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**"RELIABILITY AND QUALITY MANAGEMENT"**

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**INTRODUCTION**

Management and management control, by one definition, can be thought of as a communications network with program data flowing upward to top management for digestion and decision making. The role of Reliability and Quality (R & Q) in NASA program management is well defined by the NPC 200 series specifications and complementary procurement regulations. An examination of the flow of R & Q data is, perhaps, one of the best ways to become familiar with the scope of R & Q operations.

**RELIABILITY DATA**

The bulk of the reliability tasks are primarily influential during hardware development. They can be categorized into management, modeling, design controls, and test. Documentation includes:

1. A reliability program plan: the management document with identity as to level of effort, organization, schedule, authorities.
2. A failure mode and effects analysis with criticality ranking.
3. Periodic (monthly) narrative progress reports listing activities such as design reviews, statistical test designs, human factors, and maintainability actions.
4. Periodic (monthly) statistical reports on test results, malfunction occurrence, reliability assessment.
5. Special one-time reports on statistics, logistics, environments, operations, success probability, and operations research studies.

**QUALITY CONTROL DATA**

The quality control influence is slanted toward development hardware identification, accuracy of test equipment, and adequacy of specifications. During production, QC then becomes the key factor in assuring that all hardware meets delivery criteria, performance and dimensionality. Documentation includes:

1. The Quality Control program plan.
2. The quality monthly status report with statistics on  
procured material  
corrective actions  
manufactured parts  
material review  
tests; qualification and acceptance  
delivery quantities and schedules  
manpower, hardware, and test costs  
audits and surveys of-suppliers and in-house plant operations

3. Acceptance test plan.
4. Logbooks for each delivered item.
5. Inspection plan.

#### PROGRAM DATA

The overall health of a program is defined by program reports on:

1. Costs
2. Schedules
3. Product specification
4. Development and test plan.
5. Development progress reports (monthly)
6. Production progress report
7. Configuration (change) control report

#### APPROACH

The general NASA philosophy is that R & Q must be identifiable elements of all programs. Separate R & Q staffs are required of each prime contractor as exists within NASA. A government inspection agency, usually under the Dept. of Defense, supports NASA at the contractor's plant by conducting final inspection and hardware acceptance. In addition, for large programs, the NASA Center maintains a staff of R & Q resident people to monitor contract compliance. By these techniques, real time reaction is achieved for any material or management problem that occurs.

Technology used on space hardware and management of programs is both routine and unique. Special activities exist in such areas as metrology, non-destructive testing, telemetering, training, and data processing beyond routines used for most consumer goods.

## APPENDIX: EXAMPLES OF DATA AND SPECIAL STUDIES

### Quality Control (exerts from monthly status report)

- Q-1 Corrective actions
- Q-2 Component qualification test matrix
- Q-3 QC events; design review, test, etc.
- Q-4 Malfunctions from systems tests
- Q-5 Planning tickets (inspections)
- Q-6 Discrepancy summary (inspection)

### Program

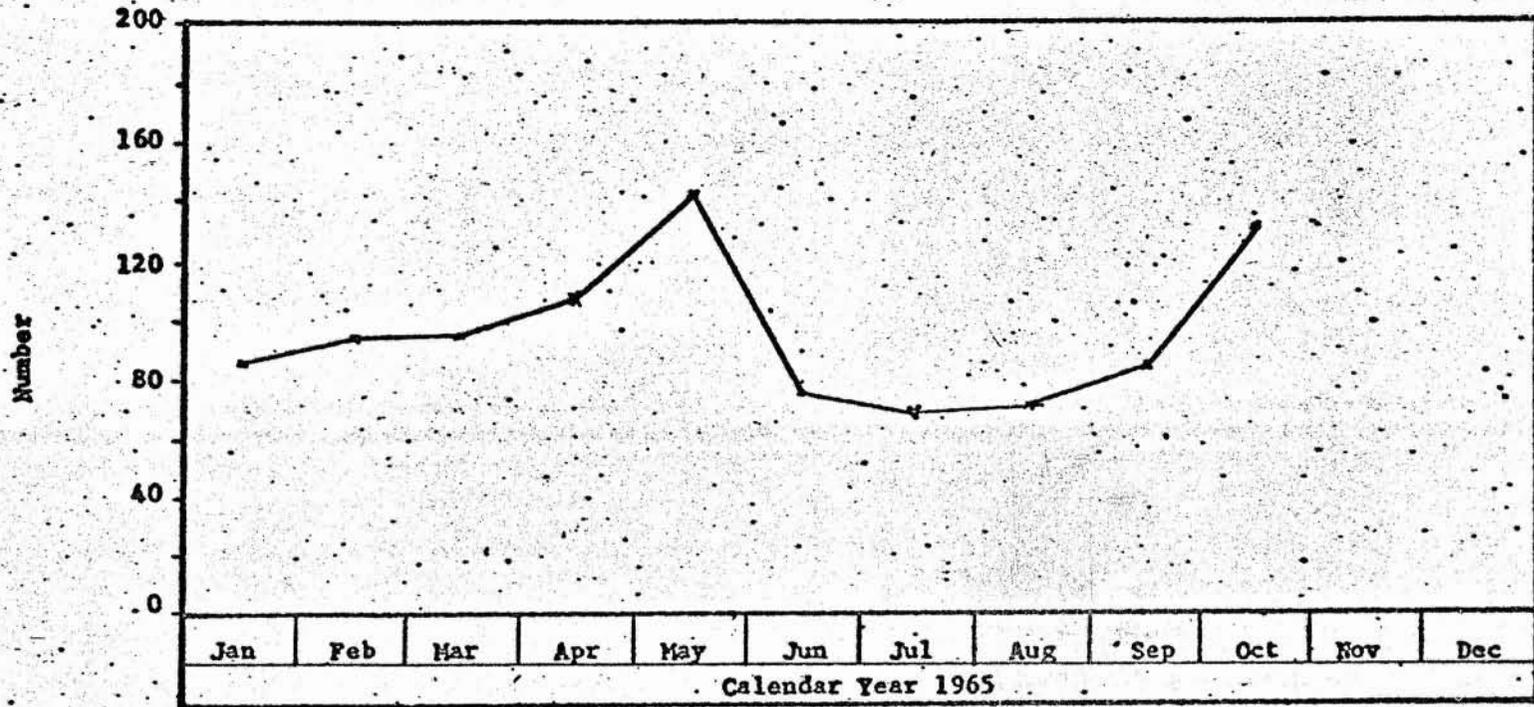
- P-1 test rate
- P-2 test schedule
- P-3 development milestones
- P-4 Line of Balance

### Reliability

- R-1-1 } Failure mode, effect, and criticality analysis
- R-1-2 } Failure mode, effect, and criticality analysis
- R-1-3 } Failure mode, effect, and criticality analysis
- R-2-1 Reliability apportionment
- R-2-2 Reliability assessment criteria
- R-3-1 Monthly status report: engine test history (malfunctions)
- R-3-2 : trend of systems tests
- R-4-1 Special one time reports: Qualification tests
- R-4-2 : Acceptance tests
- R-4-3 : demonstration tests
- R-5-1 Special studies: learning curve, manufacturing manhours
- R-5-2 : redundancy decisions
- R-5-3 : redundancy decisions
- R-5-4 : reliability demonstration incentive

LIQUID ROCKET DIVISION - CANOGA \* SUPPLIER QUALITY IMPROVEMENT SUMMARY

Corrective Action Requests Initiated



Statistics

Corrective Action Statements Approved	115	106	97	84	137	128	67	78	60	96		
Corrective Action Statements Rejected	0	3	1	4	4	1	1	1	6	2		
Current Suppliers With Suspended MR Privileges	22	28	30	31	27	31	26	33	32	31		
Supplier Surveys Completed	60	46	76	80	60	88	91	89	82	87		



**REPORT OF QUALITY CONTROL EVENTS  
October 1965**

**1 DESIGN AND SPECIFICATION REVIEW**

Design    Spec

Number of items reviewed	4	33
Number of action items submitted	7	89
Number of action items accepted	6	68
Number of action items rejected	1	21

**2 QUALIFICATION TEST PROGRAM**

F-1      J-2

Number of parts programmed for qualification	47	36
Number of parts qualified to date	18	0
Number of parts qualified during current month	1	0
Number of parts in test	16	7

**3 QUALITY VERIFICATION TEST PROGRAM**

F-1      J-2

Number of parts programmed for QVT	55	64
Number of parts tested to date	6	19
Number of parts tested during current month	0	3
Number of parts in test	6	17

**4 F-1 ENGINES**

A NASA QUAL-MSPC representative was here for a two day visit. Es confirms to overall quality improvement of recently delivered F-1 engines. Primary concern is now centered on cleaning and packaging of loose lines.

**5 MQP SYSTEM**

Quality Control and Manufacturing Services are cooperating in a series of audits of Manufacturing Quality Performance floor inputs to establish that the personnel are properly providing inputs to rework SCH's. This action is being taken to verify that present floor instructions are adequate and are being followed.

**6 CRIS**

The Quality Control program has been developed to place into effect the new Calibration Recall and Inventory System (CRIS). This system is being implemented to comply with ROP J-505, "Calibration Control of Instrumentation, Measuring and Test Equipment." Certain key aspects of the overall program are

LRD C. OGA  
F-I PRODUCTION ENGINES QUALITY ANALYSIS

MODE NO. = REPAIR ONLY  
MODE (END) = REPLACEMENT  
\* FAILURE NOT CONFIRMED

ENGINE NO. 2019

SOURCE DATA - OPERATION FAILURE REPORTS

FAILURE MODES PER TEST												QTY R/F TESTS	QUANTITY OF FAILURES				
FIRST E&M	HOT-FIRE 1		HOT-FIRE 2		HOT-FIRE 3	HOT-FIRE 4		HOT-FIRE 5	HOT-FIRE 6	HOT-FIRE 7	HOT-FIRE 8		SECOND E&M	1ST E&M	H/F	2ND E&M	TOTAL
(1) (1)	(3) (3)	5	4	(9)	5	(9)	(6)					4 (1)					
	(3) (10)					(11)	(9)					(1) (1)					
	(11)(10)											2 (8)	5	2	17	12	31
	2 (7)											(1) (1)					
	(9)											(1) (1)					
												(1) (1)					
TEST TIMES ACT / INT	151 / 150	41.4 / 40.0	41.5 / 40.0	41.4 / 40.0	41.5 / 40.0							TOTAL DURATION-CUM.- 317.2					

FAILURE DESCRIPTION  
PRIMARY MODE AND FREQUENCY.

FAILURE DESCRIPTION  
PRIMARY MODE AND FREQUENCY

<p><b>A. LEAKAGE</b></p> <p>1. Seals and/or gaskets 11</p> <p>2. Between tubes - T/C tubular 2</p> <p><b>B. DAMAGE</b></p> <p>3. Bulge in braid - Flex hose assy 3</p> <p>4. Cracks in parent metal - T/C angle bracket 2</p> <p>5. Band buckled - Nozzle extension 2</p> <p>6. Erosion at leading edge - T/C body lugs 1</p> <p>7. Threads galled - Plug/check valve 1</p> <p><b>C. OPERATION MALFUNCTION</b></p> <p>8. Actuation light - Checkout valve 1</p>	<p><b>D. ELECTRICAL MALFUNCTION</b></p> <p>9. Out of spec - Transducer 4</p> <p><b>E. MANUFACTURING DEFECT</b></p> <p>10. Misalignment - Line assembly 2</p> <p>11. Contamination - Line assembly 2</p>
-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

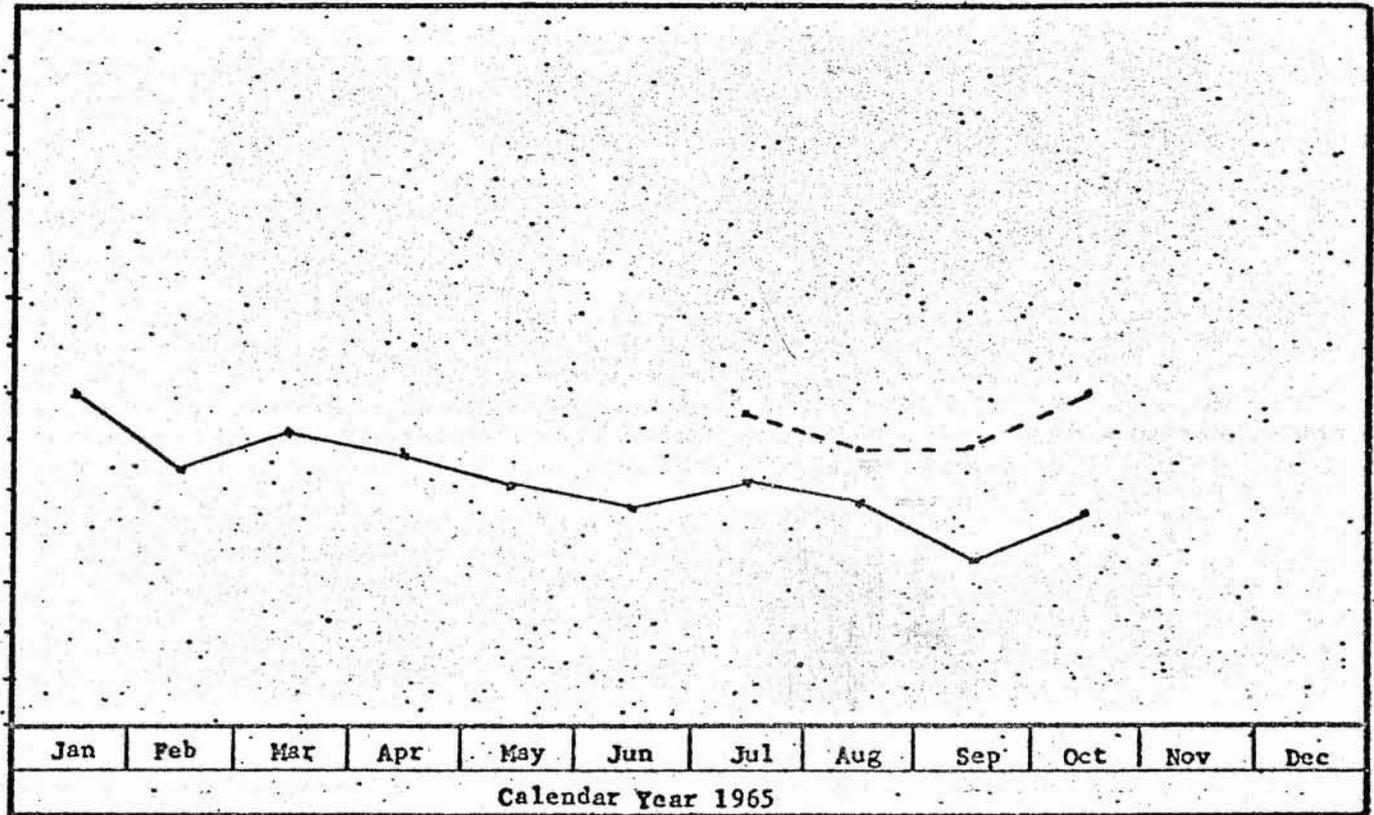
LIQUID ROCKET DIVISION - CANOGA MANUFACTURING QUALITY PERFORMANCE SUMMARY

(Planning Ticket and A.O.R. Book)

Department	Current Monthly Performance: October							Prior Three Month Average Per Month						
	No. Parts Completed	No. Parts Accepted	No. Parts Discrepant	Percent of Parts Discrepant	No. of Discrepancies	No. of Parts Scrapped	\$ Value of Parts Scrapped	AVG. No. Parts Completed	AVG. No. Parts Accepted	AVG. No. Parts Discrepant	AVE. Percent of Parts Discrepant	AVE. No. of Discrepancies	AVG. No. of Parts Scrapped	AVG. \$ Value of Parts Scrapped
501	4178	3876	302	7.2	5775	30	33315	4679	4284	395	8.4	6185	18	14426
502	12308	11626	682	5.5	2871	99	35333	19905	19220	685	3.4	2917	55	28149
504	2477	2290	187	7.5	735	1	122	5830	5516	314	5.4	992	4	590
508	27823	27176	647	2.3	6342	48	39771	33405	32801	604	1.8	3775	159	32909
509	2978	2882	96	3.2	547	2	326	4058	3752	306	7.5	768	2	300
510	3050	2970	80	2.6	2482	1	19	2781	2587	194	7.0	2032	2	55
512	2540	2451	89	3.5	1333	10	388	2268	2196	72	3.2	954	1	38
522	1068	936	132	12.4	866	2	1340	1044	908	136	13.0	648	2	3592
536	6978	6827	151	2.2	1276	2	237	10839	10689	150	1.4	922	2	1092
537	1595	1458	137	8.6	1441	0	0	2488	2335	153	6.2	984	1	246
538	9530	8777	753	7.9	2518	60	26781	8251	7566	685	8.3	3059	92	37076
544	11374	11162	212	1.9	323	0	0	22762	22634	128	0.6	247	2	417
573	1398	1252	146	10.4	1657	7	5679	654	523	131	20.0	1316	5	1388

LIQUID ROCKET DIVISION - CANOGA \* MANUFACTURING QUALITY PERFORMANCE

(---) ↑  
 15  
 10  
 5  
 0  
 Discrepancies (100's) Per 10,000 Direct Labor Hours  
 Percent of Parts Discrepant



No. of Parts Completed  
 No. of Parts Accepted  
 No. of Parts Discrepant  
 No. of Discrepancies

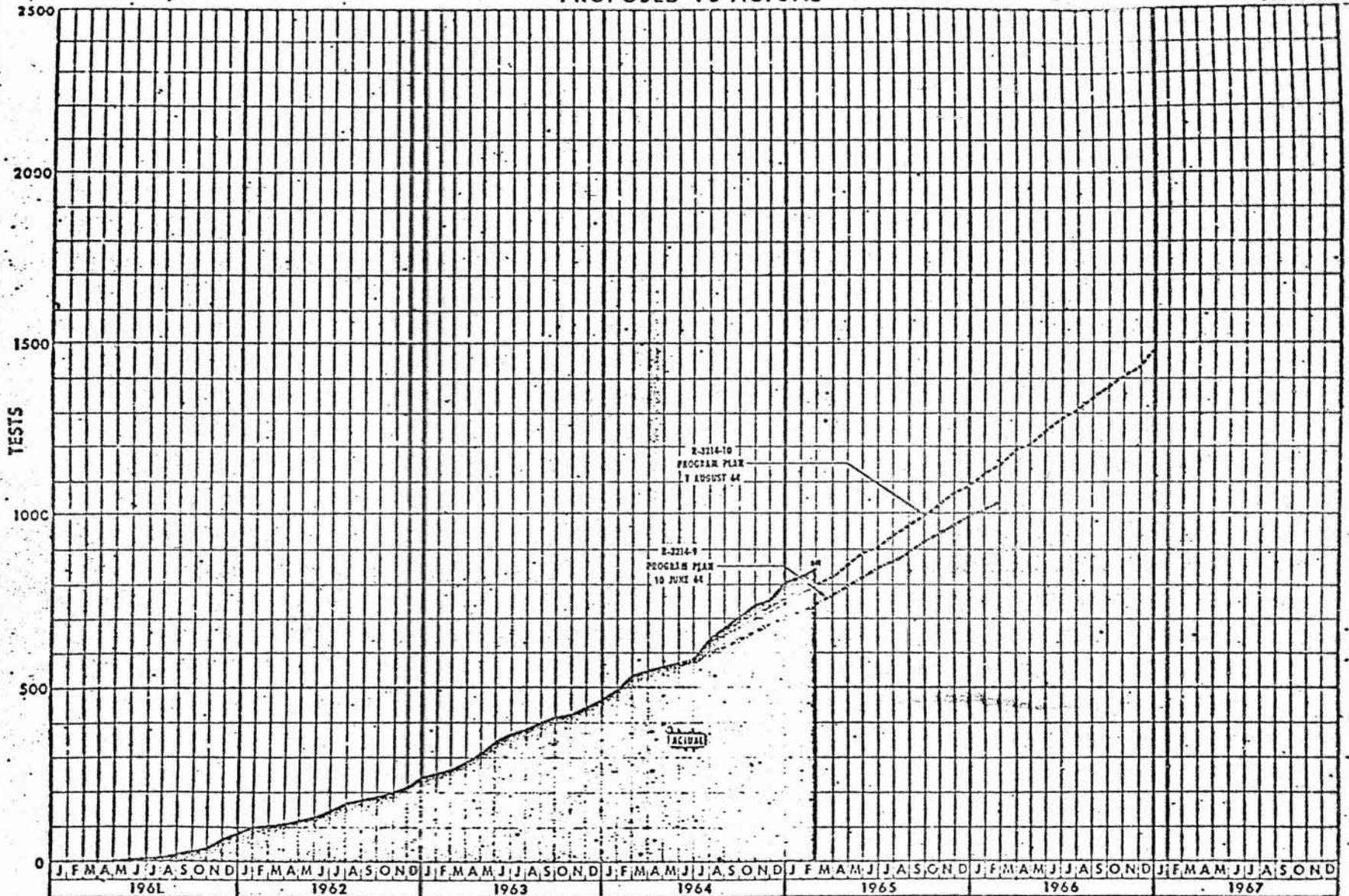
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. of Parts Completed	73042	75418	73884	66655	90295	95906	88770	72436	102006	79173		
No. of Parts Accepted	67911	71310	69393	62798	85712	91388	84148	68924	98662	75679		
No. of Parts Discrepant	5131	4108	4491	3857	4583	4518	4622	3512	3344	3499		
No. of Discrepancies	12791	13590	13519	13202	19421	21051	23836	22771	27793	28166		

Q-6

# F-1 ENGINE SYSTEM R&D TESTS

## PROPOSED VS ACTUAL

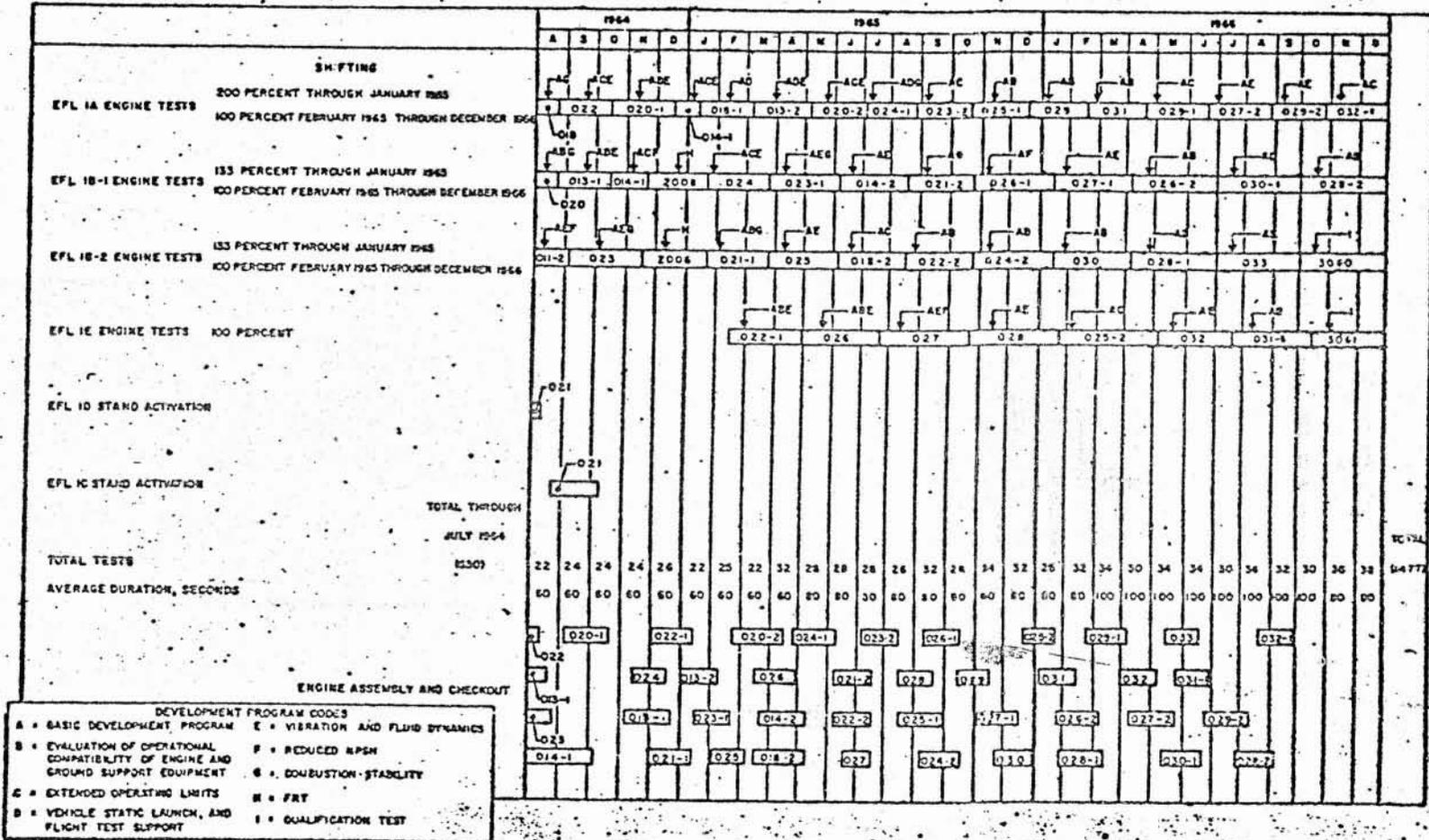
EO MAR 68



4-7-71

P-1

# F-1 ENGINE DEVELOPMENT SCHEDULE



# F-1 ENGINE DEVELOPMENT MILESTONES

MILESTONES		1959				1960				1961				1962				1963				1964				1965				1966				1967				1968				1969				1970			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4				
1	Contract Go Ahead	▲																																															
2	First Mainstage Test							▲																																									
3	First Rated Thrust											▲																																					
4	Block I Engine Design Release											▲																																					
5	Deliver F1001															▲																																	
6	Complete FRT																			▲																													
7	Deliver Flight Engines, V-501																							▲																									
8	Complete Component Qual																											▲																					
9	Complete System Qual																															▲																	
10																																																	
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NOTES

# LIQUID ROCKET DIVISION-CANOGA

## F-1 ENGINE SYSTEM

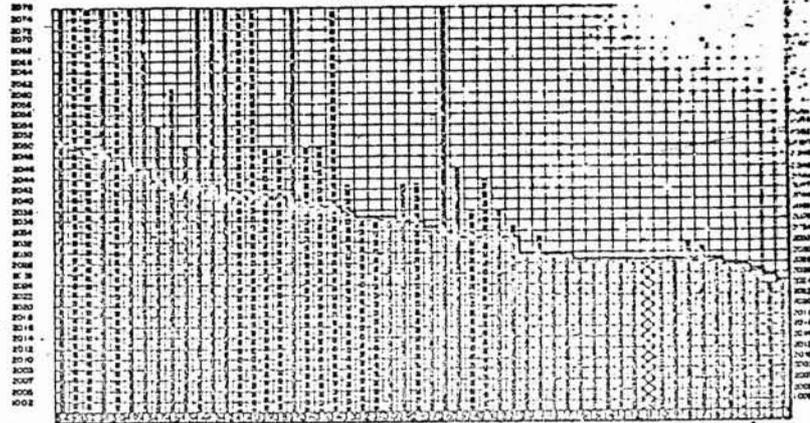
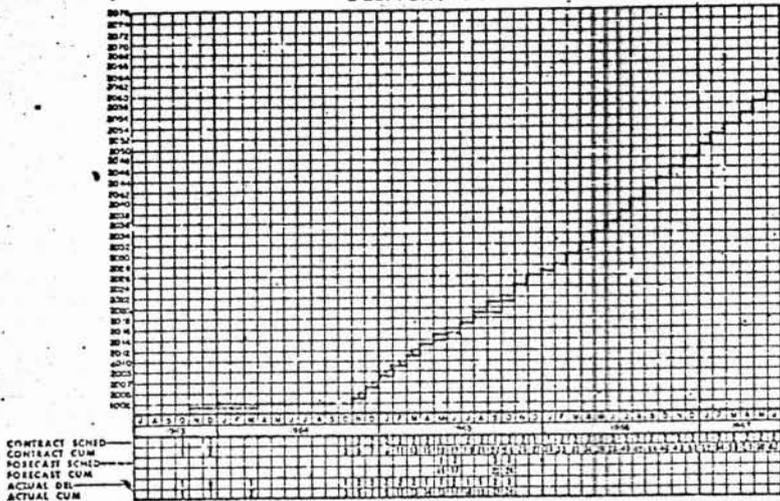
### LINE OF BALANCE CHART

DATE: 10-30-65  
REPL: 10-2-65

CONT. NO. NAS 8 5004  
ROCKETDYNE G.O. 8374 & 8375

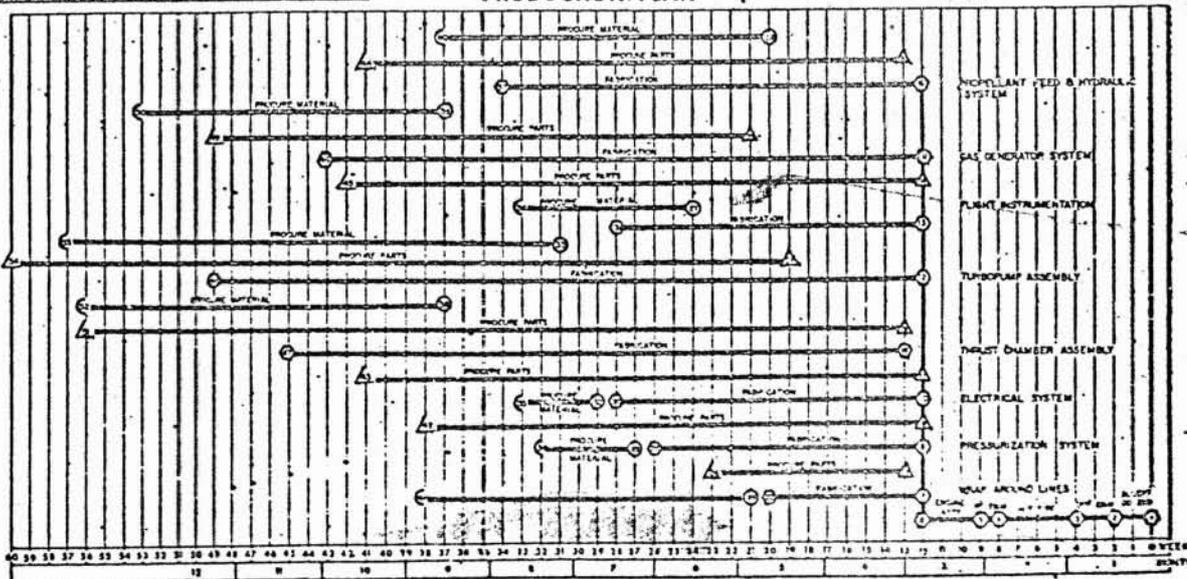
DELIVERY SCHEDULE

PROGRESS STATUS



PRODUCTION PLAN

- LEGEND**
- △ PURCHASED PARTS ORDERED
  - △ PURCHASED PARTS RECEIVED
  - C RAW MATERIAL ORDERED
  - O RAW MATERIAL RECEIVED
  - START & COMPLETION POINT
  - ROCKETDYNE SHOP OPERATIONS
  - FLOW TIME (GREEN & BLACK)
  - L.O.B. (RED)
  - X INDICATES ITEMS NOT APPLICABLE ON ENGINE AS SHOWN



### Failure Mode and Effect Analysis

Concept: MSFC Dwg 10 M30111A, "Design Analysis"

Criticality number =  $\alpha \beta k \lambda t \times 10^6$

- $\alpha$  = percentage of all failures of an item relative to the failure mode considered (failure mode frequency ratio)
- $\beta$  = probability that a specific failure will cause mission loss (vehicle loss probability). Rated in one of four classes, 0, 0 to 10%, 10% to 100%, and 100%
- k = environmental adjustment factor
- $\lambda$  = failure rate per  $10^6$  hours or  $10^6$  cycles (generic)

Operational During Flight \*Does Not Operate in Flight



**FAILURE EFFECT ANALYSIS**

B-1 ENGINE HYDRAULIC SUBSYSTEM

A<sub>1</sub> PRIOR TO FIRING COMMAND

A<sub>3</sub> IGNITION TO LIFT-OFF

A<sub>2</sub> FIRING COMMAND TO IGNITION

B FLIGHT

ITEM	DRAWING NO	ELECT REF DESIG	FUNCTION	FAILURE TYPE	FAILURE EFFECT ON SUBSYSTEM PERFORMANCE	FAILURE EFFECT ON S-18 STAGE	FAILURE EFFECT ON SA-201 VEHICLE
Assembly, Accumulator & High Pressure Manifold (1 required per outboard engine) (Continued) V-1B-28-07				External leakage of hydraulic fluid	Possible Loss - System may be unable to satisfy actuator demands.	(A <sub>1</sub> & A <sub>2</sub> ) Launch Delay - Fluid level indicator (V-1B-28-16) would indicate low fluid level.  (A <sub>3</sub> & B) Possible Loss - Adequate vehicle control can not be obtained with three engines.	Same as S-18 Stage
Transducer, Pressure (1 required per outboard engine) V-1B-28-08	** 20C85079 B92	1A127 2A126 3A127 4A126	Measures fluid pressure in the high pressure accumulator (V-1B-28-07) and sends a signal to ESS and TM indicating the value.	Failure to give a proper indication	No Effect - Loss of accurate TM data only.	(A <sub>1</sub> & A <sub>2</sub> ) Launch Delay.  (A <sub>3</sub> & B) No Effect - Loss of TM data only.	Same as S-18 Stage
Ducting, Flexible High Pressure (1 set required per outboard engine) V-1B-28-09	** 60C20689 B74 60C20687 B77		Provides fluid flow passages throughout the high pressure portion of the system.	External leakage	Possible Loss - Loss of fluid may result in system inability to meet actuator demands.	(A <sub>1</sub> & A <sub>2</sub> ) Launch Delay.  (A <sub>3</sub> & B) Possible Loss - Adequate vehicle control can not be obtained with three engines.	Same as S-18 Stage
Assembly, Reservoir and Low Pressure Manifold (1 required per outboard engine) V-1B-28-10	** 20C85062 B86	1A10 2A10 3A10 4A10	The reservoir stores return low pressure (53 psig) fluid from the actuators, pumps, and auxiliary pump case drain, and supplies fluid to the inlet of both pumps.	External leakage	Possible Loss - Loss of fluid may result in system inability to meet actuator demands.	(A <sub>1</sub> & A <sub>2</sub> ) Launch Delay.  (A <sub>3</sub> & B) Possible Loss - Adequate vehicle control can not be obtained with three engines.	Same as S-18 Stage
Quick Disconnect, Low Pressure (1 required per outboard engine) V-1B-28-11	** 20C85081 B90		Provides a connection to permit draining of the hydraulic system during filling and purging operations.	External leakage (in coupled position)	No Effect - Draining will continue until desired fluid level is obtained.	(A <sub>1</sub> ) Launch Delay.  (A <sub>2</sub> , A <sub>3</sub> & B) No Effect - Filling completed and disconnect uncoupled prior to this time.	Same as S-18 Stage
				After disconnect from the ground return line the component functions as a check valve to prevent leakage of fluid from the system.  A dust cap assembly is installed after disconnect. This cap will not prevent leakage of hydraulic fluid.	Failure to close	No Effect - Quick disconnect is closed after filling. Failure of component to close would result in a launch hold until repairs were completed.	
					DATE: June 1964	PREPARED BY: TERRY, ENGINEERING BRANCH	APPROVAL: <i>W. Brown</i>

R-1-2

SPACE DIVISION

CHRYSLER  
CORPORATION

## CRITICALITY RANKING

R-1 ENGINE HYDRAULIC

V-1B-28

ITEM	CODE	FAILURE TYPE	FAILURE MODE FREQUENCY RATIO	VEHICLE LOSS PROBABILITY	PREDICTED UNRELIABILITY	CRITICALITY NUMBER
Actuator Assembly (2 Required)	31	External Leakage	0.7	0.1	.000021848	272.768 (ca.)
		Electrical or Mechanical Failure of Servo Valve	0.2	0.1	.00003672	
		Short or Open of Feedback Transducer	1.0	0.1	.0002112	
Main Pump	26	Low Pressure Output	0.6	0.1	.000826807	57.8765
		No Fluid Output	0.1	0.1		
High Pressure Accumulator	07	External Leakage - GN <sub>2</sub>	0.5	0.1	.000378494	37.8494
		External Leakage - Hydraulic Fluid	0.5	0.1		
Low Pressure Reservoir	10	External Leakage	1.0	0.1	.000206395	20.6395
High Pressure Relief Valve	04	Failure to Remain Closed	0.6	0.1	.000240080	14.4048
High Pressure Quick Disconnect	01	Internal Leakage	0.55	0.1	.000110863	7.74746
Low Pressure Quick Disconnect	11	Internal Leakage	0.55	0.1	.000110863	7.74746
Check Valve	25	Internal Leakage	0.55	0.1	.00011086	7.74746
Bleed Valve, High Pressure	05	External Leakage	0.2	0.1	.00034900	6.98192
Bleed Valve, Low Pressure		External Leakage				

R-1-3

TABLE 1

SAMPLE F-1 RELIABILITY APPORTIONMENT

System	Weight	Reliability
System	1.000	0.99
Thrust Chamber Assembly	0.228	0.99772
Thrust Chamber Body and Dome	0.063	0.99937
Injector	0.076	0.99924
Exhausterator	0.076	0.99924
Extension Skirt	0.013	0.99987
Turbopump Assembly	0.101	0.99897
LOX Pump	0.025	0.99975
Lube System	0.050	0.99950
Turbine	0.013	0.99987
Exhaust Duct	0.013	0.99987
Gas Generator Assembly	0.038	0.99962
Combustor and Injector	0.013	0.99987
Pressure Oscillations	0.025	0.99975
Main Propellant Valves	0.038	0.99962
Main Fuel Valve	0.025	0.99975
Main LOX Valve	0.013	0.99987
Hydraulic Control System	0.089	0.99911
Igniter Fuel Valve	0.051	0.99949
Ignition Monitor Valve	0.038	0.99962
Interconnects and Ducts	0.266	0.99734
High-Pressure Propellant Ducts	0.051	0.99949
Gas Generator Propellant Feed Lines	0.051	0.99949
Small Lines	0.076	0.99924
Quick Disconnects	0.025	0.99975
Fittings	0.038	0.99962
Seals	0.025	0.99975
Electrical System	0.076	0.99924
Spark Exciter and Plugs	0.025	0.99975
Electrical Harness	0.013	0.99987
Electrical Components	0.038	0.99962
Combustion Instability	0.164	0.99836

1-2-2

RELIABILITY ASSESSMENT (Demonstration)  
of LIQUID ROCKET ENGINES

Reference: Chapter 16 of "Reliability: Management, Method, and Mathematics", Lloyd and Lipow

Considerations:

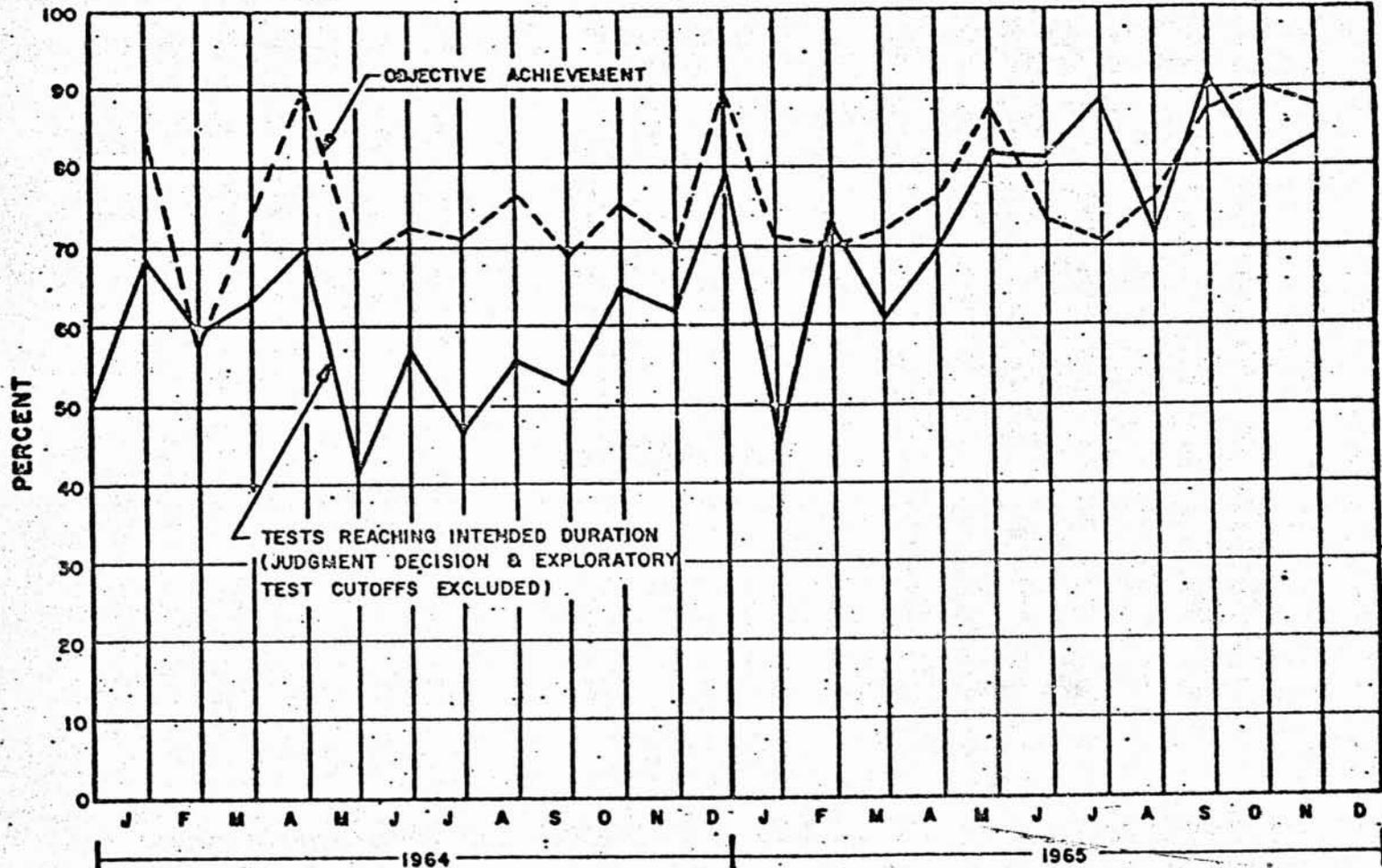
1. A static firing of a rocket engine is a reasonable simulation of a flight test.
2. Selected static tests can be used to estimate reliability.
3. Heterogeneous tests such as those to overstress conditions or with experimental or overage hardware will be excluded from the statistic. Also excluded are failures attributed to test stand failures or human factors that would have no influence during flight.
4. All tests counted will be treated binomially and success weighted as to test time. Weighting factors are established from a mortality curve using the formula:

$$w_i = \frac{p_i + \epsilon(1 - p_i)}{p_k + \epsilon(1 - p_k)}$$

where  $k$  is the time for normal operating duration  
 $i$  is the time to run duration less than  $k$



J-2  
MONTHLY TREND C. HOT FIRE TEST RESULTS



	1964												1965											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
TESTS CONDUCTED	31	34	42	35	40	28	25	31	21	23	34	38	22	23	51	67	71	47	73	72	89	84	75	
PREMATURE CUTOFFS	11	17	20	12	27	13	18	16	10	10	16	11	14	10	23	28	16	14	15	33	11	21	15	
ENGINE MALF	7	8	10	5	10	6	8	4	7	2	6	4	6	1	5	5	5	5	2	8	1	2	2	
DEL GSE MALF	-	-	-	-	1	-	-	1	1	-	-	1	1	1	-	1	-	-	-	-	-	-	1	
SUPT EQUIP MALF	1	-	-	-	-	-	-	-	-	1	-	-	-	-	2	1	-	-	-	1	-	5	1	
FACILITY MALF	1	3	1	5	8	3	-	5	-	4	4	2	3	1	4	5	3	1	2	5	3	3	5	
HUMAN ERROR-DEV	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	1	1	1	2	1	-	
HUMAN ERROR-TEST	-	-	2	-	-	2	-	2	2	-	1	-	-	1	4	2	3	-	2	-	4	1	3	
EXPLORATORY TEST	2	5	7	2	8	2	3	1	-	1	2	-	1	1	3	5	3	3	3	16	2	5	2	
JUDGMENT DECISION	-	-	-	-	-	-	7	3	-	2	3	4	3	4	2	5	1	-	4	1	-	-	1	
UNRESOLVED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1	1	-	-	5	-	

TEST OBJECTIVES	424	200	135	537	144	195	383	248	178	116	346	619	476	216	214	320	451	301	539
OBJECTIVES ACHIEVED	292	143	96	407	99	146	266	224	127	81	267	469	417	158	153	240	397	274	467

QUALIFICATION TESTS

J-2

DECEMBER 1965      200K      500 SEC.  
ENGINE #1  
3750 SEC.  
50 TESTS  
4 RATED DUR.  
SAFETY LIMITS  
PERFORMANCE  
P.U. & GIMBAL  
VIBR. & LEAK  
TEARDOWN  
INSPECT

F-1

DECEMBER 1966      1500K      150 SEC.  
ENGINE #1      ENGINE #2  
2250 SEC.      20 SAFETY LIMITS  
4 RATED DUR.      TESTS  
(1 HIGH AMB. TEMP)      INPUT LIMITS  
(1 LOW AMB. TEMP)      MALFUNCTION  
2 TESTS GIMBAL      HUMIDITY-INSPECT  
PERFORMANCE  
VIBRATION  
HEAT EXCHANGER  
TEARDOWN  
INSPECT

COMPONENT ENVIRONMENTAL TESTS

PRODUCTION ENGINE TOTAL LIFE - AT ROCKETDYNE, CUSTOMER, FLIGHT

1700 NOM  
2300 MAX

460 NOM  
1015 MAX

R-4-1

ACCEPTANCE TESTS

J-2

WEIGHT, STATIC LEAKAGE

E & M

CALIBRATION (3 HOT FIRINGS MIN.)

AVG. 315 SEC. MAX. 750 SEC.  
15 SEC. CALIBRATION  
250 SEC. P.U. EXCURSION  
50 SEC. GIMBALING

1 IN 6 ALTITUDE TEST

1 IN 6 DURATION TEST

REMOVE INSTRUMENTATION

2ND E & M (BREAK JOINTS)

F-1

WEIGHT, STATIC LEAKAGE

E & M

CALIBRATION (3 HOT FIRINGS MIN.)

AVG. 258 SEC. MAX. 450'  
ONE 150 SEC. CALIBRATION  
DEMONSTRATE HEAT EXCHANGER  
GIMBALING

NO TEARDOWN

2ND E & M

~~CHART 7~~

R-4-2

RELIABILITY DEMONSTRATION TESTS - 2/1/65

	NO. OF TESTS	SINGLE ENGINE EXPOSURES	SUCCESS / FAILURE
165 & 188 K (SINCE OCT '62)	445	445	445 / 0
200 K (PRODUCTION)	267	267	266 / 1
CUSTOMER CLUSTER TESTS	24	192	191 / 1
FLIGHTS - SATURN	8	64	63 / 1
TOTALS	744	968	965 / 3

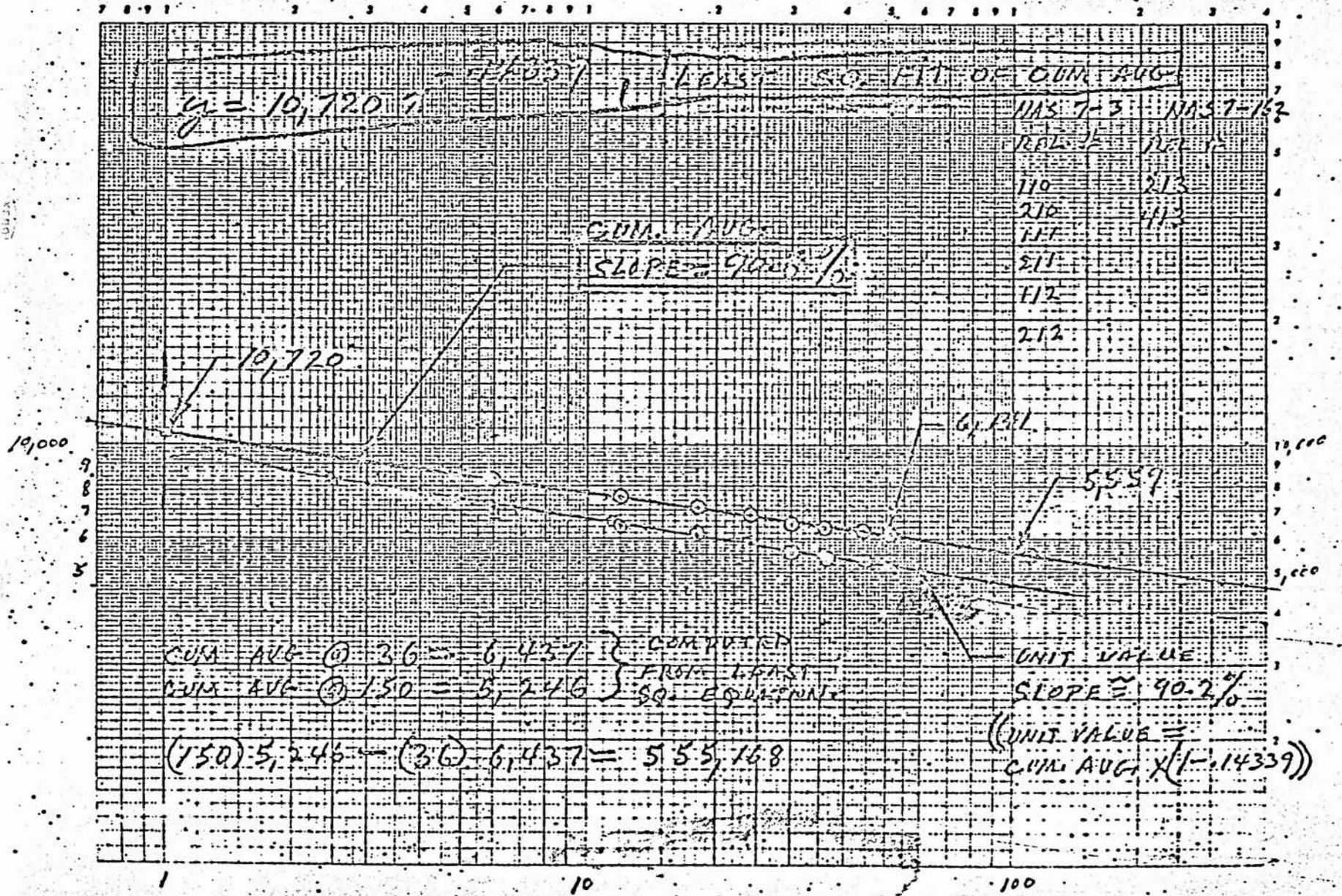
RELIABILITY S/N = .996 OR .993 R AT 9 C

- THE FLIGHT ENGINE FAILURE SHUT DOWN SAFELY, THE FUEL WAS USED BY OTHER ENGINES. THE MISSION WAS SUCCESSFUL.

CHART 15

R-4-3

# CUMULATIVE AVERAGE & UNIT VALUE



R-5-1

Nov. 23, 1965

### Theoretical Valve Reliability

<u>Single Valve</u> ( $R_o = R_c$ )	<u>Bipropellant Valve Assy</u> (2 valves)	<u>Quad Valve Assy</u> (2 Quad Valves) <u>Closing</u>	<u>Opening</u>
.90	.8100	.9606	.9291
.95	.9025	.9900	.9511
.99	.9801	.9996	.9992
.999	.9980	.999996	.999992
.9999	.9998	.99999996	.99999992

The above are based upon the equations:  
Quad Valve Assy:

$$\text{Prob. of Opening on Command} = [R_o^4 + 4R_o^3(1-R_o) + 2R_o^2(1-R_o)^2]^2$$

$$\text{Prob. of Closing on Command} = [R_c^4 + 4R_c^3(1-R_c) + 4R_c^2(1-R_c)^2]^2$$

where  $R_o$  = Prob. of single valve opening on command

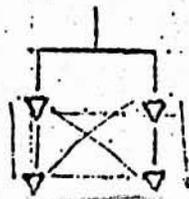
$R_c$  = " " " " closing " "

Bipropellant Valve Assy:

$$\text{Prob. of Opening on Command} = R_o^2$$

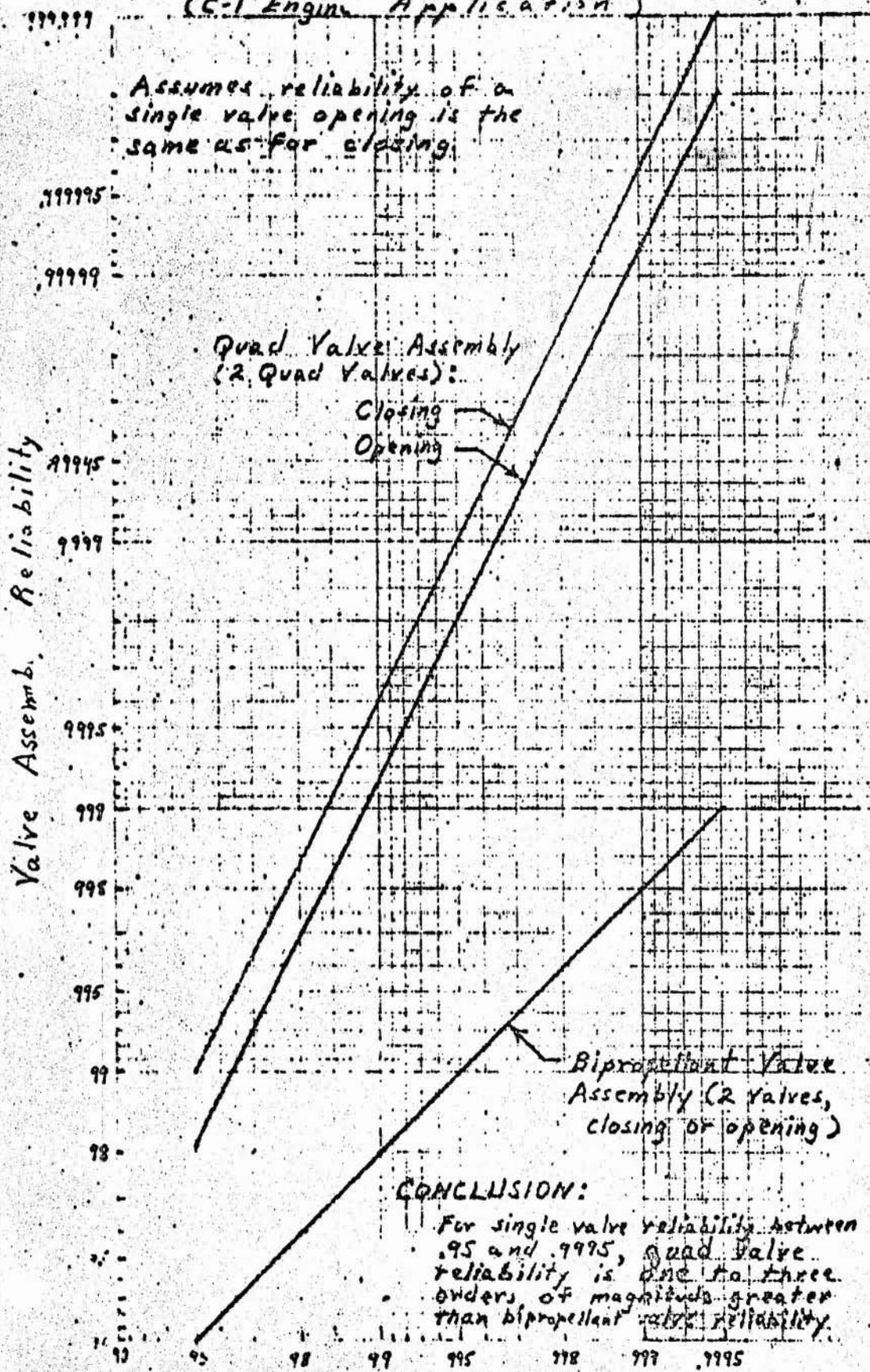
$$\text{Prob. of Closing on Command} = R_c^2$$

Quad Valve Functional Diagram:



# Theory of Reliability (C-1 Engine Application)

Assumes reliability of a single valve opening is the same as for closing.



Quad Valve Assembly (2 Quad Valves):

Closing  
Opening

Bipropellant Valve Assembly (2 valves, closing or opening)

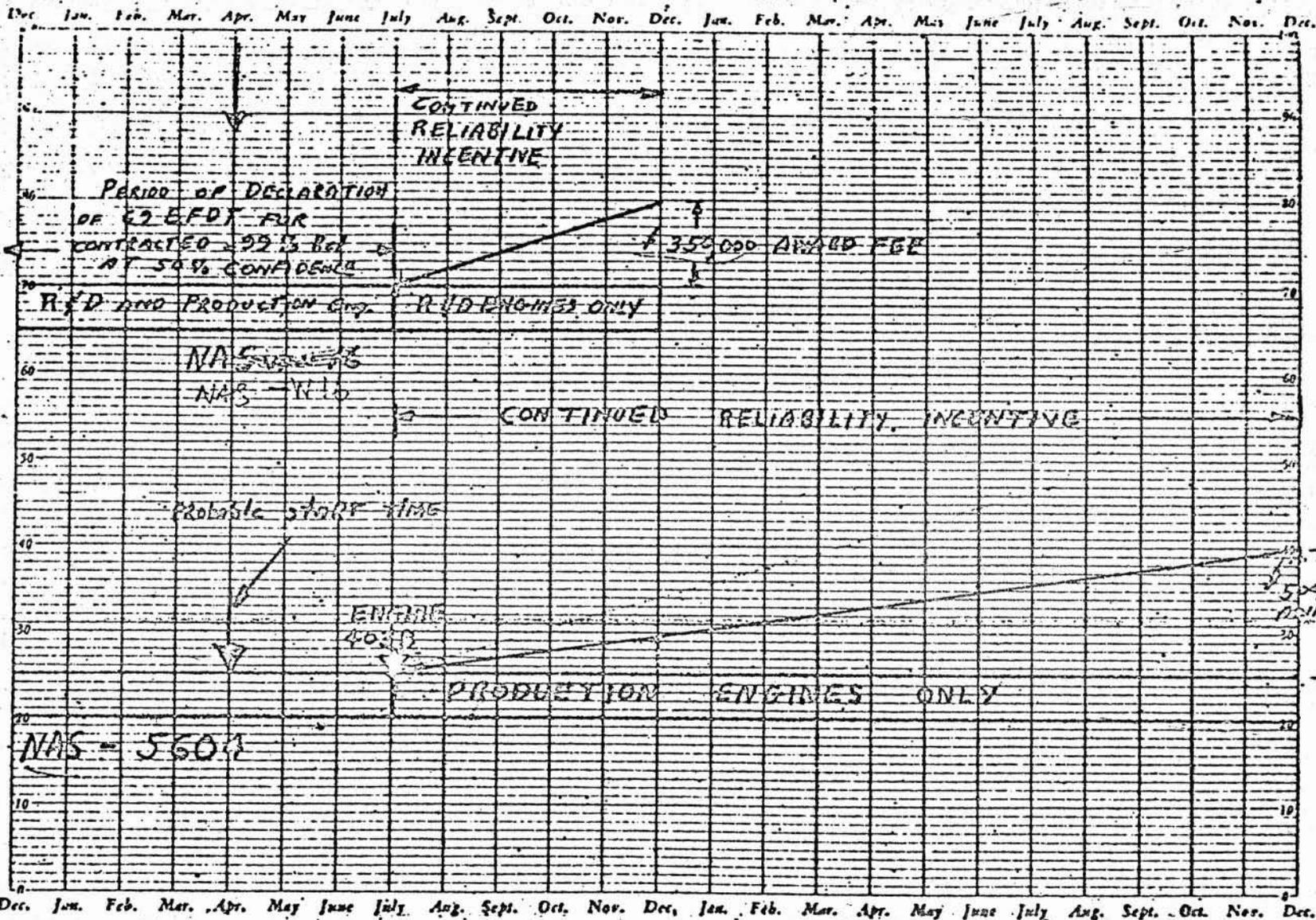
### CONCLUSION:

For single valve reliability between .95 and .9995, quad valve reliability is one to three orders of magnitude greater than bipropellant valve reliability.

Single Valve Reliability (Closing and Opening the Same)

467002

# RELIABILITY INCENTIVE PHASING



Year of 1966

Year of 1967

7/12/65

R-5-4