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CAMERA SYSTEM TEST PLAN

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SYSTEM TEST PLAN

1.0 GENERAL

1.1 SCOPE

This test plan defines tests to be conducted on the camera system and its components. The interrelationships of camera tests and tests of other subsystems and system tests at higher levels of assembly, have been considered as in the planning of these camera tests. A summary of all camera system tests is given in Figs. 6, 7, and 8.

1.2 OBJECTIVES

Tests to be performed on the camera system and its components shall provide basic engineering data required for system design and shall demonstrate that performance of the system in the space environment meets established goals. These objectives imply early definition of parameters required for design, and timely verification of design assumptions which may require design changes. The interrelationships of test, analysis, and fabrication are diagrammed in Fig. 1.

1.3 ORGANIZATION OF TEST PROGRAM

Major groups within the camera contractor's organization having responsibility for the test program are diagrammed in Fig. 2. The functions of each group, that is, Camera System Engineering, Test Engineering, the Environmental Laboratory, and Quality Assurance, are as follows.

1.3.1 Camera System Engineering

a. Design flight system.

b. Determine overall requirements of test program.

c. Determine detailed performance goals.

d. Evaluate performance as measured in test against design criteria.

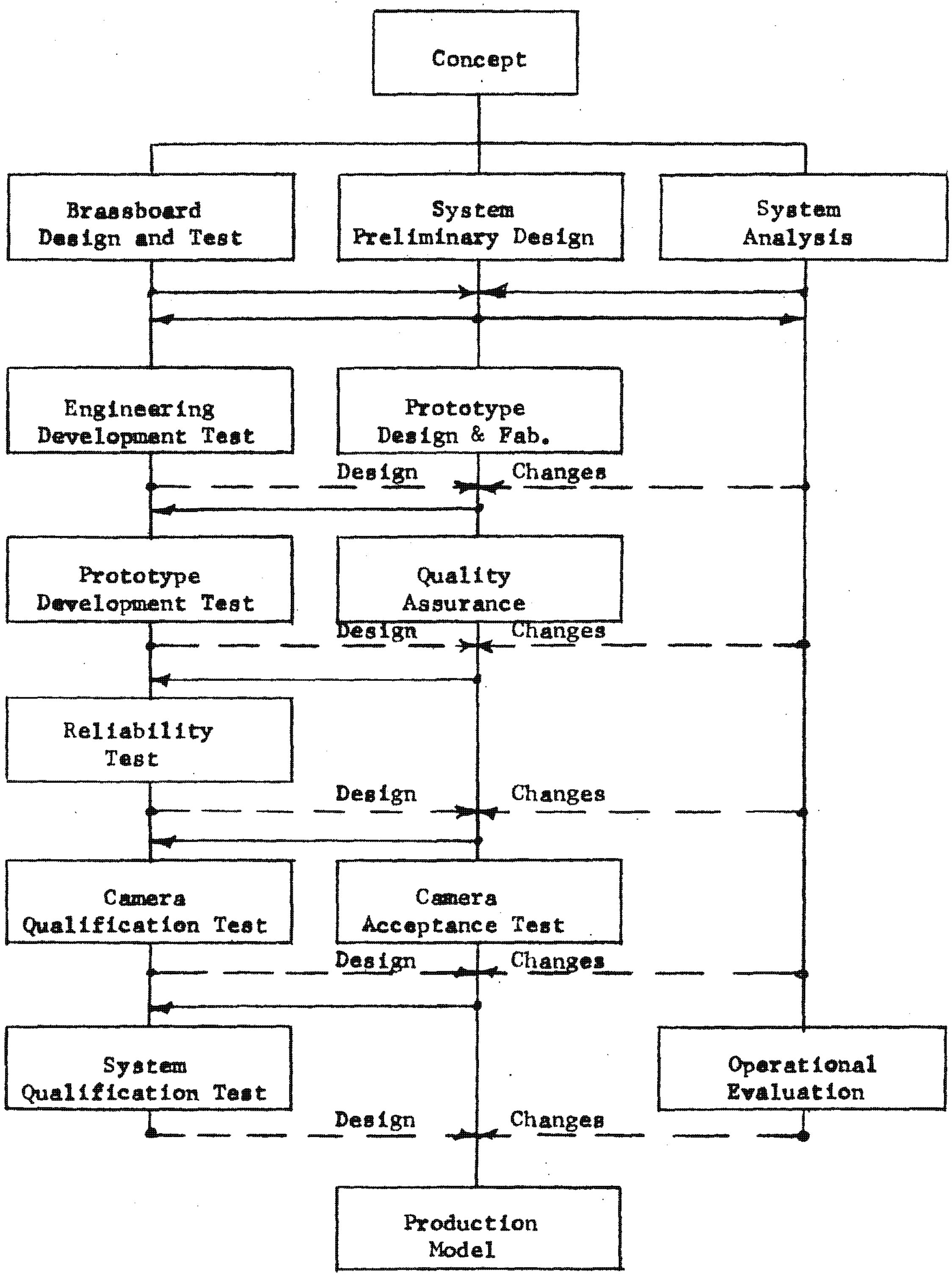

Figure 1. System Development Flow

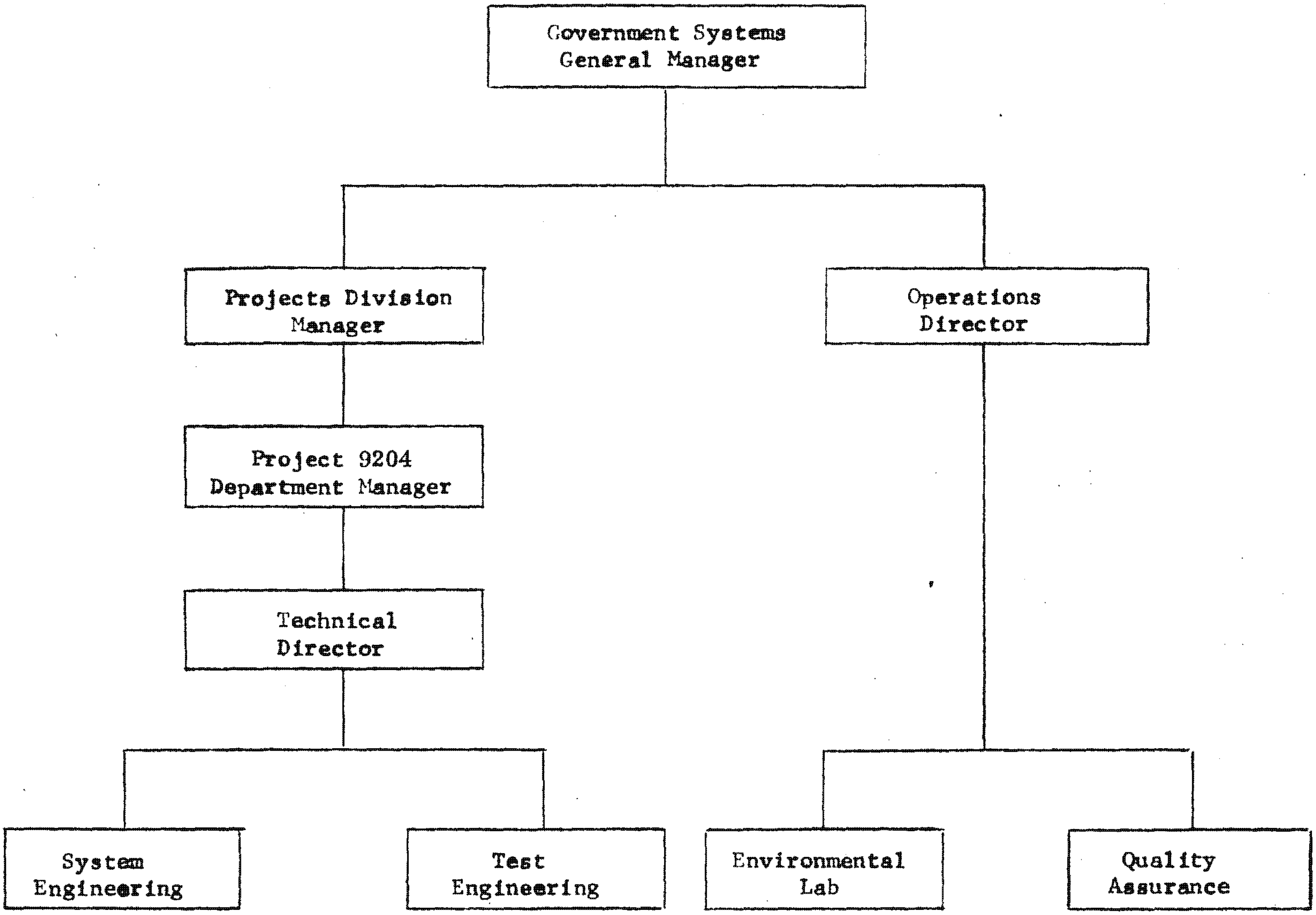

Figure 2. Test Program Organization

e. Approve test specifications and procedures.

f. Monitor all tests.

1.3.2 Test Engineering

a. Prepare test specifications and procedures.

b. Design and procure special test fixtures and instrumentation.

c. Gather and reduce data from tests.

d. Prepare test reports.

1.3.3 Environmental Laboratory

a. Provide facility and standard environmental test equipment.

b. Provide test technicians for mounting of test articles on test fixtures.

c. Responsible for all test operations in the environmental lab.

1.3.4 Quality Assurance

a. Provide inspection services for all incoming parts and subassemblies.

b. Provide inspection and authentication services at all qualification and acceptance tests.

c. Maintain laboratory calibration standards.

1.4 LEVELS OF ASSEMBLY

Major levels of system assembly are shown in Fig. 3. Subassemblies of the main camera are shown in further detail at Level V in Fig. 4. Important and meaningful tests can and should be conducted at each level of assembly below Level I for the following reasons:

a. To permit evaluation and correction of subsystem design problems or manufacturing deficiencies as early as possible in the program or in the assembly sequence;

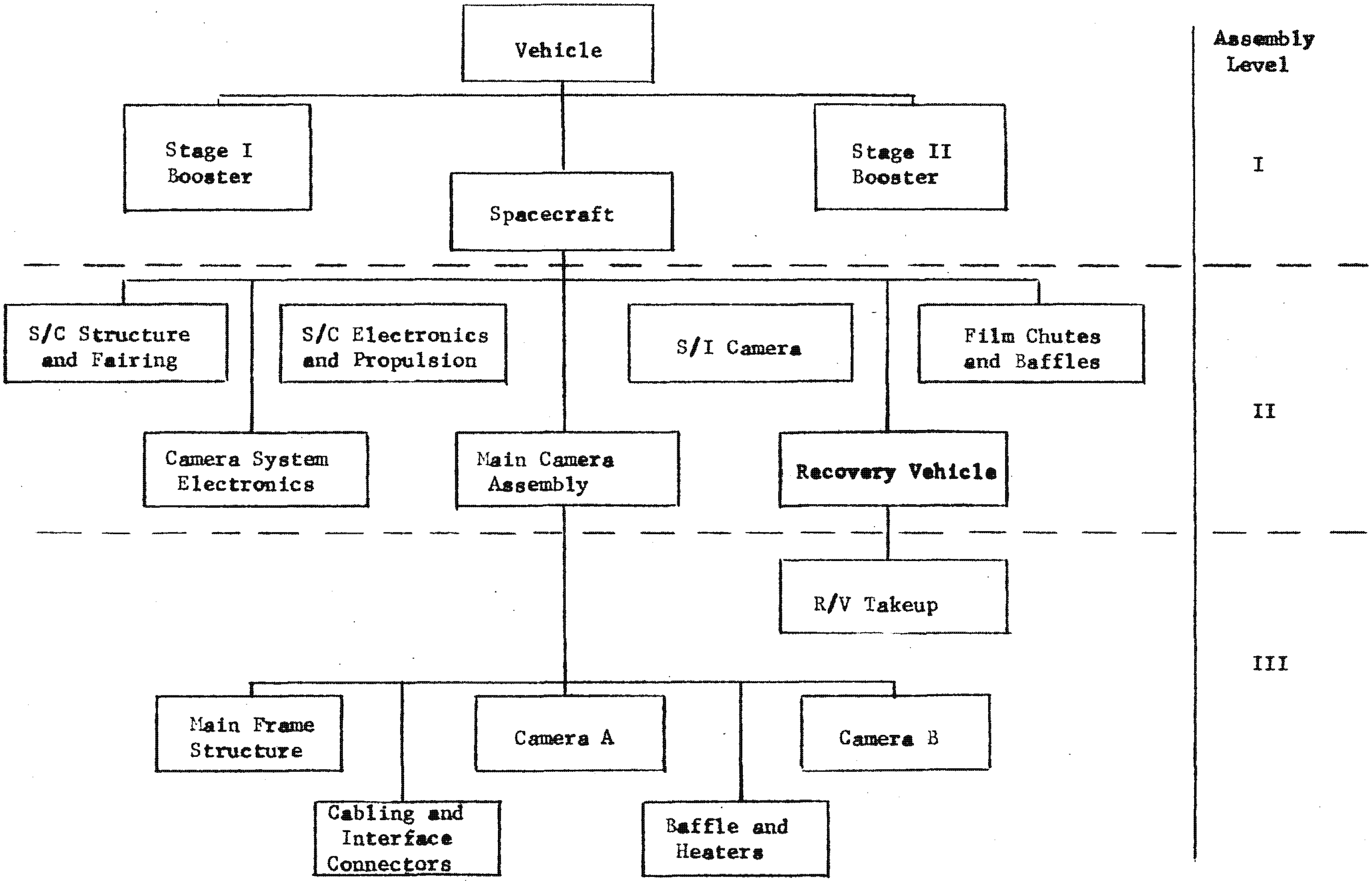

Figure 3. System Assembly Tree

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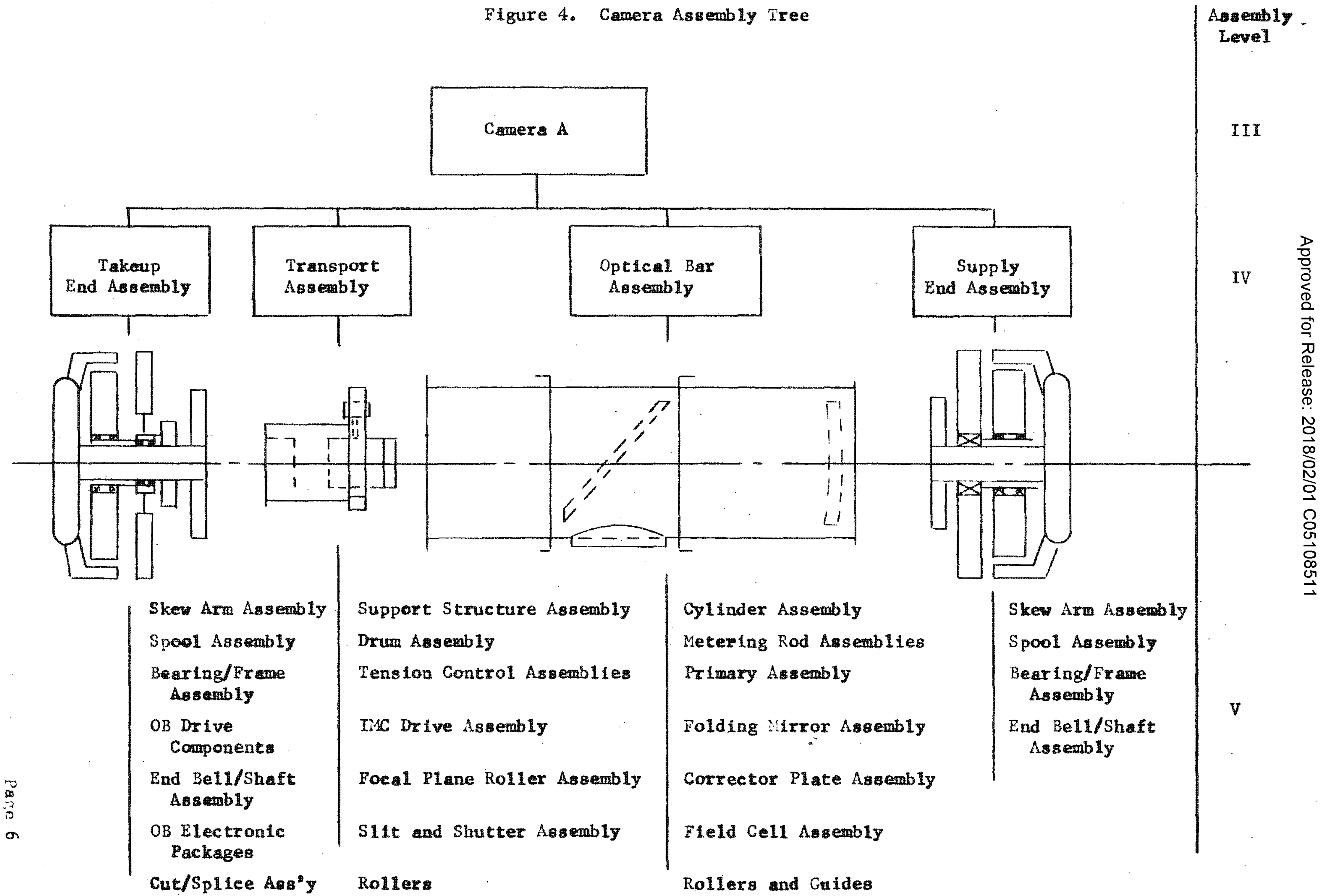
Figure 4. Camera Assembly Tree



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b. To isolate subsystem faults from those of other subsystems, permitting easier diagnosis and correction;

c. To allow parallel testing of subsystems which will tend to prevent temporary schedule delays in test of one subsystem from introducing major delays in the overall system test schedule; and

d. To provide logical test interfaces at the limits of each associate contractor's design responsibility, thus eliminating prolonged tests remote from any contractor's facility.

1.5 TYPES OF TEST

As shown in Fig. 1, development of the system comprises a flow of events leading from concept to production model. The types of test involved in this flow are defined below. Application of these tests at each level of assembly is diagrammed in Fig. 5.

1.5.1 Engineering Developmental Tests

Tests required to define parameters for design such as surface emissivities, joint damping or slip rates, film friction, etc. Later mockup tests serve to verify design assumptions of system interactions where analysis is impossible or impractical. This stage includes thermal mockups, electrical breadboards, and dynamic models.

1.5.2 Prototype Developmental Tests

Tests performed on actual prototype units, as trial assemblies; or to determine the fragility of components under environmental stress. More complex prototype assemblies will be tested when available to determine component responses where the validity of analysis or mockup simulation is questionable.

ASSEMBLY LEVEL	V										IV				III				II		
SUBSYSTEM	Skew Arm	Spool Ass'y	OB Bearing	OB Drive Components	Cut/Splice	Metering Drum	Cylinder Ass'y	Optical Elements	Thermal Components	Electrical Packages	Takeup End Ass'y	Transport Ass'y	Optical Bar Ass'y	Supply End Ass'y	Camera A	Camera B	Main Frame Structure	R/V Takeup	Main Camera Assembly	Camera Sys. Electronics	S/I Camera
ENGINEERING DEVELOPMENT	1						7	9	10	11									14		
PROTOTYPE DEVELOPMENT	2	4	4	2,5,6		4,6	8		5	6		5	12				8	5			
ELECTRICAL C/O	X	X		X	X	X				X	X	X		X	X	X		X	X	X	X
MECHANICAL C/O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OPTICAL C/O								X					X		X	X			X		X
QUAL. T/V										X		X	X		13			X	13	X	X
QUAL. VIBRATION/SHOCK	X	X		X	X	X	X	X				X	X		X			X		X	X
QUAL. RFI										X					X					X	X
QUAL. STATIC LOAD	3						X										X	X			
ACCEPTANCE T/V												X	X		13	13		X	13	X	X
ACCEPTANCE VIBRATION												X	X		X	X		X		X	X
ACCEPTANCE STATIC LOAD	3																				

CODE

1 PNEUMATIC BREADBOARD
2 COMPONENT FAILURE RATE
3 GAS BOTTLE PRESSURIZATION
[illegible] BEARING EVALUATION
5 TRIAL ASSEMBLY
6 VIBRATION FRAGILITY (COMPONENTS)
7 MATERIAL AND JOINT EVALUATION
8 VIBRATION SURVEY
9 FEASIBILITY DEMONSTRATION (UNDERWAY)
10 INSULATION AND COATING EVALUATION
11 ELECTRICAL BREADBOARD
12 OPTICAL ASSEMBLY THERMAL SENSITIVITY
13 DRT TESTS
14 THERMAL MOCKUP
C/O CHECKOUT
T/V THERMAL/VACUUM

Figure 5. System Test Summary

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1.5.3 Qualification Tests

Tests which demonstrate the ability of the system to meet performance goals during or after exposure to environmental stress greater than that expected in operational use. An overstress is commonly imposed to assure that marginal components would not fail under design conditions; and to accelerate fatigue failures. Qualification tests are performed on subassemblies to detect component weaknesses as early as possible in the system development.

1.5.4 Acceptance Tests

Tests which demonstrate a satisfactory level of workmanship and performance by subjecting production equipment to low-level environmental stress.

1.5.5 Reliability Tests

Tests intended to establish component or assembly failure rates where such data are not available from the manufacturer. A reliability group within the camera system design organization will monitor all tests for development of reliability data on each level of assembly.

1.5.6 Checkout Tests

Quality assurance checkout tests are performed on all components and assemblies to assure conformance with applicable drawings and specifications. These tests are not normally environmental, but include mechanical and electrical inspection; maintenance of calibration standards; and optical inspection. Quality assurance checks include electrical, mechanical, and optical baselines established before and after qualification and acceptance tests to determine performance degradation.

1.6 SYSTEM SIMULATION

So far as possible, real prototype hardware will be included in tests at each assembly level. To permit concurrent subsystem testing, however, accurate simulation of interacting subsystems will be required. Design of the test facilities will permit replacement of subsystem mockups by prototypes as soon as the latter are available.

FIG. 6 – SUMMARY
VIBRATION-SHOCK-LOAD TESTS

TEST ITEM	TEST TYPE	TEST PLAN SECT.	TEST NAME	PURPOSE	SPECIAL TEST EQUIPMENT	PARAMETE[RS]
ASSY LEVEL V						
GAS BOTTLES	Q/A	3.1, 5.4	BURST	ESTABLISH SAFE WORKING PRESSURE	BLAST ENCLOSURE (SUB CONTRACT)	PRESSURE
SKEW ARM ASSY	Q	3.1	VIBRATION	ESTABLISH ENDURANCE LEVELS	VIBR. FIXTURE & 15K SHAKER	INPUT & OUTPUT AC[CEL]
SPOOL ASSY	Q	3.2	"	" " "	" " " "	" "
OPT BAR ENCODER	D	3.4	FRAGILITY	" " "	" " 5K "	" "
SLIP RING	D	3.4	"	" " "	" " " "	" "
CUT & SPLICE ASSY	D	3.5	"	" " "	" " " "	" "
DRUM ENCODER	D	3.6	"	" " "	" " " "	" "
SLIT & SHUTTER ASSY	D	3.6	"	" " "	" " " "	" "
IMC ENCODER	D	3.6	"	" " "	" " " "	" "
METERING RODS	D	3.7	HYSTERESIS	ESTABLISH RESIDUAL STRAIN RATE	STATIC STAND & JACK	LOAD & STRAIN
CYLINDER MAT'LS & JOINTS	D	3.7	HYSTERESIS & SLIP	" " "	" " "	" "
OPT BAR CYLINDER	Q	3.7	STATIC LOAD	PROVE STRUCTURE DESIGN	STATIC STAND, DUMMIES & JACKS	RESIDUAL DECENTER & TI[LT]
OPT BAR CYLINDER	D/Q	3.7	VIBRATION	" " "	VIBR. FIXTURE, SLIPTABLE, & 30K SHAKER	MODE SHAPES, TRAN[SMISSIBILITY]
OPT ELM. ASSY'S (4)	D/Q	3.8	VIBR/SHOCK	ESTABLISH ENDURANCE LEVELS	VIBR FIXTURES & 15K SHAKER	INPUT & OUTPUT ACCE[L]
ELECTRONIC ASSY'S (18)	D	3.10	FRAGILITY	" " "	" " 5K "	" "
ASSY LEVEL IV						
TRANSPORT ASSY	Q/A	4.2	VIBRATION	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURES & 15K SHAKER	INPUT & OUTPUT AC[CEL]
OPT BAR ASSY	Q/A	4.3	"	" " "	VIBR. FIXTURE, SLIP TABLE, & 30K SHAKER	" "
SUPPLY SPOOL	Q	4.5	VIBR/STATIC	PROVE FILM DOES NOT SLIP ON SPOOL	VIBR FIXTURE, 15K SHAKER, CENTRIFUGE (SUBCONTR)	FILM SLIP, SCRATCH, ABRA[SION]
ASSY LEVEL III						
CAMERA ASSY	Q/A	5.1	VIBRATION	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURE, SLIPTABLE, 30K SHAKER	INPUT & OUTPUT ACCE[L]
MAIN FRAME	D	5.3	"	DETERMINE MODE SHAPES & TRANSMISSION	S/C MOCK UP, OPT BAR DUMMIES, 5K SHAKER	MODE SHAPES, TRAN[SMISSIBILITY]
MAIN FRAME	Q	5.3	STATIC LOAD	PROVE DESIGN	STATIC STAND, OPT BAR DUMMIES, JACKS	STRAINS, DEFLECTION
RV TAKE UP	Q/A	5.4	VIBRATION	PROVE DESIGN & WORKMANSHIP	FILM DUMMIES, VIBR FIXTURE, 30K SHAKER	INPUT & OUTPUT ACCE[L]
RV TAKE UP SPOOL	D	5.4	STATIC LOAD	ESTABLISH FILM SLIP LIMITS	CENTRIFUGE (SUBCONTR)	LOAD [illegible]
ASSY LEVEL II						
CAMERA ELECT. UNIT	Q/A	6.2	VIBRATON	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURE, 15K SHAKER	INPU[T] [illegible]
S/I CAMERA	Q/A	6.3	"	" " "	" " " "	" [illegible]

[redacted]

FIG. 6 - SUMMARY
VIBRATION-SHOCK-LOAD TESTS

TEST NAME	PURPOSE	SPECIAL TEST EQUIPMENT	PARAMETERS MEASURED	FORM OF
BURST	ESTABLISH SAFE WORKING PRESSURE	BLAST ENCLOSURE (SUB. CONTRACT)	PRESSURE	INSPECTION
VIBRATION	ESTABLISH ENDURANCE LEVELS	VIBR. FIXTURE & 15K SHAKER	INPUT & OUTPUT ACCELERATION	
"	" " "	" " " "	" " "	"
FRAGILITY	" " "	" " 5K "	" " "	DESIGN INF.
"	" " "	" " " "	" " "	" "
"	" " "	" " " "	" " "	" "
"	" " "	" " " "	" " "	" "
"	" " "	" " " "	" " "	" "
"	" " "	" " " "	" " "	"
HYSTERESIS	ESTABLISH RESIDUAL STRAIN RATE	STATIC STAND & JACK	LOAD & STRAIN	"
HYSTERESIS & SLIP	" " "	" "	" "	"
STATIC LOAD	PROVE STRUCTURE DESIGN	STATIC STAND, DUMMIES & JACKS	RESIDUAL DECENTER & TILT AT OPTICS	INSPECTION &
VIBRATION	" " "	VIBR. FIXTURE, SLIPTABLE, & 30K SHAKER	MODE SHAPES, TRANSMISSION, OPTICS TILT & DEFL.	DTR & INSPEC
VIBR/SHOCK	ESTABLISH ENDURANCE LEVELS	VIBR FIXTURES & 15K SHAKER	INPUT & OUTPUT ACCELERATION	" "
FRAGILITY	" " "	" " 5K "	" " "	DESIGN I
VIBRATION	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURES & 15K SHAKER	INPUT & OUTPUT ACCELERATION	INSPECTION &
"	" " "	VIBR. FIXTURE, SLIP TABLE, & 30K SHAKER	" " "	"
VIBR/STATIC	PROVE FILM DOES NOT SLIP ON SPOOL	VIBR FIXTURE, 15K SHAKER, CENTRIFUGE (SUBCONTR)	FILM SLIP, SCRATCH, ABRASION, LOAD	"
VIBRATION	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURE, SLIPTABLE, 30K SHAKER	INPUT & OUTPUT ACCELERATION	INSPECTION &
"	DETERMINE MODE SHAPES & TRANSMISSION	S/C MOCKUP, OPT BAR DUMMIES, 5K SHAKER	MODE SHAPES, TRANSMISSION	DTR
STATIC LOAD	PROVE DESIGN	STATIC STAND, OPT BAR DUMMIES, JACKS	STRAINS, DEFLECTIONS, LOAD	DTR & INSPEC
VIBRATION	PROVE DESIGN & WORKMANSHIP	FILM DUMMIES, VIBR FIXTURE, 30K SHAKER	INPUT & OUTPUT ACCELERATION	
STATIC LOAD	ESTABLISH FILM SLIP LIMITS	CENTRIFUGE (SUBCONTR)	LOAD, FILM SLIP	
VIBRATON	PROVE DESIGN & WORKMANSHIP	VIBR FIXTURE, 15K SHAKER	INPUT & OUTPUT ACCELERATION	
"	" "	" " " "	" " "	

	[illegible]OSE	SPECIAL TEST EQUIPMENT	PARAMETERS MEASURED	FORM OF REPORT
	[illegible]NT SELECTION & DESIGN	PRESSURE SUPPLY, FILM PATH MOCKUP, SIGNAL SOURCE	EXHAUST RATES, FILM TRACKING, PRESSURE, VALVE OPN'S	DESIGN INFO
	DETERMINE COMPONENT FAILURE RATES	PRESSURE SUPPLY, SIGNAL SOURCE	PROBABILITY OF FAILURE	RELIABILITY ANAL.
ARD	VERIFY COMPONENT SELECTION & DESIGN	ASSY FRAME, GAUGES, JACKS	BEARING NOISE, STIFFNESS, ECCENTRICITY, FIT	DESIGN INFO
ON	" " " "	" " " "	" " " " " "	" "
RD	" " " "	OPT. BAR MOCKUP, SUPPORT, ALIGNMENT BENCH, SIGNAL SOURCE	ENCODER ERROR, SERVO RESPONSE, FIT	" "
	" " " "	ASSY BENCH, ALIGNMENT TOOLS, SIGNAL SOURCE	" ", BEARING NOISE, SERVO RESPONSE, FIT	" "
TY	DETERMINE ASSY FAILURE RATE	ASSY BENCH, SIGNAL SOURCE	CYCLES TO FAILURE, BLADE FLUTTER, IMPACT NOISE	RELIABILITY ANAL.
ARD	VARIFY COMPONENT SELECTION & DESIGN	ASSY BENCH, ALIGNMENT TOOLS, SIGNAL SOURCE	BALL RACE STIFFNESS & NOISE, FOLLOW UP ACCURACY	DESIGN INFO
ARD	" " " "	SIGNAL SOURCES	FREQUENCY RESPONSE, TIMING, POWER, ETC.	" "
	ASSY PERFORMANCE CHECK	ASSY & ALIGNMENT BENCH	STATIC ALIGNMENT, RUNNING TORQUE	INSPECTION LOG
	" " "	ASSY & ALIGNMENT BENCH, FILM PATH, CONSOLE	FILM TRACK, ACTUATOR OPN'S, SERVO RESPONSE, BALANCE	" "
	" " "	ASSY & ALIGNMENT BENCH	STATIC ALIGNMENT, RUNNING TORQUE, ELEC. CONTINUITY	" "
	" " "	TEST STAND, CAMERA CONSOLE	FILM TRACK, SERVO OPN'S	INSPECTION LOG
	DEMONSTRATE RFI WITHIN TOLERANCE	" " , SCREEN ROOM	RF FIELD STRENGTH & SPECTRUM	" "
SS	" FILM FLATNESS	" " , FLATNESS TESTER	FILM FLATNESS AT FOCAL PLANE	" "
	ASSY PERFORMANCE CHECK	TEST BENCH, R/V TAKEUP CONSOLE	SERVO OPN'S	" "
	" " "	TEST STAND, SYSTEM CONSOLE	SEQUENCING, SERVO OPN'S, FILM TRACK	INSPECTION LOG
	" " "	ELECTRONICS UNIT CONSOLE	POWER, SEQUENCING, SERVO RESPONSE	" "
	DEMONSTRATE RFI WITHIN TOLERANCE	" " " , SCREEN ROOM	RF FIELD STRENGTH & SPECTRUM	" "
	ASSY PERFORMANCE CHECK	S/I CONSOLE, OPTICAL BENCH	S/I ALIGNMENT, ACTUATOR OPN'S, FILM TRACK	" "
	DEMONSTRATE RFI WITHIN TOLERANCE	" , SCREEN ROOM	R/F FIELD STRENGTH & SPECTRUM	" "
	OPERATIONAL FACILITY CHECK	CAMERA SIMULATOR, LAUNCH CONSOLE	PAD CABLING & HANDLING EQUIP. INTERFACE	INSPECTION LOG
	FINAL SYSTEM PERFORMANCE CHECK	PORTABLE COLLIMATOR, SYSTEM CONSOLE, ALIGNMENT TOOLS	CAMERA-S/C ALIGNMENT, ELECT. INTERFACE, IMAGE QUALITY	" "
	(S/C ENVIRONMENTAL & CHECKOUT TESTS)	CAMERA SIMULATOR	(SIMULATE SUBSYSTEM SHAPE, WEIGHT, HEAT SOURCES, ELECT LOADS & OUTPUTS)	NONE
	(R/V " " ")	R/V TAKE UP UNIT SIMULATOR	(SIMULATE TAKEUP UNIT SHAPE, WEIGHT, HEAT SOURCES)	NONE

TEST TYPE { Q - QUALIFICATION / A - ACCEPTANCE / D - DEVELOPMENT

FIG. 7 - SUMMARY
AMBIENT OPERATE TESTS

TEST ITEM	TEST TYPE	TEST PLAN SECT.	TEST NAME	PURPOSE	SPECIAL TEST EQUIPMENT	PARAMETERS
ASSY LEVEL V						
PNEUMATIC SYSTEM	D	3.1	BRASSBOARD	VERIFY COMPONENT SELECTION & DESIGN	PRESSURE SUPPLY, FILM PATH MOCKUP, SIGNAL SOURCE	EXHAUST RATES, FILM TRACKING [illegible]
PNEUMATIC SYSTEM	D	3.1	RELIABILITY	DETERMINE COMPONENT FAILURE RATES	PRESSURE SUPPLY, SIGNAL SOURCE	PROBABILITY OF FAILURE
SPOOL ASSY	D	3.2	BRASSBOARD	VERIFY COMPONENT SELECTION & DESIGN	ASSY FRAME, GAUGES, JACKS	BEARING NOISE, STIFFNESS, ECCEN[illegible]
OPT. BAR BEARINGS	D	3.3	EVALUATION	" " " "	" " " "	" " " "
OPT. BAR DRIVE	D	3.4	BRASSBOARD	" " " "	OPT. BAR MOCKUP, SUPPORT, ALIGNMENT BENCH, SIGNAL SOURCE	ENCODER ERROR, SERVO RESPONS[illegible]
METERING DRUM ASSY	D	3.6	"	" " " "	ASSY BENCH, ALIGNMENT TOOLS, SIGNAL SOURCE	" " , BEARING NOISE, [illegible]
SLIT & SHUTTER ASSY	D	3.6	RELIABILITY	DETERMINE ASSY FAILURE RATE	ASSY BENCH, SIGNAL SOURCE	CYCLES TO FAILURE, BLADE FLUT[illegible]
IMC DRIVE ASSY	D	3.6	BRASSBOARD	VERIFY COMPONENT SELECTION & DESIGN	ASSY BENCH, ALIGNMENT TOOLS, SIGNAL SOURCE	BALL RACE STIFFNESS & NOISE, FOL[illegible]
ELECT. ASSY (18)	D	3.10	BREADBOARD	" " " "	SIGNAL SOURCES	FREQUENCY RESPONSE, TIMIN[illegible]
ASSY LEVEL IV						
SUPPLY END ASSY	Q/A	4.1	CHECKOUT	ASSY PERFORMANCE CHECK	ASSY & ALIGNMENT BENCH	STATIC ALIGNMENT, RUNN[illegible]
TRANSPORT ASSY	Q/A	4.2	"	" " "	ASSY, ALIGNMENT BENCH, FILM PATH, CONSOLE	FILM TRACK, ACTUATOR OPN'S, S[illegible]
TAKE UP END ASSY	Q/A	4.4	"	" " "	ASSY & ALIGNMENT BENCH	STATIC ALIGNMENT, RUNNING TO[illegible]
ASSY LEVEL III						
CAMERA	Q/A	5.1	CHECKOUT	" " "	TEST STAND, CAMERA CONSOLE	FILM TRACK, SERVO OPN'S [illegible]
CAMERA	Q	5.1	RFI	DEMONSTRATE RFI WITHIN TOLERANCE	" " , SCREEN ROOM	RF FIELD STRENGTH & SPECTR[illegible]
CAMERA	Q/A	5.1	FILM FLATNESS	" FILM FLATNESS	" " , FLATNESS TESTER	FILM FLATNESS AT FOCAL PL[illegible]
R/V TAKE UP	Q/A	5.4	CHECKOUT	ASSY PERFORMANCE CHECK	TEST BENCH, R/V TAKEUP CONSOLE	SERVO OPN'S
ASSY LEVEL II						
CAMERA SYSTEM	Q/A	6.1	CHECKOUT	" " "	TEST STAND, SYSTEM CONSOLE	SEQUENCING, SERVO OPN'S, [illegible]
CAMERA ELECT.	Q/A	6.2	"	" " "	ELECTRONICS UNIT CONSOLE	POWER, SEQUENCING, SERV[illegible]
CAMERA ELECT.	Q	6.2	RFI	DEMONSTRATE RFI WITHIN TOLERANCE	" " " , SCREEN ROOM	RF FIELD[illegible]
S/I CAMERA	Q/A	6.3	CHECKOUT	ASSY PERFORMANCE CHECK	S/I CONSOLE, OPTICAL BENCH	S/I ALIG[illegible]
S/I CAMERA	Q	6.3	RFI	DEMONSTRATE RFI WITHIN TOLERANCE	" , SCREEN ROOM	R/F FIEL[illegible]
ASSY LEVEL I						
PAD VALIDATION	D	7.3	CHECKOUT	OPERATIONAL FACILITY CHECK	CAMERA SIMULATOR, LAUNCH CONSOLE	PAD CABLI[illegible]
SYSTEM INTEGRATION (SPACECRAFT)	A	7.4	"	FINAL SYSTEM PERFORMANCE CHECK	PORTABLE COLLIMATOR, SYSTEM CONSOLE, ALIGNMENT TOOLS	CAMERA - S[illegible]
	ALL	[illegible]	ALL	[illegible]		

FIG. 8 – SUMMARY
THERMAL-VACUUM TESTS

		SPECIAL TEST EQUIPMENT					
		CHAMBER (DIA. X LNGTH, FT)	WALL TEMP CONTROL — TRANSIENT	WALL TEMP CONTROL — GRADIENT	VACUUM (TORR)	PARAMETERS MEASURED	FORM OF REPORT
ARD	VERIFY COMPONENT DESIGN	8X15	STEADY	UNIFORM	10^{-3}	EXHAUST RATE, LEAKAGE, ACTUATOR OPN'S	DESIGN INFO
TE	PROVE DESIGN	5X5	"	"	"	TEMP. RESPONSE, RUNNING TORQUE	INSPECTION LOG
Y	DETERMINE LIFE IN VACUUM	BELL JAR	"	"	10^{-5}	TIME TO FAILURE, LINE LOADS	RELIABILITY ANAL.
E	PROVE DESIGN	5X5	"	"	10^{-3}	TEMP. RESPONSE, RUNNING TORQUE	INSPECTION LOG
ON	DETERMINE TEMP. SENSITIVITY	"	"	APERTURE HEATING	10^{-3}	FIGURE AND FOCUS CHANGE	DTR
	DETERMINE CONDUCTANCES	"	"	UNIFORM	10^{-5}	CONDUCTANCE CHANGE WITH PRESSURE	DESIGN INFO.
	" "	BELL JAR	"	"	10^{-3}	TEMP. DROP ACROSS JOINT	"
	DETERMINE α, ϵ	" "	"	"	"	ABSORPTIVITY & EMISSIVITY	"
/	CALIBRATE & EVALUATE MOUNTING	" "	"	"	"	TEMP. SENSED VS. STANDARD	"
TE	PROVE DESIGN	" "	"	"	"	TEMP. PEAK & ELECTRICAL DRIFT	INSPECTION LOG
TE	PROVE DESIGN & WORKMANSHIP	5X5	"	"	"	TEMP. RESPONSE, ALL OPN'S	DTR, INSPECTION LOG
ITY	DETERMINE OPTICAL SENSITIVITY	8X15	TRANSIENT	(TRANSVERSE & FIXIAL, SOLAR ON APERTURE)	"	EFFECTS OF GRADIENTS AND TRANSIENTS ON FOCUS AND IMAGE QUALITY	DTR
	PROVE DESIGN & WORKMANSHIP	8X15	STEADY	UNIFORM	"	VAC. FOCAL SHIFT, IMAGE QUALITY	INSPECTION LOG
	PROVE DESIGN & WORKMANSHIP	8X15	MISSION PROFILE	VEHICLE SIM.	10^{-5} AIR / 10^{-3} HE	FULL FIELD DYNAMIC RESOLUTION, ALL OPN'S	INSPECTION LOG
	" " "	5X5	STEADY	UNIFORM	10^{-3}	TEMP. RESPONSE, ALL OPN'S	" "
	MOCK UP EVALUATION OF TEMP FIELD	20X25	MISSION PROFILE	VEHICLE SIM.	10^{-5}	SPACE/TIME TEMP RESPONSES	DTR
	PROVE DESIGN & WORKMANSHIP	20X25	" "	" "	10^{-5} AIR / 10^{-3} HE	CENTER FIELD DYNAMIC RESOLUTION, ALL OPN'S	INSPECTION LOG
	" " "	5X5	STEADY	UNIFORM	10^{-3}	TEMP RESPONSE, ELECTRICAL RESPONSE	" "
	" " "	5X5	"	"	10^{-3}	TEMP RESPONSE, ALL OPN'S	" "

DTR – FORMAL DEVELOPMENT TEST REPORT

Approved for Release: 2018/02/01 C05108511

FIG. 8 – SUMMARY
THERMAL-VACUUM TESTS

TEST ITEM	TEST TYPE	TEST PLAN SECT.	TEST NAME	PURPOSE	SPECIAL TEST EQUIPMENT: CHAMBER (DIA. X LNGTH, FT)	WALL TEMP CONTROL: TRANSIENT	WALL TEMP CONTROL: GRADIENT	VACUUM (TORR)	PARAMETE…
ASSY LEVEL V									
PNEUMATIC SYSTEM	D	3.1	BRASSBOARD	VERIFY COMPONENT DESIGN	8X15	STEADY	UNIFORM	10^{-3}	EXHAUST RATE, LEAKAGE…
SPOOL ASSY	Q	3.2	VAC. OPERATE	PROVE DESIGN	5X5	"	"	"	TEMP. RESPONSE, RUN…
SLIP RING	D	3.4	RELIABILITY	DETERMINE LIFE IN VACUUM	BELL JAR	"	"	10^{-5}	TIME TO FAILURE, LINE…
METERING DRUM ASSY	Q	3.6	VAC. OPERATE	PROVE DESIGN	5X5	"	"	10^{-3}	TEMP. RESPONSE, RU…
OPTICAL ELEMENTS (4)	D	3.8	EVALUATION	DETERMINE TEMP. SENSITIVITY	"	"	APERTURE HEATING	10^{-3}	FIGURE AND FOCUS CH…
INSULATION	D	3.9	"	DETERMINE CONDUCTANCES	"	"	UNIFORM	10^{-5}	CONDUCTANCE CHAN…
CONTACT RESISTANCE	D	3.9	"	" "	BELL JAR	"	"	10^{-3}	TEMP. DROP ACROSS…
SURFACE PROPERTIES	D	3.9	"	DETERMINE α, ε	" "	"	"	"	ABSORPTIVITY & E…
TEMP. TRANSDUCERS	D	3.9	CALIBRATION	CALIBRATE & EVALUATE MOUNTING	" "	"	"	"	TEMP. SENSED VS. T…
ELECT. ASSY'S (18)	D/Q	3.10	VAC. OPERATE	PROVE DESIGN	" "	"	"	"	TEMP. PEAK & ELE…
ASSY LEVEL IV									
TRANSPORT ASSY	D/Q/A	4.2	VAC. OPERATE	PROVE DESIGN & WORKMANSHIP	5X5	"	"	"	TEMP. RESPONSE, …
OPTICAL BAR ASSY	D	4.3	THERM. SENSITIVITY	DETERMINE OPTICAL SENSITIVITY	8X15	TRANSIENT	{TRANSVERSE & AXIAL, SOLAR ON APERTURE	"	EFFECTS OF GRADIEN… FOCUS AND IMAGE QU…
OPTICAL BAR ASSY	Q/A	4.3	THERMAL/VAC.	PROVE DESIGN & WORKMANSHIP	8X15	STEADY	UNIFORM	"	VAC. FOCAL SHIFT, …
ASSY LEVEL III									
CAMERA	Q/A	5.1	THERMAL/VAC.	PROVE DESIGN & WORKMANSHIP	8X15	MISSION PROFILE	VEHICLE SIM.	{10^{-5} AIR; 10^{-3} He}	FULL FIELD DYNAMIC RE…
R/V TAKE UP	Q/A	5.4	VAC. OPERATE	" " "	5X5	STEADY	UNIFORM	10^{-3}	TEMP. RESPONSE, A…
ASSY LEVEL II									
CAMERA SYSTEM	D	6.1	THERMAL/VAC.	MOCK UP EVALUATION OF TEMP FIELD	20X25	MISSION PROFILE	VEHICLE SIM.	10^{-5}	S…
CAMERA SYSTEM	Q/A	6.1	" "	PROVE DESIGN & WORKMANSHIP	20X25	" "	" "	{10^{-5} AIR; 10^{-3} He}	CE…
CAM. ELECT UNIT	Q/A	6.2	VAC. OPERATE	" " "	5X5	STEADY	UNIFORM	10^{-3}	TE…
S/I CAMERA	Q/A	6.3	" "	" " "	5X5	"	"	10^{-3}	T…

D- DEVELOPMENT
Q- QUALIFICATION

2.0 TEST PARAMETERS

2.1 AMBIENT ELECTRICAL TESTS

2.1.1 Subassembly and Component Checkout

Components and groups of components which can be tested as subassemblies will be checked and qualified separately to establish probable failure modes and performance specifications under simulated ambient operating conditions.

1. Motors - In addition to verification of the motor parameters used in the servo design, the motors will be checked for insulation resistance, armature resistance, hot spots, brush resistance, and brush noise. Analysis of these test results with regard to specifications and failure modes will reduce the chances of marginal motor performance.
2. Encoders - The encoders, with their electronics, will be tested for missing pulses and pulse jitter to speeds in excess of that required for system operation to determine if marginal operation may exist. After mounting, the encoders will be checked for pulse position accuracy. The encoders and associated electronics will be checked for electrical irregularities which indicate the possibility of later failure.
3. Solenoids - The solenoid parameters of interest are coil resistance, inductance, hot spots, and torque or force through the operating range of travel.
4. Tachometers - Tachometers will be tested for insulation resistance, brush noise and ripple, output impedance, and output voltage as a function of speed in both directions of rotation and over a speed range in excess of that required by the system design.

5. Amplifiers - Amplifiers will be tested for input and output impedance, power output, efficiency, gain and phase versus frequency, and a check that all voltages and signal amplitudes are correct and within design tolerences for each stage.

6. Relays - Relays will be checked for coil resistance, inductance, contact resistance and bounce, operating and release time.

7. Logic Modules - The logic subassemblies will be inspected and checked to determine that the electrical parameters are within the design tolerences. In addition to impedance levels, voltages, and currents; such things as pulse width, rise time, pulse delay, and maximum pulse rate will be checked.

8. Wiring Harnesses - Wiring harnesses and connectors will be inspected for proper compliance with specifications. Such factors as cable temperature rise and effectiveness of shielding and crosstalk will be determined during the test program.

9. Power Supply Regulators - The power supply regulators will be tested to determine their efficiency, regulation, transient response, and performance under overload conditions.

2.1.2 Subsystem Checkout

The subassemblies will be combined into subsystems and tested to determine their compliance with design specifications. Simulation of signals and assemblies will be used wherever it will expedite evaluation of the actual hardware or design.

1. Spool Servo Subsystem - The servo response of the subsystem will be completely determined for compliance with the design specifications. The tests will include determination of the frequency, phase, and transient response over a range of film speeds and accelerations. It will be necessary to simulate the film drum subsystem until the actual film drum hardware is available and fully tested.

2. Bar Servo Subsystem - The components which will require simulation until actual hardware is available will be the optical bar inertial load and the control logic. The torque motor and encoder will be assembled on the shaft and the motor and encoder parameters determined. Particular attention will be paid to the encoder alignment and positional accuracy. The subsystem servo response characteristics will be measured for both normal torque loads and disturbances as well as for overload conditions to determine the performance margins.

3. Drum Servo Subsystem - A breadboard of the control logic and an inertial model of the film drum will be required. The complete servo response will be measured and checked against the design specifications.

4. Film Position Sensor - The film position sensor will be tested by rotating a piece of film with a punched hole in it between the infrared source and the receiver. The output pulse amplitude and waveform will be checked over a range of operating speeds and supply voltages. A piece of live film will be used and developed to determine that the IR filters are not letting through any wavelengths that will detrimentally expose film.

5. Fiducial and Data Block - The fiducial and data block consist of the lamp circuits and the power converter. The testing of the lamp output and exposure time will be done using live film which is moving at a known velocity. The power converter output will be monitored while the lamps are firing to ascertain that it can, in fact, provide and maintain the required voltage over the range of lamp firing rates used. If the control logic is not available at the time, it will be simulated to provide the proper firing rates.

6. IMC Servo Subsystem - The torque motor and the encoder can be assembled to the lead screw and a simulated load attached to the nut. The IMC is a position servo and as such the servo response tests involve such things as static angular error and the following angular error at various speeds. Complete testing and verification of design goals will be done.

7. Slit Control Subsystem - The slit control servo loop will be tested for its response as a position servo.

8. Control Logic and Programmer - The control logic and programmer will be tested for correct function, timing, wave shape, and pulse amplitudes at normal, high and low supply voltages. Some simple simulation will be required to generate control commands and encoder outputs.

9. Momentum Balance - The momentum balance servo can readily be run as a separate subsystem and its servo response determined using the control logic.

10. RV Spool Servo Subsystem - The servo response of the RV spool servos will be completely determined and the interaction of the RV spool servos and the camera spool servos tested for proper and reliable operation.

2.1.3 System Checkout

There are several classes of tests which the completed system must undergo: Servo response characteristics, synchronization of various parts of the system, electrical interfaces, and power distribution.

1. Servo Response Characteristics - As the simulated inertial loads, bearing and viscous friction, and torque disturbances used in the subsystem testing may not have exactly represented those of the

completed system, the servos must be retested to obtain actual operating data. The tests will include phase, frequency, and transient responses taken over a range of voltages, film speeds, and accelerations.

2. Synchronization - Typical of the things which must be synchronized to the bar rotation are the film drum velocity, the IMC velocity and position, the momentum balance velocity, the shutter timing, the fiducial and data block operation, and the time of brake operation. It must be established that everything is working as a coherent system.

3. Electrical Interfaces - The electrical interfaces of the system can now be checked for proper operation and signal levels between the interrelated parts of the system and the vehicle. Careful attention must be paid to developing diagnostic information based on the information available from these signals.

4. Power Distribution - With actual system loads available, the voltage regulators, power distribution wiring, and the ground system, must be carefully checked for any abnormalities which may indicate possible trouble. Voltage drops and transient noises on the lines should be recorded for future reference.

2.1.4 System RFI

The camera system shall be tested with equipment and procedures consistent with range requirements in order to assure tolerable mutual radio frequency interference with other items installed in the vehicle and to assure effective total system operation. RFI tests will be conducted on major electrical assemblies in a screen room, with instrumentation to measure emitted RF field strength and spectrum at all points on the test object.

2.2 AMBIENT MECHANICAL/OPTICAL TESTS

2.2.1 Subassembly and Component Checkout

Components and subassemblies will be tested to assure conformance with applicable specifications and drawings. Ball bearings, shafts, film drive drum, rollers, motors and encoders, require dimensional inspection to insure proper fits in following subassemblies. Subassemblies with rotating parts such as film rollers, metering drum, focal plane rollers, and the assembled camera will undergo tests of static and dynamic balance. These tests will require support fixtures for the bearings and equipment to drive the rollers, plus force transducer instrumentation to measure dynamic balance. Subassemblies will be checked for bearing noise, static and dynamic torque, eccentricity of rotating parts and alignment. For instance the focal plane rollers shall be checked for runout, bearing noise, static and dynamic torque, roller parallelism, and dynamic balance.

2.2.2 Optical Checkout

Optical components and subassemblies will be checked at ambient for image quality to determine the effects of mounting stress. These tests will require optical test equipment such as large aperture jig transits, alignment theodolites, and astronomical quality large aperture collimators.

Both static and dynamic focus tests will be required to assure optimum image quality and focal surface location.

Alignment of the optical axis and optical bar and film metering drum orientation is required to ascertain they are within the tolerances allowable by the system error budget.

2.2.3 System Checkout

1. Optical Bar/Interface Alignment - The optical bars are positioned relative to the truss mounting plane with their axes of rotation parallel to the orbital plane and lines of sight 15° to nadir. Alignment instrumentation suitable to locate the truss interface plane and optical bar rotation axes is required for this alignment.

2. Film Tracking - The film path from the main camera assembly to the recovery vehicle requires alignment to assure proper film tracking from the cut/splice assembly on the optical bar skew arm to the cut/seal assembly and recovery vehicle infeed rollers. Light tightness and film tracking tests will be required to assure acceptable performance.

3. Line of Sight/Vehicle Alignment - The optical lines of sight require alignment to the vehicle attitude reference. Since the fiducial marker is projected on to the back of the film, it may also be used to locate the optical bar line of sight. A large aperture jig transit will be squared on to the flat surface of the corrector lens and then translated to coincide with the line of sight as determined by the fiducial marker. The vehicle attitude reference will be aligned to this reference.

2.3 THERMAL TESTS

2.3.1 Environmental Parameters

The spatial environment is characterized by extremely low pressures, and the predominance of radiation as a mode of heat transfer. In the case of an earth orbiting space vehicle, the transient temperature behavior of a vehicle surface segment may be obtained through the solution of the following differential equation.

$$wc_p \frac{dT}{d\theta} = \alpha_s AF_s S + \alpha_E F_E AE_E + \alpha_R F_R AR_E + Q - \epsilon_s \sigma AT^4$$

where;

T = temperature of shell, °R

t = time, hours

w = mass of satellite surface, LBM

C_p = specific heat, btu/LBM - °F

A = surface area of satellite, ft^2

Q = lateral heat load, btu/hr

σ = Stephan-Boltzmann constant 0.1713 x 10^{-8} btu/hr-ft^2-°F

α_s = solar absorptivity of satellite

α_E = infrared absorptivity of satellite

α_R = absorptivity to reflected solar

F_S = geometric form factor for direct solar radiation

F_E = geometric form factor for planetary emission

F_R = geometric form factor for reflected solar radiation

S = solar constant, btu/hr-ft^2

E_E = planetary emission, btu/hr-ft^2

R_E = reflected solar energy from planet, btu/hr-ft^2

ϵ_s = emissivity of satellite surface

The solution to this equation for a complex system can only be obtained with modern digital computer techniques. Even using such techniques, input to the computer requires creation of a model, which is complicated by heat absorbing capacity, localized heat sources, geometry of radiating surfaces and the conduction mode of heat transfer. In the case of the main camera assembly, a model containing approximately 150 nodes is required to approximate the transient temperature field within and on the surface of the system. The imposed heat flux on vehicle surfaces is both time and space dependent.

Tests to be conducted are dependent, in large part, on analytical prediction of average temperature levels and gradients. Utilization of these magnitudes constitutes a valid approach if the parameters used as input to the analyses are well-founded. Such is the case only if test and analyses are related in a logical plan of system development.

The environment that the test chamber must simulate are the vacuum conditions and the thermal radiation field experienced by a near earth satellite. Here simulation does not mean an exact duplication of the actual conditions that occur but rather the creation of environmental conditions that will produce essentially the same thermal response as occurs in the actual system.

The thermal radiation field to which the camera system will be exposed is composed of the direct solar radiation (insolation), the solar energy reflected from the earth (albedo), and the energy emitted by the earth (earthshine). For any surface of the camera system, then, the impinging radiation at a given time has a spectral character and intensity that depends on the direction from which the radiation is coming. Relative to a given surface of the system, this radiation field is continually varying with time or the position of the satellite in its orbit. There are no existing facilities that can duplicate all the features of this space thermal environment at one time. Some facilities can simulate the parallel energy of the insolation,that is adequate for deep space simulation, however, when near earth satellites are considered duplication of the directions of the spectrally correct radiation coming from the earth to the various surface elements of the system is currently beyond the testing art.

An alternate and preferred approach to the simulation of the energy impinging on each element of surface is the simulation of the energy absorbed by each element of the surface. This approach eliminates the need for duplicating the directions and spectral content of the impinging energy on all opaque surfaces. For surfaces transparent to the short wave radiation of the insolation and albedo radiation, it is still necessary to simulate the spectral content of the radiation but this can be confined to the limited areas where transparent materials occur. It is this approach that is used in the current test program to achieve the proper "hot-house" effect.

2.3.2 Properties of System

The subsystem evaluation program provides early identification of problem areas, and information needed for correction; but requires isolation of the subsystem from the remainder of the system except insofar as simulation is possible. Actual hardware will be utilized in subsystem tests whenever possible. If scheduling forces the use of thermal mock-ups of components, exceptional care in the design of these mock-ups will be required to assure significant test results.

The use of mock-ups, if valid results are to be obtained, places stringent requirements on duplication of surface finish, geometrical relationships, and other significant properties.

1. Surface Emissivity and Absorptivity - Since radiation is the predominant mode of heat transfer in space, close control must be maintained over the determination of these properties. Total hemispherical valves are easily obtained through existing thermophysical measurement techniques, near the room temperature level.

2. Geometrical Configuration Factors - The view factor is defined as the fraction of energy emitted from a black emitter which is intercepted by a receiving surface. Surface orientation and directional characteristics require exact duplication in test facility design.

3. Conduction Paths - The evaluation of thermal conduction paths requires that thermal conductivities and the configuration be defined. Discontinuities in the structure, and interfaces as found in bearings present formidable analytical problems. The temperature field in composite structures must be determined through test.

4. Heat Capacity - The heat capacity of a body assumes importance when thermal transients are involved. The design of a radiating panel whose temperature must vary with time, requires analysis considering the heat capacity of the panel. Thermal effects are damped in the camera structure, through its heat capacity, when subjected to external forcing.

5. Coefficients of Expansion - Thermal coefficients of expansion and their matching is of particular significance in the optical assembly where small thermal growths, with a change in temperature level, result in defocusing. In addition, differential

expansion across a bearing can result in accelerating failure through frictional heating, in precision bearings, and eventual seizure. Analytically determined coefficients of expansion for optical metering rods will be obtained through alloying and checked with dialotometers. Thermal testing of the optical system at prescribed temperature levels is required for complete evaluation.

2.3.3 Parameters of Response

The overall objectives of the thermal test program are to obtain the basic thermal data required as input for thermal design and then of proving experimentally that the optical system as designed can operate satisfactorily in the imposed space thermal environment.

Thermal tests to be performed will generally fall into three classes: 1 - those that provide basic information needed in the thermal, structural, and optical design; 2 - those that test and suggest changes in the thermal designs of complete assemblies, such as a single camera, and 3 - those that test the design of the complete system in order to evaluate the interaction of the various parts. The last of the latter tests, after developmental design changes have been made, become the qualification tests.

In most of these tests, it will be necessary to make measurements of other quantities in addition to the temperature measurements. For example, in tests of the thermal behavior of surface finishes, it will be necessary to measure heat-flow rates either by calorimetry or with heat-flow meters. In tests of optical subassemblies, such as the field flattener, it will be necessary to pass collimated light through the units to make optical-measurements as temperature gradients and various levels are imposed on these elements. For the system as a whole, strain gage measurements and laser interferometers will be required to check the alignments and distortions of the optical elements during thermal test. Temperature distributions alone yield a check on the thermal design, however, their allowable ranges and distributions cannot be predetermined with certainty by analysis alone but must be established through measurements of their consequences.

Specifically, the objectives of the thermal tests can be listed in their chronological order as follows:

1. To evaluate those inputs to the thermal design that require experimental information. This covers such quantities as the thermal behavior of specialized surface finishes to be employed in the camera system where handbook data are either unavailable or inadequate. In addition, some information on the thermal absorption characteristics of the refractor materials in the system will be required. It will also be necessary to experimentally evaluate heat conduction paths within structurally complex subassemblies (bearings, drives, yokes, etc.) and within assemblies (mirror-bezel combinations, lens-lens tube combinations, etc.) needed as input in the thermal design. Emphasis should be placed here on actual contact resistances to heat flow that cannot be evaluated analytically.

2. To establish temperature requirements of mechanical, electronic, and optical components, and their immediate surroundings from the viewpoint of reliability and loss of performance.

3. To evaluate complete assemblies, such as a single camera, by means of temperature measurements, strain measurements, and optical tests to establish conformance with the thermal design and the necessary temperature limits throughout the unit.

4. To evaluate the complete system (cameras, support-structure, vehicle skin) in order to determine the <u>interaction</u> of the thermal stresses and strains of the various parts and their optical consequences. Again, temperature limits will be evaluated and design changes suggested by these results in developmental tests. The final test of this series will act as the qualification test.

2.4 VACUUM TESTS

2.4.1 Environmental Parameters

Although the pressure outside the orbiting spacecraft is on the order of 10^{-8} mm Hg, the internal pressure will be much higher. The principal source of internal pressurization will be operation of the gas-lubricated film rolls, with almost negligible contributions from outgassing of the film and other materials. Since the pressure level significantly affects a number of system functions, as discussed in the following section, the system test program must accurately determine the pressure field existing during system operation. It follows that the test facility must have the capability to produce the gas flow rates expected from point to point in the system, and that the system mockup must accurately represent the orifice areas existing from zone to zone.

Preliminary analysis of the gas-bars indicates a required mass flow rate per bar of 3.3×10^{-6} lb/sec of Helium exhausting to nil ambient pressure. The analysis neglects the effect of supersonic shock produced at the edges of the bearing area, where expansion will be large. Using the figure, the pressure within the camera increases from zero to a steady value of 6×10^{-2} mm Hg in one half second from start of flow. At this pressure, the mean-free-path of Helium molecules is about 0.01 inch, so a continuum flow model is used. When expanded to 10^{-5} mm Hg, the system flow through 30 gas bars is 22.8×10^{6} liters/second; this excludes the recovery takeup system which does not operate concurrently.

2.4.2 Response Parameters

1. Film Bar Gas Consumption - Gas consumption and pressure levels have been predicted with viscous flow theory. In the low pressure region, however, experimental effort is required to fix parameters and minimize flow rates. Shock waves at the edge of

the film, where the gas discharges into an extremely low pressure zone, must be studied to determine their effect on gas consumption and film stability and control.

2. Focal Shift - The refractive index of air produces a shift in the focal length of the optics when measured at ambient. This shift will be measured and the focal plane set at the proper location for vacuum operation.

3. Material Degradation - The degradation of materials in the vacuum environment can be attributed to evaporation and out-gassing. Certain plastic materials become embrittled or change dimensionally with loss of their water content. Particular emphasis must be placed on the evaluation of film when its water content is diminished.

4. Lubrication Degradation - The conventional organic base materials are not suitable for bearing lubrication in the vacuum environment. Loss of volatiles, accompanying vacuum operation, greatly diminishes their lubrication properties. Dry lubricants, or operation without lubrication, if periods of operation are brief, must be evaluated as alternates.

5. Insulation Effectiveness - The effectiveness of reflective-type insulation is lessened as the pressure is increased. At increased pressure levels, gaseous conduction, acting in parallel with radiation, must be considered. The information provided below shows the diminished effectiveness of NRC-2 as pressure is increased (Source: N.R.C., Cambridge, Mass.).

Crinkled Foil
65 layers/inch

Pressure (mm Hg)	Apparent K(Btu/hr-ft-°R)
1.0	5×10^{-3}
1×10^{-2}	2×10^{-4}
1×10^{-5}	2.4×10^{-5}

Since the system is pressurized with the gas released from film bars, venting techniques and the efficiency of the insulation design must be evaluated in the environmental test chamber.

6. Corona Discharge - The passage of film over a system of rollers or gas bars results in an accumulation of charge and eventual discharge as corona. Partial illumination and exposure of film through corona results. Since corona currents have most often been experienced in the pressure range from 10^{-3} to 10^{-2} mm Hg, the usual and most successful means of preventing discharge has been to pressurize the film transport area to 5 x 10^{-2} mm Hg or higher pressure.

Extreme difficulty is encountered in the prediction of corona as related to pressure level, film speed, and transport materials and configuration. It is therefore imperitive that tests be conducted with control over these parameters and with flight hardware. A continuing investigation of the basic parameters of corona discharge is underway at Ion Physics Corp., a subcontractor to the camera manufacturer.

2.5 VIBRATION AND SHOCK TESTS

The vibration test plan described below emphasizes a strong developmental phase to provide early data on component fragility and system response. These data are the basis for minimum-weight design of components and bracketry, and specification test levels.

It is important to understand the circumstances in which component parts survive or fail in order to achieve a successful design and related quality assurance test program. The qualification level for a component, mounted a tier or two interior to major support and primary structure, is usually specified as a uniform vibration level that the part can sustain at all frequencies. Components can, however, withstand much higher levels except at critical frequencies.

The excitation that a component can survive at each discrete frequency determines the "fragility" of the component. Thus, the component installation should be designed to assure that the vibration excitation of the component as part of the assembly does not exceed the component fragility level; and the component qualification test should duplicate the spectral response of the installation.

With an understanding of component fragility, structural dynamics of the system, and the relationship of these to the qualification spectrum, system weight and component failures due to vibration can be minimized by the following:

a. Selection of the component type and optimum mounting to suit the environment.

b. Obtaining and using fragility data.

c. Placing structural resonances at optimum frequencies.

d. Engineering model resonance testing.

e. Mechanical design flexibility for ease of modification.

f. Realistic qualification and acceptance testing based on actual response spectra rather than arbitrary specification levels.

2.5.1 Environmental Parameters

The dynamic load environment during powered flight consists of two principal components:

a. Quasi-static lateral and longitudinal loads associated with rigid body and low frequency elastic body responses from lift off through second stage engine cutoff. (This includes maneuver loads and accelerations.)

b. Complex vibration (sinusoidal, random, acoustic, and shock) associated with:

1. Aerodynamic and propulsion perturbances at in-flight conditions such as Mach 1, maximum αq and pogo (11-13 cps propulsion instability).

2. Staging transients.
3. Payload separation transients.

Extensive flight data corresponding to these environmental conditions on Titan II are available (Ref. 1). Statistical analyses have been performed in order to provide reasonably reliable input power spectral density levels at various points on the Titan II launch vehicle, typical components, and at the operational re-entry vehicle attachment ring.

In addition, drop, hoist, and transportation loads will be experienced by shipping containers for the system and components. Tests on these containers will be required to demonstrate that they survive these environments and attenuate the response felt at the components to less than flight levels. Tests on AGE are beyond the scope of this plan.

Qualification and acceptance load levels will be based on the measured complex environment at the launch vehicle/spacecraft interface, and transmissibility data derived from developmental test and analysis. The type of test to be imposed on an assembly (random, sine, shock, acoustic, or a combination thereof) is determined from evaluation of the relative severity of all types of environment in the region of the specific component failure mode (e.g., overload at a finite frequency, cumulative fatigue damage, or both). Hence, the resonance survey and fragility test results (development tests) are applicable. Based upon past experience, static testing (in lieu of dynamic) should suffice to qualify the truss structure, major component attachments and the spacecraft/structure interface joint. Acceptance of this structure should be made on the basis of a successful qualification test and fabrication adherence to engineering drawings, tolerances, etc.

Ref. 1 - BSD TDR 63-189, "The Acoustic and Vibration Environment of the Titan II Vehicle"; prepared by Bolt, Beranek, and Newman, September 1963.

Internal components which are sensitive to the complex vibration environment will be tested in an all-random vibration test using properly shaped directional power spectral density input (Ref. 2) over a given duration, with the components hard mounted to a shaker. Random excitation below 50 cps will not be applied in the lateral direction, since no lateral random energy exists in flight below this frequency. Random energy below 50 cps does exist in the thrust direction. Sinusoidal vibration at low frequency (such as pogo vibrations) will be duplicated in test of assemblies with low-frequency resonances. Acoustic energy will be included as an equivalent random energy in the test. Discrete shock loading in the Titan II system has usually not been significant compared to quasi-static and random effects.

Test durations for qualification, acceptance, and fragility testing must be carefully chosen to avoid causing fatigue failures where none would be caused by flight conditions. Fragility tests will be high-level, short-duration so that failure is caused by stress well over the fatigue limit. Since fatigue limit allowables are generally 1/3 to 1/2 of static failure stress in light metals, allowable responses during qualification will be specified as a factor of 2 to 3 below fragility levels to account for prolonged testing.

Final determination of vibration and shock test levels will be based on analysis performed by the camera manufacturer and its consultant, Mechanics Research, Incorporated, in cooperation with the vehicle manufacturer. It is expected that the latter will perform a comprehensive loads analysis in the low-frequency region, and will compute responses of a simplified spring-mass model of the main camera to ascent dynamic loads such as gust. Acceptance test levels will be based on limit load, and qualification test levels will be 1.5 to 3.0 times limit load, depending on the mode of failure and function of the component.

Ref. 2 - Report 1083, "Procedures Utilized in Developing All-Random Vibration Test Specifications for Titan III"; prepared by Bolt, Beranek, and Newman, January 1964.

2.5.2 Properties of the System

Experience has shown that exact simulation of the flight environment at all levels of assembly is unreasonable, both technically and economically. Large assemblies cannot be accommodated on shakers with sufficient rigidity or capacity to simulate the interface loads exactly, nor are response levels at component locations reproducible from one system to another over a broad spectrum. A balanced effort between design and test functions can, however, assure component survival for a given mission. This is done by dividing the system into subassemblies which can be tested realistically, and by feeding response data from system developmental tests into the design early enough to permit incorporation of indicated design changes.

The parameters of particular importance in developmental surveys are resonant frequencies, mode shapes, and transmissibilities from a logical test interface to locations of critical components. Since physical damage (fracture, as opposed to effects on operating instruments) is generally produced in the lowest-frequency modes of response of an installation, these are the most important to determine. These modes are fortunately the easiest to model or analyze, and are the most reproducible between test articles.

Since conditions of support have an important effect on system dynamic response, it is essential that the lower half of the spacecraft be simulated by a mass and stiffness model. If a prototype spacecraft structure is not available at the time of main camera surveys, the camera manufacturer will construct a simplified model which will suffice to duplicate dynamic interactions between spacecraft and main camera. The same model will also be usable for thermal/vacuum tests on the system following vibration survey.

Measurement of transmissibilities from the spacecraft skin to camera components not mounted on the main camera truss is not practical without use of a prototype spacecraft forward structure, since damping and mass/stiffness details cannot be modeled. Responses of camera subsystems such as the camera electronics unit, S/I camera, and recovery take-up, must be determined in a prototype spacecraft survey by the spacecraft manufacturer, or estimated from existing flight data.

2.5.3 Parameters of Response

As noted above, the parameters to be measured in survey are mode shape, resonant frequency, and transmissibility. The former are of particular importance as confirmation of the camera dynamic model for analysis of low-frequency response to flight transients; and for determination of servo response with support flexibility. A large amount of flight data exists to define vibratory energy present at the booster (or spacecraft) skin. The transmissibilities measured in camera survey are directly applicable to prediction of the amount of this energy - and its spectral distribution - which reaches camera components. This assumes that the energy of response of a component is primarily energy transmitted mechanically from the vehicle. The measured acoustic environment is, in fact, of comparatively low level except where responses of large-area panels are concerned. It is not practical to mount the entire spacecraft/camera assembly on a shaker or cluster to simulate all directions of excitation at the booster interface. Instead, the spacecraft model will be floated on a soft foundation, and excitation applied at the points of attachment to the main camera by a relatively small shaker or shakers. Transmission through the camera support truss will not be sensitive to damping in the spacecraft model, but system mode shapes and thus truss response will depend on reasonable simulation of the mass and stiffness of the spacecraft near the camera interface. The total response predicted at a point on the camera in a given direction is then the sum of measured response components in that coordinate due to excitation in all coordinates at each camera/spacecraft interface point. A response component in a given bandwidth is the product of transmissibility and excitation within the bandwidth.

Since prototype optical bar and main frame structures are not available at the same time, two surveys will be conducted:

1. To determine transmission from the spacecraft interface to the main optical bar bearings.
2. To determine transmission from the optical bar bearings to components attached to the optical bar.

In the first test, optical bar mass dummies will be attached at the bearing frames. In the second test, component mass dummies will be attached at appropriate locations. In both cases, the mass dummies serve also as load points for static load testing.

Response data gathered during qualification and acceptance tests on subassemblies and components are useful only to diagnose failures which did not occur in earlier component fragility tests. Qualification and acceptance tests will therefore be less thoroughly instrumented than the developmental tests.

Operational vibration data will be obtained through flight telemetry from locations near the principal expected noise sources: the optical bar main bearings and film drum bearings. These data will be useful for diagnosis of degradation in photographic performance or incipient bearing failure. The outputs of these channels, supplemented by additional sensors during early ambient operating test, will serve to indicate design changes required to minimize vibration response at the focal plane.

2.6 STATIC LOAD TESTS

2.6.1 Environmental Parameters

The designing environment for structure supporting large components at relatively low resonant frequencies may be considered static, since higher mode deflection or stress responses of the system are significantly lower than low mode responses for a given energy input. As noted in the preceding section, little energy exists in the random vibration environment below 50 cps. Thus, the critical loading for primary structure occurs at the times of maximum thrust or lateral acceleration. Preliminary analysis has indicated that the maximum thrust load condition is far more severe in effect on the camera support truss and optical bars than the maximum αq condition.

In addition to the static thrust level at second stage burnout, increments of load are transmitted to the camera from steering transients, slosh, and engine shutdown shock. Static equivalents to these dynamic loads will be determined analytically, and added to the thrust level in arriving at the design limit load. The duration of peak loading is very short (on the order of seconds) and the structure temperature is near ambient so creep effects are not of importance; this is not to say that hysteretic effects are negligible. The direction of lateral load in flight is undefined, so test loads will be applied separately in the two principal lateral directions.

Simulated acceleration load levels for qualification test will be carried to design ultimate load, i.e., 1.25 times limit load. Design deflections will be determined on the basis of limit load only. Static burst tests on the gas supply system will be carried to 1.50 times working pressure for acceptance and 2.50 times working pressure for qualification.

2.6.2 Properties of System

Since all items to undergo static test are kinematically mounted, there is no need for simulation of supporting structure at higher levels of assembly. All tests will be run on rigid support frames. Load distribution under steady acceleration will be simulated by jack loads applied to rigid load points at principal mass locations. The load points will be the same static mass models used for vibration surveys.

2.6.3 Response Parameters

Since the support truss and optical bar are designed primarily to satisfy stiffness criteria, determination of ultimate capability is of secondary concern. Since load paths in both structures are clearly defined, there is no need for elaborate strain gage instrumentation, except in the region of the optical bar aperture cutout. The major problem area to be faced is the occurrence of permanent set due to hysteresis or joint slip which could disturb relative alignment of the optical elements or of the elements relative to the axis of rotation. Average residual strains as low as 10×10^{-6} inch/inch in the optical bar structure could degrade optical performance detectably. Early developmental tests on the specific materials proposed for use in the bar will determine allowable stress levels and joint configurations to maintain residual strains below acceptable limits. The first optical bar static test will be instrumented with precision gaging rods and collimators to measure residual displacement and tilt of elements after load.

2.7 RELIABILITY TESTS

2.7.1 Test Data

The extensive tests planned herein on all levels of assembly will provide ample operating data on which to base a realistic reliability estimate for the camera system. In the case of components of doubtful reliability, early prototype testing will be accomplished to indicate the magnitude of the problem and permit redesign if necessary; of particular concern are electro-mechanical linear actuators, such as the pneumatic system valves and capping shutter.

A reliability engineer within the System Design organization will be cognizant of all failure reports and reliability estimates. Component failures will be documented throughout the prototype test program, for correlation with required failure rates. Determination of the acceptability of a given component will be based on the following analysis.

2.7.2 Reliability Acceptance Criteria

The test plan is based on an exponential failure distribution and utilizes a sequential analysis. The plots in Fig. 9 can be applied as test criteria for reliability testing of parts, assemblies and subsystems. Three pairs of lines represent criteria for 90, 95 and 99 percent confidence in test results. When a given confidence level is chosen, cumulative test cycles vs. cumulative test failures for one or more units under test are plotted until an accept or reject decision is reached. In some cases it may be desirable to truncate testing to force a decision (see Fig. 10) at a predetermined total test time.

Calculations are based on equal consumer and producer risks ($\alpha = \beta$) and a discrimination ratio of 1.5. This discrimination ratio establishes that the test will accept only items whose reliability

(Mean Cycles Between Failure - MCBF) is equal to the minimum requirement and will reject items whose reliability falls to 2/3 of the minimum.

$$k = \text{Discrimination Ratio} = \frac{M_o \text{ (Min. MCBF)}}{M_1 \text{ (Reject Level MCBF)}} = 1.5$$

X = No. of Observed Failures

α = Producer's Risk = 0.10 for this example

β = Consumer's Risk = 0.10 for this example

T/M_o = Total Test Cycles/Required MCBF

The accept line is computed by:

$$\frac{T}{M_o} = \frac{h_o}{M_o} + \frac{m}{M_o} X$$

where:

$$\frac{h_o}{M_o} = 2 \ln \frac{1 - \alpha}{\beta}$$

$$\frac{m}{M_o} = 2 \ln k$$

then:

$$\frac{T}{M_o} = 2 \ln \frac{1 - 0.10}{0.10} + 2 \ln 1.5 X$$

$$\frac{T}{M_o} = 4.4 + 81 X$$

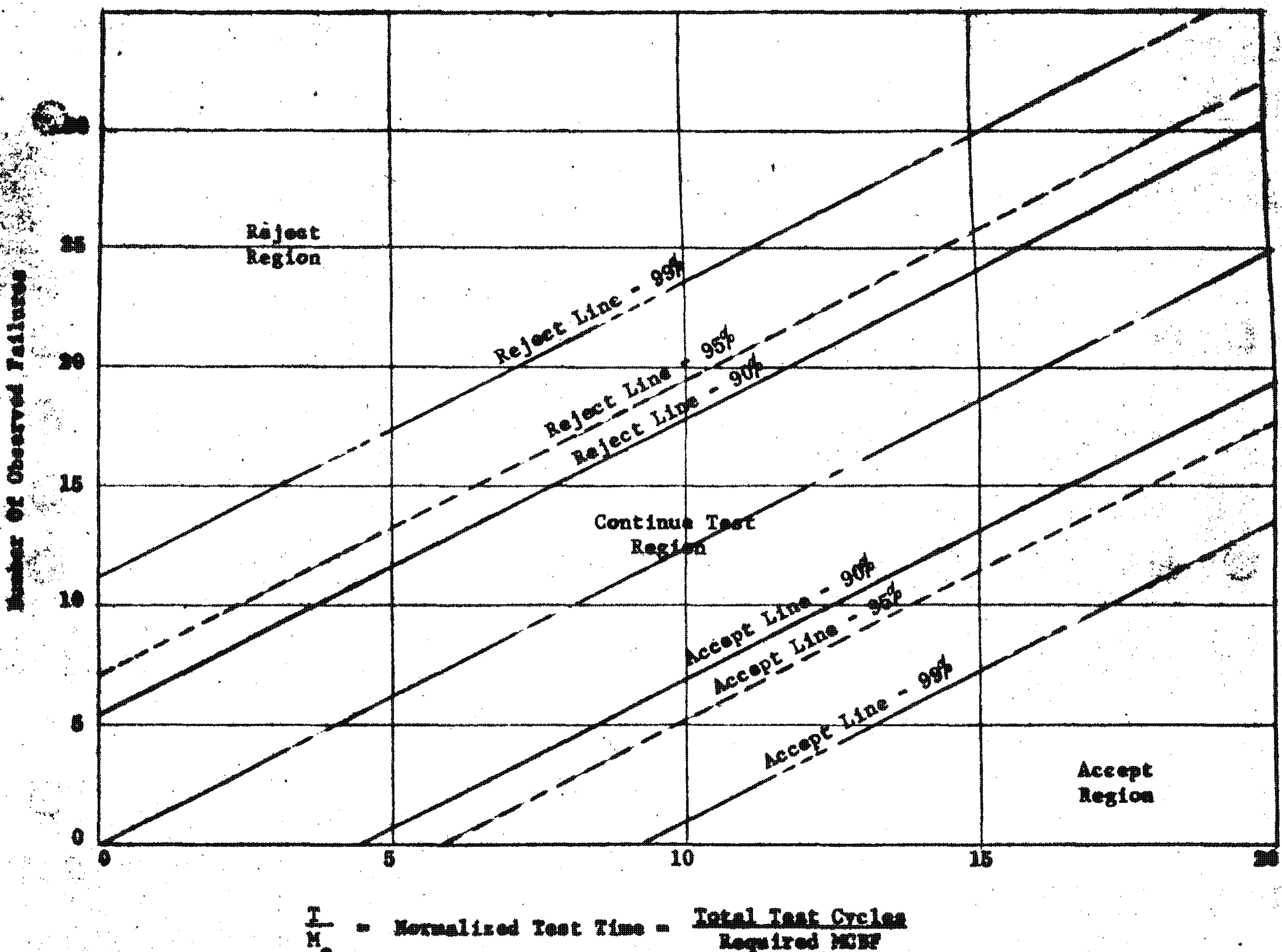

Figure 9. Exponential Sequential Test Plans (α = β; 90, 95, and 99% Confidence)

Approved for Release: 2018/02/01 C05108511

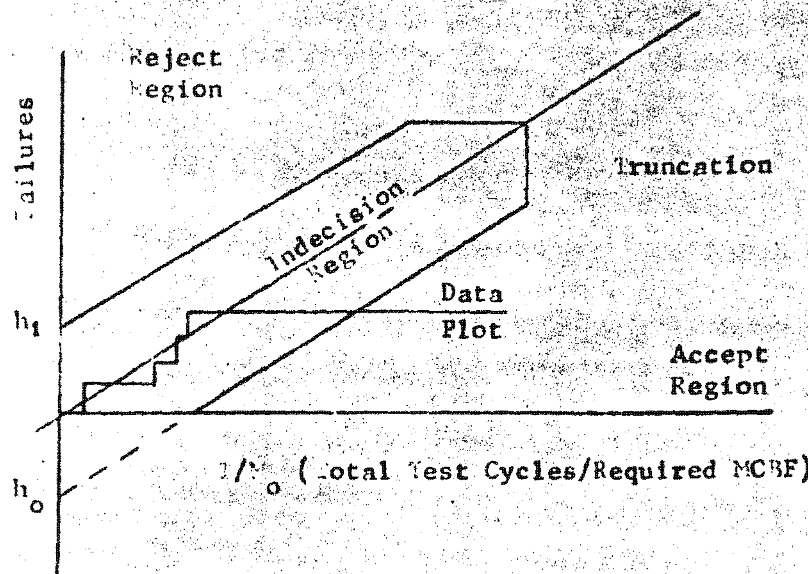

Figure 10. Truncation Testing

The reject line is computed by:

$$\frac{T}{M_o} = \frac{h_1}{M_o} + \frac{m}{M_o} X$$

where:

$$\frac{h_1}{M_o} = -2 \ln \frac{1 - \beta}{\alpha}$$

then:

$$\frac{T}{M_o} = -2 \ln \frac{1 - 0.10}{0.10} + 2 \ln 1.5 X$$

$$\frac{T}{M_o} = -4.4 + 0.81 X$$

2.8 PHOTOGRAPHIC TESTS

Photographic tests will be made at various places in the camera assembly sequence. The purpose of these tests will be to assess the quality of the camera system after each major addition of equipment to the optical bar. By keeping a control of the effect of all major operations, those causing photo-optical deterioration can be singled out and the design or manufacture can be improved.

2.8.1 Target Collimator

All photographic resolution tests will be performed using a 200-inch equivalent focal length, 30-inch aperture paraboloid collimator to image the target at infinity. This collimator will be of the Newtonian form, having a small diagonal to allow the target to be located outside the collimated beam. The diagonal will be of the minimum size required to cover the target format and the aperture cone. The central aperture obstruction in the collimator will be of about 4 inches diameter.

Because of the small field of the paraboloid collimator, the target format will be limited to a fraction of an inch. For a 200-inch f/10 collimator the maximum angular image errors, the combination of astigmatism and coma are as follows:

Format Diameter	Astigmatism and Coma
0.1 inch	0.09 seconds of arc
0.2 inch	0.18 seconds of arc
0.3 inch	0.27 seconds of arc

In the panoramic system which has a resolved angle of about 1 second of arc, it appears unwise to allow more than about 0.1 second of arc collimator aberration. For this reason the target array will be kept to about 2 x 2 mm for the high resolution section of the target.

It is possible to expand this format to about a 1 inch dimension through the use of correcting optics several inches in front of the target plane. However, at this time it appears unwise to use the additional optics, which would cause some straylight.

2.8.2 Target Format

The target will have provision for several types of test. Included will be Mil. Standard 150 resolution targets of high contrast and of 2:1 contrast, and sine wave targets of high contrast. The sine wave targets will have frequencies which when imaged in the focal plane of the camera system will provide 50, 100, and 150 lines per millimeter. Thus, for the 200 inch e.f.l. collimator, 30 cycles per millimeter in the target will suffice.

The central section of the target array will be used to assess critical imagery in the order of 50 to 200 lines per millimeter. This section will be limited to a 2 x 2 millimeter square area as discussed in Section 2.8.1. The 2 x 2 millimeter area will be as follows:

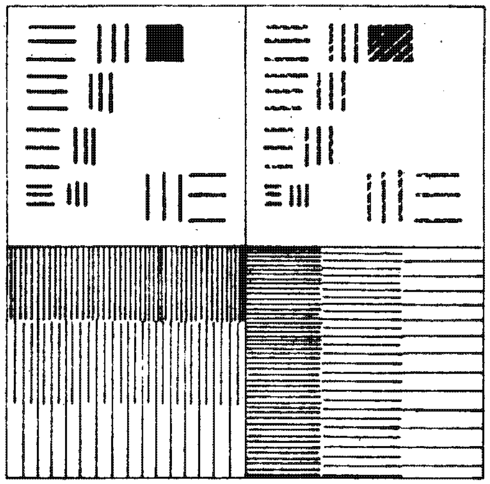

Fig. 11 - Central Section of Target Array

Target motion in the order of 12 inches per second will be required in the collimator to simulate the maximum V/h value of 0.06 radians per second. In addition the target must be centered on the collimator axis at the time that the photographic system makes its exposure. To prevent minor synchronization errors between target position and camera position from affecting the quality of collimation, the target format will be repeated ten times along the line of target motion. This will provide a line of targets 20 mm long. Synchronization will then need to be only accurate enough so that one of these sets of targets will be on the axis of the collimator. The targets will all be mounted on a 2" x 2" target plate.

To provide for measurement of camera resolutions poorer than 50 lines per millimeter during the camera adjustment period, coarser resolving power targets of high contrast will be placed along the edges of the line of high resolution units. These targets representing much poorer resolved angles of the camera system can be located somewhat away from the center of the collimator field.

The complete target format will thus be as shown in Fig. 12

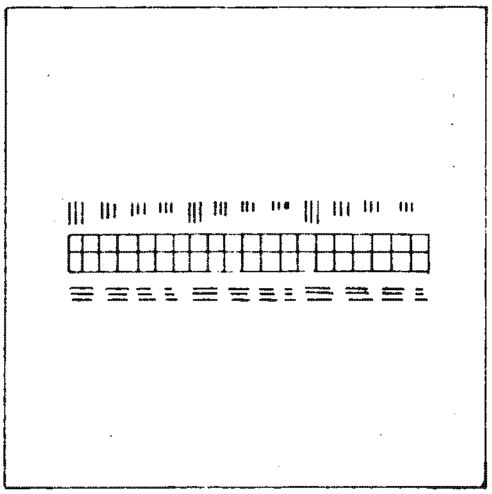

Fig. 12. Complete Target Format

The light source behind the targets will be such as to illuminate the target area uniformly with no more than a 10 percent total variation in level. The source as seen from the mirror position will uniformly illuminate the paraboloid mirror with no more than a 10 percent variation over the surface. In addition the complete light source must just be visible from the edge of the collimator tube at the end where the mirror is mounted.

The spectral quality of the source will be mean noon sunlight. This may be achieved by employing a tungsten source and a simple glass sunlight correcting filter.

A suggested source is a small opal type lamp such as the PH IIIA used for photo enlarging. This source should be imaged by a weak condensing system, onto the paraboloid collimator. This will provide approximately the required uniformity of illumination.

The brightness of the source will be adjusted through the use of neutral density filters to give target image densities of 1.0 for exposure times in the region of 1 millisecond to 10 milliseconds.

2.8.3 Target Drive

To simulate the V/h values to be experienced under operational conditions, the target must move during the exposure. The velocity of movement depends on the V/h value to be simulated. The linear velocity V_c required will be as follows:

V_c = V/h f_c where f_c is the equivalent focal length of the collimator

The target velocity will be capable of being set to 21 discrete velocities providing seven V/h values for each of three positions along the format.

Scan Synchronization

Since the camera can see the collimator target only once during a complete rotation, the target drive must be synchronized with the camera rotation. The target must be moving at the proper rate and must be on the collimator axis at the time the exposure is taken. Since the target is moving at about 12 inches per second maximum, and the target strip is about 0.8 inch long, the exposure must occur at the correct time $\pm$ 0.03 seconds. This is the timing accuracy required in the starting of the target drive.

Cross-Track V/h Simulation

Cross-track V/h simulation will be provided by rotating the V/h drive in the focal plane of the collimator. There will be 5 angular positions for this V/h drive to give proper simulation for scan positions of -55 degrees, -40 degrees, 0 degrees, +40 degrees, and +55 degrees. The V/h drive will have to be rotated a maximum of about ± 12 degrees to provide this simulation.

2.8.4 Photographic Processing

Preliminary photographic testing for focus and image quality will take a small amount of film, less than 100 feet. However, operational acceptance testing will involve 5000'foot lengths of material, and qualification testing a full film load of 34000 feet. Every attempt will be made to recycle the film and pack the targets reasonably close together; however, with one small exposed area (a fraction of an inch in dimension) per 30 feet of material it will require two recyclings to obtain one exposure per 10 feet. On this basis a processor which can handle 5000 feet of film rapidly may be required. This with two recyclings will allow 500 separate images to be formed on the film. To allow later evaluation of the processing, corona, and evaluation of the sine wave modulation tests, sensitometric data will be placed two inches in from the edge at 3 feet intervals. These data will be placed on the film by a unit built into the processor.

The time required to process this film at 40 feet per minute will be in the order of 1 hour and 15 minutes. This time is estimated on the basis of a machine which has a throughput time of 2 minutes and employs 120 x 90 developer at 68°F. This development has been tested in the laboratory with type 4404 film. The film developed in this way is found to give its inherent resolution.

2.8.5 Interpretation of Results

Resolution

The resolving power targets will be read using a binocular microscope of whatever power suits the observer best. Generally, one unit of power per line per millimeter is the maximum magnification which can be gainfully employed in reading resolution. On this basis, a binocular microscope which provides powers from about 10 X to about 200 X will be sufficient for resolution measurements.

A single observer will read all the targets on any one test run to maintain uniformity of judgment.

Sine Wave Modulation

The sine wave modulation targets will be read with a flying spot scanning type micro photometer. The results obtained here will be compared to the modulations required for this test phase.

Corona

To detect the presence of corona the film will be examined for obvious density variation above the normal fog density. The sensitometric steps will be read on a Macbeth Ansco densitometer, and the results tabulated. Any anomalies in the results from step wedge to step wedge will be further investigated.

Fiducial Marks and Data Block

The fiducial marks and the data block will be examined for proper exposure and focus. Measurements will be made between all fiducial marks on selected frames to ascertain that the timing system is working properly.

Frame Registration

To determine whether the frames have been properly located with respect to the frame indicator holes, a measurement will be made. The distance from the 0 scan angle target to the frame indicator hole in the film will be measured to the nearest millimeter for selected frames.

2.8.6 Slit and Shutter Operation

To determine proper slit operation a strobotac will be employed at the entrance aperture. The actual opening of the slit will be recorded on the film as an area of dense exposure. Measurement of this area will determine the size of the slit opening.

Shutter operation will be determined by placing a continuous light source in the aperture of the system. The length of the frame and the time of shutter closure will be recorded on the film.

Internal light baffle effectiveness will be determined by flooding the system aperture with diffuse light except in the collimator beam. Straylight will be shown by increased background density.

External light baffle effectiveness will be tested by flooding the spacecraft with light from the outside. Light leaks will again show up as variations in the background density of the film.

3.0 ASSEMBLY LEVEL V TESTS

3.1 SKEW ARM ASSEMBLY

3.1.1 Pneumatic System Prototype Brassboard

The purpose of these tests is to:

1. Define the design parameters for the pneumatic system, under both ambient and temperature/vacuum environments. The parameters of main interest are film friction, film corona, film tracking and steering, pressure regulation, valve control, and gas selection.

2. Verify design assumptions on gas selection and flow rates, and pressure control system.

The brassboard shall consist of an abbreviated version of the film transport assembly using a metering drum and servo control to drive a continuous film loop at appropriate speeds. The film track shall include a skew roller (air bar), tension control roller (dancer), drag roller, and steering mechanism.

The pneumatic system shall include a supply of both helium and nitrogen, pressure regulator, flow regulator, and control system. Tests shall be made at both ambient and at pressure on the order of 10^{-3} mm Hg.

3.1.2 Gas Bottle Static Burst Qualification

One gas bottle shall be tested at 2.5 times working pressure to qualify for use in an area containing personnel. The testing and certification shall be done at the sub-contractor's facility.

3.1.3 Pneumatic System Component Failure Rate

The prototype pneumatic system components (valves and regulators) shall be tested at ambient pressure to determine component failure rates.

3.1.4 Assembly Vibration Qualification

The skew arm assembly shall be subject to the vibration envelope per Section 2.5.2 to demonstrate the alignment of the skew arm rollers is maintained, and support for the gas bottles and regulator system is sufficient. The skew arm assembly will be mounted to a vibration test fixture. Measurements of roller position, torque, and arm position will be made before and after vibration to detect any component weakness.

3.1.5 Gas Bottle Pressurization Acceptance

The gas bottles shall be tested at 1.5 times working pressure to demonstrate satisfactory workmanship. The testing shall be done at the sub-contractor's facility.

3.2 SPOOL ASSEMBLY

3.2.1 Trial Assembly

One prototype spool assembly including the spool, dummy film load and torque motor shall be assembled under clean room conditions to determine assembly technique, bearing fits and eccentricities, torque motor fits and centering requirements, bearing preload technique, bearing noise, stiffness, runout and static and dynamic friction.

3.2.2 Vibration Qualification

The above spool assembly including the torque motor and dummy film load shall be mounted in a vibration test fixture and subjected to the vibration envelope per Section 2.5.2. The above performance characteristics shall be measured after vibration plus visual inspection for any component weakness.

3.2.3 Thermal/Vacuum Qualification

The spool assembly will be operated in vacuum for a simulated duty cycle to assure that the spool torquer does not overheat and that the spool bearings do not seize. Tests will be run at the expected ambient temperature extremes, with radiant view factors simulated. A film path mockup will be provided which simulates drag on the torquer due to film tension.

3.3 OPTICAL BAR MAIN BEARINGS

The prototype main bearings shall be mounted on a test fixture to determine bearing mounting technique, fit and preload requirements, resistance to self alignment, stiffness, noise, and bearing friction at both ambient and temperature environments.

3.4 OPTICAL BAR DRIVE COMPONENTS

3.4.1 Optical Bar Drive Prototype Brassboard

The optical bar drive shall be simulated using a dummy optical bar mounted in a rigid stand similar to that used in the system feasibility brassboard. The dummy optical bar should reasonably simulate the prototype bar weight, moment of inertia and stiffness. Assembly sequence and procedure, encoder mechanical alignment and accuracy, preload requirements, bearing noise and runout can be ascertained by installing the prototype bearings, self-aligning housing, flexure fittings, and torque motor drive to the dummy optical bar. Prototype film spool shafts with an equivalent film weight will be added at this time to determine their effects on the optical bar bearings in terms of bearing friction, brinelling, and torque.

3.4.2 Encoder and Slip Ring Fragility

Prototype encoder and slip ring assemblies shall be mounted and aligned on separate test fixtures which represent the prototype optical bar end shaft. Assembly sequence and technique, instrumentation, optical encoder and mechanical slip ring alignment will be demonstrated. The encoder and slip ring assemblies will be vibration tested in three axes to determine component fragility levels.

3.4.3 Slip Ring Vacuum Life Test

A test fixture similar to the one above will be used to support the slip ring assembly, optical bar bearings and torque motor. The unit will be life tested in a vacuum chamber at a pressure on the order of 10^{-3} mm Hg. A simulated slip ring electrical load will be provided during the test.

3.5 CUT/SPLICE ASSEMBLY VIBRATION FRAGILITY

The cut/splice assembly shall be mounted on a vibration test fixture with an abbreviated film path to allow operation of the cut/splice cycle. The unit shall be subjected to increasing levels of vibration in octave band bursts. Performance of the cut/splice operation shall be evaluated after each burst of vibration to determine assembly fragility.

3.6 TRANSPORT ASSEMBLY

3.6.1 Transport Drum Assembly

The prototype metering drum, momentum balance wheel, torque motors, encoders, and bearings shall be assembled in their housing to evaluate assembly and alignment procedures, bearing noise and runout, bearing preload and stiffness, and drum eccentricity. The encoder shall be mounted on a vibration test fixture and tested in three axes to determine component fragility.

The assembly will undergo a thermal/vacuum qualification test to assure that motors do not overheat and bearings do not seize during operation. The test will be run in vacuum at the expected uniform temperature extremes, with radiant view factors and conduction paths simulated.

3.6.2 Capping Shutter

A developmental test program is required for the capping shutter assembly to define the design parameters for blade friction, blade release mechanism response times, blade acceleration, velocity, and impact characteristics, and blade flutter modes under vibration. A breadboard will suffice for initial test work during which high speed motion pictures will be used to verify design assumptions. Three prototype shutters shall be life tested in parallel to initiate gathering of reliability data on both the subassembly and component parts. One of the prototype units shall be mounted on a vibration test fixture and vibration tested in three axes to determine component fragility. The prototype units shall be tested for blade speed, blade impact vibrations, metal fatigue, wear, gaulling, and response time at intervals during a life test. The life test shall be for approximately 20 times the mission cycles.

3.6.3 Slit Assembly

The prototype slit assembly shall be tested to ascertain proper servo response, slit curtain tension, and slit width parallelism. Slit width symmetry about the center line shall be verified for various openings of the slit.

One of the prototype assemblies shall be mounted on a vibration test fixture and vibration tested in three axes to determine component fragility.

3.6.4 IMC Drive

A prototype IMC Brassboard will be used to verify the IMC design. The prototype IMC drive system including the torque motor, ball screw and encoder will be mounted to a test fixture containing a simulated film drum assembly and prototype linear bearings. Linear bearing alignment, assembly procedures, drive accuracy and bearing static and dynamic friction will be evaluated. The accuracy of follow up between rotation of the ball screw and translation of the drum will be measured.

A separate IMC encoder will be mounted in a vibration test fixture and vibrated in three axes to determine component fragility.

3.7 CYLINDER ASSEMBLY

3.7.1 Material Development Tests

The optical bar structure consists of a cylindrical beryllium shell and invar metering rods. Extremely small relative strains in the skin or metering rods between the assembly and operational phases will be detrimental to the optical performance of the system.

Since strain data at low stress levels is not available, a material developmental test program is required and is described below.

1. Invar Development Tests

The metering rods will be a special iron/nickel alloy similar to invar whose thermal coefficient of expansion is matched to that of the quartz primary mirror. The maximum residual strain that is permissible for the metering rods is 2×10^{-6} in/in. Several specimens of the selected material will be prepared for use in creep and hysteresis tests.

The creep tests will be performed by applying a constant uniaxial load to each test speciman at a specified, controlled temperature, and measuring the elongation at various times and the resulting residual strain upon removing the load. Several load levels will be used, including the maximum steady-state load encountered by the metering rods during powered flight. The hysteresis tests will be conducted by subjecting each test specimen to a cyclic uniaxial load for several rates of loading and measuring the strain from which a hysteresis loop can be plotted. The cyclic load will correspond to the maximum dynamic load experienced by the metering rods during powered flight, with a frequency range from 0 to 200 cps.

2. Beryllium Development Tests

The cylindrical shell of the optical bar is constructed of a beryllium alloy which is subjected to axial and lateral dynamic loads. In order to evaluate the creep and hysteresis effects in beryllium, several beryllium test specimens will be prepared and creep and hysteresis tests will be performed, as described above for the invar development tests.

3.7.2 Joint Evaluation and Development Tests

The cylinder assembly contains several types of joints employing body bound rivets and bolts. The magnitude of slip at these joints under flight load is extremely critical in view of the stringent optical tolerances.

Factors affecting the amount of slip are the size of the yield zone created around a fastener during assembly, yield properties of the material, fastener clamping force, and load. Loads include flight static and vibratory components, and thermal stress developed with change in temperature of a joint between dissimilar materials. Joint development will be paced by a test program including static and vibratory loads applied to several joint configurations. The optimum configuration for each application will be selected from initial test results; allowable load, tolerancing, and reliability data will be developed in succeeding tests.

3.7.3 Cylinder Assembly Qualification Tests

Qualification tests are planned for the optical bar cylinder assembly to demonstrate the ability of the assembly to meet the optical performance criteria during or after being subjected to environmental loads similar to those experienced in operation. The test assembly will include the end bells, shafts and bearing, with mass-simulated components for the optical elements, the transport assembly, skew roller assemblies and the film spools. The bearings will be mounted on a rigid structural test stand. The following qualification tests will then be performed on the assembly:

1. Static Load Tests

The optical bar assembly above will have high-precision optical alignment marks and mechanical gaging points at key locations. Prior to loading, the assembly will be optically aligned by use of collimators. Then a static 1 g lateral load will be applied to the assembly by pulling the dummy masses in the horizontal direction. While maintaining the constant 1 g load, the optical alignment is checked again.

The assembly will then be subjected to combined lateral and axial limit loads, and unloaded after a specified time. After the load is removed, an optical alignment check will be made to determine if any critical deformations have occurred. In addition, an inspection will be made for any fractures that may have occurred. If this test is successful, the optical bar will be rotated 90° about its roll axis, and the combined load tests repeated.

2. Vibration Test

The above optical bar assembly will be mounted horizontally on a vibration table. The assembly will be optically aligned prior to the test. It will be vibrated at the limit load level transmitted from the vehicle to the bearings, as determined by Section 2.5.2 of this plan. Accelerations will be monitored at critical locations during the test to observe any excessive response. After the test, the optical alignment will be checked and an inspection for physical damage conducted. The test will be repeated in the other two orthogonal axes.

3.7.4 Cylinder Vibration Survey

The optical bar assembly, as described in the previous section, will be installed on a vibration table. Accelerometers will be mounted on bracket interfaces for all major subassemblies such as those for the transport assembly, skew roller assemblies, film spools, optical elements, and other critical locations. The assembly will then be vibrated sinusoidally at low level, and the responses will be recorded. From the data mode shapes and transmissibility curves can be plotted which then can be used to determine the vibration inputs to the subassemblies. The above procedure will be repeated in the other two orthogonal directions.

3.8 OPTICAL ELEMENT ASSEMBLIES

3.8.1 Developmental Vibration Tests

A developmental series of vibration tests will be conducted as part of the program feasibility study to investigate the validity of the design approach to mounting of the three principal optical elements in their bezels, mounting of the optical assemblies to the camera structure, and general structural configuration. These tests will identify resonance, transmissibility and areas of structural weakness while proving the ability of the design to hold the elements fixed within specified optical tolerances.

A standard test procedure will be followed. Resonant modes of the test assembly will be determined by varying the frequency of the applied vibration slowly through a specified bandwidth at a low input level. Individual resonance surveys will be conducted with vibration applied along each of three mutually perpendicular axes of the test specimen. The test assembly will then be vibrated at qualification test levels for a period comparable to that anticipated during operation in each of three perpendicular axes.

3.8.2 Vibration Qualification

Vibration qualification tests will be conducted on one of each prototype optical assembly to demonstrate the ability of the assembly to meet performance goals after exposure to the operational environment. The test procedure will be similar to that defined in the preceding section with qualification levels defined in accordance with Section 2.5.2 of this plan.

3.8.3 Shock Qualification

Tests will be performed on one of each prototype optical assembly to prove its structural integrity and ability to meet specifications after exposure to a shock condition equivalent to that expected in operation.

A standard shock testing procedure will be followed such that the impact acceleration and impulse duration will be comparable to the maximum condition encountered during operation. The impulses will be applied in the three principal directions of the test specimen. Response will be measured with appropriate instrumentation.

3.8.4 Test Inspection

Following each vibration and shock test, each element of the optical assembly will be visually checked for signs of mechanical failure. Measurements will be made of critical assembly dimensions, and an optical inspection of surface figure will be conducted to detect any degradation.

3.8.5 Optical Element Thermal Tests

Prior to tests of the entire camera, it will be necessary to evaluate the distortions of one set of prototype optical elements resulting from the expected heat flux and temperature field.

Thermal tests of these elements should be made in vacuum while they are mounted in a manner as will be employed under use. These thermal-optical tests are quite complex and will be performed jointly by project personnel and the Optical Department.

The deformations to be studied may be divided into two groups. First are simple deformations which approximate changes in curvature or power. These may not necessarily affect imagery but will certainly affect focus. The second are deformations which will affect image quality and, most likely, focus as well. The quality of element figure will be measured by one or more of three measuring devices: a Foucault tester, an unequal path interferometer, or an equal path interferometer (Perkin-Elmer). The Foucault test will be useful when the prime concern is to measure curvature change in the optics or for rotationally symmetric figure change. The other two devices are useful in the case of irregular figure changes on optical surfaces.

Curvature change tests will require a temperature controlled structure to establish the spacing between light source and mirror. For example, a .001" spacing change on a 26" dia x 125" radius sphere represents 1/4 λ curvature change. This also implies that the structure should pass unstrained through the wall of the vacuum chamber. In all test set-ups it is desirable to bring the wavefront out of the vacuum tank through a window. A plane parallel plate may be used for the window if calculations show that the spherical aberration of the wavefront due to the window is negligible.

The test of the primary mirror will begin with the Foucault test to get an accurate measurement of curvature changes. At the same time it can be determined if significant figure change has occurred. The test should then be rerun and the magnitude of figure change measured with an interferometer. The chief argument for doing curvature and figure tests separately is that curvature tests require careful control of the separation between the light source and the mirror under test. If this is lost during the test, the data collected will be useless. While doing figure tests, if one does not have to concern himself with curvature measurements at the same time, the set-up may be changed at any time during the test to obtain best sensitivity of figure measurement.

The other element tests will make use of the interferometer to measure surface curvature or thickness change.

Fig. 13 shows a schematic of test apparatus required in the evaluation of reflective elements. Noteworthy here is the isolation of the optical measurement equipment for the test chamber environment. This general arrangement is adaptable to either the Foucault tester or interferometer.

The heat flux that strikes the surface of the optical element must be uniformly distributed over its front surface. In order to determine what

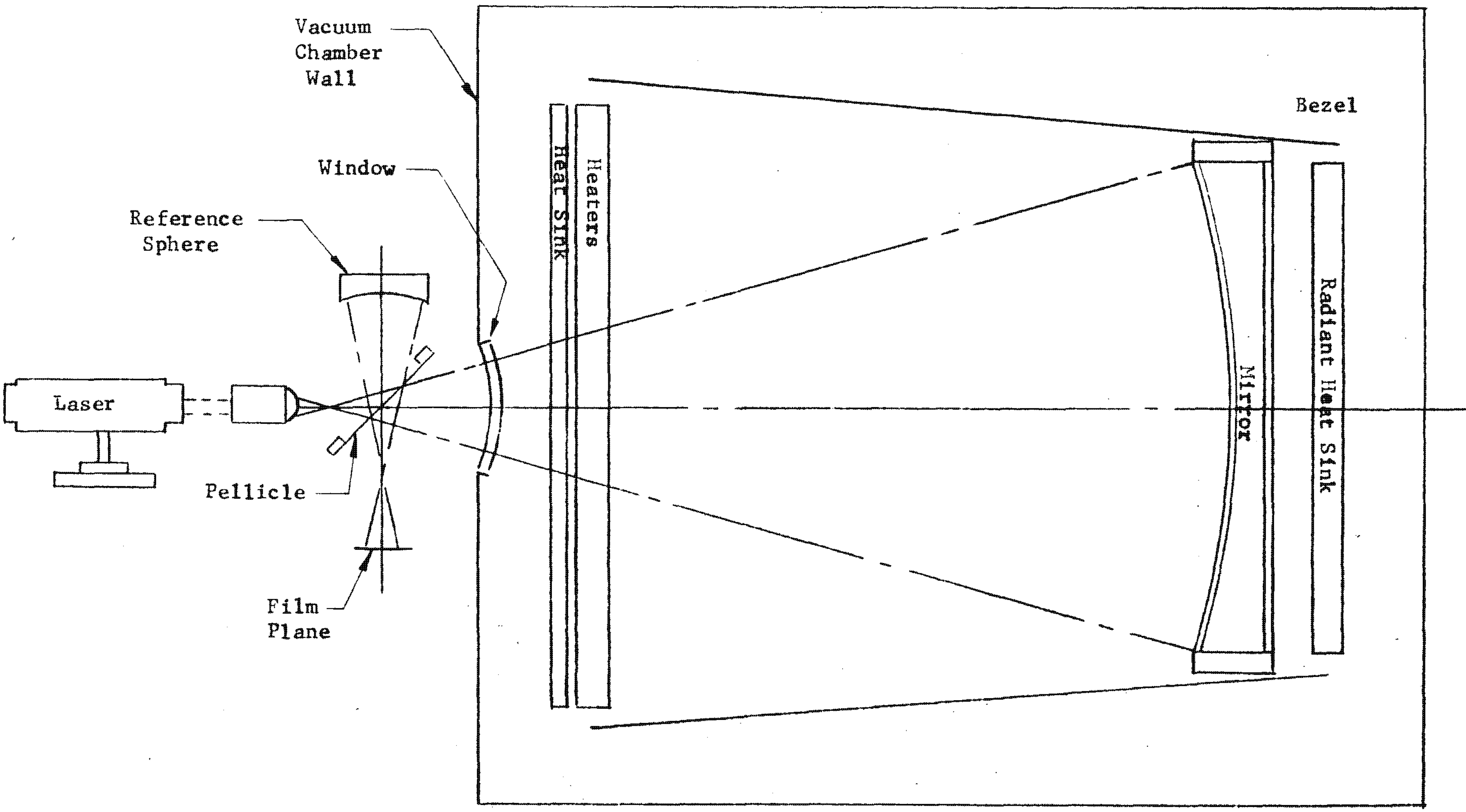

Figure 13. Test Apparatus for the Thermal Evaluation of Mirrors

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nonuniformity exists and to correct for it, a calibration scheme shall be used. A thin sheet of steel, the same diameter as the mirror, will be placed in the chamber in the same location as the mirror. Calibrated copper-constantan thermocouples mounted to the sink side of the sheet and to the sink itself will provide information on temperature difference. By adjusting power into the heater plate and maintaining a constant temperature at the sink, the desired heat flux information may be obtained.

3.9 THERMAL CONTROL COMPONENT TESTS

To obtain the empirical information necessary in the thermal design of the system, it will be necessary to perform several basic thermal tests. The tests fall into the general categories of:

1. Establishing the radiative character of the surface finishes employed where handbook data are insufficient.

2. Evaluating conduction paths in complex structures or where joints are present.

3. Evaluating the effectiveness of multilayer thin radiation shields under a variety of mounting techniques.

4. Establishing the behavior through self heating and mounting techniques of flight-temperature transducers.

The precautions indicated by proposing that these quantities be measured rather than by employing estimates are necessary because control of temperature differences between the various parts of the camera will have to be maintained to a few degrees of temperature.

3.9.1 Surface Finishes

In establishing the radiative character of most of the surface finishes employed in the camera, attention will be given primarily to total hemispherical emissivities at surface temperatures near 70°F. These values are directly useable for both the absorption and emission characteristics of the internal diffuse surface finishes. For finishes upon which albedo and solar energy will impinge, it will be necessary to supplement the total hemispherical measurements with measurements of spectral reflectivity.

Total hemispherical emissivities can be measured by suspending specimens having the proper surface finish in the bell jar lined with cold panels. The heat-flux rate and the temperature of the specimens and cold panels will be measured. Heat-flux rates from the specimens will be obtained either from their rate of temperature drop or from the amount of electrical dissipation required to maintain their temperatures within the cold panel environment.

For reflective surfaces and glass elements having antireflection coatings, it will also be necessary to determine the spectral absorptivities of these surfaces because they are exposed to short wavelength albedo and possibly solar radiation. A standard laboratory spectrophotometer usable up to wavelength of 3 microns will be suitable for these measurements. Depending on the glass employed in the corrector plate and field flattener, it may be necessary to obtain new spectral transmission data in the range of wavelengths in the albedo and solar spectrum.

3.9.2 Conduction Paths

The evaluation of the conduction paths within the solid elements of the camera structure has to be supplemented often with experiment. For example, the conduction path between the cell and elements of the field flattener occurs through plastic shims whose range of contact resistances to heat flow can only be evaluated experimentally through repeated tests of various samples. Another example of a heat-conduction path that requires experimental determination for accurate design is in the image motion compensation mechanism holding the film drum which will probably employ sliding bearings whose contact resistances must be evaluated empirically. Other regions where conduction paths can only be estimated analytically are the joints between the structural elements. The general technique of evaluating conduction paths will employ a sample characteristic of the actual structure. The sample will be placed in a small test chamber and one end will be heated and the other cooled, with all other surfaces well insulated by means of radiation shields. A balance between the heat introduced and removed will indicate the magnitude of the unidirectional heat flow. The measured values of the heat-flow rate, cross-sectional areas, and the temperature variation along the specimen will permit evaluation of the conductances or resistances associated with the conduction path.

3.9.3 Insulation Effectiveness

One factor of extreme importance in the current design philosophy will be the effectiveness of the radiation shielding placed around the camera system. Because the behavior of light, multi-layer radiation shielding depends considerably on the manner in which it is mounted, tests with various numbers of layers and tightness of packing are contemplated. Two types of radiation shielding are currently contemplated to be tested. One is aluminum coated crinkled mylar produced by the National Research Corporation. The other is also made of aluminum coated mylar but separated by a porous paper. The latter is made by Linde. The test will evaluate different degrees of tightness of wrap and mounting technique with variable ambient pressure level.

The test procedure will consist of vacuum pumping to 1×10^{-5} Torr. When the desired pressure level is obtained, electric heat will be slowly applied until the heater stabilizes at the desired temperature. Electrical power input may then be measured and the apparent K determined, since the other required parameters are known.

A schematic of the test facility is shown in Fig. 14. The concentric arrangement provides for a centally located and electrically heated shell with two identical specimens located at the inner and outer sides. Two temperature controlled shrouds surround the test assembly and are spaced 2 inches from the insulation. This annulus is open at both ends to permit airflow outward during pumpdown.

With precrinkled foil it is difficult, if not impossible, to separately determine to what extent the two modes of heat transfer (conduction and radiation) participate. Tests conducted as described at various chamber pressures will provide required design information in the form of an apparent conductivity. The steady state apparent value (Kap) is defined by:

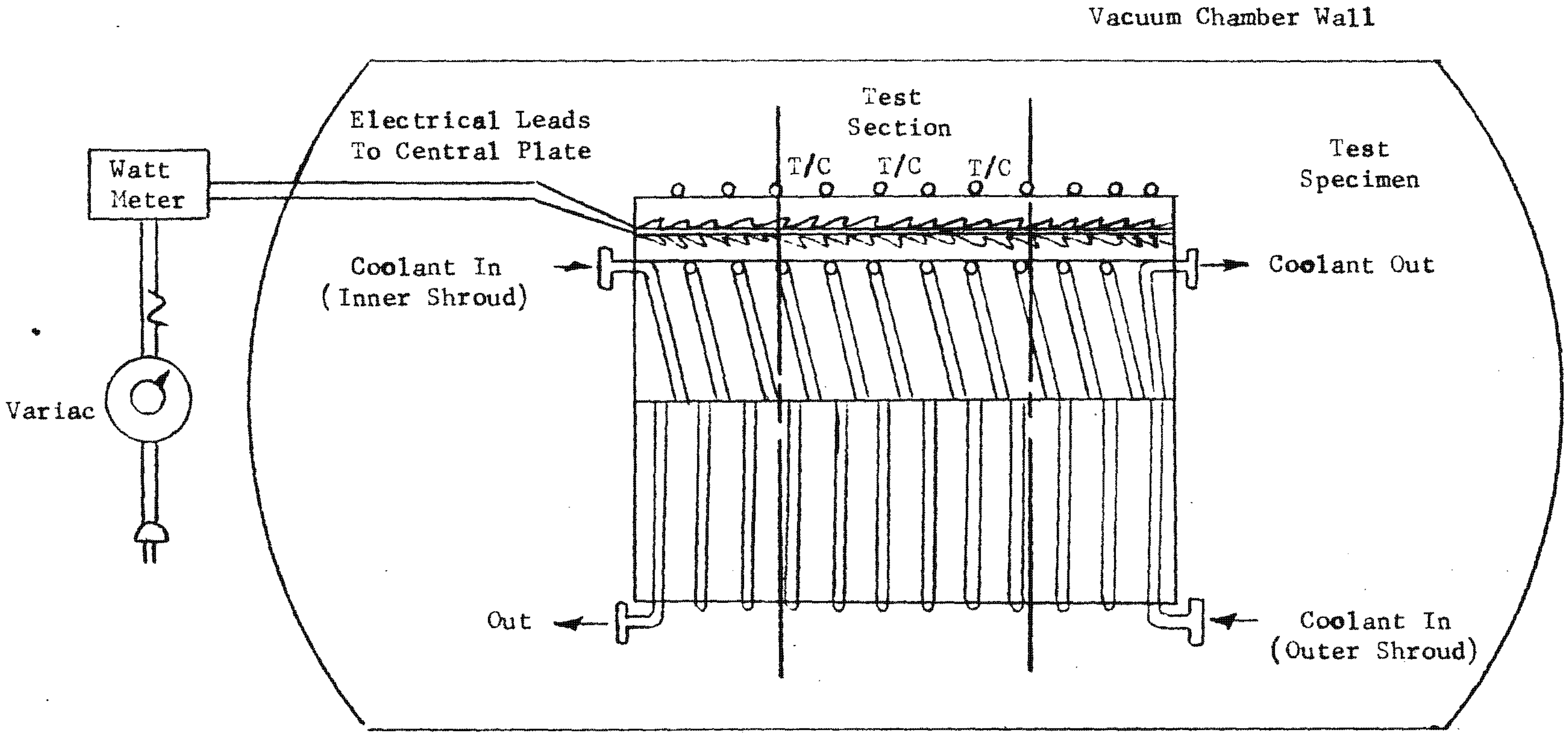

Figure 14. Test Apparatus for the Evaluation of Super Insulation

$$Kap = \frac{Q\,L}{A\,\Delta T} = Btu/hr\text{-}ft\text{-}^{o}F$$

and Q = Input electrical energy to heater, Btu/hr

L = Multiple layer thickness, ft (65 layers/in)

A = Heat flow area, ft^2

ΔT = Temperature difference, ^{o}F (T heater - T sink)

3.9.4 Temperature Transducers

Any temperature transducers to be employed in the flight articles will also require test. Past experience with transducers compatible with spacecraft telemetry or servo systems has indicated the possibility that serious self heating of their resistance elements can occur. The errors introduced by such self heating depend on the voltage supply, the construction details of the transducer, the thermal contact resistance of the mounting technique, and the conduction and radiation characteristics of the surface to which the transducer is attached. The proposed tests include mounting of the flight transducers on representative panels of camera structure, instrumenting the structure with thermocouples, feeding the transducers with the proper voltage, and measuring the differences in temperature as read by the transducers and thermocouples. Again the panels will be mounted in the vacuum evnironment produced by the bell jar or the small vacuum chamber.

3.10 ELECTRICAL SUBASSEMBLIES

The following sequence of tests is applicable to all 18 functional electronic subassemblies noted on drawing No. SK67779. Checkout equipment will be provided to exercise and measure all operating parameters; this equipment will include feed-through leads necessary to operate the subassemblies in a vacuum. The subassemblies are modularized for ease of replacement in the event of malfunction during system test. Thus acceptance tests at this level are omitted since equivalent tests will be conducted at the camera level. Qualification tests are included to permit early identification and correction of design faults.

3.10.1 Breadboards

All functional units will be breadboarded to verify basic circuit design and refine component selection.

3.10.2 Vibration Fragility

One of each functional unit will be vibrated to determine its tolerance of vibration when non-operating. Increasing levels of sinusoidal vibration will be rapidly swept through octave bandwidths until failure occurs; the level at this point defines fragility within the bandwidth. The failure is repaired and the test continued for a reasonable number of bandwidths and for three directions of excitation. Ambient electrical checkouts before and after vibrating determine the point of failure.

3.10.3 Thermal/Vacuum Qualification

One of each functional unit will be operated in a pressure of 10^{-3}mm Hg for durations simulating the operational duty cycle. Chamber temperature will be maintained at the expected operational ambient limits. Performance will be monitored continuously during operation.

3.10.4 Thermal/Vacuum Developmental Tests

A thermal evaluation of electronic equipment will be conducted on mock-ups which provide simulated heat sources and all surrounding surfaces which influence radiant heat transfer. The tests will be performed in an enclosure whose temperature will be uniform spatially, but may be varied with time. Proper evaluation of equipments must include the temperature rise during operation and decline with camera inactivity. In a test of this type it is important that surface finishes and materials of construction be identical to those intended for prototype hardware. Exterior surfaces which "see" the test item must also closely resemble those anticipated within the space vehicle.

Optical Bar Electronics

Fig. 15 shows a schematic of the test facility for the evaluation of

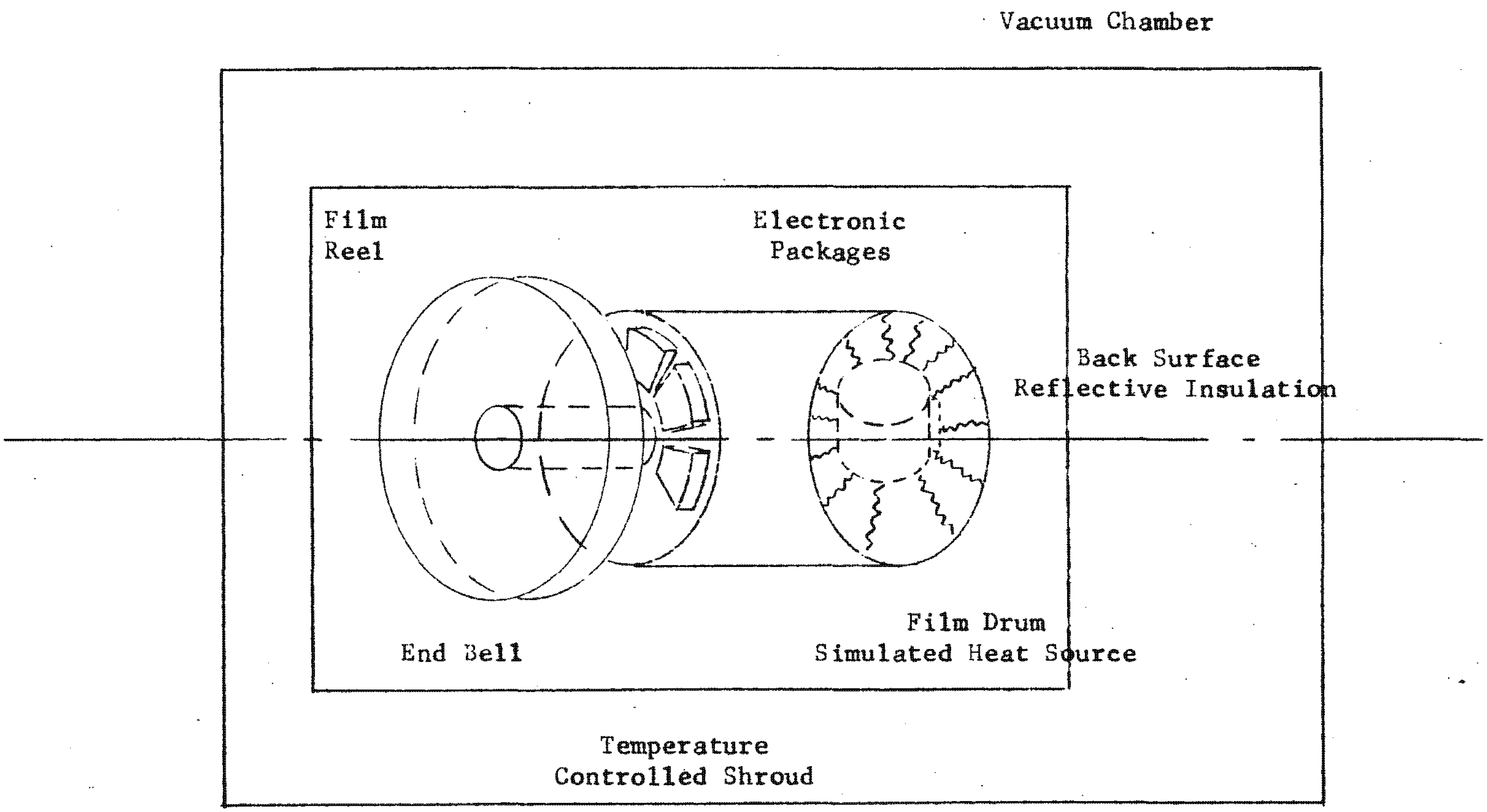

Figure 15. Test Facility for the Thermal Evaluation of Electronic Equipment

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electronic packages attached to the end bell of the optical bar. Since the film reel acts as a heat sink and blocks the field of view to the surroundings it must be included in the test assembly. The film drum in close proximity to the end bell is a heat source and must also be included. Instrumentation for this test will consist of thermistors for temperature measurement, mounted on and near electronic elements. The chamber will be pumped to a vacuum of 10^{-8} mm Hg to eliminate convection. Test procedure will consist in the following:

1. Temperature in the shroud will be regulated to the desired level.

2. After steady state prevails, readings from temperature measuring instrumentation will be recorded.

3. The electronic equipment mockups will be operated for the maximum anticipated duration.

4. At the end of the operational period a decay period will be allowed and temperature monitored.

The proper conduct of this test will provide information on temperature rise and decay in the electronic packages for a typical period of operation.

Camera System Electronics Unit

A similar test will be conducted on a mockup of the camera system electronics unit in a shroud which simulates the surroundings of this unit on the spacecraft.

4.0 ASSEMBLY LEVEL IV TESTS

4.1 SUPPLY END ASSEMBLY

The supply end assembly shall be checked both mechanically and electrically to assure conformance to applicable specifications and drawings. These checks will also include ball bearing static friction, skew arm roller alignment to the film spool, static and dynamic balance, and spool brake actuation.

4.2 TRANSPORT ASSEMBLY

4.2.1 Ambient Checkout

The transport assembly shall be checked both mechanically and electrically to assure conformance to applicable specifications and drawings. Roller alignment, tension sensor operation, steering roller mechanism, slit, torque motor, and capping shutter operation, IMC response, and linear IMC slide bearing alignment shall be inspected to ascertain proper functioning. Many of the test procedures developed for feasibility testing of drum/optical bar synchronization and film tracking will be applicable to prototype checkout. A simulated film path and checkout console will be provided to exercise the assembly.

4.2.2 Qualification Vibration

One prototype transport assembly shall be used for the vibration qualification test. The assembly shall be mounted on a suitable vibration test fixture and tested per the parameters of Section 2.5.1 to demonstrate the assembly meets the performance goals after environmental overstress and to detect assembly component weakness.

4.2.3 Developmental Thermal/Vacuum Test

Careful thermal-structural tests of components will also be required. One prime example of such a test is with the drive-drum assembly and the film positioning rollers that will maintain the focus of the system. Here the local heating introduced by the power dissipated in the torquers causes local expansions that could defocus the system. A pre-qualification test on this unit will be made in a small test chamber where the environment as seen by the drive-drum assembly within the camera system is simulated with panels whose temperatures can be adjusted. Some temperature control at the attachment points of this unit will also be required to assure the proper conduction heat exchange in the test. The test then will consist of operating the drive-drum assembly with proper tension in the film and measuring temperatures at various locations within the assembly and the movement of the film positioning rollers relative to a reference plane. Dial gages or laser interferometers can be used to make these movement measurements. During this test it will be necessary to also monitor the power consumed by the unit to determine any binding in the bearings.

4.2.4 Qualification T/V

The above test fixture supporting the transport assembly shall be used for the qualification thermal vacuum test. The unit shall be tested to demonstrate satisfactory performance of the slip rings, torque motors, encoders, and structural response to temperature change. Optical instrumentation shall be used to monitor focal surface position during thermal cycling.

4.2.5 Acceptance Vibration

Each prototype assembly shall be mounted on a test fixture and subjected to low level vibration to demonstrate a satisfactory level of workmanship.

4.2.6 Acceptance T/V

Each prototype assembly shall be operated in a thermal/vacuum environment to demonstrate a satisfactory level of workmanship.

4.3 OPTICAL BAR ASSEMBLY

The optical bar is the lowest level assembly of the camera optics, and as such will be thoroughly tested before proceeding with assembly of the complete camera. Past experience has indicated that tests at this level frequently identify fabrication faults which are easily correctable before access to adjustment points is impaired by assembly of other components.

4.3.1 Thermal Sensitivity Test

The first production optical bar with real optics will be subjected to a test which defines the effect on optical performance of various thermal responses. These data are essential for diagnosis of optical effects in later system thermal simulations where temperature gradients and transients are measured.

The optical bar will be installed in a vacuum chamber with thermal shrouds arranged in zones. In place of the transport assembly, a fixture with a static camera back will be installed behind the focal plane. The camera back will contain provisions for remote focus adjustment and frame transporting between exposures. An initial set of through-focus exposures will be made to check out the installation and establish focus at a chamber pressure of 1 mm Hg and thermal ambient. All photographic tests will be made on a static target at center field of a full-aperture collimator.

After alignment and checkout, a series of tests will be run from one steady thermal condition to another. At several times during the transient response cycle, through-focus exposures will be made to determine focus shift and degradation of image quality. Direct readout of temperature sensors will indicate when thermal equilibrium is reached. The tests will include the following:

1. Uniform Temperature Change - Maintain the chamber wall temperature constant over the complete area, change the temperature level in several incremental steps.

2. Transverse Gradient - From a uniform ambient temperature, establish a transverse temperature gradient tending to curve the optical bar. Repeat test from steady ambient to several magnitudes of steady gradient; and in the two principal transverse directions of the bar.

3. Axial Gradient - From a uniform ambient temperature, establish a linear longitudinal temperature gradient tending to defocus the system. Repeat the test from steady ambient to several magnitudes of steady gradient.

4. Incident Radiant Effect - Install a radiant source simulating the true spectral distribution of incident radiation in operation. The radiant view factor from the aperture to the source will be approximated with baffles, and the source will be aimed directly at the aperture. A mask will be rotated in front of the source to simulate the effect of rotating the optical bar into its baffle. The primary objective of the test is to determine the magnitude of "green house effect" heating of the optical elements, so the chamber walls will be maintained at a uniform temperature of 70°F.

4.3.2 Optical Bar Vibration Qualification

The first prototype optical bar assembly will undergo qualification testing prior to the thermal sensitivity tests outlined in the preceding section. The static camera back and transport mass model will be installed during these tests to measure optical degradation due to environmental stress. Mass models will be installed on the optical bar simulating the installation of major components in the end assemblies. Prototype optical bar bearings will be installed between the end shafts and vibration fixture.

Before vibrating, a series of through-focus exposures will be made at ambient against a static target at center field. The optical system will be fine tuned as necessary to reach design performance. After vibration at levels established in accordance with Section 2.5.2 of this plan, the optical bar will be replaced in the optical test fixture. A second series of ambient through-focus exposures will be made to detect focal shift or degradation in optical quality. Note that the camera back design must be rugged enough to withstand vibration without shifting longitudinally.

4.3.3 Optical Bar Thermal/Vacuum Qualification

Following vibration test and checkout, the optical bar will be installed in a vacuum chamber. A series of through-focus exposures will be made at a pressure of 1 mm Hg and ambient uniform temperature. The film plane will be set at best focus on the basis of these exposures. The pressure will be lowered to 10^{-5} mm Hg, and the chamber wall temperature varied to simulate the worst expected temperature magnitudes and gradients in the optical bar, and through-focus exposures repeated to detect any image degradation. Note that the chamber temperature distribution will be controlled to achieve a specified response in the optical bar, rather than a specified heat flux. This eliminates the need for modeling emissivities and view factors, which could at best be approximated on such a small-scale test. By the same reasoning, radiant simulation on the aperture is omitted since the magnitude of its effect would depend on fairly crude models. This does not obviate the need to determine sensitivity of the optics to a known radiant heat flux, as proposed in Section 4.3.1 of this plan.

4.3.4 Optical Bar Vibration Acceptance

Each optical bar leaving the optical assembly area will be dummy loaded and vibrated at acceptance levels determined in accordance with Section 2.5.2 of this plan. The primary objective of the test is to assure that the optical elements do not move out of position due to joint slip or material hysteresis. Optical resolution will be checked before and after test by a series of through-focus exposures against a static target.

4.3.5 Optical Bar Acceptance Thermal/Vacuum Test

Following vibration test and checkout, the optical bar will be installed in a chamber and a vacuum pumped to 1 mm Hg. A series of through-focus exposures will be made to determine vacuum focus shift. The chamber temperature will be cycled to produce maximum expected temperature limits in the optical bar. Exposures will be made at intervals to assure that resolution is not degraded nor the focus shifted.

4.4 TAKEUP END ASSEMBLY

The takeup end assembly shall be checked both mechanically and electrically to assure conformance to applicable specifications and drawings. Checks of ball bearing static friction, skew arm roller alignment to the film spool, film spool brake, film spool static and dynamic balance optical bar encoder, optical bar and spool torque motor operation, and slip ring operation will be made at this time.

4.5 SUPPLY SPOOL QUALIFICATION

One prototype supply spool will be loaded with live film at Eastman Kodak for evaluation of film response to the launch load environment. The loaded spool will be vibrated at qualification levels and centrifuged to simulate the worst launch static load conditions. Vibration will be applied along the axis of rotation only, with the spool mounted on its prototype bearings and shaft. Any evidence of film slip toward the flanges will be noted. After test, the film will be unspooled and inspected for scratches or abrasion. The required centrifuge time will be purchased at another facility.

5.0 ASSEMBLY LEVEL III TESTS

5.1 CAMERA QUALIFICATION TESTS

The following set of qualification tests will be conducted on the first complete camera assembly. All subassemblies will have undergone acceptance tests as appropriate, so the camera wear status is the same as expected for a production unit. The qualification cycle must be a fair simulation of mission stress and duration; the camera cannot be expected to endure repeated or prolonged testing at this level without wear-out.

5.1.1 Checkout Tests

The camera manufacturer will provide a checkout console which contains simulation of all drive servo electronics and logic normally contained in the camera system electronics unit. The camera will be exercised by the console, and performance data recorded on the console. An electrical and mechanical baseline will be established before qualification testing. The optical baseline will be established in the vacuum chamber at ambient temperature and a pressure of 1 mm Hg. A short series of exposures will be made of dynamic targets at center scan only, and fine tuning of the optics accomplished as necessary. Film will be removed from the takeup spool manually for processing.

5.1.2 Film Flatness Test

A set of lights will be installed in front of the focal plane of the camera in the vacuum chamber. The chamber will be pumped to 10^{-3} mm Hg and the camera operated for a short series of exposures. The lights are arranged across the film width in pairs with converging beams, and are flashed at fixed intervals. Film exposed during the test will be unspooled manually from the takeup for processing. The distances between projected line pairs and between successive flash exposures will be measured to establish flatness of film at the focal plane both cross-track and along-track.

5.1.3 Vibration Test

The camera will be removed from the chamber, installed on a vibration fixture, and vibrated at levels established in accordance with Section 2.5.2 of this plan.

5.1.4 Thermal/Vacuum Tests

Qualification tests of the camera in the thermal/vacuum environment will be divided into several stages due to limitations on chamber pumping capacity. This series of tests constitutes a thorough series of photographic tests across the full frame to prove camera performance. The tests include, in sequence:

1. Optical checkout in the chamber at a pressure of 1 mm Hg. A short series of exposures against a dynamic target will be made to verify that performance has not been degraded in the vibration test.

2. Vacuum optical checkout at a chamber pressure of 10^{-3} mm Hg, with Helium lubricant in the film bars. This test will assure that corona is not present during system operation. A short series of photographs against a dynamic target at center scan will be exposed for checkout. The thermal environment will be uniform and stable at ambient. Pumping capacity of the chamber will not be sufficient to maintain a pressure lower than 10^{-3} mm Hg during gas bar operation.

3. Thermal/vacuum test at a chamber pressure of 10^{-5} mm Hg, with Nitrogen lubricant in the film bars. The operating duty cycle of the camera will be simulated for thermal effect so far as possible in the small chamber, although chamber pumping capacity is not sufficient to maintain the pressure ambient at 10^{-5} mm Hg while film bars are operating. At pressures higher than 10^{-5} mm Hg, the camera insulation loses efficiency to a significant extent, so thermal simulation will be restricted to allowing the camera to soak to a predicted temperature gradient and to follow spacecraft transients while non-operating. During operating cycles, which will be spaced to allow steady-state temperature gradients to form across the optical bar, transient thermal response cannot be accurately simulated because of degraded insulation efficiency. Radiation incident on the aperture is <u>not</u> simulated during this test, since transient responses are not realistic. The test will encompass a typical sequence of operating cycles, including film recycling to complete exposure of all frames. A full film load of 34000 ft. will be exposed during the test. Photographic test operations are described in the next section.

5.1.5 Photographic Tests

Full-format photographic tests conducted at the individual camera level are intended to exercise all camera functions affecting photographic performance, particularly image motion compensation (IMC). Since the IMC function varies from end to end of the frame format, the test must include features which permit testing at several scan angles. The structural design of the system, however, does not permit undegraded performance except with the line-of-sight horizontal due to sag of the optics under earth gravity load. Two options are available to satisfy the requirements for horizontal line of sight and variable scan angle to target:

1. Electrically change the optical bar encoder reference position from zero at horizontal to another position. Phasing of the IMC function will be maintained about the new encoder zero reference.

2. Physically rotate the optical bar so that the line of sight is horizontal at a given scan angle.

The latter option provides a more complete test, and the camera manufacturer will, accordingly, provide a mounting frame for the camera in the chamber which can be rotated remotely, while maintaining required alignment with the target projector and collimator.

The complete series of photographic tests will include exposures on both sides of zero scan angle and across the full field width at various light levels. All exposures will be against dynamic targets driven to simulate cross-track and along-track components of image motion.

5.2 CAMERA ACCEPTANCE TESTS

The acceptance test series conducted on each camera follows the same general sequence as the qualification tests performed on a single camera, at reduced stress levels and duration.

5.2.1 Checkout Tests

The camera is loaded with film and exercised by the checkout console to assure proper film tracking and electrical performance. A short sequence of center-scan target exposures will be made from the chamber at a pressure of 1 mm Hg to establish the camera optical baseline.

5.2.2 Film Flatness Test

A short segment of film will be exposed by lamps as described in Section 5.1.2 of this report. The film segment will be removed manually, processed, and gauged for film flatness. The test will be conducted at a chamber pressure of 10^{-3} mm Hg.

5.2.3 Vibration Test

The camera will be installed in a fixture and vibrated at levels established in accordance with Section 2.5.1 of this plan.

5.2.4 Thermal/Vacuum Tests

The camera will be installed in the chamber and subjected to the following series of tests:

1. Optical checkout at a pressure of 1 mm Hg. A short series of exposures will be made at center-scan against a dynamic target to verify that performance has not been degraded in vibration test.

2. Vacuum checkout, at a pressure of 10^{-3} mm Hg with Helium lubricant in the film bars. This test constitutes a corona test and a Helium leak test. A short series of exposures will be made against a dynamic target.

3. Thermal/vacuum test at a chamber pressure of 10^{-5} mm Hg and Nitrogen lubricant in the film bars. Typical mission duty cycles will be simulated during exposure of a film load of 5000 ft. Thermal simulation will be restricted as defined by Section 5.1.4 of this plan. Photographic tests against dynamic targets will cover scan angles on both sides of center-scan and across the full field width.

5.3 MAIN FRAME STRUCTURE

For reasons developed in Section 2.5.1 of this plan, tests on the main frame of the camera assembly will be restricted to a vibration survey and a static load qualification.

5.3.1 Vibration Survey

The main frame structure will be loaded with dummies simulating the mass distribution and attachment details of the cameras. A set of prototype optical bar bearings will be installed on one of the dummies. The complete assembly will be installed in a mockup of the lower half of the spacecraft, and floated with soft mounts from the floor. Vibration will be applied with a shaker at the attachment points of the main frame to the spacecraft. Mode shapes of camera response and transmission to the cameras will be recorded. Data from the two camera dummies will indicate the attenuation obtained through the optical bar bearings, to determine if bearing simulation is essential in optical bar vibration tests.

5.3.2 Static Load Test

Jack loads will be applied to the camera dummies, simulating acceleration loads on the system. Inertial loads due to the truss itself will be simulated by an increment applied to camera loads.

Deflections of the cameras will be measured at limit load and after unloading, to determine non-recoverable set. Member stresses will be measured by strain gages at critical points for correlation with analysis and for determination of secondary stress effects near the joints. After residual set measurement, loading will be carried to the ultimate load level. The test will be repeated with thrust load plus lateral load in each of two perpendicular directions.

5.4 RECOVERY TAKEUP UNIT

Tests conducted on this unit are complicated by the need to interface requirements with both the recovery vehicle manufacturer (for re-entry effects and installation) and the spacecraft manufacturer (for launch and orbital effects and operation). The test series will include the following.

5.4.1 Trial Assembly

The first set of prototype parts will be expended in a trial assembly. This operation will include initial fit-up and performance checks. A console will be provided by the camera manufacturer to control test operations of the unit, and to simulate all electrical circuits passing through the takeup unit/recovery vehicle connector.

5.4.2 Electrical and Mechanical Checkout

Each unit will undergo ambient checkout tests at completion of assembly to demonstrate performance with no film load, including spool/roller alignment, running torque, servo response, and pneumatic system operation.

5.4.3 Vibration Qualification Tests

The camera manufacturer will vibrate one takeup unit to qualification levels established in accordance with Section 2.5.1 of this plan. The test will simulate the launch vibration environment only, with no film load. The gas bottle will not be pressurized during this test.

Launch vibration qualification of the recovery vehicle will be performed with a mass model of the empty takeup unit. Re-entry vibration will be neglected in comparison with static load on the full unit.

The unit will be operated before and after vibration qualification to demonstrate performance.

5.4.4 Static Load Qualification Tests

The trial assembly takeup unit will be static loaded to simulate re-entry loads with full spools. A jack load will simulate the force exerted on the main support shaft and frame by the spools. The load will depend on the worst response expected for atmospheric deceleration or water impact. Satisfactory performance is demonstrated if the unit structure survives without fracture or significant displacement of the film center of mass. The gas bottle will be separately subjected to a static burst qualification test.

5.4.5 Thermal/Vacuum Qualification Test

The takeup unit which underwent vibration qualification will be operated in a vacuum of 10^{-3} mm Hg; a full film load of 34000 ft. will be spooled on to the unit during the test. Following demonstration of satisfactory performance in vacuum, the unit will be integrated into the camera system thermal/vacuum qualification test described in Section 6.1 of this plan.

5.4.6 Vibration Acceptance Test

Each takeup unit will be installed in a fixture and vibrated by the camera manufacturer.

5.4.7 Thermal/Vacuum Acceptance Test

Each takeup unit will be operated independently at the expected uniform temperature extremes in a vacuum for checkout without film; and as an integral part of the camera system for final acceptance, as described in Section 6.1 of this plan.

5.4.8 Gas Bottle Tests

Gas bottles will be subjected to static pressurization and leak tests as specified in Section 3.1 of this plan.

5.4.9 Recovery Vehicle Integration

One prototype takeup unit and console will be provided the recovery vehicle manufacturer for test of operating interactions between the systems. Production takeup units will be shipped with the other camera system components for integration with the recovery vehicle at the launch site.

5.4.10 Takeup Spool Development

One prototype takeup spool will be loaded with live film at the same tension to be used for the prototype takeup. This spool will be installed in a centrifuge and loaded to the maximum acceleration expected during the recovery sequence. After test, the film will be inspected for evidence of slip along the axis of rotation. If slip has occurred, the film will be unspooled and inspected for scratches and abrasion. The required centrifuge time will be purchased at another facility.

6.0 ASSEMBLY LEVEL II TESTS

The camera system qualification and acceptance tests at this level constitute the first integrated test of the main camera assembly, baffles, electronics, recovery takeup, and S/I Camera. It is essential that a comprehensive mission profile in a thermal/vacuum environment be performed on the integrated system before leaving the camera manufacturer's plant to assure that all system interactions are checked out. Customer acceptance of production units will be at this time. A thorough system checkout will be conducted between tests to establish a performance baseline and detect any deviations. The camera manufacturer will provide a checkout console to produce vehicle signals and record camera responses.

System interactions include electrical, thermal, and mechanical effects. All camera functions are controlled from the camera system electronics, including S/I operation and recovery takeup. The electronic assembly also contains main camera control logic and high power servo amplifiers. These components are simulated for test operation of individual cameras.

Mechanical effects of particular importance are the vibrational response of the cameras during operation on the support truss; and thermal response of critical bearing surfaces. Thermal distortions of the support truss are important to the extent that they exercise the self-alignment features of the design, but the design is based on isolation of the camera bearings from support effects as far as possible.

6.1 CAMERA SYSTEM THERMAL/VACUUM TESTS

6.1.1 Thermal Simulation

The radiative thermal environment is simulated during individual camera tests, but the complex view factors of the system including blockage of one camera by the other and effects of the baffled window aperture can only be approximated at the individual camera level.

The effectiveness of optical bar insulation in damping and the magnitude of steady gradients can be accurately determined only in prolonged soak tests where the pressure environment, vehicle leak rate and vehicle temperature distribution are simulated. Further, the effectiveness of camera thermal design features for dumping heat to the vehicle cannot be simulated with less than a full vehicle model including sink capacity and cross-radiative view factors.

Thermal control of the cameras depends on transient response limits - in few cases do local temperatures reach a steady state during operation - so a reasonable simulation of a mission profile is required, including worst orbital parameters and a typical duty cycle.

The system test will also include simulation of radiation incident on the aperture, including albedo, earthshine, and insolation. Variation in direction and intensity and spectral content of these components will be simulated. Such a test is not practical at the individual camera level, since blockage and re-radiation by the window baffle cannot be simulated without a complete vehicle model.

6.1.2 System Mockup

A mockup of the spacecraft structure on which to mount the camera subsystems will be constructed by the camera manufacturer. The mockup will include true geometry and insulation as well as dummy heat sources and simulated load paths and thermal inertias. This mockup will also be used for vibration surveys preceding system thermal developmental test.

If a prototype structure is available from the spacecraft manufacturer in time to satisfy camera schedule requirements, it is highly desirable to substitute the prototype for the mockup.

The system mockup will also include simulation of the recovery vehicle thermal inertia and insulating properties, to determine response of the takeup unit during operation. A prototype recovery vehicle should be employed, if available.

6.1.3 Pressure Environment

Due to feasibility limitations on pumping capacity, as will be discussed in Section 8.5 of this report, system thermal/vacuum tests will be conducted in two regimes:

1. Test with Helium lubricant for film path gas bars at a chamber ambient pressure of 10^{-3} mm Hg. At this pressure, significant gaseous conduction through the optical bar insulation will occur.

2. Test with Nitrogen lubricant at a chamber ambient of 10^{-5} mm Hg. At this pressure, gaseous conduction is negligible.

During single camera tests, pumping capacity is sufficient to maintain a pressure of 10^{-5} mm Hg only with the camera non-operating. Thus a thermal mission simulation is possible only on the system level.

6.1.4 Photographic Tests

Qualification and acceptance tests on production systems will include dynamic resolution tests at center-scan only of both cameras. Image quality determined at this level of assembly will be compared to results of the individual camera tests to indicate any performance degradation. Since full-field tests at center - and extreme - scan positions were conducted on the individual cameras, performance will be predicated on acceptable center-scan results at the system level.

6.1.5 Thermal Mockup Test

To provide the earliest possible confirmation of system thermal analyses, the spacecraft mockup will be assembled with dummy camera subassemblies containing accurate simulation of heat sources, thermal capacity, and surface properties. Operating cycles will be duplicated and temperature gradients and transients noted on the optical bar structure and electrical components. Since real optics will not be used in this test, the temperature results will be correlated with analysis and with data from the optical bar thermal sensitivity test to predict optical response. Absolute limits on duty cycle duration and sequencing will be explored in this test.

6.1.6 System Qualification Test

Following assembly and checkout of camera subsystems on the spacecraft mockup, two tests will be conducted in thermal/vacuum environments:

1. Corona qualification, one day test duration. A minimum of 5,000 feet of film will be cycled within the cameras over durations simulating typical duty cycles and exposure of all frame sequences. At the completion of camera operation, the film will be spooled into the recovery vehicle takeup over a simulated intra-vehicle film path. Helium lubricant will be used in the film bars. Chamber ambient pressure will be 10^{-3} mm Hg, temperature cycled to approximate the expected optical bar response. This test will constitute a Helium leak test of the pneumatic system. Dynamic resolution tests will be performed at this time only to check out the test installation.

2. Thermal qualification, a mission simulation of about five days duration. The film bar pressurization system will be purged and filled with dry Nitrogen. Chamber ambient pressure will be 10^{-5} mm Hg, and temperature of the chamber walls will be cycled to simulate the calculated heat flux to the spacecraft skin during orbital passes. The cameras will be operated in the presence of simulated radiant input to the aperture, on a duty cycle representing the worst projected conditions. Between operating cycles, the camera will continue to soak in conditions simulating orbital heat flux. At the completion of main camera dynamic resolution test, film will be

spliced to a leader and spooled into the recovery vehicle takeup over a simulated intravehicle film path. The test will also include operation of the stellar/index camera as controlled by the camera system programmer. Static targets will also be exposed on the S/I film load.

A complete film load of 34,000 feet will be expended in each camera of the Main Camera Assembly during the test. Film will be recycled within the cameras to complete exposure of all frame sequences.

6.1.7 System Acceptance Test

System acceptance will be based on operating tests in a simulated thermal/vacuum environment, with the same test arrangement as for qualification. The test will be divided into two parts:

1. Short duration checkout with Helium lubricant in the gas bars at a chamber pressure of 10^{-3} mm Hg. A short sequence of frames will be exposed with a dynamic target simulator. The exposed film will be manually unspooled from the camera takeup for processing and inspection. Chamber temperature will be maintained at ambient.
2. Short duration mission simulation with Nitrogen film bar lubricant at a chamber pressure of 10^{-5} mm Hg and complete thermal simulation. The test will cover the same steps as the system qualification at a reduced time span. Mission simulation will be two days, and film use will be 5,000 feet minimum. The film will be recycled to complete three exposure passes, and will be spooled to the recovery vehicle takeup. Dynamic targets will be exposed at the center of each scan. Typical duty cycles will be observed. The S/I camera will also be operated in its normal duty cycle against static targets.

6.2 CAMERA SYSTEM ELECTRONICS

No developmental tests on the assembled camera system electronics unit are planned since the packages of which it is composed are individually tested for thermal response and vibration fragility. The qualification unit will be instrumented to assure that component response limits are not exceeded. Since the components are inherently rugged, these response limits are relatively high. A console simulating all input/output connections to the electronic assembly; and containing readout equipment for recording performance will be provided by the camera manufacturer for checkout of the unit.

6.2.1 Vibration Tests

The camera system electronics unit will be vibrated at qualification and acceptance levels to be determined in accordance with Section 2.5.2 of this report. Performance will be checked before and after vibration.

6.2.2 Thermal/Vacuum Tests

The electronics unit will be qualified and accepted as part of the camera system assembly in a simulated thermal/vacuum environment. A vacuum operate test will be performed on the unit before any system test. The vacuum operate test will consist of operating and monitoring performance of the unit during exposure to a pressure less than 10^{-3} mm Hg for a period of less than one hour at the expected uniform temperature extremes. This test assures that no low-pressure electrical effects such as arcing are present.

6.2.3 RFI Test

A qualification test of one camera system electronics unit will be conducted to assure that operating RF transmission is within limits tolerable by the spacecraft.

6.3 S/I CAMERA TESTS

Design of the S/I Camera is not within the scope of this program. For planning purposes, the following tests are proposed to assure that interactions of the S/I with the remainder of the camera system are checked out. It is assumed that mechanical, electrical, and optical checkouts have been performed on the S/I before entering this test sequence. Appropriate consoles and alignment benches will be provided by the S/I Camera manufacturer.

6.3.1 Vibration Tests

The S/I Camera unit will be vibrated at qualification and acceptance levels to be determined in accordance with Section 2.5.2 of this report. Performance at ambient will be checked before and after vibration.

6.3.2 Thermal/Vacuum Tests

The S/I Camera will be qualified and accepted as part of the camera system assembly in a simulated thermal/vacuum environment. A vacuum operate test will be performed on the unit before any system test. The vacuum operate test will consist of a short series of exposures of a static target at a chamber pressure less than 10^{-3} mm Hg, and at the expected uniform temperature extremes.

6.3.3 RFI Test

A qualification test of one S/I Camera will be conducted to assure that operating RF transmission is within limits tolerable by the spacecraft.

7.0 ASSEMBLY LEVEL I TESTS

As noted in the preceding section, delivery of the camera system to the customer is predicated on successful completion of system tests at the camera manufacturer's facility. This section establishes requirements for camera simulators at the spacecraft manufacturer's facility, and for final integration tests on the camera system in the field.

7.1 SPACECRAFT ENVIRONMENTAL TESTS

The spacecraft contractor will conduct environmental development, qualification, and acceptance tests on the spacecraft in parallel with camera system tests. Following the same rationale by which system simulation was developed for camera tests, camera simulation will be required for spacecraft tests. The camera manufacturer will construct an accurate mass, spatial, and thermal model of the main camera on a prototype truss structure for use in spacecraft tests. Models of the S/I camera and camera system electronics unit will also be provided. The system electronics unit model will include simulation of all camera electrical loads and output signals for checkout of the camera spacecraft electrical interface.

Note that equipments existing at the spacecraft manufacturer's facility - or anywhere else in the country - are of limited use for integrated system testing, since:

1. Vacuum pumping capacity is inadequate to maintain 10^{-5} mm Hg with film gas bars operating.

2. No optical facilities are installed (collimators, target drives, etc.).

3. Unidirectional solar simulation does not permit thermal simulation without moving the spacecraft, which would prohibit optical testing,

4. Thermal radiation incident on the aperture is not simulated. The special facility which provides these features is required only for camera testing. Economics alone argue against duplicating the facility for testing higher levels of assembly after the camera is thoroughly evaluated.

7.2 RECOVERY VEHICLE ENVIRONMENTAL TESTS

A prototype recovery takeup unit will be provided the recovery vehicle manufacturer for vibration testing. The tests will include a survey with instrumentation which defines responses at points on the takeup unit to be specified by the camera manufacturer, and a qualification test. Vibration acceptance tests of the recovery vehicle will be performed with a dummy mass simulating the takeup unit. A console provided with the takeup unit will permit operation with simulated film drag during thermal-vacuum testing of the recovery vehicle, to duplicate the takeup heat load.

7.3 PAD VALIDATION

A second mass and spatial model of the main camera will be fabricated for pad validation, including handling procedures and vehicle integration. An electrical simulator of all camera system loads and output will be included in the model of the camera system electronics unit. This model will include provision for checkout of ground test circuits to and from the camera console in the block-house.

7.4 SYSTEM INTEGRATION AND CHECKOUT

Final integration of the camera and spacecraft will be in the Mission Assembly Building (MAB) at the launch site. Camera system and spacecraft will be shipped separately to the MAB.

7.4.1 Camera Checkout

Film will be loaded into the main camera and the system checked for operation at ambient before integration with the spacecraft. This operational check will include a static photographic test as the final optical check on the main camera. The test will be performed at ambient temperature and pressure with a portable collimator and target projector to be provided by the camera manufacturer. The target will be defocused a specified distance with respect to the collimator to compensate for the known vacuum focal shift of the camera. The test must be performed at center field, with film stationary and line of sight horizontal.

7.4.2 Camera/Spacecraft Alignment

A large-aperture theodolite will be employed to measure the angle from a line of sight projected from the focal plane of each main camera to the vehicle attitude reference in each of three planes.

7.4.3 Camera/Spacecraft Integration

Ambient operating tests will be performed to check out interactions of the camera and spacecraft.

These tests will include:

1. Command validity and sequencing.
2. Power supply continuity and regulation accuracy.
3. Telemetry calibration and sequencing.
4. Installation of film path and test of film tracking to the recovery vehicle.
5. Installation of light baffles and verification of spacecraft light tightness.

Film spooled into the recovery vehicle during these tests will be removed manually. Live film will be loaded onto the cameras when all checkout tests in the MAB have been completed satisfactorily. Gas supply for the camera film bars will be pressurized in the MAB before the camera compartment is sealed. No further camera operating tests will be performed on the pad.

8.0 TEST EQUIPMENT

8.1 ELECTRICAL CHECKOUT

In addition to the normal lab type test equipment, there are requirements for some special test and simulation equipment.

1. Subassembly Test Equipment - In addition to the normal lab equipment, the subassembly testing will require a strip chart recorder, a jig to test encoder position accuracy, and a dynamic torque testing setup.
2. Subsystem Test Equipment - The special subsystem test equipment needed consists of a variable speed film drive, dummy inertial loads, and control logic and programmer simulator testing the various subsystems.
3. System Test Equipment - The additional system test equipment requirement is for a control console to simulate the vehicle interface and control signals.

8.2 MECHANICAL AND OPTICAL CHECKOUT

1. Surface plates and alignment benches large enough to accommodate the supply end assembly, takeup end assembly, and the film transport assembly.
2. Alignment fixtures for the optical bar, film transport drum, and IMC encoders.
3. Three collimators and an optical bench to monitor IMC linear travel.
4. Test frame to support the supply and takeup end assemblies at the main bearings and force transducers for static and dynamic balancing.

8.3 VIBRATION EQUIPMENT

8.3.1 Shakers

Vibration shakers of three sizes are required to perform the development and qualification vibration tests for the system main frame, optical bar assembly and system subassemblies.

1. The first vibration system required to test the optical bar and main cameras comprises two shakers rated at 28,000 pounds each sine vector or 28,000 pounds random with a 84,000 pounds peak pulse capacity.
2. The second shaker would be used for component and sub-assembly qualification testing, and is rated at 10,000 pounds sine vector, or 10,000 pounds random with a 25,000 pounds peak pulse capacity.
3. The third shaker required for calibrating transducers or as a portable shaker for resonant surveys has a capacity of 150 pounds sine vector.

8.3.2 Fixtures and Tables

The 10,000 pound and 30,000 pound shakers will be mounted on inertia blocks and isolated to maintain low transmissibility of forces to the surrounding building and equipment. A slippery table for testing the main cameras in a horizontal attitude will be provided.

8.3.3 Amplifiers and Signal Sources

A power amplifier rated at 175 KVA output power will be used to drive the shakers. Automatic sine sweep, shock pulse, and noise generator capability will be included in a master control console.

8.3.4 Instrumentation

Velocity and acceleration transducers and strain gages will be used to monitor the response at critical locations of the test specimens during a vibration test.

In addition, a Columbia Research Laboratory Vibration and Shock Monitoring Recording System will be used to graphically record the responses on paper. The recorder has a 12 channel capacity.

A minimum of 50 automatic equalizing filters are required with the above shakers, to shape the spectra of random inputs.

A fixed-bandwidth harmonic analyzer is required to monitor random input spectra and to determine output spectra. A six-channel magnetic tape recorder, X-Y plotter, and tape loop transport will be provided as peripheral equipment to the spectrum analyzer for rapid recording and readout of power spectral density data.

8.4 STATIC LOAD

8.4.1 Optical Bar Stand

The optical bar stand is a structural test bed to support the optical bar assembly at its bearings for qualification static test. There will be provisions to attach steel loading cables with load cells through hydraulic jacks to the base of the frame. These loading cables are used to exert a load on the mass-simulated sub-assemblies in the optical bar.

8.4.2 Main Frame Stand

The main frame test stand will be a steel framework bolted to a concrete pad. With the optical bars removed, rigid pipe shall be installed in the bearing housings and loads applied at the locations of the centers of gravity of the optical bars. The loads shall be applied through load cells by hydraulic jacks and cables. Based on the results of analytical studies, highly-stressed truss members shall be instrumented with strain gages, and the actual forces in these members as a function of the applied loads shall be measured.

In addition to member stresses, displacements at selected joints will be measured with dial gages. This data will be useful information for various dynamic analyses (e.g., dynamic response, servo-coupling).

Both sets of data (member stresses and joint displacements) shall be compared to calculated values to ascertain the validity of the mathematical model of the structure. If necessary, the mathematical model shall be adjusted to correspond accurately with the test results.

8.4.3 Loading Jacks

The loading jacks shall be hydraulically actuated and of sufficient capacity to apply at least twice the maximum test load. Applied forces shall be measured with load cells.

8.4.4 Instrumentation

1. Optical Alignment Equipment - The equipment that will be needed to check the optical alignment of the optical bar assembly after each static test are a theodolite and 6 precision optical alignment flats with cross-hairs at their centers.

2. Load Cells - Load cells will be required in four capacities: 100, 500, 2000, and 10,000 pounds. The sensitivity of the load cells should not be less than 1/2 percent of capacity.

3. Strain Gages - Strain gages will be required which are capable of reading strains as low as 2 microinches per inch.

4. Displacement Gages - Dial indicators and linear displacement transducers are required with the following resolutions and ranges: gages capable of reading displacements in increments of 0.0001 inches with maximum displacements of 0.010 inches; reading increments of 0.0005 inches with a maximum value of 0.050 inches; and reading increments of 0.001 inches with a maximum capacity of 0.1 inch.

8.5 THERMAL/VACUUM TEST

8.5.1 System Test Facility

The camera system manufacturer will construct a chamber of sufficient capacity to optically test the complete camera system in a mockup spacecraft. This facility is shown in Fig. 16.

Generally, the test equipment will have to be able to simulate the space induced environments as experienced by components, assemblies, and the complete system in sufficient detail to assure significant tests. In addition, the equipment will have to provide means for simultaneously measuring the temperatures of the test models and the significant consequences of these temperatures (e.g., the optical quality of the complete system). Thus, a large vacuum chamber must be used which can simulate the space thermal environment to the entire system and where optical performance of the system can be measured simultaneously.

1. A configuration that can support the entire system (cameras, support structure, and vehicle skin) in a manner such that thermally induced forces and moments acting between the main elements of the system are unrestrained.

This, for example, will permit the expansions and contractions of the skin and mounting ring to transmit into the optical system as will occur in space. The use of strain gages to ascertain and separate the effects caused by gravity will be required here.

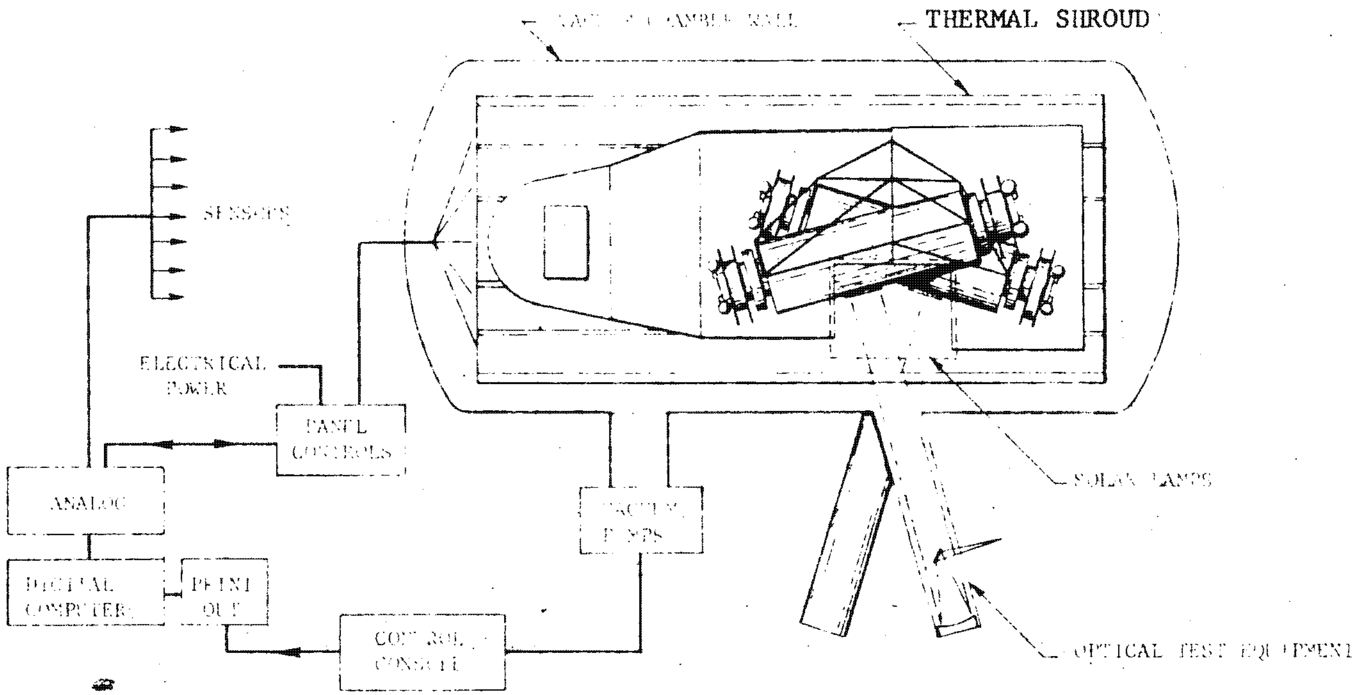

Fig. 16 Test Facility - Camera System in Vehicle with Spatial Simulation

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2. Means of simulating the thermal environment in space to the degree required for valid testing.

For example, only absorbed energy need be simulated in the vicinity of the skins. At the first optical element of the system, however, it will be necessary to simulate the direction, magnitude, and spectral content of the environmental energy entering the optical system in order to achieve a proper simulation of the energy distribution within the various elements of the camera during operation.

3. A pressure level and pumping rate adequate to eliminate significant heat conduction within the air between layers of superinsulation and to avoid inhibiting outgassing or leaks in the system.

To accomplish the above, it is proposed that the model of the system, including the spacecraft skin, be encased in an envelope whose inner configuration is identical with the model's outer shape but is slightly larger. This envelope will be blackened on the inside and contain tubing through which liquid nitrogen will be passed[1]. Within this envelope will be a "birdcage" made up of a mosaic of individual heater wire panels mounted on an electrically and thermally insulated frame. The mosaics of wire heaters will be controlled individually and when turned off will be sufficiently "transparent" so that the mockup can "see" the cold panels beyond. The object, then, will be to program the surface temperature history of each wire panel to simulate the energy that would be absorbed in flight by the region of the model that is directly opposite the wire panel. The panel temperatures are set according to the following equation.

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[1] Adequate for simulating space - no need to go as low as liquid helium temperatures; error caused is approximately + 0.6°F in the temperature levels of the model.

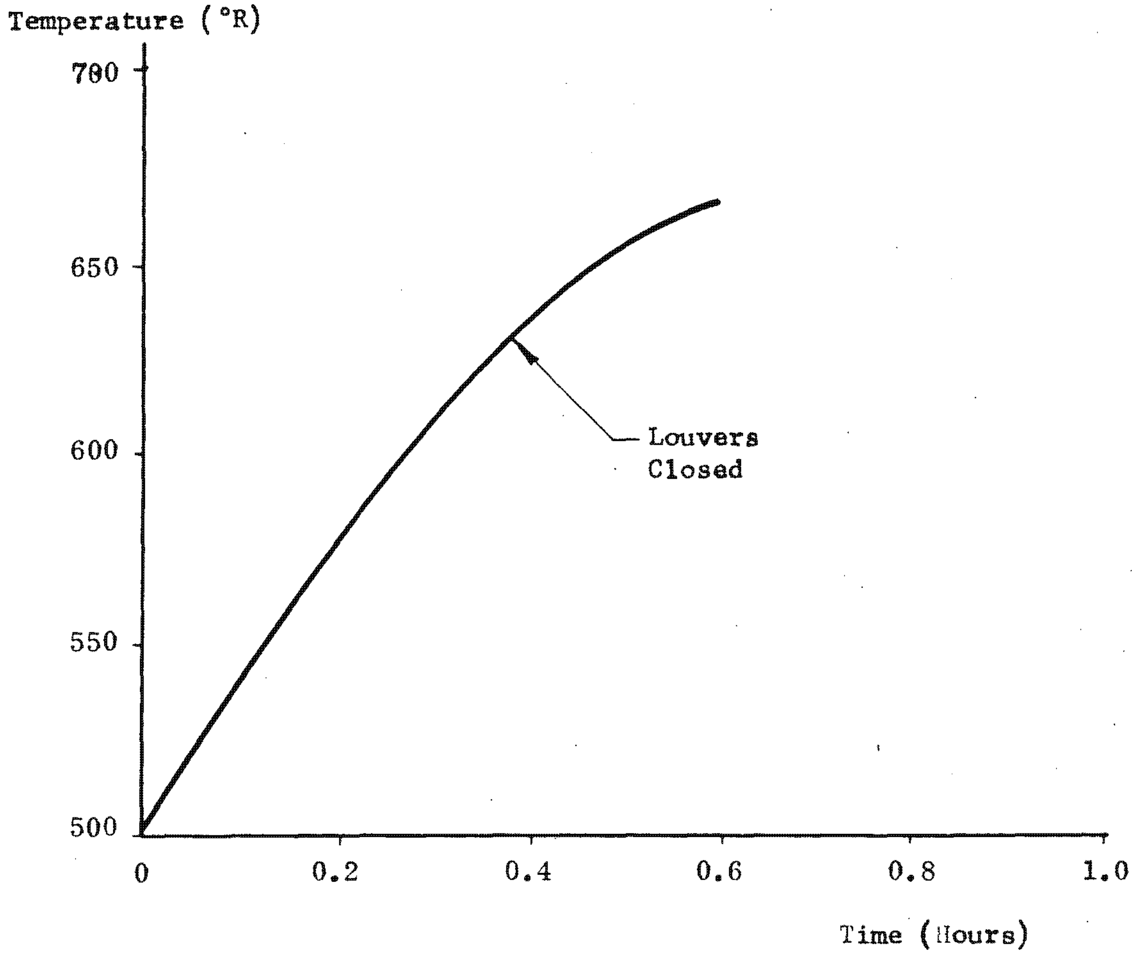
$$T_p = \sqrt[4]{\frac{\Sigma \alpha_i \, G_i}{F \sigma}}$$

where:

- σ — Stefan-Boltzman constant
- α_i — average absorptivity over model surface opposite a panel corresponding to irradiation i (i = 1, 2, 3)
- G_1 — direct insolation (from analyses)
- G_2 — reflected or albedo radiation (from analyses)
- G_3 — earthshine (i.e., surface emitted radiation) (from analyses)
- F — factor accounting for the geometric form factor between the wires and the surface of model and the area of the wires

This proposed arrangement permits simulating the internal and surface temperature responses of the model without resorting to expensive solar simulators. In addition, by controlling local wire panels that only influence the model surfaces directly opposite them, the usual geometric difficulties that occur in chambers of the same order of magnitude in size as the model are eliminated. Also, the ease of programming wire panel temperatures, where heating alone need be considered, makes the suggested approach attractive. The time response of the temperature-control panels has been calculated and is shown in Fig. 17. For economy of power, an array of reflecting louvers has been included between heating panels and cold wall; the louvers would be closed with heater power on.

The test facility shown in Fig. 16 provides all the essential characteristics described previously. It consists in a chamber 20 feet in diameter and 25 feet long with liquid nitrogen



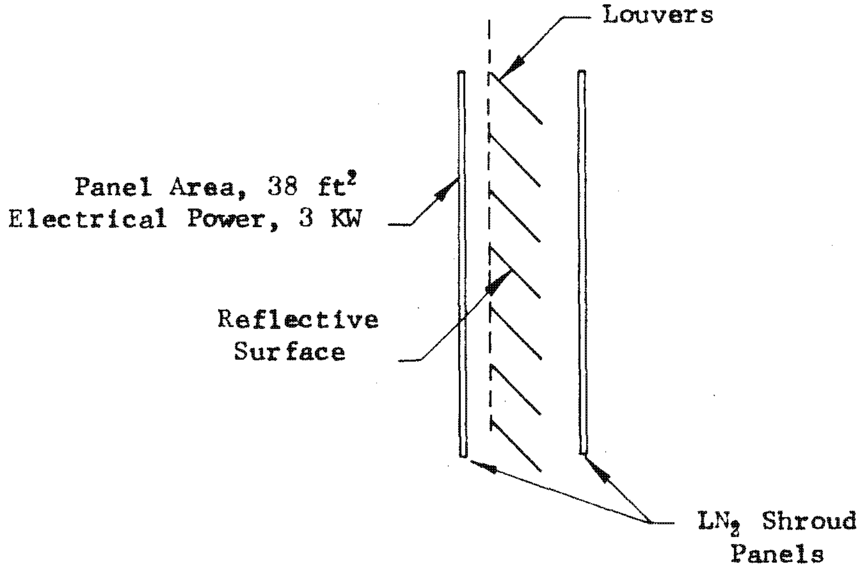


Figure 17. Temperature Response of Program Controlled Panels (Heating Period)

cooled walls. A chamber having these dimensions will permit the thermal evaluation of the camera section of the vehicle along with the recovery vehicle. There are sixteen program-controlled electric heating panels surrounding the vehicle structure with a spacing from panel to vehicle of approximately two inches. With panel temperatures controlled by a digital-analog computer combination, all incident heat flux variations with time can be produced, consistant with maximum response time. Programmed incident heat flux used during test will, of course, be determined through a previous analysis.

A difficult problem exists in providing the solar input (direct solar and albedo) with proper directional characteristics at the cut in the vehicle. The approach to this problem is to use an array of solar simulation lamps with diffuse reflection coming from plates as shown in Fig. 18. To prevent direct irradiation of the vehicle from the lamps, reflectors are employed as shown. In addition, since the vehicle cut must also see a cold surface representing the earth, cutouts in the diffuse reflecting surface provide "see-through" openings to the outermost cold panel.

Fig. 19 is a block diagram of the chamber thermal control system. The flexibility inherent in computer control cannot be duplicated, in transient cases, by any other known means. Additionally, the computer permits immediate data reduction to strain and temperature parameters for interpretation during a test.

There are special problems involved in the design of the thermal vacuum chambers required for the development and test of the camera system. The utilization of gas bars in the film transport system introduces gas loads to the vacuum pumping system which are far in excess of normal specimen outgassing. These gas loads dictate the sizing and methods used to evacuate the vessel.

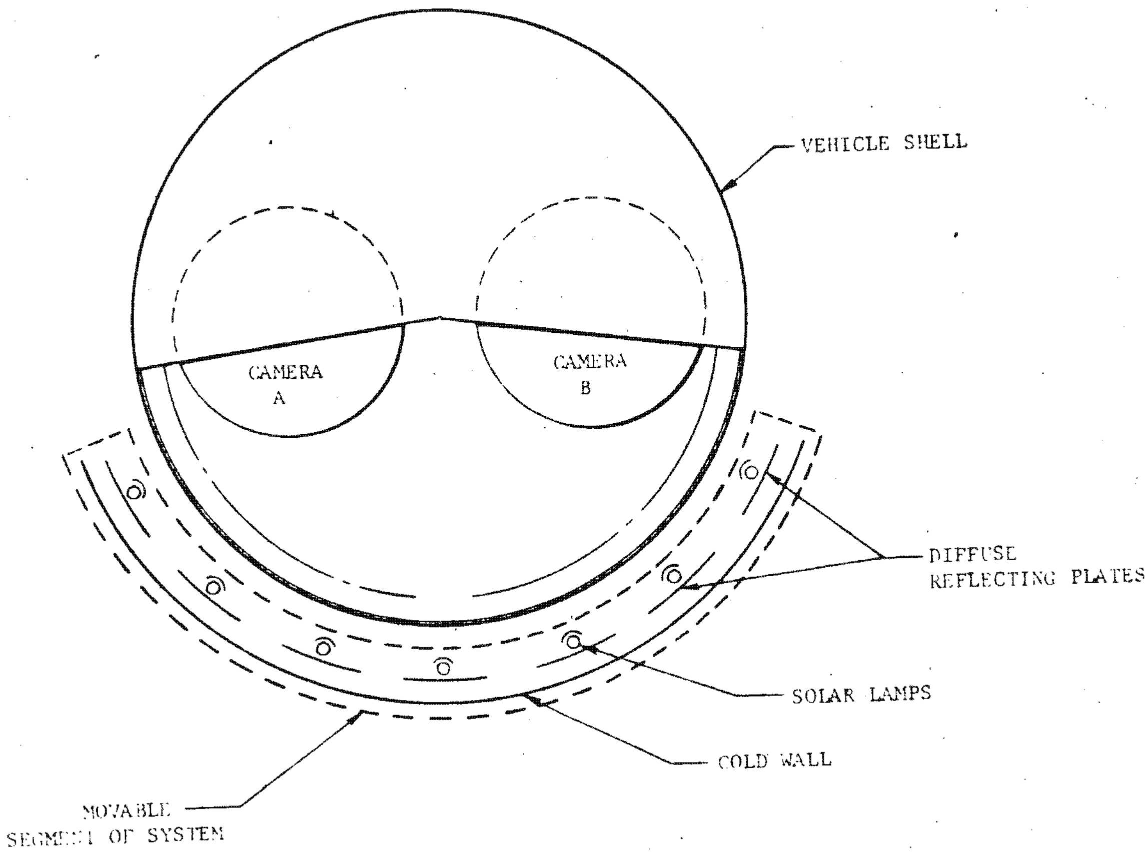


Fig. 18 Solar Simulation of Vehicle Cut

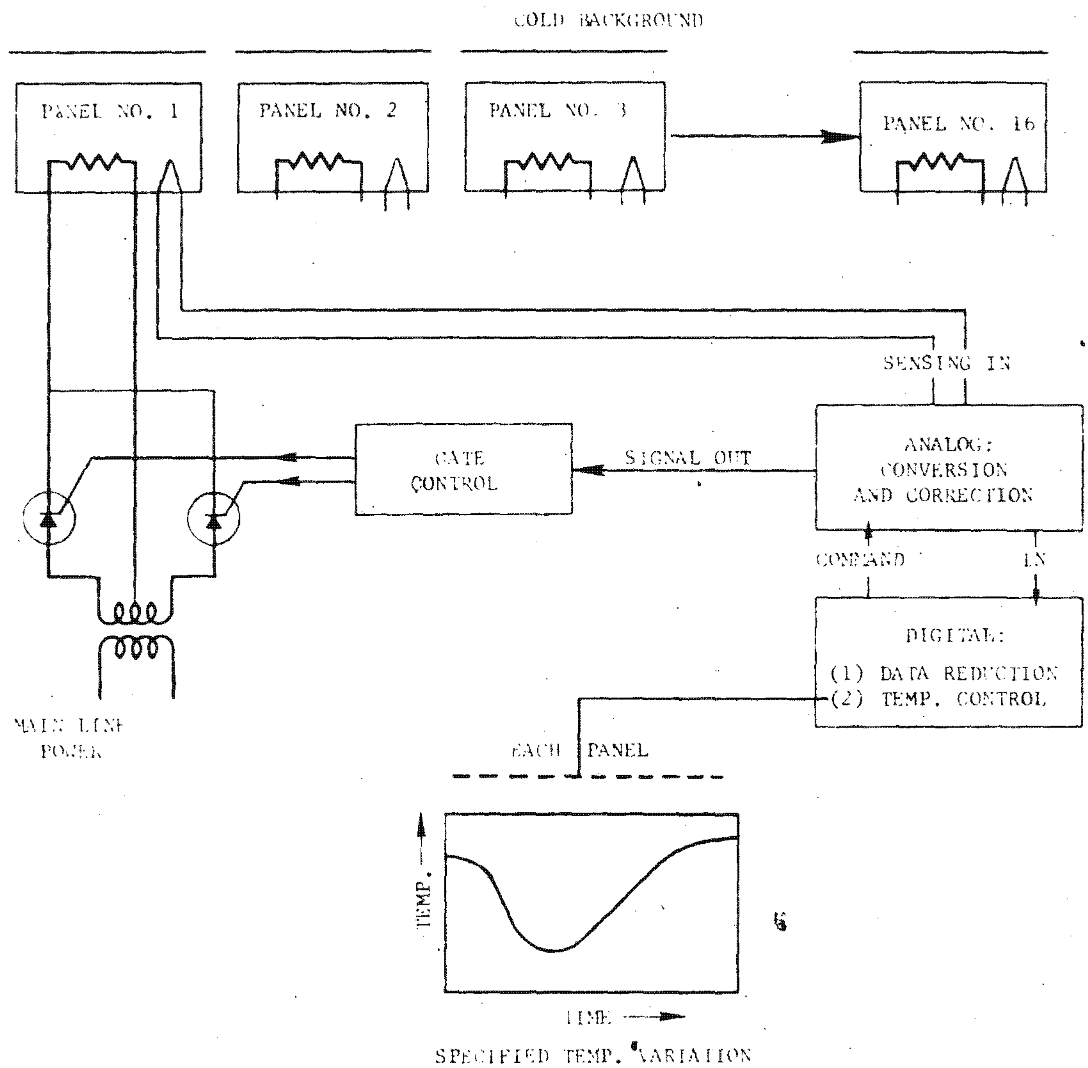


Fig. 19. Test Chamber Heated Panel Control

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The calculated gas loads that will be introduced into the pumping system are as follows. These are dynamic or operating gas loads.

	Gas Load	Outgassing
At Standard Atmosphere	5.6 L/sec He	Negligible
At 1 mm Hg	228 L/sec He	Negligible
At 1 micron Hg	228×10^3 L/sec He	4×10^3 L/sec
At 1×10^{-5} mm Hg	22.8×10^6 L/sec N_2	39×10^3 L/sec
At 1×10^{-6} mm Hg	228×10^6 L/sec N_2	60×10^3 L/sec

The ability to handle gas loads of this proportion is limited by several factors. Since practically all gasses can be pumped with mechanical pumps and oil diffusion pumps, the primary pumping system will be mechanical and diffusion pumps. This combination is effective to a point where no physical room is left to install diffusion pumps without enlarging the size of the chamber beyond reasonable proportion. With the gas loads liberated by the camera gas bars, specimen outgassing, inherent leak rate of the chamber seals and absorbed contamination of the chamber and shrouds, it is feasible to evacuate the chamber with diffusion pumps to 1 micron Hg with Helium as the liberated gas. Ten NRC 48" high speed diffusion pumps, baffled with LN_2 cold traps rated at 40×10^3 L/sec at 1×10^{-4} Hg would handle these gas loads and reduce the pressure to approximately 8.5×10^{-4} mm Hg, and maintain a desired pressure level between 50 microns and 8.5×10^{-4} mm Hg by regulating the pumping capacity through selective switching in and out of diffusion pumps.

At the 1×10^{-3} mm Hg pressure level, it then becomes necessary to introduce an additional pumping media because of the chamber size versus pump capacity tradeoff and in consideration of the expansion of the masses with each decade it is not feasible to attempt to evacuate the chamber below 1×10^{-3} mm Hg with diffusion pumps. The tertiary pumping system proposed is that of cryo-pumping with dense gas helium at 20°K. At this point the gas used in the gas bars must be nitrogen. To continue to use helium would require the use of hydrogen in the cryo panels which would introduce far too many hazards. The pumping speeds of cryo panels using dense gas helium at 20°K will condense out 3.6×10^3 L/sec of dry nitrogen per square foot of cryo panel surface. This value decreases with time as the cryo surfaces become contaminated with nitrogen molecules and consequently, reduce the capture coefficient of the cup panels. Therefore, the surface area must be adequate to accommodate the flow of molecules for the time required and shaped to best intercept the flow of molecules. During camera-off cycles, the temperature of the cryo panels can be elevated to drive off absorbed molecules which can be evacuated by the ten diffusion pumps. Careful temperature regulation can "clean up" in part the cryo panels without saturating the diffusion pumps. Because of helium conservation laws, it is necessary to refrigerate dense gas helium and use a closed loop system which does not waste appreciable amounts of helium. Since cryo pumping speed is a function of surface temperature, helium refrigeration equipment must also be sized to accommodate the heat transfer through chamber walls and heat loads generated by the specimen and thermal shrouds. This is calculated at 1.4 KW. To attain the vacuum levels required (1×10^{-5} mm Hg). It will be necessary to have 7,000 square feet of cryo panels. Theoretically, this array of cryo panels, assisted by the diffusion pumps and backed by mechanical pumps should pump the 22.8×10^6 L/sec of liberated nitrogen and the 39×10^3 L/sec of film outgassing and maintain the required 1×10^{-5} mm Hg during thermal optical tests.

It is noted at this time that no where in existance is there such a pumping capacity as we require. It is within the state of the art, however, this requirement has never arisen. Some facilities require large pumping capacities, for instance, the General Electric chamber at Valley Forge has a capacity of 3.5×10^6 L/sec and the new NASA facility at Houston has a requirement of 10×10^6 L/sec.

The installation we will require, will exceed the largest capacity. The chamber size is not completely defined but it will be approximately 20 feet in diameter and 25 feet long.

8.5.2 Camera Test Facility

Two chambers will be installed to test individual cameras in a thermal/vacuum environment, as shown in Fig. 20. Temperature will be controlled by a fluid-cooled jacket and eight zones of electrical heating elements. Pumping capacity will be sufficient only to draw down to 10^{-5} mm Hg with the camera non-operating.

Within each chamber will be a test stand which will accept the camera at its main bearing housings. The stand may be remotely actuated to rotate the baring housings through 120 degrees, and to yaw the camera $\pm$ 2 degrees with respect to the collimator axis. These features permit full-format photographic testing while the line-of-sight during test remains horizontal.

8.5.3 Small Chambers

A number of small vacuum chambers will be required for test of mechanical and optical subassemblies and components. Typical size for these chambers will be 5 feet diameter by 5 feet long, which would accommodate the recovery takeup unit, transport, and S/I camera.

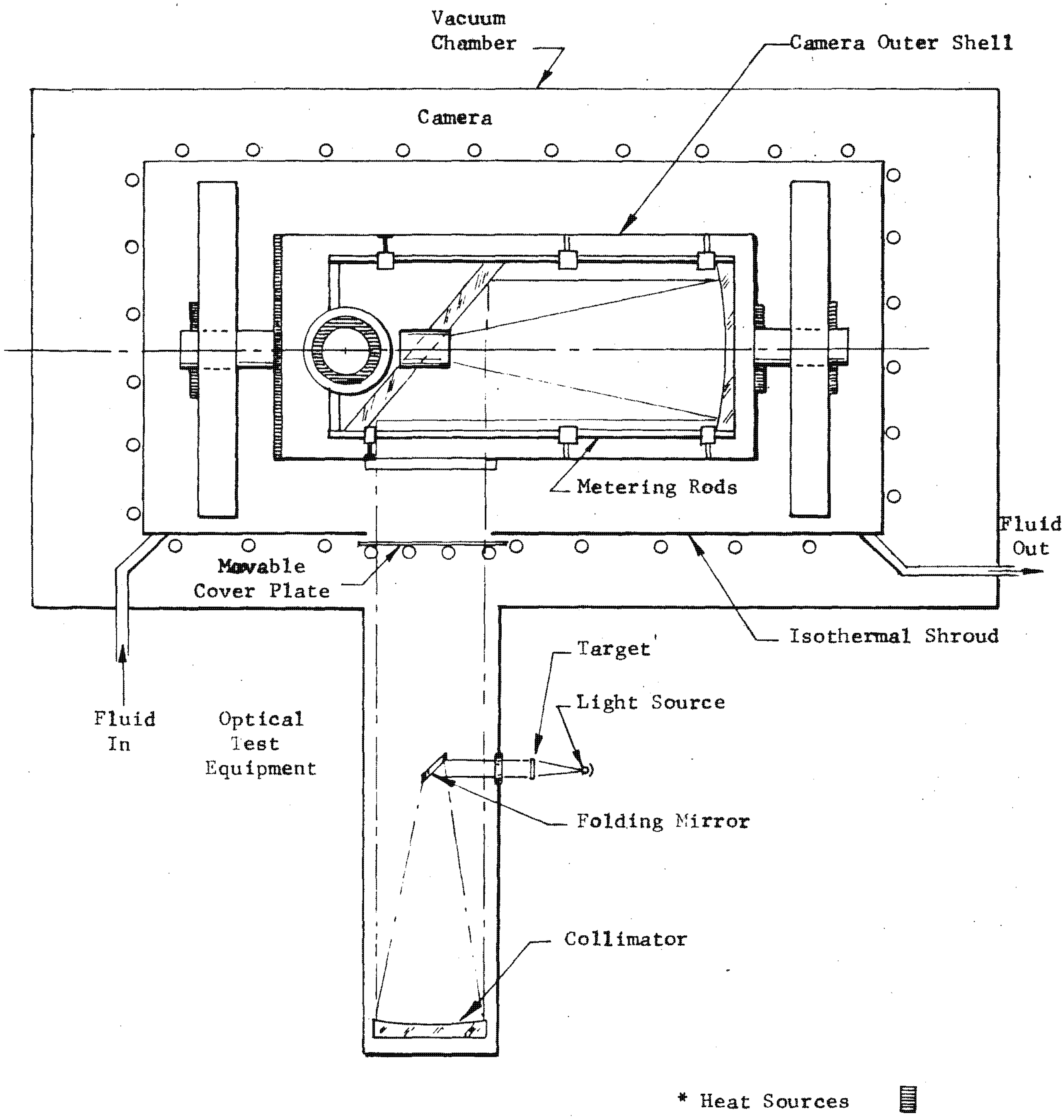

Figure 20. Single Camera Test Schematic Temperature Level Evaluation

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