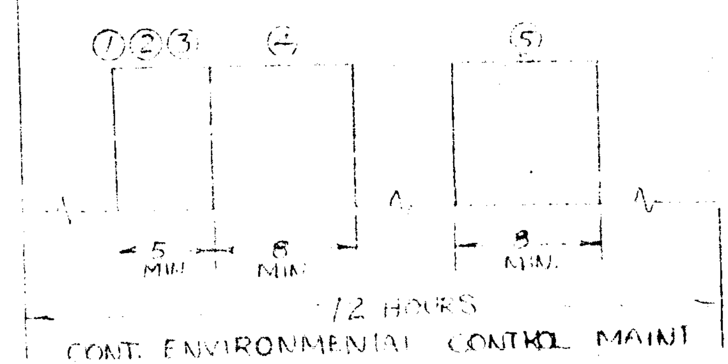
Crew Timeline



<u>Exp Function</u>

1. Power Application
2. Recorder Start
3. Voice Annotation
4. Test Cycle
5. Data Dump
6.

Exp Timeline



Crew Task	No. Performances	Total Operate Time M Hr	Exp Hr
1	1	.75	72 hrs
2 & 3	51 (max)	4.3	
4	17 (max)	.3	
5	1	.1	

Operation Constraints, Target Light, Dark, Sun Angle, etc.

None

~~[illegible] minimize all rates 5 minutes prior to, and during 8 minute test cycles. Requires stabilized drift mode.~~

<u>Controls</u> <u>Displays</u>

Controls and displays shared with experiment S017 hardware provided with S017 experiment.

8/25/7

1.82

Title: Frog Otolith Function

V(a) Alignment N/A

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1				
2				
3				
4				

V(b) Pointing and Stabilization N/A

Types	Limit Cycle Amplitude ~~Accuracy~~	Hold Time	Max Permissible Rates
Any			~~Ref. Operational constraints on Timeline Chart~~ It shall be an operational goal to minimize all rates 5 minutes prior to, and during the 8 minute test cycles.

Maneuver Requirement

Calibrate Target Track

8/25/7

A.83

Experiment No. T004

Title: Frog Otolith Function

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	Self contained in data system provided with S017.			
H. K.	(See Remarks Note 2)			

Remarks

1. In order to meet experiment objectives, test cycles must continue during sleep cycles. To satisfy this requirement, the following functions must be initiated via up link data system:

   a) Frog power on

   b) Recorder start

   c) Recorder stop (required only if transmission is lost during data dump cycle)

   d) Transmitter power on

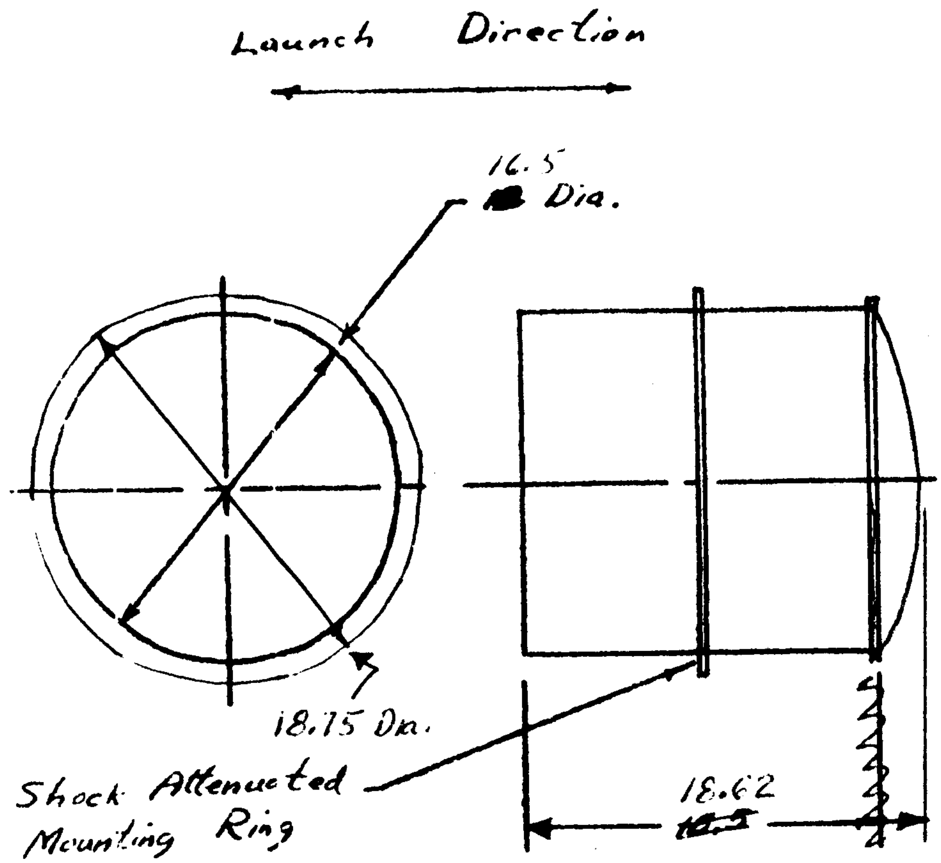
   e) Recorder read-out

   These controls will parallel those existing on the C&D panel supplied as part of the S017/T004 data system.

2. Housekeeping Data

   a) Crew log

8/25/7



T004 FROG OTOLITH FUNCTION

9/1/7

A.84.01

EXPERIMENT NUMBER

E06-1

Title

Metric Camera

MSC Contact	Leonard Nicholson	AC 713 HU3-4611	
PI	Leonard Nicholson	AC 713 HU3-4611	
Contractor	Not Selected as yet 8/22/67		
GSE Contact	Unknown		
MMC Analyst	W. Nobles		
Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
		10 mos.	13 mos.

8/25/7
A.85

Exp No. E06-1

Title: Metric Camera

I. Functional Description

The System consists of one terrain-mapping camera and one stellar-reference camera integrated into a single unit. The terrain camera will contain a 6-inch focal-length lens and the frame size will be 9 inches by 9 inches.

The exposures of the terrain camera will be controlled by between-the-lens, high efficiency shutter and the exposure interval will be controlled by a preset intervalometer.

The terrain camera will also be equipped with a reseau. The principal function of the reseau is to provide a precisely calibrated grid with patterns on the film negative during exposure. The extent of film shrinkage or expansion may be determined by comparing the grid exposed on the photograph with known dimensions of the reseau.

The stellar cameras will contain lenses of approximately 6 to 10 inches focal length, aperatures of approximately 1:2, and exposed format of approximately 70 by 70 mm.

8/25/7
A.86

Exp. No. E06-1

Title: Metric Camera

II. Physical Parameters (Ref Dwg ______________________)

	Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1	Camera & Magazine	200#	20#	7540	1440	24x15x21	12x12x10
2							
3							
4							

F.O.V.	Aperture	Window Matl	Min/max between Components	C. G.
Terrain Camera 74°	8 in.	Glass (Optical Quality)	N/A	Unknown
Stellar Camera 13°	2½ in.	Glass (Optical Quality)	N/A	Unknown

Stellar camera points 15° above the plane perpendicular to terrain camera LOS.

Boost Orientation Constraints	Flight Orientation Constraints
None	None

Connector Type and Locations

Unknown

Mounting Provisions

Unknown

Removal Envelope of Data Cassette

Film cassette will probably be on back of camera body.

8/25/7
4.87

Exp No. E06-1

Title: Metric Camera

III. (a) Power Requirements

	Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1	Camera	0	250	400	28	± 5
2						
3						
4						

Warm-up requires 30 sec. at 250 watts.

Power Profile

Not available as yet.

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (0.1 ohm)
10%		

Electromagnetic Interference (EMI): Visible light should not be scattered into the camera FOV.

Requirements

Tests Run by Manufacturer- Distortion calibration, shutter and film advance

Wiring Diagram - Ref Dwg ______________________

8/25/7

4.88

Exp. No. E06-1

Title: Metric Camera

III. (b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Camera	0 to + 32°C	-100 to +40°C	± 5° C	± 5° C
2					
3					
4					

Heat Source	Critical Control Points
Film advance motor, heater	Lens cone, film cassette

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1.	Camera	2-15PSIA	2-15PSIA	Air or O_2	None
2					
3					
4					

8/25/7

Exp. No. E06-1

Title: Metric Camera

IV. Crew Requirements

Crew Task

1 Orient spacecraft to acquire star field for cal.

2 Photograph star field

3 Reorient S.C. to LOCal Vertical

4 Visually acquire target

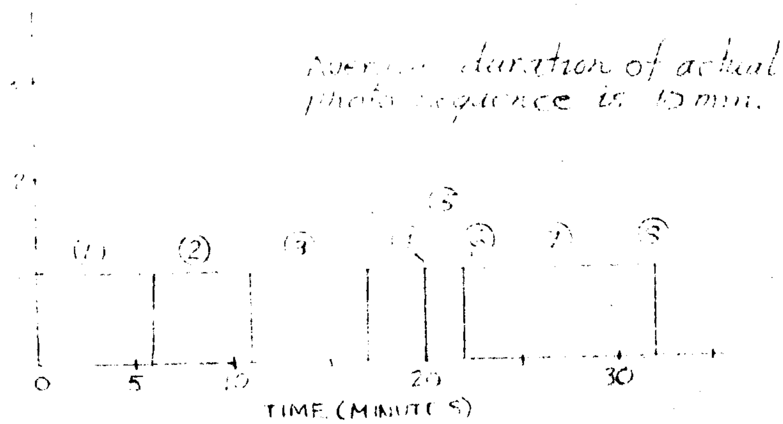
5 Describe target conditions

6 Turn on camera

7 Monitor camera performance

8 Turn off camera

Crew Timeline



Note: Calibration maneuver (steps 1 thru 3) should be performed at least two times during the mission, but need not be performed each sequence.

Exp Function

1 Warmup (30 sec)

2 Operate (10 min - average)

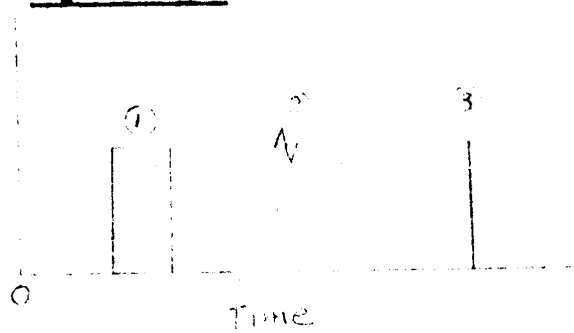
3 Off

4

5

6

Exp Timeline



No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
6 per SAD for 5 SAD's (30 Total)	6	5	Over Continental U.S. Sun angles > 60° preferred, > 30° are acceptable.

Controls

one 3-position (Off, Operate-auto, Operate-man.)

Displays

Frame counter
Statuslamp (Operate)

8/25/7
A.90

Exp No. ECG - 1

Title: Metric Camera

V. (a) Alignment

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1	Camera	± 1/2°	No Requirement	Mounting Pads
2				
3				
4				

V. (b) Pointing and Stabilization

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local Vertical ±1.0° but known to 0.1° 3σ	± 0.5°	12 Min/Seq.	0.05°/sec.

Maneuver Requirement

Calibrate	Target Track
Reorient to photograph Star field (once during mission)	None

8/25/7
A.91

Exp No. E06-1

Title: Metric Camera

VI. Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	None	Film	—	—
H. K.	Approx. [redacted]			
	11	Analog (0-5v)	0.1 sps	8 bps

Remarks

8/25/7

Exp. No. E06-1

Title Metric Camera

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: 1. Experiment simulator (1ea); 2. Experiment test set (2 ea); 3. Experiment shipping container (2 ea); 4. Lens Cover Set (2 ea); 5. Experiment holding fixture (2 ea); 6. Boresight equipment (1 ea); 7. Glassplates (super film); 8. Handling Cart (1); 9. Installation sling (1 ea); 10. Film (test); 11. Film shipping container (5 ea).

2. Simulator supplied with experiment? Yes X No____

3. Humidity limits: Operating: $<$95% R.H. Survival: $<$95% R.H. Low Limit Unknown.

4. Cryogenic Servicing: Commodity: None
Quantity: --- Temperature: --- Pressure: ---

5. Vacuum Servicing Requirements: None

6. Ground Calibration: Black body temperature: None
Temperature Tolerance: None

7. Checkout and Malfunction Isolation Test Connectors:
Will special connectors paralleling operational connectors be supplied?
Remarks:

8. Input and Output Signal Characteristics:

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals?
0-50 feet 50-100 feet 100-200 feet

10. Power Requirements for Experiment GSE:

11. Launch Pad Operations Requirements (include equipment needed):
Checkout: Experiment test set
Alignment: Boresight equipment
Adjustment: Experiment test set
Calibration: Experiment test set, holding fixture, glass plates

12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours); None

13. Experiment Shipment: Will reusable shipping container be supplied: YES
Is there any problem associated with shipment of this experiment as an integral part of the carrier? NO

14. Special handling requirements during installation on carrier: None

15. Manufacturer's understanding of Acceptance Testing Requirements at his facility:

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility:

8/25/7

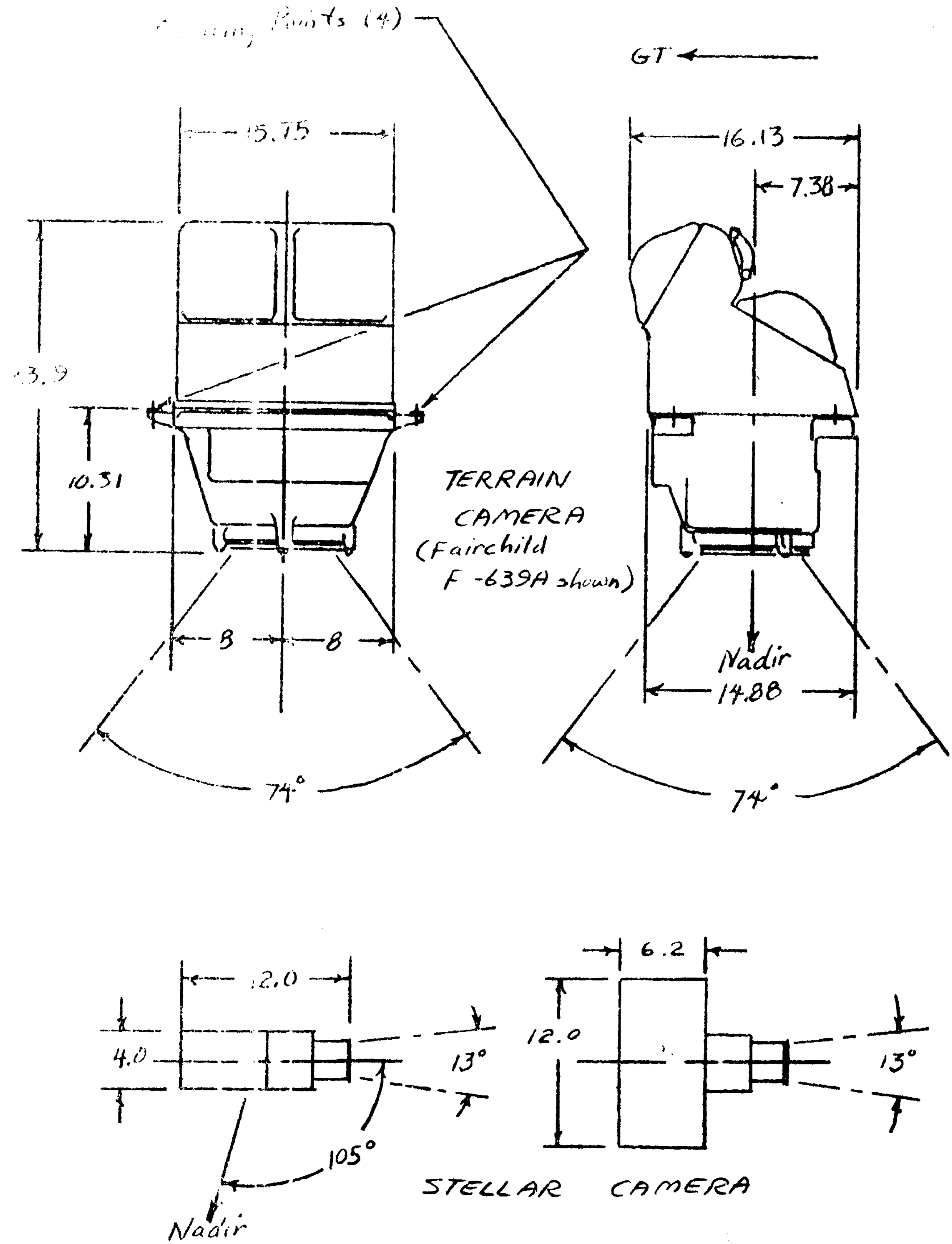
Exp. No. E06-1

Title Metric Camera

17. Other GSE Requirements: No radiation sources in vicinity of film storage.

8/25/7

A.94



EOG-1 METRIC CAMERA

EXPERIMENT NUMBER

[redacted]
E06-4

TITLE

MULTISPECTRAL CAMERA

MSC Contact	Leonard Nicholson 713 - 483-4611
PI	Leo Childs MSC - 713 - 483-4611
Contractor	Hasselblad (Paillard, Linden, N.J. 201 - 381-5600)
GSE Contact	Mr. Jerry Kovanda 201 - 381-5600 X712
MMC Analyst	W. O. Nobles X3584

Hardware Status Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
GFE	[redacted] 8/68	2/69

8/25/7
A.95

Exp No. ~~S042~~ S066 U

Title Multispectral Camera

I Functional Description

The system consists of 6, 70 mm format cameras commonly boresighted and synchronized to each other and to other sensors in the spacecraft system as may be required by the mission. The cameras shall be frame type with low distortion matched lenses.

The cameras shall cycle automatically and the astronaut will be provided with a start-stop control. A film cycling indicator and an exposure control.

8/25/7

A. 96

Exp. No. E06-4

Title Multispectral Camera

II Physical Parameters (Ref Dwg ____________________)

	Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1	Camera (6 ea) + 1 cassette/cam	5.55	1.3	124	35	9.79 x 5.18 x 3.42	3.42 x 3.47 x 3.54
	total	33.3	7.8	1680	384	10 x 12 x 14	12 x 8 x 4
2	Magazine (1 ea)	1.3	1.3	64	64	3.42 x 3.47 x 3.54	3.42 x 3.47 x 3.54
	total	15.6	15.6	768	768	16 x 12 x 4	16 x 12
3	Intervalometer and Control Box	5.0	0	12	0	2 x 2 x 3	0
		53.9	23.4	2460			

F.O.V.	Aperture	Window Matl.	Min/max between Components	C.G.
36° across flats	2 1/2" (6 ea)	glass (optical quality)	Mount as close as possible	

Boost Orientation Constraints

None

Flight Orientation Constraints

None

Connector Type and Locations

Mounting Provisions

The six cameras will be mounted to a common frame capable of maintaining the 30 sec colinearity required.

Removal Envelope of Data Cassette

Film magazines (4"x4"x4") are mounted on rear of camera body.

9/1/7
8/25/7

Exp No. F06-4

Title Multispectral Camera

III(a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1 Camera (all power is internal)					
2					
3					
4					

Power Profile

not applicable (see above)

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (0.1 ohm)
No requirement	No requirement	Not applicable

Electromagnetic Interference (EMI): No light (4,000 to 10,000 Angstroms) to be reflected into camera FOV.

Requirements

Tests Run by Manufacturer Distortion plots, transmission plots

Wiring Diagram - Ref Dwg ____________________

8/25/7
4.98

Exp No. S042 F06-4

Title Multispectral Camera

III(b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Camera	0^oc to + 32^oc	-10^oc to + 35^oc	[redacted] ±10°C	[redacted] N/C
2	Magazine	0^oc to + 32^oc	-10^oc to + 35^oc	No requirement	No requirement
3					
4					

Heat Source	Critical Control Points
Film transport Motor	Film Magazines

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1	Camera	[redacted] NONE	2-15 PSIA	Air or [redacted] O_2	None
2	Magazine	[redacted] NONE	2-15 PSIA	Air or [redacted] O_2	None
3					
4					

8/25/7
4.99

Exp. No. E06-4

Title Multispectral Camera

IV Crew Requirements

Crew Task

1 Visual acquisition of target

2 Describe target conditions

3 Switch camera system to automatic mode

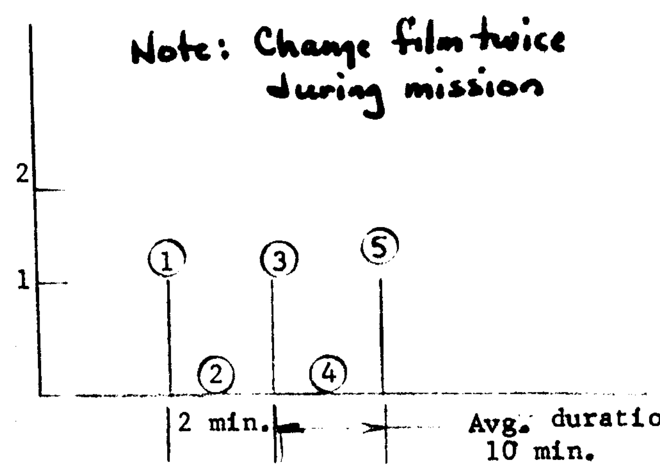
4 Monitor camera performance

5 Switch system off

6

7

Crew Timeline



Approximately 6 operate segments per S.A.D. (over U.S.)

Exp Function

1 Off

2 Operate-auto

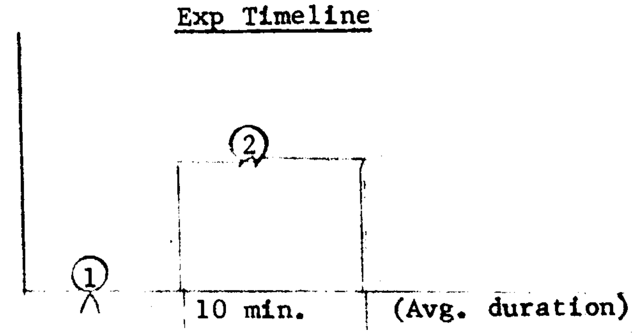
3 Operate-manual (failure mode)

4

5

6

Exp Timeline



No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
6 per S.A.D. 5 S.A.D.'s	6 hours	5 hours	over continental U.S. sun angle 30° above horizon

Controls

one 3 position control
off, operate - auto, operate-manual

Displays

Film remaining counter
Status lamp - operate

8/25/7

A.100

Exp No. Col-4

Title Multispectral Camera

V(a) Alignment

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1	Camera (6 ea)	± 10 min.	30 sec. colinearity required between cameras	Mounting pads
2				
3				
4				

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local Vertical	± 0.5°	10 min/sequence	0.03 deg/sec.

±1° but known to 0.5°, 3σ

Maneuver Requirement

Calibrate	Target Track
None	None

8/25/71

A.101

Esp No. ~~[illegible]~~ E06-4

Title Multispectral Camera

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	None	film	N/A	N/A
H.K.	Monitored by astronaut and recorded on voice tape			

Remarks

8/25/7

A,102

Exp No. [redacted] E06-4

Title Multispectral Camera

VII GSE Requirements

1. GSE normally provided with experiment 1. Experiment shipping container (2 ea) 2. Experiment test set (2 ea.) 3. Experiment simulator (1 ea) 4. Film shipping container (4 ea) 5. Collimator (3 ea) 6. Lens Cover set (4 ea) 7. Boresight equipment (1 ea)

2. Simulator supplied with experiment? Yes X No ______

3. Humidity limits: Operating 5 to 50% RH Survival 0 to 90% RH

4. Cryogenic Servicing: Commodity None

   Quantity ______ Temperature ______ Pressure ______

5. Vacuum Servicing Requirements None

6. Ground Califbration: Black body temperature N/A

   Temperature Tolerance N/A

7. Checkout and Malfunction Isolation Test Connectors:

   Will special connectors paralleling operational connectors by supplied? ______ Remarks ______

8. Input and Output Signal Characteristics:

	Stimulus	Measurement	Amplitude	Frequency/Time
DC Voltage				
AC Voltage				
Square Wave				
Pulse				
Ramp				
Others (Discrete/Digital)				

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals?

   0-50 feet ______ 50-100 feet ______ 100-200 feet ______

8/25/7

A.103

Exp No. ~~[illegible]~~ Ecc. 4

Title Multispectral Camera

10. Power Requirements for Experiment GSE:

Voltage____________ Current_____________ Frequency_____________

Ground Checkout Requirements for functional sensor protective devices (less covers, aperture covers, etc) Check operation

11. Launch Pad Operations Requirements (include equipment needed):

    Checkout: Experiment test set

    Alignment: Collimator and boresight equipment

    Adjustment: Experiment test set

    Calibration: Experiment test set

12. Status monitoring Requirements between launch pad evacuation and launch (could be as much as 48 hours) None

13. Experiment Shipment: Will reusable shipping container be supplied? <u>Yes</u>
    Is there any problem associated with shipment of this experiment as an integral part of the carrier? Colinearity of cameras is critical and could be distrubed during shipment.

14. Special handling requirements during installation on carrier None

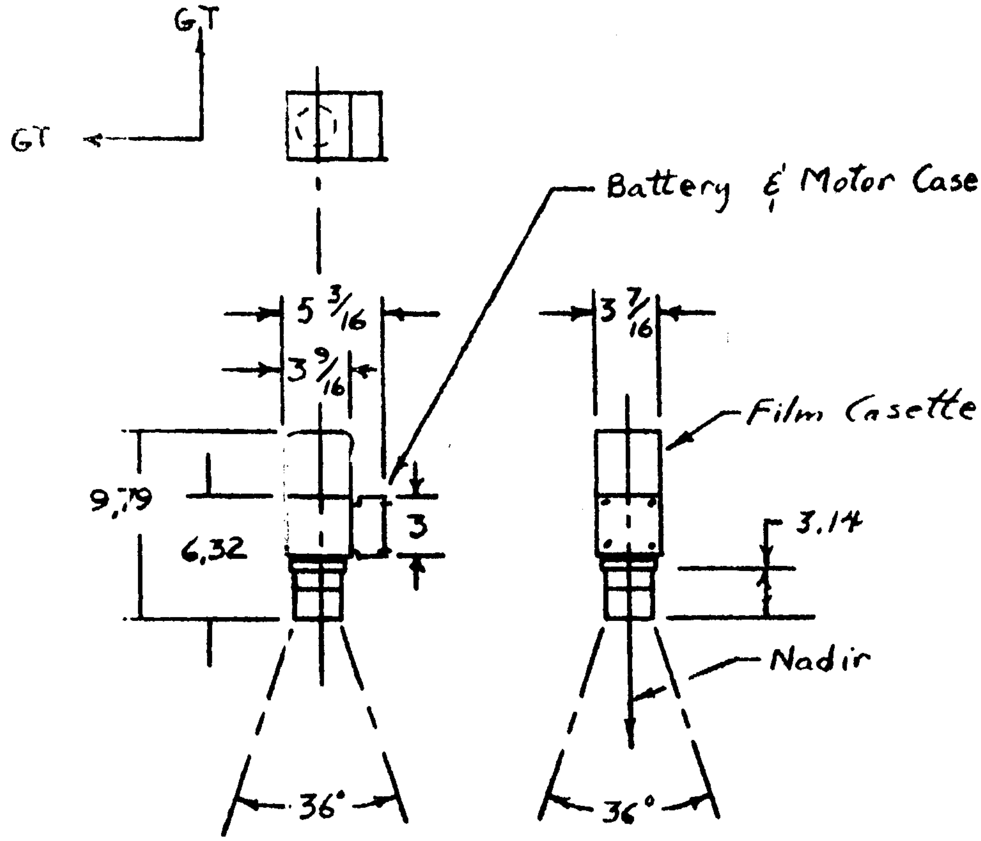
15. Manufacturer's understanding of Acceptance Testing Requirements at his facility____

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility ______________________________

17. Other GSE Requirements None

8/25/7

A.104



(Hasselblad camera shown)

EO6-4 ([redacted]) MULTISPECTRAL CAMERA

9/1/7

A.104.01

Date: 21 August 1967

EXPERIMENT NUMBER

E06-7

TITLE

iR [redacted] Imager

MSC Contact	Name	Address	Telephone
PI	Leo Childs	MSC Houston	
CONTRACTOR	HRB Singer Attn: Jack Cannon	State College, Pa.	814-238-4311, X571
GSE CONTACT	Jack Cannon	State College, Pa.	814-238-4311, X571
MMC ANALYST	Art Cunningham		X4167

Hardware Status	Delivery of:	[redacted]	Integration [redacted] Unit	Flight Unit
Aircraft unit exists and has been flown Space hardening requires redesign of film cassette and transport mechanism		[redacted].	10 mos.	10-14 mos.

8/25/7
A.105

Exp. No. E06-7

Title IR ~~Wide Range~~ Imager

II PHYSICAL PARAMETERS (Ref. Dwg. HRB Singer 90424)

Component	Weight Ascent	Weight Return	Volume (in³) Ascent	Volume (in³) Return	Dimensions Ascent	Dimensions Return
1. Scanner	110	0	[redacted] 5680	0	[redacted] 16x32.625x10.875	0
2. Supply Film Cassette	5	0	243	0	9X9X3	---
3. Take up Film Cassette	5	5	243	243	9X9X3	9X9X3
	120	5	6166			

F.O.V.	Aperture	Window Matl	Min/max Between Components
120°	3" x 6"	None-	As close as possible

Boost Orientation Constraints	Flight Orientation Constraints
None	Scanner 18" dimension along nadir, 33" dimension along ground track

Connector Type and Locations

2 Coax connectors (power) location unknown
1 Data connector probably 10 pin coax, location unknown

Mounting Provisions

Hard mounted, with scanner unpress, take up film cassette pressurized - requires film chute feed through to inside carrier.

Removal Envelope of Data Cassette

Retrieval cassette 9X9X3", 5 lbs.
probably can be lifted straight off, after unlatching operation.

III(a) POWER REQUIREMENTS

Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1. Scanner	34 [redacted]	130 [redacted]	170 [redacted]	28 vdc and 115 vac	± 5V 400 cps
2. Supply Film Cassette	0	0	0	Approx. 2 watts avg.	
3. Take Up Film Cassette	0	0	0		

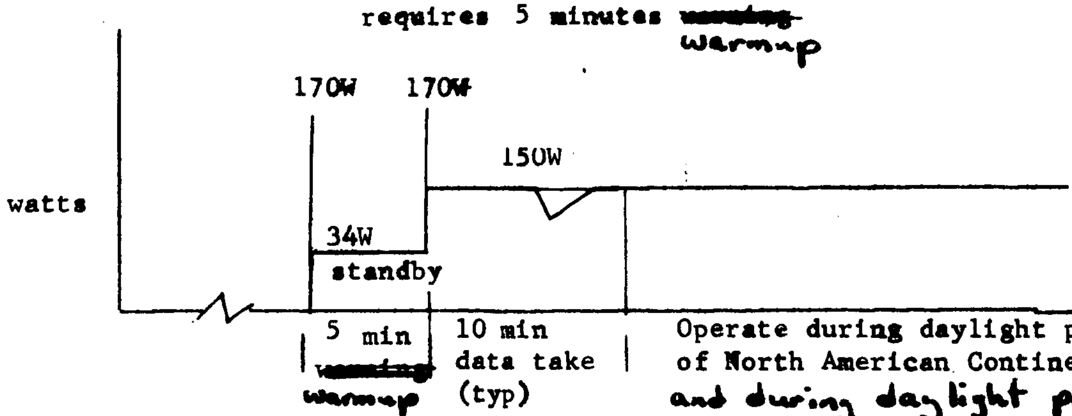
9/1/7
8/25/7
A.106

Exp. No. E06-7

Title ~~Wide Range~~ IR Imager

Power Profile

Experiment can be turned off (no power) requires 5 minutes ~~warmup~~ warmup



Operate during daylight passes of North American Continent (5.0 hrs.) and during daylight passes of other land/sea masses (6.0 hrs.) 11 hours total

III(b) THERMAL CONTROL

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1.	Scanner	-40 to +60°C	-50 to +100°C	±10°C	10°C/foot
2.	Supply Film Cassette	+2 to +35°C	-50 to +40°C	Not critical	Not critical
3.	Take up Film Cassette	+2 to +35°C	-50 to +40°C	Not critical	Not critical

Heat Source

Malaker cooler, for detector cooling, dissipates 30W continuously

Critical Control Points

Detector must be maintained at -196°C. Can be accomplished by maintaining Malaker cooler below 70°C

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1.	Scanner	Unpress	Req'd	None	Pressure interface between scanner and film cassette. Film chutes feeds film through interface. Cassette body can provide pressure seal. For retrieval film must be cut, chute must be sealed, cassette pressurized to 5 psi.
2.	Supply Film Cassette	Unpress	O.K.	None	
3.	Take Up Film Cassette	Press	Req'd.	100% O_2 Compatible	

8/25/7

A,107

Exp. No. E06-7

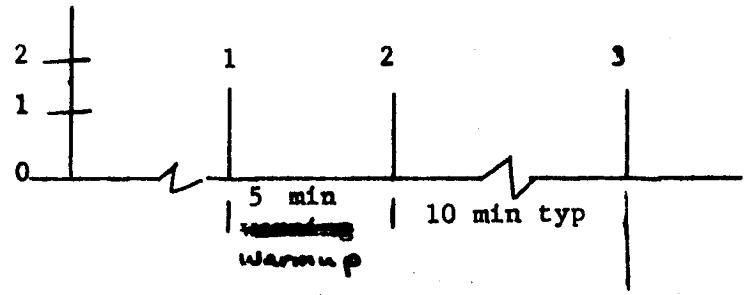
Title EC [redacted]e Imager

IV CREW REQUIREMENTS

Crew Task

1. Switch to standby
2. Switch to operate
3. Switch to off

Crew Timeline

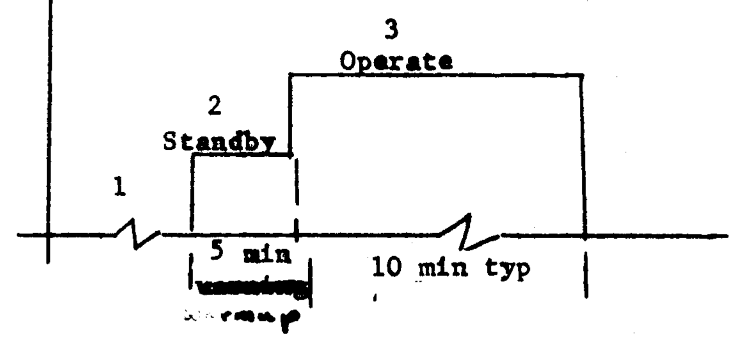


Exp. Function

1. Off
2. Standby
3. Operate (record data)

Exp Timeline

Operate during daylight [redacted] ~~American Continent~~



No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr
30	1.0	[redacted] 11.0

Operation Constraints, Target Light, Dark, Sun Angle, Etc.

Experiment operates only over North American Continent during daylight (5 hrs). Cloud coverage should be less than 40%.) and over other land/sea masses during daylight (6 hours) for 11 hours total.

Controls

1. Off/Standby/Operate 3 position switch

Displays

1. Go/No-Go Status lamp

8/25/7

A.108

Exp. No. E06-7

Title ~~IR Wide Range~~ IR Imager

V(a) ALIGNMENT

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1. Scanner	± 0.5°	± 0.1° IR Spectrometer, IR Radiometer, and Support camera	Optical Surface
2. Film Cassette	---		

V(b) POINTING AND STABILIZATION

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local vertical ±1°	±0.5°	10 min typ per target for 30 targets	Dead Band Mode Rates

M Maneuver Requirement

Calibrate	Target Track
None	None

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/ Bit Rate
Expt	None	-----	------	-----
H.K.	4	Analog (0-5V)	See below	

Remarks

Expt data recorded on film
Housekeeping data, 4 parameters, can be supplied in 0-5V range.
MMC to sample (~1 sample per minute or less required) encode, and TM.
Experimenter would like capability to TM, in real time only, the video signal (on command from the CM). Signal frequency is 100-340 KCPS, one channel.

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: General purpose oscilloscope, VTVM, power supplies, vacuum pump (small).

2. Simulator supplied with experiment? No

3. Humidity limits: Operating: 95% Survival: 95%

8/25/7
4.109

Exp. No. E06-7

Title ~~Wide Range~~ IR Imager

4. Cryogenic Servicing: Commodity: He tank (gas) to fill refrigerator
   Quantity: Small Temperature: Ambient Pressure: 250 psi

5. Vacuum Servicing Requirements: Small fore-pings provided with experiment for evacuating Malaker Cooler.

6. Ground Calibration: Black body temperature: Ambient
   Temperature Tolerance: $\pm$ 10°C but known to $\pm$ 0.01°C

7. Checkout and Malfunction Isolation Test Connectors: Will special connectors paralleling operational connectors be supplied: No

8. Input and Output Signal Characteristics: None

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals? 50-100 feet

10. Power Requirements for Experiment GSE:
    Voltage: 110 VAC Current: 15 amps Frequeney: 60 cps
    Ground Checkout Requirements for functional sensor protective devices (less covers, aperture covers, etc): Aperature cover provided with experiment-check operation on command from CM.

11. Launch Pad Operations Requirements (including equipment needed):
    Checkout: Load film as late as possible prior to launch, and evacuate Malaker Cooler.
    Alignment: None
    Adj Adjustment: None
    Calibration: None

12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours): TM housekeeping parameters.

13. Experiment Shipment: Will reusable shipping container be supplied? Yes
    Is there any problem associated with shipment of this experiment as an integral part of the carrier? NO

14. Special handling requirements during installation on carrier: None

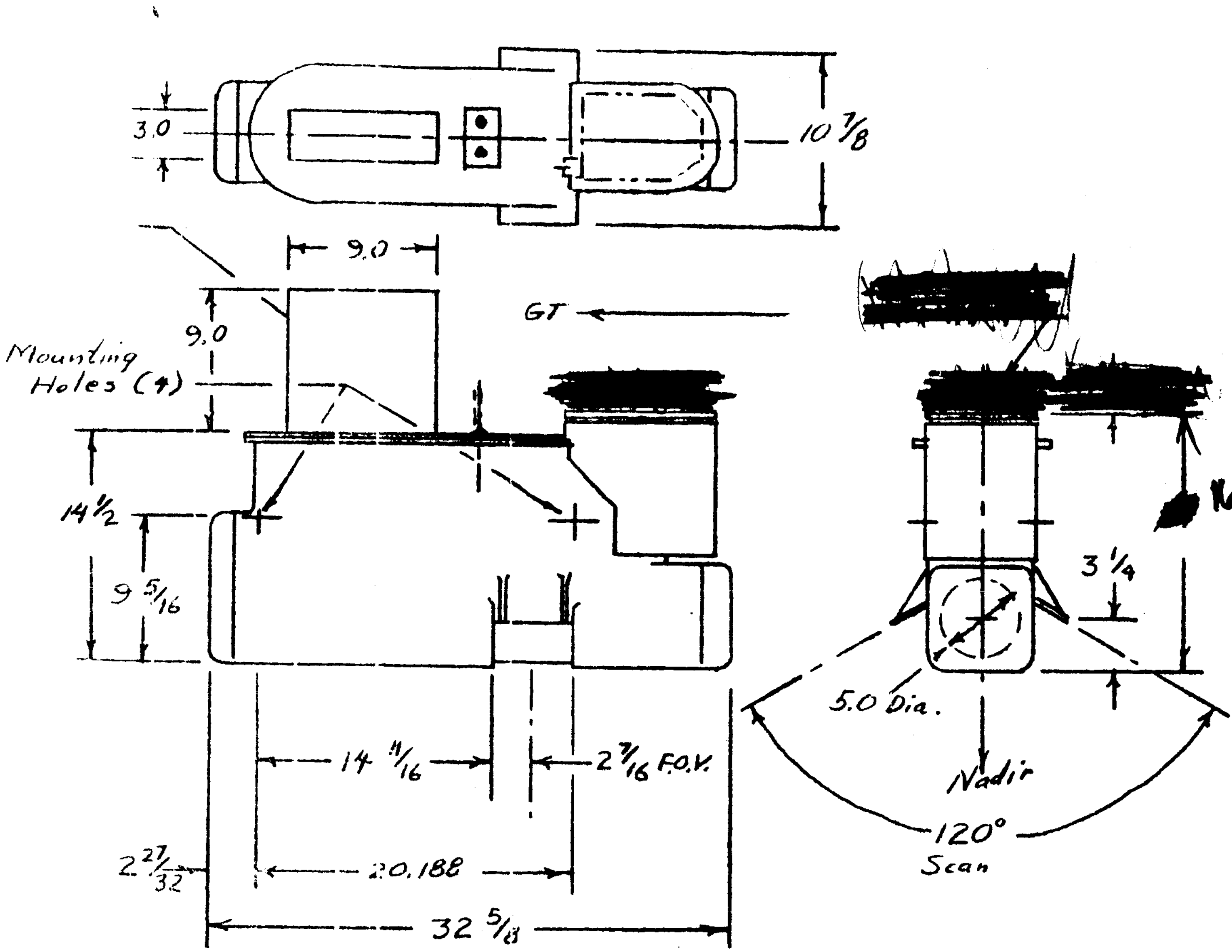
15. Manufacturer's understanding of Acceptance Testing Requirements at his facility: EC to perform Acceptance Testing with MMC cognizance.

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility: Bench C/O and calibration with EC cognizance.

17. Other GSE Requirements: None

8/25/7

A, 110



(Singer Reconofax XI shown)

EOG-7 IR IMAGER

9/1/7

A.110.01

Date: 21 August 1967

EXPERIMENT NUMBER

E06-9a

TITLE

IR RADIOMETER

MSC CONTACT	"Ike" Eichelmann	HU3-4611
PI		
CONTRACTOR		
GSE CONTACT		
MMC ANALYST	A. Cunningham	X4167

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Aircraft unit delivery 9/67	[redacted]	8 mos.	12-14 mos.

8/25/7
A.111

Exp. No. E06-9a

Title IR Radiometer

II. PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Radiometer/ Electronics	30	0	1771	0	23"X11"X7"	N/A

F.O.V.	Aperature	Window Matl	Min/max between Components	C.G.
0.4°	7"X11"	None allowed, however, protective cover required to prevent contamination of optics	N/A	

Boost Orientation Constraints	Flight Orientation Constraints
None	23" dimension point to nadir

Mounting Provisions

Hard mount to external rack.

Removal Envelope of Data Cassette

No data cassette

IIIa POWER REQUIREMENTS

Component	Power (Watts) Standby	Power (Watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1. Radiometer/ electronics	0	60	70	28V	

Note: Warmup requires 5 minutes at 30 watts.

8/25/7
A.112

Exp. No. E06-9a

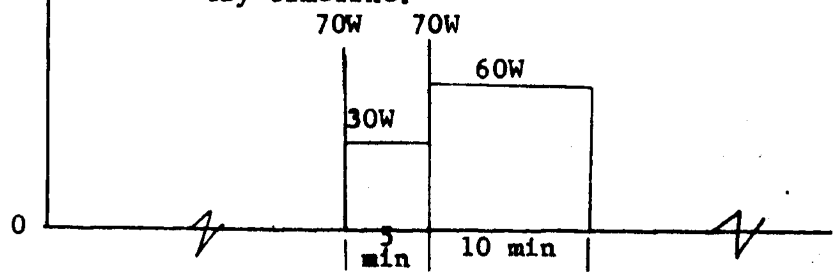
Title IR Radiometer

III(a) (continued)

Power Profile

Experiment desires at least two 7 minute operations per day. Use 10 minutes per pass as defined by the standard applications day timeline.

Watts



Note: The IR Spectrometer (E06-98) operates simultaneously with the IR Radiometer, the IR Imager and the support camera, with one frame each 5 seconds during radiometer operation.

III(b) THERMAL CONTROL

Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1. Radiometer/ Electronics	-10 to +40	-50 to +75	± 10°	10°/foot

Heat Source	Critical Control Points
Radiometer motor (1)	

Environment

Component	Press req. Stowed	Press req. Operate	Type Atmosphere	Press Interfaces
1. Radiometer/ Electronics	Unpress Req.		none	none

8/25/7

Exp. No. E06-9a

Title IR Radiometer

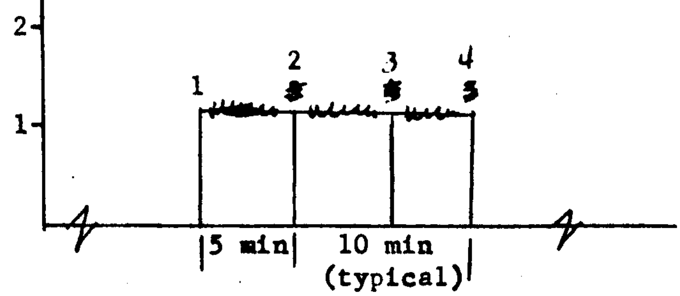
IV CREW REQUIREMENTS

Crew Task

1. Turn on experiment to warmup
[redacted]
2. Turn instrument on to operate
3. Monitor status indicator
4. Turn instrument off

Crew Timeline

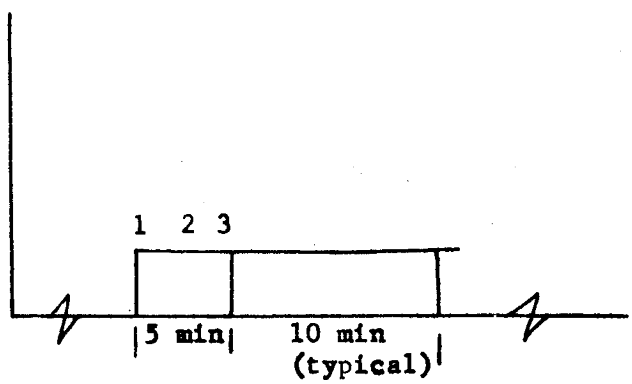
30 total operations



Exp Function

1. On-Off
2. Warmup
3. Operate

Exp Timeline



No. Performances

6 passes per day X 5 days = 30

Total Operate Time	
M Hr	Exp Hr
1.0	7.5

Operation Constraints, Target, Light, dark, sun angle, etc.

Operate only during daylight, only over continental U.S. Rainy weather or snow cover is not acceptable

Controls	Displays
Off	Lamp indicator (1)
Warmup	
Operate	

8/25/7

A.114

Exp. No. E06-9a

Title IR [redacted] Radiometer

V(a) ALIGNMENT

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1.	Radiometer/ Electronics	± 0.1°	± 0.03° to support camera ± 0.1° to spectrometer and IR Imager	Optical surface provided

V(b) POINTING AND STABILIZATION

Types	Limit Cycle Amplitude [redacted]	Hold Time	Max Permissible Rates
Local Vertical ±1° but known to 0.1° 3σ	[redacted] ±0.5°	10 minutes per pass, 30 passes	1°/sec

Maneuver Requirement

Calibrate	Target Track
none	none

Note: Roll at least once during mission at 1°/sec through 90° to sweep instrument F.O.V. through the atmosphere. (Prefer to roll five times during mission for this purpose.)

Roll to acquire the moon with instrument F.O.V. once during mission.

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	1	Digital, 10bit Serial	1900 sps	19K bps
H.K.	5	Analog 0-5V	[redacted] 0.5 sps	[redacted] 4 bps

Remarks

1. Support camera shutter pulse required in housekeeping data train.

2. Reaction control system operation - time correlation with respect to experiment operation required.

3. Time to one second, orbital parameters, voice annotation required.

8/25/7

4.115

Exp. No. E06-9a

Title IR Radiometer

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: Equivalent to one rack of electronic checkout equipment 3' X 3' X 5'. Vacuum test set (bell jar and associated gear); one cryoflask.

2. Simulator supplied with experiment? Yes___ No X

3. Humidity limits: Operating: 95% Survival: 95%

4. Cryogenic Servicing: Commodity: LN_2
Quantity: 25 liters Temperature: 77°K Pressure: Ambient

5.

5. Vacuum Servicing Requirements: Vacuum test set provided with experiment for calibration.

6. Ground Calibration: Black body temperature: 77°K
Temperature Tolerance: ---

7. Checkout and Malfunction Isolation Test Connectors: Will special connectors paralleling operational connectors be supplied? Yes

8. Input and Output Signal Characteristics: None

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals? 0-50 feet.

10. Power Requirements for Experiment GSE: Voltage: 110V; Current: 10 amps; Frequency: 60 cps
Ground Checkout Requirements for functional sensor protective devices (lens covers, aperture covers, etc): Check lens cover operation.

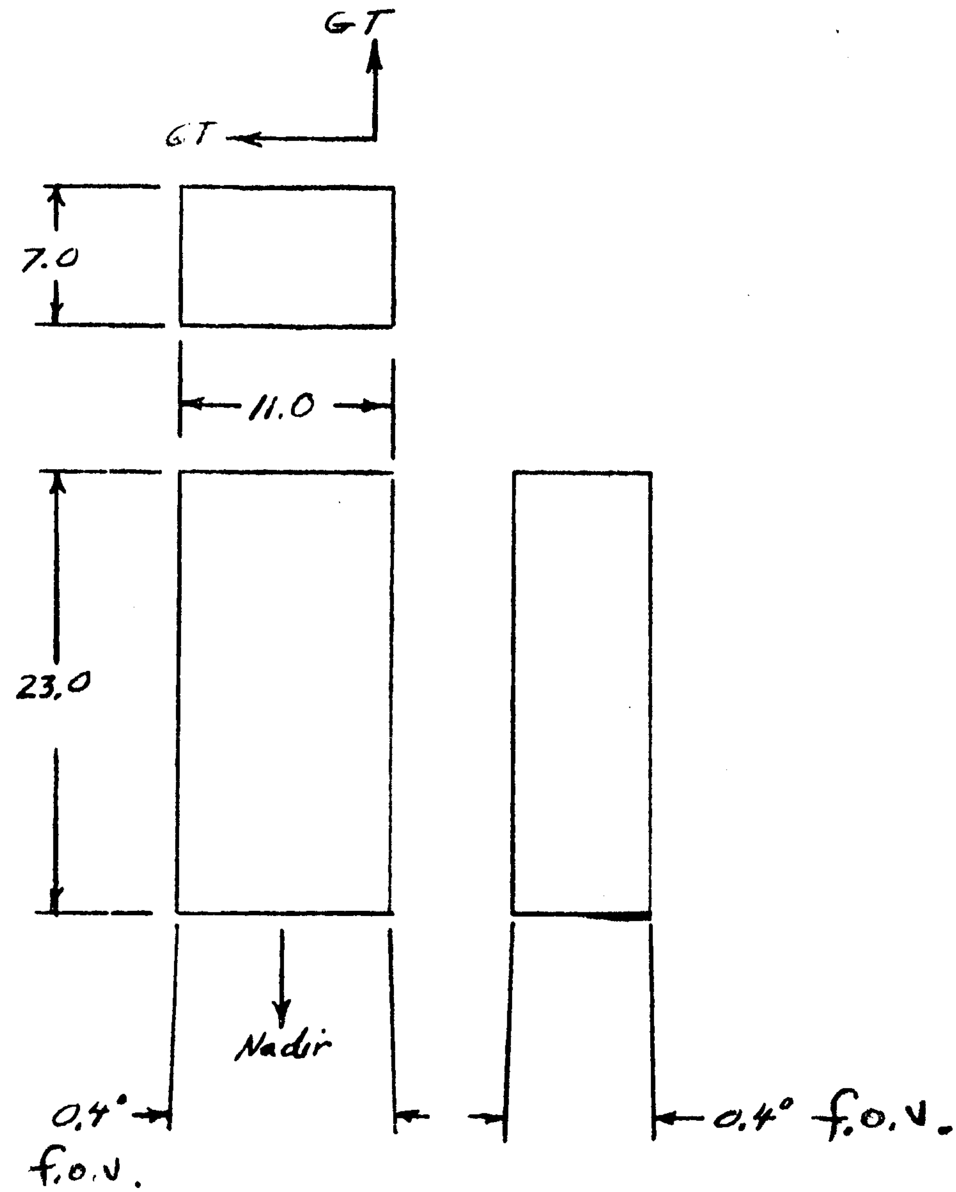
11. Launch Pad Operations Requirements (include equipment needed):
Checkout: Load cryogenics; Alignment:--; Adjustment: --; Calibration: --

12. Status monitoring Requirements between launch pad evacuation and launch (could be as much as 48 hours): Activateeexperiment, monitor T/M data.

13. Experiment Shipment: Will reusable shipping container be supplied? Yes
Is there any problem associated with shipment of this experiment as an integral part of the carrier: No

14. Special handling requirements during installation on carrier: None

8/22/7
A.116



E06-9a IR [redacted] RADIOMETER

9/1/7

[redacted]

A.116 01

Date: 22 August 1967

EXPERIMENT NUMBER

E06-9b

TITLE

IR SPECTROMETER

MSC CONTACT	"Ike" Eichelmann	HU3-4611
PI		
CONTRACTOR		
GSE CONTACT		
MMC ANALYST	A. Cunningham	X4167

Hardware Status	Delivery of:	[redacted]	Integration [redacted] Unit	Flight Unit
Aircraft Unit Available		[redacted]	8 mos	12-14 mos.

8/25/7
A.117

Exp. No. E06-9b

Title IR Spectrometer

II PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in³) Ascent	Volume (in³) Return	Dimensions Ascent	Dimensions Return
1. Spectrometer/ Electronics	50	0	4800	0	30"X20"X8"	

F.O.V.	Aperture	Window Matl	Min/max between Components	C.G.
014	8" X 20"	None allowed, however, protective cover required to prevent contamination	N/A	

Boost Orientation Constraints	Flight Orientation Constraints
none	30 inch dimension pointed to nadir

Mounting Provisions

Hard mount to external rack

Removal Envelope of Data Cassette

None

III(a) POWER REQUIREMENTS

Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerances
1. Spectrometer/ Elect.	25*	40	60	28V	

*5 minute warmup only

8/25/7

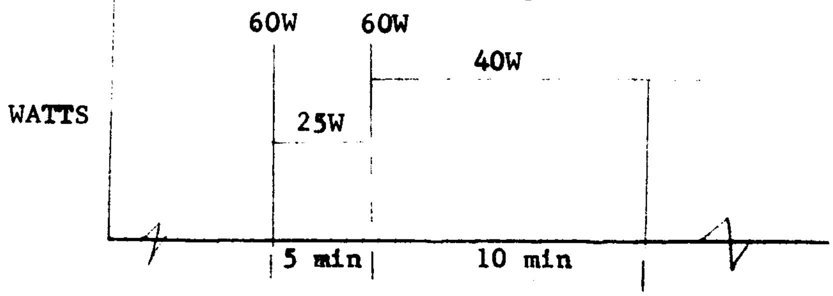
A.118

Exp. No. E06-9b

Title IR Spectrometer

Power Profile

Experiment desires at least two 7 minute operations per day. Use 10 minutes per pass as defined by the standard applications day timeline



Note: The IR spectrometer, IR radiometer, IR imager, and the support camera operate simultaneously. One camera frame required each 5 seconds during spectrometer operation

III(b) THERMAL CONTROL

Component	Operate	Survive	Temp Stability	Temp Gradients
1. Spectrometer/ Electronics	-10 to +40°C	-50 to +75°C	± 10°	10°/foot

Heat Source	Critical Control Points
Spectrometer motors (2)	

Environment

Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1. Spectrometer/ Electronics	Unpress.	Req.	----	---

8/25/7

A.119

Exp. No. E06-9b

Title IR Spectrometer

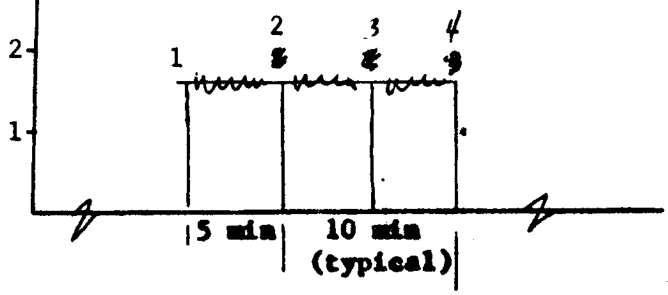
IV CREW REQUIREMENTS

Crew Task

1. Turn on experiment to warmup
~~2. Visually acquire and describe target area~~
2. Turn instrument on to operate
3. Monitor status indicator
4. Turn instrument off

Crew Timeline

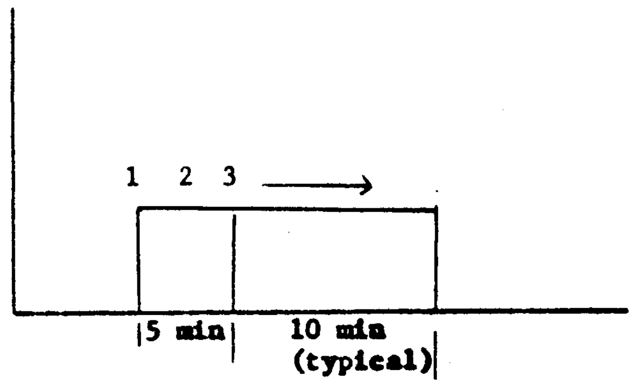
30 total operations



Exp Function

1. On-Off
2. Warmup
3. Operate

Exp Timeline



No. Performances

6 passes per day X 5 days =

30

Total Operate Time

M Hr	Exp Hr
1.0	7.5

Operation Constraints, Target, Light, dark, sun angle, etc.

Operate only during daylight, only over continental U.S. Rainy weather or snow cover is not acceptable

Controls

Off
Warmup
Operate

Displays

Lamp indicator (1)

6/25/7

A.120

Exp. No. E06-9b

Title IR Spectrometer

V(a) ALIGNMENT

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1. Radiometer/ Electronics	± 0.1°	± 0.03° to support camera ± 0.1° to spectrometer and IR Imager	Optical surface provided

V(b) POINTING AND STABILIZATION

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local Vertical ±1° but Known to 0.1° 3σ	~~±0.1°~~ ±0.5°	10 minutes per pass, 30 passes	1°/sec

Maneuver Requirement

Calibrate	Target Track
none	none

Note: Roll at least once during mission at 1°/sec through 90° to sweep instrument F.O.V. through the atmosphere. (Prefer to roll five times during mission for this purpose.)

Roll to acquire the moon with instrument F.O.V. once during mission.

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	1	Digital, 10bit Serial	1900 sps	19K bps
H.K.	5	Analog 0-5V	~~[illegible]~~ 0.5 sps	~~[illegible]~~ 4 bps

Remarks

1. Support camera shutter pulse required in housekeeping data train.
2. Reaction control system operation - time correlation with respect to experiment operation required.
3. Time to one second, orbital parameters, voice annotation required.

8/25/7

A.121

Exp. No. 206-9b

Title IR Spectrometer

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: Equivalent to one rack of electronic checkout equipment 3' X 3' X 5'. Vacuum test set (bell jar and associated gear); one cryoflask.

2. Simulator supplied with experiment? Yes___ No X

3. Humidity limits: Operating: 95% Survival: 95%

4. Cryogenic Servicing: Commodity: LN_2
Quantity: 25 liters Temperature: 77°K Pressure: Ambient

5.

5. Vacuum Servicing Requirements: Vacuum test set provided with experiment for calibration.

6. Ground Calibration: Black body temperature: 77°K
Temperature Tolerance: ---

7. Checkout and Malfunction Isolation Test Connectors: Will special connectors paralleling operational connectors be supplied? Yes

8. Input and Output Signal Characteristics: None

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals? 0-50 feet.

10. Power Requirements for Experiment GSE: Voltage: 110V; Current: 10 amps; Frequency: 60 cps
Ground Checkout Requirements for functional sensor protective devices (lens covers, aperture covers, etc): Check lens cover operation.

11. Launch Pad Operations Requirements (include equipment needed): Checkout: Load cryogenics; Alignment:--; Adjustment: --; Calibration: --

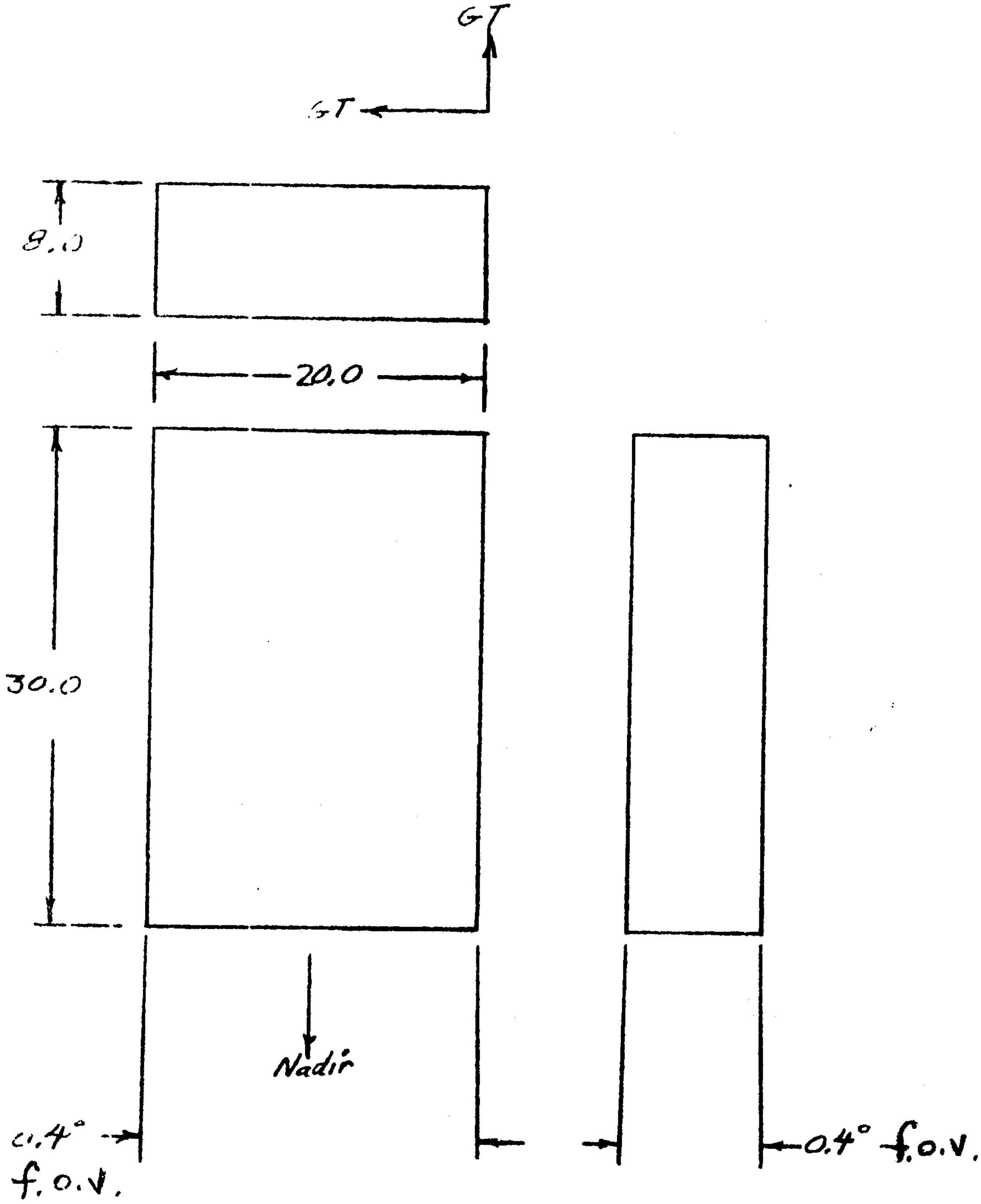
12. Status monitoring Requirements between launch pad evacuation and launch (could be as much as 48 hours): Activateeexperiment, monitor T/M data.

13. Experiment Shipment: Will reusable shipping container be supplied? Yes
Is there any problem associated with shipment of this experiment as an integral part of the carrier: No

14. Special handling requirements during installation on carrier: None

8/25/7

A.122



E06-9[redacted]b IR [redacted] Spectrometer

9/1/7

A.122.01

Date: 8/16/67

EXPERIMENT NUMBER

E06-11

TITLE

MULTIFREQUENCY MICROWAVE RADIOMETER

MSC Contact	Name	Address	Telephone
PI	Leo Childs	Houston	HU3-4611
CONTRACTOR	Space General Attn: George Oister	El Monte, Calif.	443-4271
GSE CONTACT	George Oister	El Monte, Calif.	443-4271
MMC ANALYST	Kent O'Kelly		X3584

Hardware Status	Deliver of:	[redacted]	Integration [redacted] Unit	Flight Unit
Aircraft microwave radiometer available		[redacted]	[redacted] 8 mos.	12 [redacted]

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A, 123

Exp. No. E06-11

Title Multifrequency Microwave Radiometer

II PHYSICAL PARAMETERS

Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1. Antennas/electronics	50	0	44208	0	24"X48"dia	0

F.O.V.	Aperture	Window Matl	Max/min between Components	C.G.
20°	48" dia.	none allowed	Radiometers mounted behind antennas within antenna envelope	

Boost Orientation Constraints	Flight Orientation Constraints
None	24" dimension along nadir

Mounting Provisions

Hard mount

Removal Envelope of Data Cassette

None

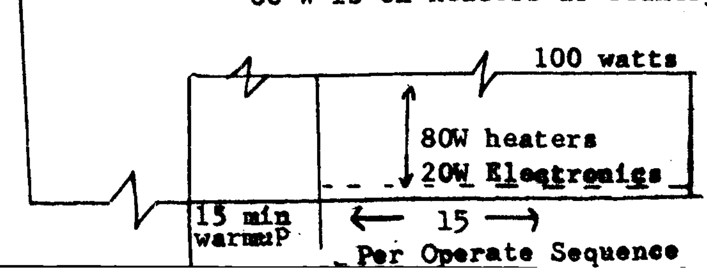
III(a) POWER REQUIREMENTS

Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1. Antenna/ Electronics	20 80	20 electronics 80 heaters		28 vdc ± 5 Experiment has internal voltage regulator	

Power Profile

Operate only over continental USA and coastal waters

Note: Electronics required 20W of power. When heaters are on, an additional 80W are required. Can turn experiment off completely; allow 15 minutes for warmup. Can reduce warmup time to one minute if 80 W is on heaters as standby power.



8/25/7
A.124

Exp. No. [illegible]6-11

Title Multifrequency Microwave Radiometer

III(b) THERMAL CONTROL

Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1. Antenna/ electronics	0-50° +40° preferred	-65 to +100	± 10°C on radiometers	10°C/foot across antenna face

Heat Source — **Critical Control Points**

Radiometer units require thermal control of the unit to ± 10°C. This temperature variation can be from any reference temperature between 0 and 50°C; however, +40°C is preferred. The EC will control critical points within the radiometers to ±1°C.

Environment

Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1. Antenna/ Electronics	Unpress	Req'd	---	---

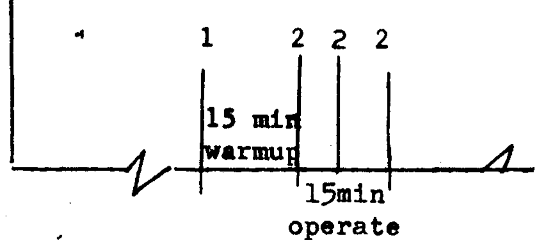
IV CREW REQUIREMENTS

Crew Task

1. Switch instrument on-off
2. Monitor status lamp periodically

Crew Timeline

Experiment operates only over [redacted]
USA and coastal waters



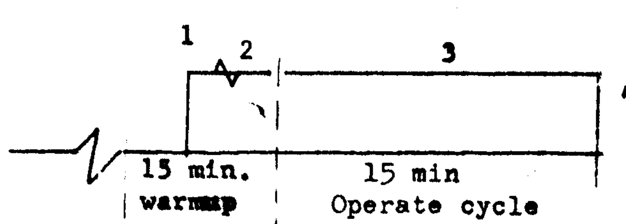
Exp. Function

1. On-off
2. Warmup (same as operate; allow 15 minutes)
3. Operate

Note: Can cut warmup time to one minute if 80W heater power is on as standby

Exp Timeline

Experiment operates only over [redacted]
USA and coastal waters



8/25/7

A.125

Exp. No. E06-11

Title Multifrequency Microwave Radiometer

No. Performances	Total Operate Time M Hr	Exp Hr	Operation Constraints, Target Light, Dark, Sun Angle, Etc.
Periodic monitor of status lamp indicator	0.1	Continuous desired	None

Controls	Displays
On-Off	Status lamp

V(a) ALIGNMENT

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1.	Antenna/ Electronics	± 0.5° but known to ± 0.05°	± 0.5° to electrically scanned microwave radiometer	Optical surface provided

V(B) POINTING AND STABILIZATION

Types	~~[illegible]~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Local Vertical	±0.5° ~~[illegible]~~	~~Continuous~~ 5 HRS	Dead band mode rates

±1° but known to 0.2° 3σ

Maneuver Requirements

Calibrate	Target Track
Roll S/C to look at space once per day standard applications day	None

VI DATA REQUIREMENTS

Function	No. Channels	Format	Sample Rate	Feq Response/Bit Rate
Expt	1	Digital (10 bit serial)	5 sps	50 BPS
H.K.	1	Analog (0-5V)	5 sps	Only on command 8 bit accuracy

Remarks

H. K. Channel (only on command)
Consists of analog signals internally multiplexed. Must be encoded by MMC with 8 bits/sample, 5 SPS

Synch signal (2400 cps, multiple or submultiple should be available to experiment.

8/25/7

A.126

Exp. No. E06-11

Title Multifrequency Microwave Radiometer

VII GSE REQUIREMENTS

1. GSE normally provided with experiment: (a) 1 electronics checkout rack 5'X4'X3', (b) various pieces of small special equipment - 1/2 volume of electronics checkout rack

2. Simulator supplied with experiment? NO

3. Humidity limits: Operating: 100% Survival: 100%

4. Cryogenic Servicing: Commodity: LN_2 for blackbody, calibration Quantity: 100 liters Temperature: --- Pressure: ---

5. Vacuum Servicing Requirements: Yes, but not defined (EC provided)

6. Ground Calibration: Black body temperature: LN_2 temp (-196°C) Temperature Tolerance: ±1°C (EC provided)

7. Checkout and Malfunction Isolation Test Connectors: Will special connectors paralleling operational connectors be supplied? YES

8. Input and Output Signals Characteristics: None - only 28 vdc power source.

9. Allowable cable lengths for connecting portable checkout equipment to experiment without adversely affecting command or response signals? 100-200 feet.

10. Power Requirements for Experiment GSE:
Voltage: 115V Current: 10 amps Frequency: 60 cps
Ground Checkout Requirements for functional sensor protective devices (less covers, aperture covers, etc.): None

11. Launch Pad Operations Requirements (include equipment needed):
Checkout: None
Alignment: None
Adjustment: None
Calibration: None

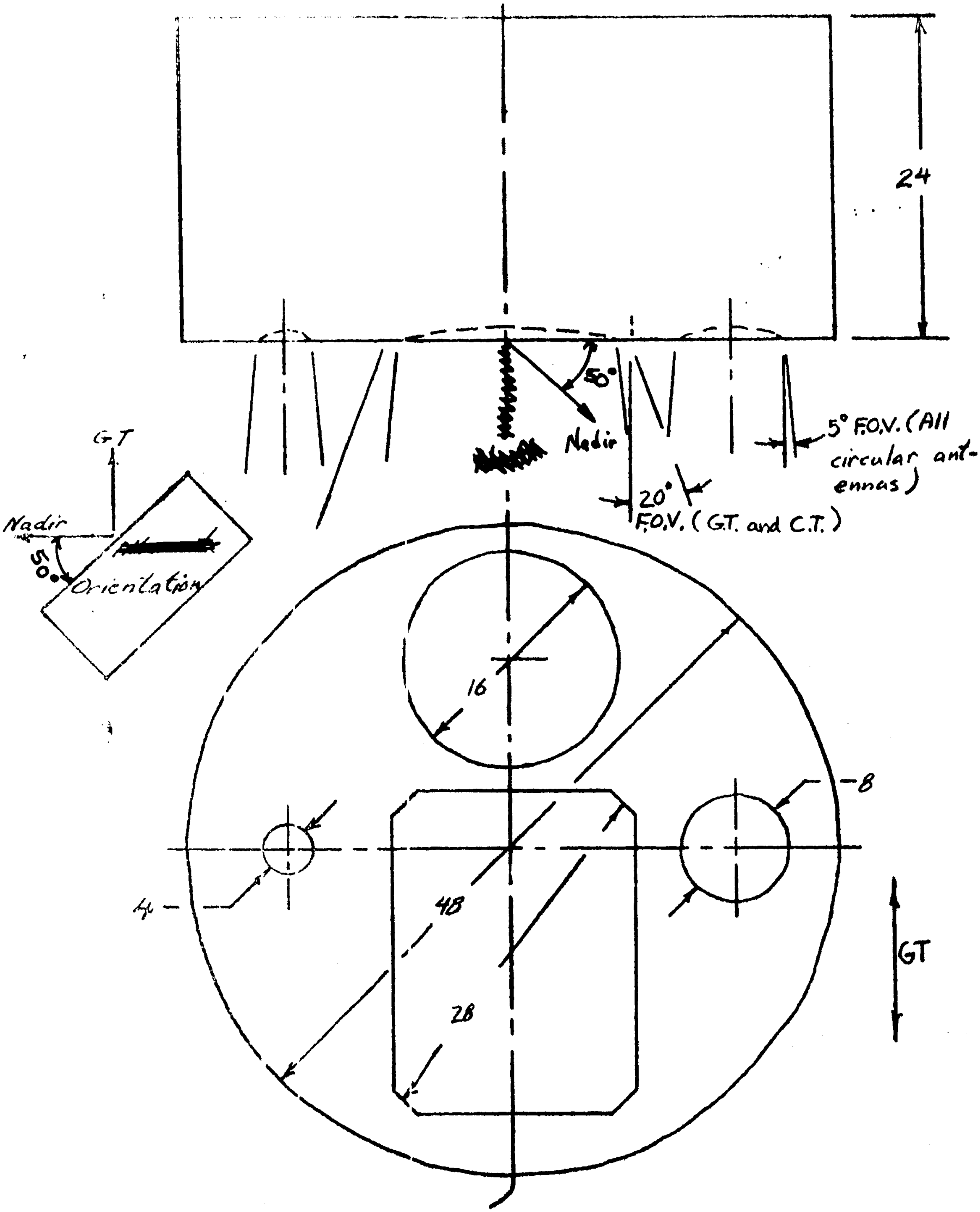
12. Status monitoring requirements between launch pad evacuation and launch (could be as much as 48 hours): Data line and housekeeping functions.

13. Experiment Shipment: Will reusable shipping container be supplied? YES Is there any problem associated with shipment of this experiment as an integral part of the carrier? NO

14. Special handling requirements during installation on carrier: None

15. Manufacturer's understanding of Acceptance Testing Requirements at his facility: EC to perform acceptance testing under MMC cognizance.

8/25/7



E06-11 MULTIFREQUENCY MICROWAVE RADIOMETER

9/1/7

A.127.01

Exp. No. E06-11

Title Multifrequency Microwave Radiometer

16. Manufacturer's recommendations for Receiving and Compliance Testing Requirements at integrator's facility: ----

17. Other GSE Requirements: None

8/25/7

A.128

EXPERIMENT NUMBER

D008

Title

Radiation Measurement

MSC Contact	Capt. Donahue	AFSFO	483-3542
PI	Lt. Joseph F. Janni	Air Force Weapons Lab Kirtland Air Force Base	
Contractor	AVCO (Active Unit)	Kirtland Air Force Base Tulsa	
GSE Contact			
MMC Analyst			
Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently Available			

8/25/7
A. 129

Exp No. D008

Title: Radiation Measurement

I. Functional Description

This experiment contains two types of sensors; one to measure radiation dose rate, and one to measure total dosage.

The experiment consists of one active dosimeter (dose rate) on a 6½ foot flexible cord, and five passive dosimeters (total dose).

Measurement of dosage rates (crew participation required) during passage through SAA is required for a minimum of three passes (six passes desired) and also three passes outside the anomaly. Based on three passes through SAA, experiment/crewtime is approximately 36 minutes, and based on three passes outside anomaly, experiment/crewtime is approximately 48 minutes.

The active unit requires power for the entire mission (liftoff through splashdown) and two channels of high level (0-5V) telemetry. The five passive units must be recovered.

The experiment will be located in the CM for boost, operation and reentry. Installation interface, power and TM requirements will be provided from the CM.

8/25/7

A, 130

Exp. No. D008[redacted]

Title: Radition Measurement

II. Physical Parameters (Ref. Dwg MH01-12075-136 Active Dosimeter
MH01-12078-136 Passive Dosimeter)

	Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent	Dimensions Return
1.	Active Dosimeter	2.5	2.5	102	102	4 x 8 x 3.18	
2.	Passive Dosimeter	0.5(ea)	0.5(ea)	13½(ea)	13½(ea)	6 x 1.5 x 1.5 (ea)	
3.							
4.							

F.O.V.	Aperture	Window Matl	Min/max between Components	C. G.
N/A			One passive dosimeter to be mtd in close proximity to active unit (no max/min given)	

Boost Orientation Constraints

N/A

Flight Orientation Constraints

Active dosimeter to be moved around crew and cabin in accordance with outline in D008[redacted] D.E.P.

Connector Type and Locations

1-Deutsch ME 414-0304-0005 part of active dosimeter

2-Deutsch ME414-0303-0002 mates with connector above

Mounting Provisions

Active dosimeter and passive dosimeters to be mounted in CM if possible. Requires M&R Contract. Modified operation permitting mtg in carrier not considered in best interest of experiment objectives.

Removal Envelope of Data Cassette

N/A

8/25/7
A.131

Exp No. D008

Title: Radiation Measurement

III. (a) Power Requirements

	Component	Power (watts) Standby	Power (watts) Operate	Peak	Voltage Nominal	Voltage Tolerance
1	Active Dosimeter	0.25	0.25		27.5 VDC	± 2.5
2						
3						
4						

Power Profile

Noise & Ripple Tolerance

Transient Tolerance

Feedback to Buss (0.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref DWG MH01-12076-116

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A,132

Exp No. D008

Title: Radiation Measurement

III. (b) Thermal Control

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1	Active Dosimeter	110°F Max	110°F Max		
2	Passive Dosimeters				

Heat Source	Critical Control Points
Insignificant	

Environment

	Component	Press Req. Stowed ✓	Press Req. Operate ✓	Type Atmosphere	Press Interfaces
1	Active Dosimeters	Press.	Pref.	Compatible with 100% O_2	None
2	Passive Dosimeters	Press.	Pref.	"	

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Exp. No. D008

Title: Radiation Measurement

IV. Crew Requirements

Crew Task / **Crew Timeline**

1 Perform measurements during pass thru SAA

2 Perform measurements during pass outside SAA

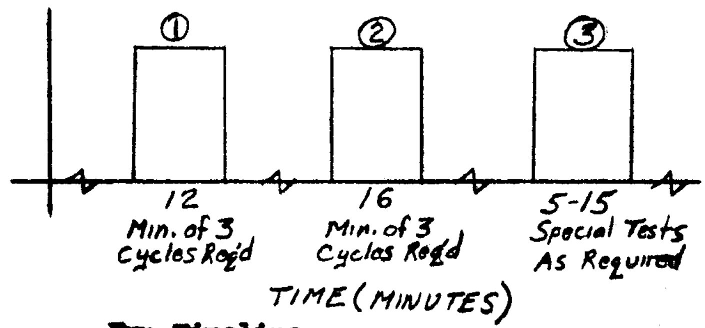
3 Perform special measurements

4

5

6

7



Exp Function / **Exp Timeline**

1 Perform radiation measurements

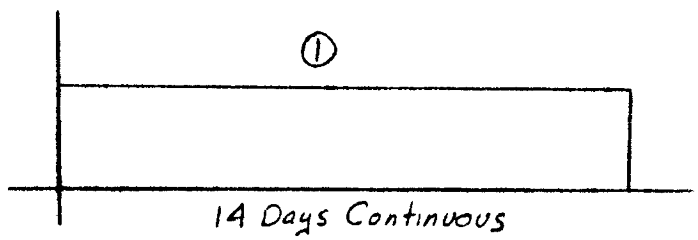
2

3

4

5

6



No. Performances	Total Operate Time: M Hr	Exp Hr	Operation Constraints, Target Light, dark, sun angle, etc.
3 passes (min) - SAA	0.6	Cont.-14 day	Do not allow radiation sources in close proximity to dosimeters
3 passes (min) - outside SAA	0.8	[redacted]	
Special tests	~ 1.0		
Quantity unknown			

Controls	Displays
Self Contained	

8/25/7

A,134

Exp No. D008

Title: Radiation Measurement

V. (a) Alignment

	Component	To Carrier	To Other Expt. (Specify)	Alignment Mechanism
1	N/A			
2				
3				
4				

V. (b) Pointing and Stabilization

Types	~~Accuracy~~ Limit Cycle Amplitude	Hold Time	Max Permissible Rates
N/A			

Maneuver Requirement

Calibrate	Target Track

8/25/7

A.135

Exp No. D008

Title: Radiation Measurement

VI. Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/ Bit Rate
*Expt	2	0-5V	1 sps	
H.K.	(See Remarks)			

* Note: Data should use BCD or floating binary format

Remarks Housekeeping Data:

1 Crew Log

2 Ephemeris Data (time correlated)

a) latitude, longitude
b) altitude

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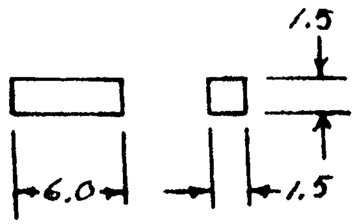
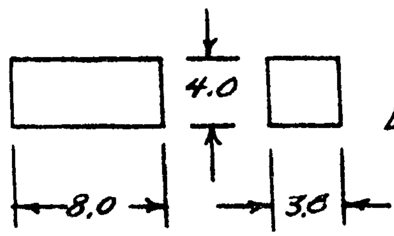
4,136



PASSIVE
DOSIMETER
(5 Required)



ACTIVE
DOSIMETER
(1 Required)

D008 RADIATION

9/1/7

A.136.01

EXPERIMENT NUMBER

D009

TITLE

SIMPLE NAVIGATION

Contact	Name	Address	Telephone
MSC PI	Capt. John Donohue Capt. Terry R. Morris Capt. Anthony E. Barth	USAF at NASA/MSC AF Avionics Lab Wright Patterson AFB, Ohio	HU 3-3542
Contractor	Kollsman Instr. Corp.	Elmhurst, N. Y.	
GSE			
MSC Analyst			

Hardware Status	Delivery of: [redacted]	Integration ~~Qual~~ Unit	Flight Unit
Presently available			

8/25/7

A.137

Title: Simple Navigation

I Functional Description

The equipment provided for this experiment will permit onboard measurements of celestial sightings (via a sextant), and optical ranging measurements (via a stadimeter).

The experiment will involve the following measurement sequences:

Night/Sextant - 1 run of 6 readings - 27 minutes

Day/Stadimeter - 3 runs of 9 sightings - 40 minutes

Night stadimeter - 2 runs of 9 sightings - 25 minutes

Night/Sextant/Stadimeter - 3 runs of 4 sightings - 30 minutes

Total crew time less than 10 hours

The instruments will be hand held, and viewings will be made from the CM right hand viewing window. A second astronaut is required to log data results and housekeeping data.

The G&N system will be used for pointing the spacecraft in the general vicinity of stars desired for sighting, and the manual control will be used for fine pointing and hold during observation sequences.

The equipment (including accessories such as flight log, charts and graphs) will be stowed in the carrier for boost, operated in the CM and returned to the carrier prior to re-entry maneuvers.

Since it is not planned to return the stadimeter or sextant, the flight log of all sighting and computations must remain in the CM.

An estimate of 21 lbs of RCS is given for performance of these sightings.

8/25/7

A.138

Experiment No. D009

Title: Simple Navigation

II Physical Parameters (Ref *AF Operating Manual-3/65*)

Component	Weight Ascent	Weight Return	Volume (in^3)* Ascent	Volume (in^3)* Return	Dimensions Ascent
1. Sextant	5.8 [redacted]	0	216	0	6 11/16 x 5 27/37 x 5 9/16
2. Stadimeter	4.4 [redacted]	0	235	0	7 3/8 x 6 3/8 x 5 1/16
3. Accessories	0.8 [redacted]	0.8 [redacted]	42 [redacted]	42 [redacted]	7x6x1 [redacted]

*NOTE: Only the flight log must be returned.

F.O.V.	Aperture	Window Matl	Min/Max between Components	C. G.
14° with a [redacted] 74° range	-	High Quality Optical	N/A	

Boost Orientation Constraints	Flight Orientation Constraints
N/A	N/A

Connector Type and Locations

N/A

Mounting Provisions

Instruments are hand held during operation.
Requires special stowage container in the carrier for ascent.
Requires temporary mounting provision in CM between sighting sequences.

Removal Envelope of Data Cassette

N/A

8/25/7
A,139

Experiment No. D009

Title: Simple Navigation

III(a) Power Requirements

	Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1.	(Self Contained Batteries)					
2.	Nickel Cad, Part No. (Kollsman) 10409900050					
3.						
4.						

Power Profile

N/A

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (0.1 ohm)

Electromagnetic Interference (EMI): Ref MSC Qual Test

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg ____________________

8/25/7

4.140

Experiment No. D009

Title: Simple Navigation

III(b) Thermal Control N/A

	Component	Temp Range Operate	Temp Range Survive	Temp Stability	Temp Gradients
1.					
2.					TBD
3.					
4.					

Heat Source	Critical Control Points

Environment

	Component	Press Req Stowed	Press Req Operate	Type Atmosphere	Press Interfaces
1.	Sextant	Press -	Pref	100% O_2 compatible	None
2.	Stadimeter	Press -	Pref	//	
3.	Accessories	Press -	Pref	//	
4.					

8/25/7

A.141

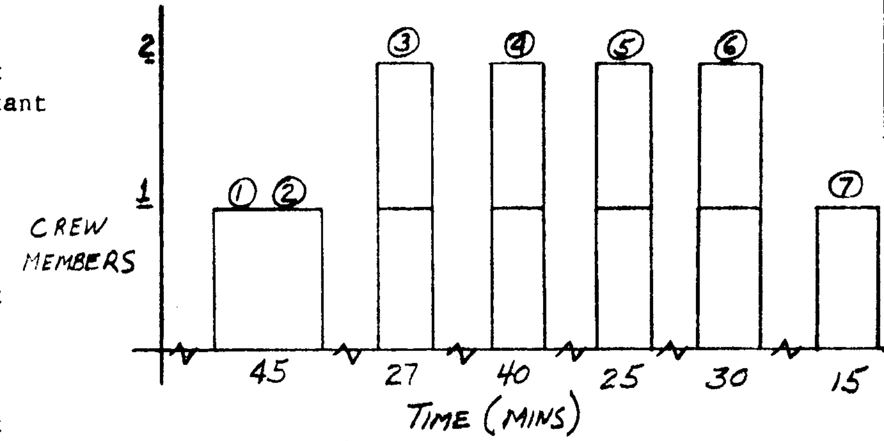
Experiment No. D009

Title: Simple Navigation

IV Crew Requirements

Crew Task	Crew Timeline

1. Remove from stowage
2. Perform equipment checkout
3. Sequence #1 and log 1 night pass - 6 readings (ea) sextant
4. Sequence #2 and log 3 day passes - 9 readings (ea) stadimeter
5. Sequence #3 and log 2 night passes - 9 9 readings (ea) stadimeter
6. Sequence #4 and log 3 night passes - 4 readings (ea) sextant and stadimeter
7. Return experiment to carrier



Exp Function	Exp Timeline

1.

2. Experiment function/timeline is identical to crew timeline shown above.

3.

4.

5.

6.

[redacted] Sequence	No. Performaces	Time/ Perf	Total M Hr	Operate Time Crew Members	Operation Constraints, Target Light, Dark, Sun Angle, etc.
1	1	27	27 x 2	(MINUTES)	Day and night sightings.
2	3	40	120 x 2	"	Night sighting require
3	2	25	50 x 2	"	cabin lights dimmed
4	3	30	90 x 2	"	

Controls	Displays

- Self Contained -

8/25/7

A.142

Title: Simple Navigation

V(a) Alignment N/A

	Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1.				
	Manually Controlled			
2.				
3.				
4.				

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
Course Mode	$\pm 5^{\circ}$	Ref timeline	[redacted]
[redacted]			[redacted]
[redacted]	Allowable Deadband		1.0°/sec. Allowable
Star Acquisition			

Maneuver Requirement

Calibrate Target Track

7/1/7

8/25/7

A.143

Experiment No. D009

Title: Simple Navigation

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	None			
H.K.	(See remarks)			

Remarks

Housekeeping Data

1. S/C position in geocentric latitude and longitude
2. Attitude (above earths surface)
3. Acceleration parameters
4. Orbital parameters (inclination, perigoe, etc.)
5. Voice Recording
6. Flight log

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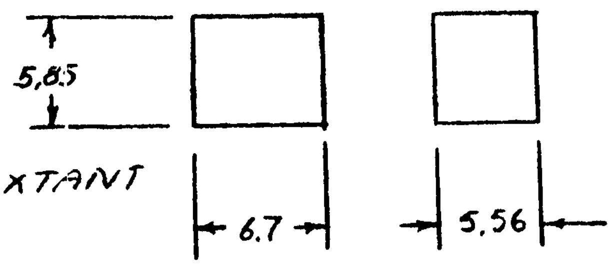
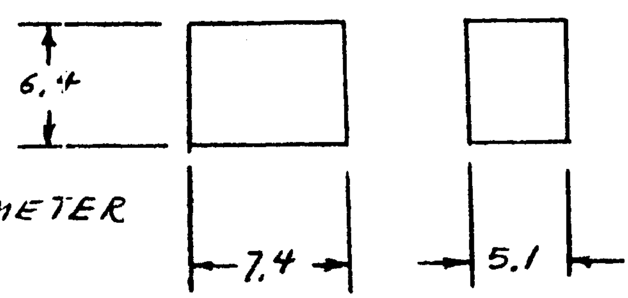
A, 144

SEXTANT



STADIMETER



DC09 SIMPLE NAVIGATION

9/1/7

A.144.01

EXPERIMENT NUMBER

S016

TITLE

TRAPPED PARTICLE ASYMMETRY

MSC Contact	Steve Mansor	MSC - Houston	483-5046
PI	Dr. H. H. Heckman	Lawrence Rad. Lab	415/843-2740
Contractor	Space Sciences Lab	Univ. of California	
GSE Contract			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently Available			

8/25/7
A. 145

Exp. No. S016

Title: Trapped Particle Asymmetry

I Functional Description

The experiment hardware consists of a nuclear emulsion package and a background emulsion cube. The objective is to study the properties of the proton component of the geomagnetically trapped radiation in the South Atlantic anomaly.

A background emulsion cube remains in the stowage container and is used as a measure of background radiation during flight.

The main emulsion package is designed to mate with the airlock extension rod to be deployed through the airlock.

Since the ratio of desired radiation measurements to background radiation is low for the proposed 140 n. m. orbit, long periods of exposure (estimate 10 days continuous minimum) are required.

In order to establish the pitch-angle distribution of these trapped particles, the orientation of the emulsion with respect to the magnetic field of the anomaly is very important. An earth vertical orientation of the spacecraft coupled with a programmed roll maneuver will satisfy experiment objectives.

A hardware change to the main emulsion stack will probably be required. This will consist of modifying experiment mounting plate or internally reorienting emulsion elements in order to obtain an angle of approximately 45° to the A/L extension rod.

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A.146

Exp. No. S016

Title: Trapped Particle Asymmetry

II Physical Parameters (Ref Dwg # A2 (Space Science Lab))

	Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent ✓	Dimensions Return ✓
1	Main Nuclear Pkg	8	8	68	[redacted] 68	5" dia x 3 1/2	
2	Background Nuclear Stack	.25	.25	1	[redacted] 1	1" x 1" x 1"	

Note: Size and Weight does not include stowage provisions.

F.O.V.	Aperture	Window Mat'l	Min/Max between Components	C.G.
180° x 180°				

Boost Orientation Constraints

N/A

Flight Orientation Constraints

1. [redacted]
2. Minimize obstructions within F.O.V.

For boost and re-entry stowage, orient main emulsion stack so that primary G-loads are normal to experiment axis.

Connector Type and Locations

N/A

Mounting Provisions

Mounts to telescoping rod to be extended thru A/L

Removal Envelope of Data Cassette

N/A

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8/25/7
4,147

Exp. No. S016

Title: Trapped Particle Asymmetry

III(a) Power Requirements

Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance

No power required

Power Profile

N/A

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Base (0.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg ____________________

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A, 148

Exp. No. S016

Title: Trapped Particle Asymmetry

III(b) Thermal Control

	Component	Temp Range Operate	Survive	Temp Stability	Temp Gradients
1	Main Nuclear Stack	$< 140°F$	$< 140°F$		
2	Background Nuclear Stack	"	"		
		No minimum temp reqt's			

Heat Source	Critical Control Points
None	

Environment

	Component	Press Req Stowed	Operate	Type Atmosphere	Press Interfaces
1	Main Nuclear Stack	Press Pref.	Unpress Reqd	Vacuum	Telescoping Rod (Part of A/L) and
2	Background Stack	"	Press. Pref.	Compatible with 100° O_2	A/L cannister 'O' ring seal

8/25/7

A. 149

Exp. No. S016

Title: Trapped Particle Asymmetry

IV Crew Requirements

Crew Task

1 Prepare A/L (Carrier)

2 Remove Exp. From Stowage (Carrier)

3 Place Exp. in cannister and attach telescoping rod

4 Attach cannister to A/L

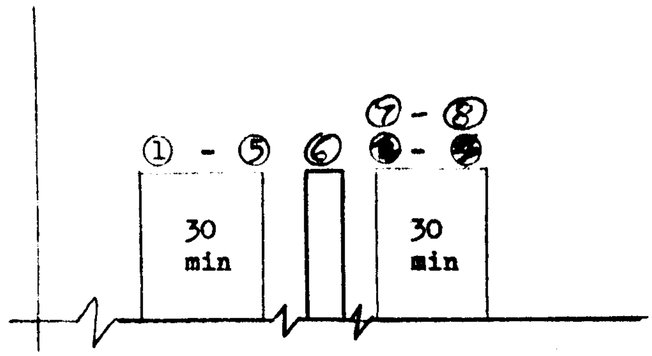
5 Operate A/L and extend package

6. *Perform Programmed Maneuvers*

7 Reverse procedures 3, 4 and 5

8 Stow main emulsion and B.G. emulsion in CM

Crew Timeline



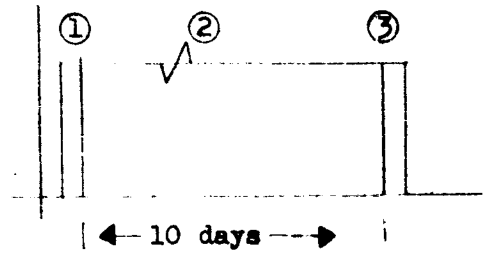
Exp Function

1 Deploy Experiment

2 Expose Experiment

3 Retrieve Experiment and Stow

Exp Timeline



No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr
1	* 1 hour	240 (min.) *HRS*

** Note: If a manual roll maneuver is req'd. for orienting the emulsion during passes thru SAA, approximately 7 additional hours of crew time will be required.*

Operation Constraints, Target Light, dark, sun angle, etc.

1 Emulsion must not be exposed to radiation sources other than those it is designed to measure (SAA)

2 80% (min) of all passes thru SAA must [redacted] *satisfy experiment pointing & stabilization requirements.*

Controls	Displays
None	Required

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A, 150

Exp. No. S016

Title: Trapped Particle Asymmetry

V(a) Alignment N/A

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude	Hold time	Max Permissible Rates
Earth Vertical with programmed roll maneuver	Within cycle limits of G&N in fine mode hold	5-15 min per pass of SAA	G & N deadband cycle limits
Maintain passage normal to magnetic field ±2°	[redacted]	Approx. 60 passes of SAA to be programmed.	

Note: A computer program subroutine or a programed manual operation will be required to satisfy pointing requirements. Pointing will consist of holding earth vertical and performing a programmed roll maneuver. Roll rates will be of the order of 2 to 3 degrees per minute.

Maneuver Requirement

Calibrate Target Track

9/1/7
8/25/7
·A.151

Exp. No. S016

Title: Trapped Particle Asymmetry

VI Data Requirements

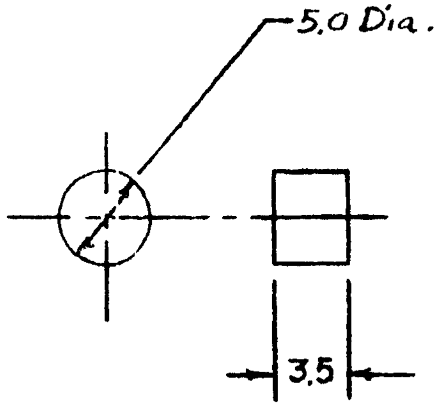
Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	None			
H.K.	See Remarks			

Remarks

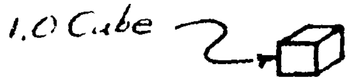
Housekeeping Data

1. Crew Logbook
2. Voice Recording of pertinent astronaut observations during experiment exposure period

8/25/7



PRIMARY EXPERIMENT PACKAGE



BACKGROUND EMULSION STACK

S016 TRAPPED PARTICLE ASYMMETRY

9/1/7

A.152.01

EXPERIMENT NUMBER

S018

TITLE

MICROMETEORITE COLLECTION

Contact	Name	Address	Telephone
MSC	Steve Mansur	MSC - Houston	483-5046
PI	Dr. C.L. Hemenway	Dudley Observatory	
Contractor	Dudley Observatory		
GSE			
MMC Analyst			

Hardware Status	Delivery of:	[redacted]	Integration [redacted] Unit	Flight Unit
Currently available				

8/25/7
A.153

Experiment No. S018

Title: Micrometeorite Collection

I Functional Description

The experiment has two purposes

1. To collect small micrometeorites and to measure directly fluxes of larger micrometeorite particles at satellite altitudes.

2. Carry out biological exposure and collection experiments.

The collection device consists of a series of resting rectangular boxes of three sections. The device is deployed by using an extension rod to telescope the rectangular boxes outward through the carrier scientific airlock.

The experiment will be stowed in the carrier for ascent, operated from the carrier scientific airlock, and stowed in the CM prior to re-entry. If possible, this experiment should be operated in the carrier [redacted] scientific airlock such [redacted] that any RCS activity will not contaminate collection surfaces. (with forward thrusters disabled). The [redacted] airlock must [redacted] also permit a free unobstructed view as required for this experiment.

A minimum of 8 hours exposure is required, however more time is highly desireable - up to 40 hours. Multiple exposures are acceptable but should be minimized. Experiment exposure during crew sleep cycle appears to be a satisfactory method of accomplishing objective. Exposure during periods of minimum experiment activity, such as during the day of rest, would also be satisfactory.

8/25/7

A.154

Experiment No. S018

Title: Micrometeorite Collection

II Physical Parameters (Ref Dwg AP-004 (Dudley Observatory Drawing)

	Component	Weight Ascent	Weight Return	Volume (in^3) Ascent	Volume (in^3) Return	Dimensions Ascent ✓	Dimensions Return ✓
1.	Collection Device	5.5	5.5	98.5	98.5	5 1/8 x 5 1/8 x 3 3/4	
2.							
3.							
4.							

F.O.V.	Aperture	Window Matl	Min/Max between Components	C. G.
180° x 180°	-	-		

Boost Orientation Constraints	Flight Orientation Constraints
N/A	Requires extention through A/L. Tumbling mode desireable

Connector Type and Locations

N/A

Mounting Provisions

Device permits mounting to A/L telescoping rod.

Removal Envelope of Data Cassette

N/A

8/25/7

A.155

Experiment Number S018

Title: Micrometeorite Collection

III(a) Power Requirements N/A

	Power (watts)			Voltage	
Component	Standby	Operate	Peak	Nominal	Tolerance
1.					
2.					
3.					
4.					

This experiment requires no power.

Power Profile

N/A

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (o.1 ohm)

Electromagnetic Interference (EMI):

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg N/A

8/25/7
A.156

Experiment No. S018

Title: Micrometeorite Collection

III(b) Thermal Control

	Component	Temp Range Operate	Survive	Temp Stability	Temp Gradients
1.	Collection Device	40-85°F	40-85°F		
2.					
3.					
4.					

Heat Source	Critical Control Points
N/A	

Environment

	Component	Press Req Stowed	Operate	Type Atmosphere	Press Interfaces
1.	Collection Device	Press. Pref	Unpress. Req'd	Vacuum	At extension rod and 'O' ring seal on A/L Cannister

8/25/7

A.157

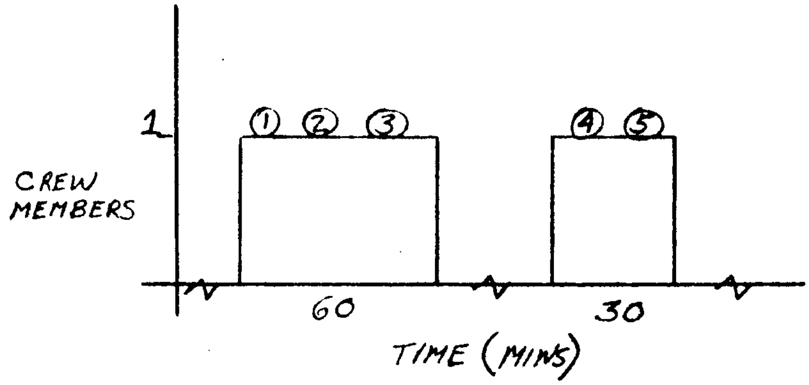
Experiment Number S018

Title: Micrometeorite Collection

IV Crew Requirements

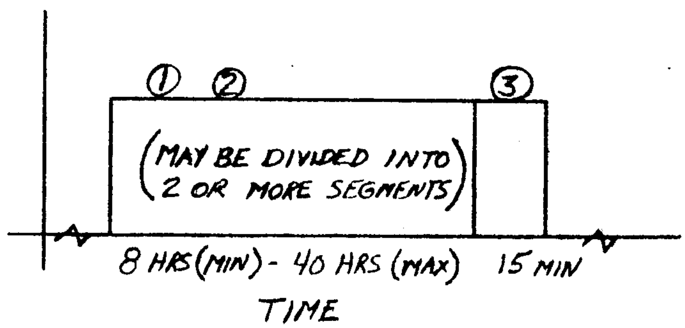
Crew Task	
1.	Unstow from Carrier
2.	Place in A/L
3.	Extend Exp with telescoping rod
4.	Retract experiment and stow in CM
5.	Record data
6.	
7.	

Crew Timeline



Exp Function	
1.	Extend experiment thru airlock
2.	Expose collection device
3.	Retract and stow
4.	
5.	
6.	

Exp Timeline



Task	No. Performances	Total Operate Time M Hr	Total Operate Time Exp Hr	Operation Constraints, Target Light, Dark, Sun Angle, etc.
1	1	45 min		1. No RCS or waste dump
2	1	10 min		2. Requires 180° x 180° FOV with min interference
3	1	5 min	8 hr to 40 hrs	[redacted]
4	1	15 min		
5	1			

Controls Displays

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A.158

Experiment No. S018

Title: Micrometeorite Collection

V(a) Alignment N/A

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism

1. Not required, however some exposure to deep space is required; a tumbling mode is desireable.
2.
3.
4.

V(b) Pointing and Stabilization N/A

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates

Maneuver Requirements

Calibrate	Target Track

8/25/7

Experiment No. S018

Title: Micrometeorite Collection

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	Self Contained			
H. K.	(See Remarks)			

Remarks

1. Housekeeping Data
   a) Crew logbook
   b) S/C attitude data

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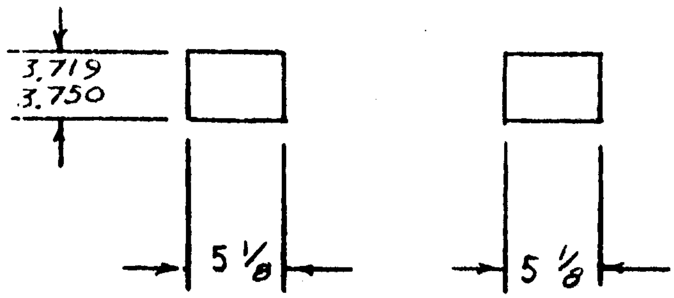
A.160



S018 MICROMETEORITE COLLECTION

9/1/7

A.160.01

EXPERIMENT NUMBER

T002

TITLE

MANUAL NAVIGATION SIGHTINGS

Contact	Name	Address	Telephone
MSC	Mark Lee	MSC	HU 3-5046
PI	D. W. Smith	Ames Research Center	
Contractor	Kollsman Inst. Corp.	Elmhurst, N.Y.	
GSE			
MMC Analyst			

Hardware Status	Delivery of: [redacted]	Integration [redacted] Unit	Flight Unit
Presently available			

8/25/7
A.161

Experiment No. T002

Title: Manual Navigation Sightings

I Functional Description

The primary purpose of this experiment is to investigate the theoretical aspects of navigation in which a navigator using a hand-held sextant can make angular measurements between celestial bodies with a standard deviation of 12 arc seconds or less from a vehicle rotating about all three axis at rates up to 1.5 degrees/second. Consideration of the results of these experiments will verify the feasibility for use of such techniques for midcourse navigation of vehicles on lunar and interplanetary missions.

The calibrated sextant used for these observations will be capable of measurement accuracy of ± 10 arc seconds. Sightings will be made on the dark side of the orbit to alleviate problems encountered with light scattering on the spacecraft viewing window. The sextant requires an event timer cord to initiate a time "hack" reference to 0.2 seconds. Measurements at time of observation include cabin pressure and temperature in the vicinity of the viewing window (thermometer provided with experiment).

Calibration of the viewing window is required after installation. The right hand viewing window in the CM is recommended. Some real-time voice communications will be required.

A total of 56 observation periods (20-30 min. each) of 15 sightings are desired, however preliminary evaluation of time constraints indicate that only one complete work period of 8 to 10 passes can be devoted to this experiment.

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A.162

Experiment No. T002

Title: Manual Navigation Sightings

	Component	Weight Ascent	Weight Return	Volume (in³) Ascent	Volume (in³) Return	Dimensions Ascent [redacted]	Dimensions Return
1	Sextant	[redacted] 6.5	[redacted] 6.5	395	[redacted] 395	8.28x6.28x7.59 [redacted]	[redacted] Same
2	Accessories	[redacted] 0.8	[redacted] 0.8	42 [redacted]	42 [redacted]	7x6x1 [redacted]	[redacted] Same
3							
4							

NOTE: [redacted]
Vol's and weights do not include stowage provisions.

F.O.V.	Aperture	Window Matl	Min/Max between Components	C. G.
25° with a range of 70°	-	Special High Quality, calibrated (assume right hand CM view window)	N/A	

Boost Orientation Constraints	Flight Orientation Constraints
N/A	As required (hand held)

Connector Type and Locations

Kollsman Inst. Corp.
Connector No. 48415800030

Located on upper left hand side of instrument

Mounting Provisions

N/A Hand held for operation

Stowage Provisions TBD (Sextant has slide bracket on base)

Removal Envelope of Data Cassette

N/A

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A.163

Experiment No. T002

Title: Manual Navigation Sightings

III(a) Power Requirements

	Component	Power (watts) Standby	Operate	Peak	Voltage Nominal	Tolerance
1.	Sextant	-Self Contained -			2.5 v	
2.	Accessories	N/A			N/A	
3.						
4.						

NOTE: Requires replacement batteries if exp. exceeds 7-9 hours Kollsman Instr. Corp. Part No. 10415800130 Battery, Nickel Cadmium, 2.5v

Power Profile

N/A

Noise & Ripple Tolerance	Transient Tolerance	Feedback to Buss (0.1 ohm)
N/A		

Electromagnetic Interference (EMI): Ref MSC Qual Test

Requirements

Tests Run by Manufacturer

Wiring Diagram - Ref Dwg 80415800010 - Kollsman Instr. Corp.

8/25/7

Experiment Number T002

Title: Manual Navigation Sightings

III(b) Thermal Control

	Component	Temp Range Operate	Survive	Temp Stability	Temp Gradients
1.	Sextant	TBD			
2.	Accessories				
3.					
4.					

Heat Source	Critical Control Points
N/A	

Environment

	Component	Press Req Stowed	Operate	Type Atmosphere	Press Interfaces
1.	Sextant	Press.	Pref	Compatible with 100% 0^2	None
2.	Accessories	Press.	Pref		
3.					
4.					

8/25/7

9.165

Experiment No. T002

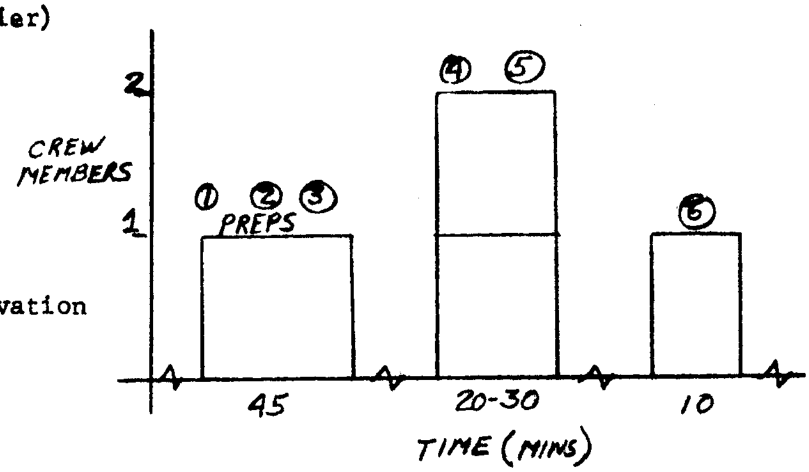
Title: Manual Navigation Sightings

IV Crew Requirements

Crew Task

1. Remove exp from stowage (assume stowage in carrier)
2. Perform operational CK.
3. Attach Event timer cord
4. Orient S/C
5. Take sightings and log (15 sightings per observation period)
6. Stow exp logbook and [redacted] Sextant [redacted] in CM
7.

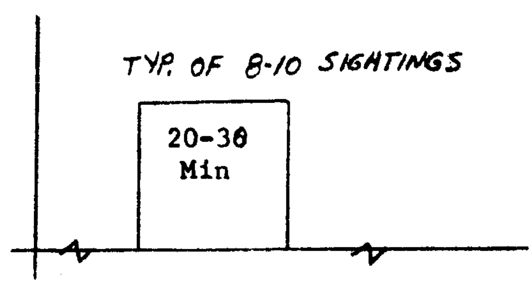
Crew Timeline



Exp Function

1.
2.
3. (same as crew requirements)
4.
5.
6.

Exp Timeline



No. Performances	Total Operate Time M Hr	Exp Hr.	Operation Constraints, Target Light, Dark, Sun Angle, etc.
8-10	Man #1-[redacted] hrs 6 Man #2-[redacted] hrs 5		1. Dark side of orbit 2. Cabin lights turned down to low level

Controls **Displays**

Self Contained

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Experiment No. 1002

Title: Manual Navigation Sightings

V(a) Alightnment N/A

Component	To Carrier	To Other Expt (Specify)	Alignment Mechanism
1.			
2.			
3.			
4.			

V(b) Pointing and Stabilization

Types	Limit Cycle Amplitude	Hold Time	Max Permissible Rates
[redacted] [redacted]	± 0.5° (fine mode) or	20-30 Min	± 0.25°/sec
Course Mode Acquisition Of Desired Stars	± 5.0° (Course mode) as required	20-30 Min	± 0.25°/sec

NOTE: Hold time 20-30 Min for each period (8-10 required)

Maneuver Requirement

Calibrate Target Track

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Experiment No. 1002

Title: Manual Navigation Sightings

VI Data Requirements

Function	No. Channels	Format	Sample Rate	Freq Response/Bit Rate
Expt	1	0-5 vdc	5 sps (min)	Resolution required to ± 0.2 sec for "time hack"
H. K.	(See Remarks)			

Remarks

H. K. Data

1. Cabin Temp in vicinity of S/C window thermometer to be mounted near window manually read and recorded.
2. Cabin pressure
3. Crew Log (refer to DEP for details)
4. G&N Data
   a) S/C altitude (± 2500 ft.)
   b) Attitude (± 0.5 minute)
   c) Velocity
5. Voice Recording

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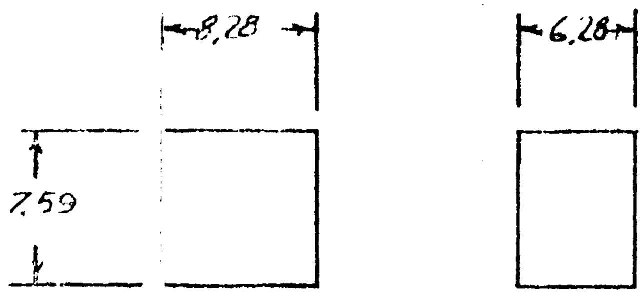
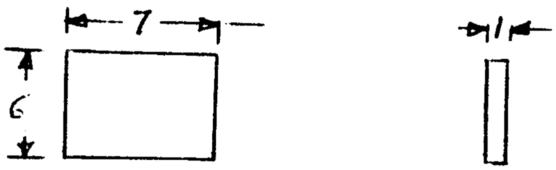


SEXTANT



ACCESSORIES

T002 MANUAL NAVIGATION SIGHTING

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A.168.01