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Armed Services Technical Information Agency

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SYSTEM 112A

QUARTERLY RELIABILITY REPORT

REPORT NO. 56-989-120

FC

1 MAY 1959

BELL Aircraft CORPORATION

CONFIDENTIAL

SYSTEM 112A
RASCAL WEAPON SYSTEM

CONTRACT NO. AF33 (038)-15069

REPORT NO. 56-989-120

1 MAY 1959

prepared for THE RELIABILITY DEPARTMENT
BY TECHNICAL PUBLICATIONS

BELL Aircraft CORPORATION

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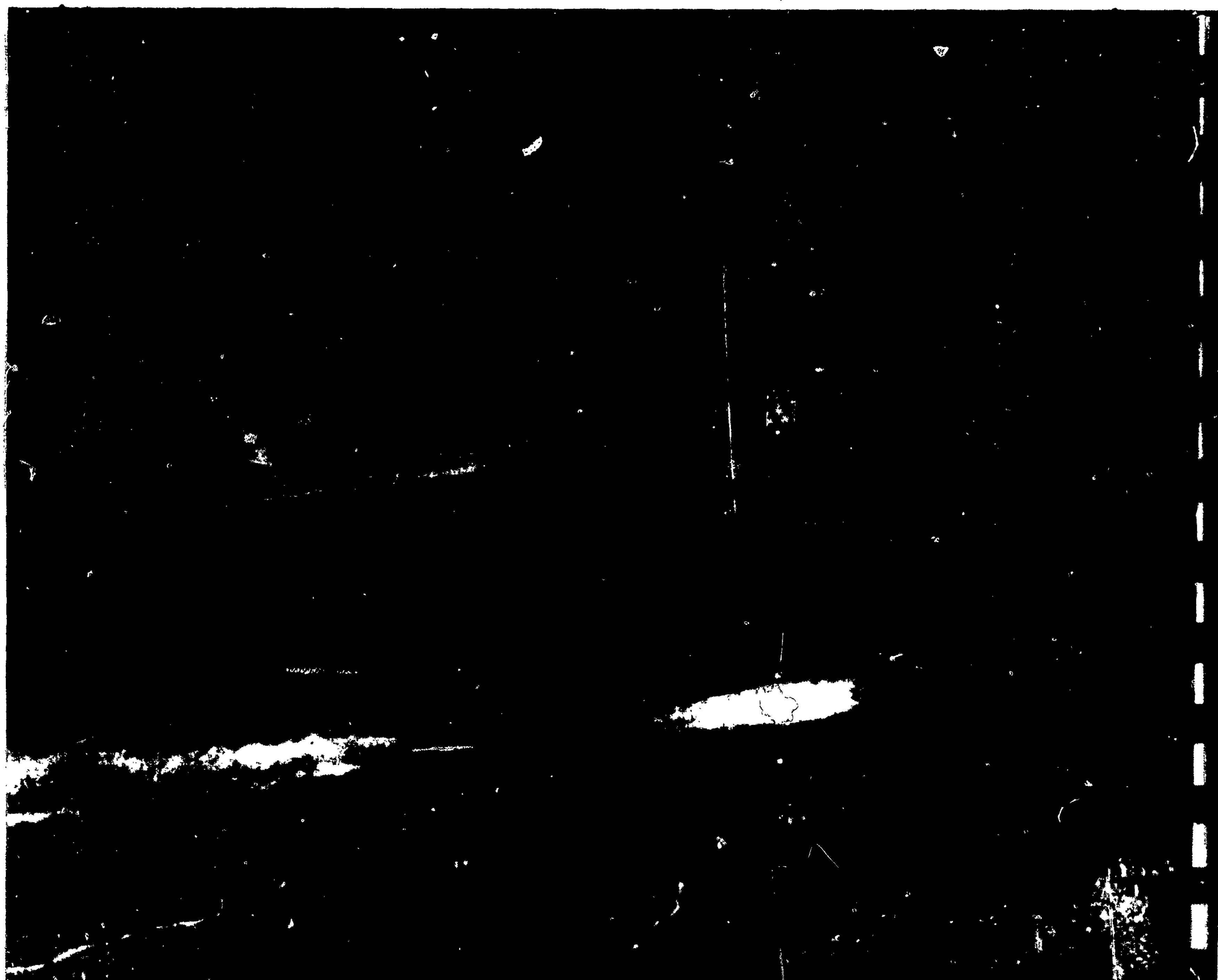

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GLOSSARY

Definitions

1. System: Consists of one or more components capable of performing one of the principal end-functions of the weapon system. Examples: guidance system, propulsion system, electrical system, fuzing system.

2. Component: Normally a combination of detail parts, subassemblies, and assemblies, and is a self-contained element of a complete operating system which performs a function necessary to the operation of the system. Examples: receiver, transmitter, power supply, turbine.

3. Component Part or Detail Part: An element of a component of such construction that it is not practically or economically feasible to disassemble for maintenance purposes. Examples: resistor, relay, coil, capacitor, vacuum tube.

4. GAM-63A: The official USAF designation for the Rascal Missile; the letters GAM indicate Guided Aircraft Missile.

5. Director Aircraft: The airplane, usually a modified B-47 bomber designated DB-47, which carried the GAM-63A, launched it, and directed it toward the target.

6. Reliability: The probability that equipment operating in a specified range of environmental conditions will demonstrate acceptable performance during a specified period of operation.

7. Operational Reliability: For a military weapon system, a function of the Use Reliability multiplied by the Inherent Reliability.

8. Inherent Equipment Reliability: The built-in reliability of equipment which exists at the end of the production process, i.e., at the point of delivery from the factory to the using agency.

9. Use Reliability: A function of the effect of various maintenance and application factors on the reliability of equipment in the hands of the using agency, i.e., after delivery from the factory.

Abbreviations

1. E&ST: Employment and Suitability Testing
2. RRC: Reliability Report Card
3. TOTR: Test Operating Time Report
4. EDR: Equipment Discrepancy Report
5. MTBF: Mean-Time-Between-Failures

SECTION I INTRODUCTION

This is the twentieth and last in a series of quarterly progress reports on the System 112A Reliability Program. The Rascal program was terminated in December 1958. The quarterly reports have provided a comprehensive view of the reliability program; depicting the types of tests which provide reliability data, showing the analyses employed in determining actual reliability factors for Rascal equipment, and evaluating reliability progress throughout the research and development phase as well as the military-use phase of the Rascal program.

The twentieth report presents (1) a summary of the major reliability efforts and evaluation of the reliability results of testing at the component and system levels in the factory, (2) a final report and analysis of the test results observed in the Logistics Depot, at Eglin AFB (E&ST program), and at McCoy AFB, and (3) a description of the outstanding reliability improvements incorporated in the Rascal Weapon System.

A detailed summary of all airborne missions which have taken place at AFMDC (Holloman) and Eglin Air Force Base since the beginning of the full-scale reliability program, in October 1955, is also presented. Analyses of the airborne missions, with conclusions, are also contained in this report.

A. THE RASCAL WEAPON SYSTEM

The Rascal (GAM-63A) Weapon System was an airborne instrument of warfare designed to provide DB-47 bomber aircraft with an increased capability for attacking and destroying heavily defended strategic targets. Principal elements were: (1) GAM-63A missiles, (2) DB-47 director aircraft, (3) ground support equipment, and (4) training aids.

The GAM-63A missile was a rocket-powered, supersonic, air-to-surface missile weighing approximately 18,200 pounds. It could deliver a 2800-pound warhead 90 nautical miles with maximum speed in excess of Mach 2.5. At a missile range of 75 nautical miles, it was capable of providing an airburst of a special warhead with a horizontal circular probable error of not more than 1500 feet and, excluding errors in weather prediction and target intelligence, a vertical standard deviation of not more than ±405 feet. Principal dimensions of the GAM-63A were: length, 32 feet; maximum diameter, 4 feet; and maximum horizontal span, 17 feet.

A rocket propulsion system using inhibited fuming nitric acid and jet fuel as propellants supplied 12,000 pounds of thrust for a short period to accelerate the missile to supersonic velocity. At the end of the thrust phase, the rocket engine entered a bypass phase, continuing to supply power for the generation of electrical energy and hydraulic power, while the missile flight became a controlled glide.

During the gyro-stabilized midcourse portion of the flight, an inertial range-computing system computed the range-to-go and caused the missile to enter the terminal dive automatically. During the terminal portion of the flight, a radar relay and command system enabled the guidance operator in the director aircraft to send course correction signals to the missile. The guidance operator also had the capability to initiate terminal dive, and could operate the missile's unattended search radar and transmit azimuth correction signals during midcourse flight.

In a typical mission the director aircraft, using a standard bombing-navigational system, proceeded to a predetermined launch area. Immediately prior to launch, information regarding aircraft ground velocity, heading, and range-to-target was imparted to the missile to serve as initial condition data for its non-emanating guidance system. After launch, the missile was under control of this gravity-referenced system during the midcourse phase of the flight. Missile altitude was controlled by an aneroid altimeter until terminal dive. At a predetermined range from the launch point, the missile's inertial range-computing system caused it to enter a nominal terminal dive. During the dive, an unattended search radar in the nose of the missile illuminated the target area, and the radar return from the target was relayed from the missile to the director aircraft, where the radar display was viewed on the azimuth and elevation indicator which showed the position of the missile relative to the target. By sending guidance commands via the microwave link, the guidance operator made corrections to the dive and azimuth attitudes of the missile to assure a detonation within the required accuracy.

B. RELIABILITY ORGANIZATION

The Director of Reliability directed, coordinated, and controlled Rascal reliability efforts within the operating divisions. An operational group, the Reliability Control Section, supported the Director of Reliability and the various organizations within the Corporation.

The Reliability Control Section performed the following functions on the Rascal reliability program:

(1) Collection and processing of basic reliability data on successes, failures, and operating times. To insure that reporting of data was complete, rapid, and accurate, reliability representatives were stationed at Air Force Plant 40 (System 112A Logistics Depot), Eglin AFB, AFMDC (Holloman), McCoy AFB, and in critical factory test areas.

(2) Analysis of reliability data. Recommendations were made to management concerning problem areas where corrective actions would provide the most rewarding reliability returns for a given expenditure of dollars and manpower.

(3) Reporting to management the effectiveness of corrective action taken, to insure "closing the loop".

(4) Providing reliability data and analyses to various operating organizations within the Corporation and to various Air Force agencies.

(5) Preparation, for management, of evaluation reports covering the success of the entire Rascal reliability program.

C. THE RASCAL RELIABILITY PROGRAM

Formal reliability efforts at Bell Aircraft Corporation date from 1951, when a small engineering group was established to study reliability problems from both design and test points of view. A group of six people surveyed the industry and documented techniques which would be applicable to a complex weapon system. Reliability analyses were performed on data gathered from various test centers. By the end of 1953, the reliability effort resulted in a contractual requirement for this quarterly reliability report for the Rascal weapon system.

The original reliability effort was expanded, in October 1955, into a full-scale reliability program from the Rascal weapon system.

The first missile of the reliability program, GAM No. 75, incorporated the Bell rocket engine (LR-67BA-9) and numerous other improvements over earlier missiles.

In the GAM Nos. 75-85 block of missiles, tubes were aged, components were reworked and reinspected, and limited-environmental tests were initiated on all components. Beginning with GAM No. 87, most electronic parts were 100% tested prior to use in components, components were built in accordance with improved standards, and extensive composite system tests and supplementary tests were conducted on missiles in factory testing. Similar reliability efforts were conducted on production director aircraft guidance systems beginning with AN/APW-17 system No. 107, after all systems were reworked to incorporate outstanding modifications. The prototype AN/APW-17 systems, used at Holloman to launch R&D missiles, were modified and then retested under environmental conditions.

Further reliability efforts included the establishment of numerous additional control drawings, the use of high-reliability design techniques, part application reviews, design reviews, more effective preventive maintenance techniques, increased evaluation of defective parts, and the use of more effective quality control and procurement techniques.

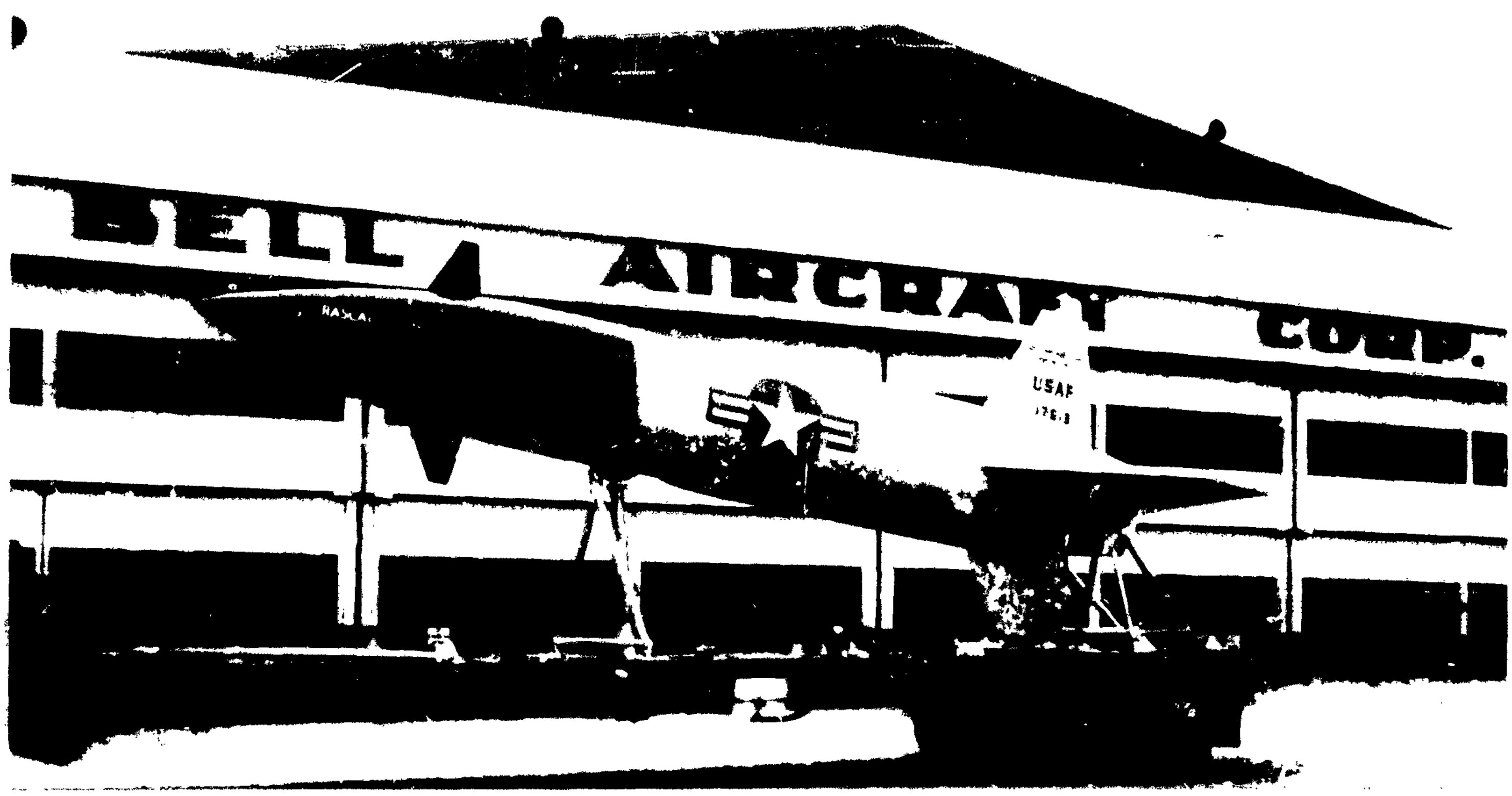
Life tests were conducted on all components of the weapon system except telemetering equipment. Approximately 85 composite system tests were conducted on the life-test missile, GAM No. 78, under various ambient and environmental conditions.

The Bell Aircraft reliability reporting system originated in 1953 and was made fully effective throughout the Corporation in February of 1956. During the period February 1956 through December 1958, the following reliability reports were accumulated:

Equipment Discrepancy Reports	-	25,830
Reliability Report Cards	-	107,935
Test Operating Time Reports	-	30,000

The above reports cover failures, successes, and operating times of Rascal equipment.

The more than 163,000 reliability data reports collected on the Rascal reliability program were used as a basis for identifying and defining adequacies and inadequacies in the weapon system and served to provide a measure of the effectiveness of taking corrective action on the various problems encountered on the program.



SECTION II RELIABILITY CONTROL ACTIVITIES

A. ANALYSIS OF FAILURE RATES OF ELECTRONIC COMPONENTS UNDER VARIOUS ENVIRONMENTS

In February of 1958, an analysis was made of the reliability performance of 144 electronic components under various levels of environmental stress and when used under various complexity environments (operated as individual components or operated in systems or missiles). This analysis was published in Bell Aircraft Corporation Report No. 56-989-117.

The original analysis of the effects of environment on the failure rate of electronic components was extended to include all missiles from GAM No. 75 to GAM No. 221. The analysis includes only component failures caused by parts or circuits. Failures attributed to human errors or causes and dependent failures were excluded from the analysis in order to show more accurately the direct effect of the various environments upon the operation of the physical hardware.

The scope of the analysis and the statistical validity of the results of the analysis are best shown by noting that the entire study was based on:

(1) Number of individual components analyzed	- Over	2,080
(2) Observed number of component failures	-	3,217
(3) Number of component-hours of testing	- Over	520,000

The three groups of electronic components, totaling 24 components per missile, represented 52.2% of the complexity of the entire missile as shown below:

Group of Components	Number of Components Per Missile	Percent of Total Missile Complexity
Servo	14	16.3%
Non-Emanating Guidance (Inertial Range Computing System)	5	4.6%
Emanating Guidance	5	31.3%
Total	24	52.2%

The effect of test environments on electronic components utilized in GAM Nos. 75 to 221, with the failure rate expressed in mean-time-between-component-failures, in hours, is graphically presented in Figure 1. The tests shown in Figure 1 consisted of:

(1) Factory Tests:

(a) All component-level testing, including limited-environmental tests on all components.

(b) Precomposite (subsystem) tests and composite system tests on missiles.

(2) Field Tests:

(a) Ground and airborne tests at AFMDC (Holloman) on components in GAM Nos. 75 to 101, less GAM Nos. 78, 86, 92 and 95.

(b) Ground and airborne tests at Eglin Air Force Base on components in GAM Nos. 102 to 117.

The following conclusions have been made from the test results shown in Figure 1.

(1) The observed mean-time-between-component-failures was inversely proportional to the respective complexity of each group of components.

(2) The severity of the individual physical environments during the limited-environmental tests on components was relatively greater than the actual physical environments experienced by components during missile-level tests.

(3) The limited-environmental tests acted as a debugging operation as evidenced by a more than ten-to-one decrease of failure rate during the final 24-hour bench test as compared to the initial bench test.

(4) The reliability calculated for the missile electronic components during the factory composite system tests has given a very close estimate of the reliability which could be anticipated during actual airborne flight operations in the field.

(5) The four-to-one increase in failure rate of electronic components between the final bench check and the composite system test of the missile is due almost entirely to interaction effects and the effect of placing the 24 electronic components in the confined and restricted-access areas in the missile.

An analysis of the data from the various blocks of missiles (groups of ten missiles) used to compile Figure 1 revealed that the same general trend shown for all missiles, GAM Nos. 75-221, appeared in the analysis of each block of missiles.

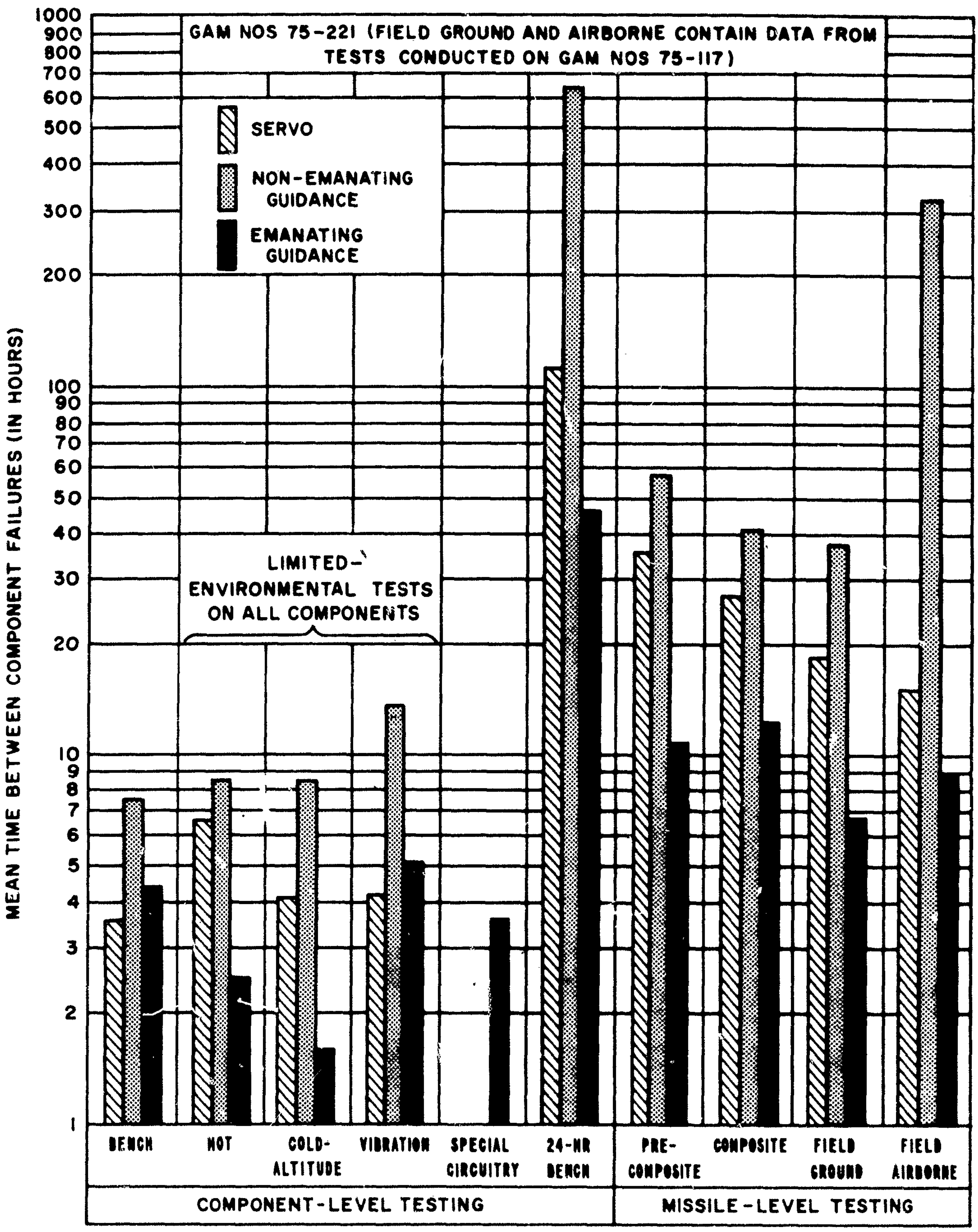


Figure 1. Mean Time Between Electronic Component Failures Under Various Test Conditions

B. MASTER CHECK LIST OF RELIABILITY PROGRAM PRACTICES

An informal check list of reliability practices, maintained by the Director of Reliability to control the reliability activities of the Rascal reliability program, was expanded for application to other reliability programs. The check list was published as:

"Master Check List of Reliability Program Practices"
Reliability Handbook 7-58-2954-9
Fourth Edition, dated 17 February 1959

The "Master Check List of Reliability Program Practices" has been found to be valuable as an aid in establishing and conducting reliability programs and as an educational device in the field of reliability.

C. IDEA-FOR-IMPROVEMENT PROGRAM

The idea-for-improvement program inaugurated in October of 1955 played a significant role in the Rascal reliability program. A total of 895 ideas for improvement, pertaining to the Rascal weapon system and initiated on the Equipment Discrepancy Report (EDR) form, were received, processed, and directed to the proper authorities. The benefit derived from this voluntary and personal effort of Bell Aircraft employees is shown below:

Number of ideas for improvement resulting in a change incorporated in the Rascal weapon system	587 (65.6%)
Number of ideas for improvement resulting in a change suggested but not incorporated because of termination of the Rascal program	35 (3.9%)
Number of ideas for improvement answered but not considered adequate for a change	266 (29.7%)
Number of ideas for improvement not answered because of termination of the Rascal program	7 (0.8%)
Total -	895 (100.0%)

D. ANALYSIS OF OBSERVED RELIABILITIES AND ESTABLISHED RELIABILITY GOALS OF SYSTEMS, SUBSYSTEMS, AND COMPONENTS

Effective with the initiation of the expanded reliability program in October 1955, a comparison of the observed reliability was made to the established reliability goal for each system, subsystem, and component on a continuing basis.

TABLE I

COMPARISON OF OBSERVED RELIABILITIES AND ESTABLISHED RELIABILITY GOALS FOR TACTICAL RASCAL SYSTEMS

Major System	Observed Reliability(1) (In Per Cent)		Airborne Reliability Goal (In Per Cent)	
	Factory* Tests	Field** Tests	R & D*** Phase	Operational**** Phase
Missile	63.0	55.0	64.6	82.3
Propulsion	82.9	75.8	90.2	95.5
Flight Control	96.6	95.1	94.1	97.3
Non-Emanating Guidance (Inertial Range Computing System)	98.5	98.6	98.4	99.3
Emanating Guidance	93.9	89.8	83.8	92.4
GAM Auxiliary	85.1	86.1	93.0	96.8
Fuzing	100	100	99.7	99.9
Director Aircraft	Not Applicable	80.5	69.6	85.1
Guidance	Not Applicable	82.0	74.3	87.6
Miscellaneous	Not Applicable	98.2	93.6	97.1

* Factory tests based on GAM Nos. 75 to 221.

** Field tests based on GAM Nos. 75 to 117 and corresponding Director Aircraft Systems.

*** Established for airborne missions using GAM Nos. 75 to 101.

**** Established for airborne missions using GAM Nos. 122-134 and 201-222.

Note (1): Included in these reliability calculations were failures caused by human errors, inadequate maintenance, and inadequate procedures, as well as by inherent unreliability of equipment.

Table I shows the reliability goal established for each tactical major system of the missile and the director aircraft for the R&D phase and for the operational (squadron-use) phase of the Rascal program. An over-all tactical weapon system reliability goal of 45% was mutually agreed upon, by the Air Force and the Contractor, for airborne operations during the R&D phase. An over-all tactical weapon system goal of 70% was established by the Contractor as a design objective for airborne missions during the operational (squadron-use) phase of the program. No reliability goal was established for the weapon system specifically for the E&ST phase of the program. The reliability growth curve shown in Bell Aircraft Corporation Report No. 56-989-117 (page 33) was used as a moving-goal objective for the E&ST and operational-use phases of the program.

Shown in Table I are the observed reliabilities experienced on tactical major systems during factory and field tests on the Rascal missile and during field tests on the director aircraft. Six of the major systems were observed to be better than the established R&D goals; two were observed to be less.

Appendix D shows the observed reliabilities and established reliability goals for all subsystems and components of the tactical weapon system. The corresponding information given above for Table I also applies to Appendix D.

The reliabilities of components, subsystems and systems were calculated on the following bases:

(1) Missile, less Propulsion System: The probability of no failures during one hour of factory or field operation.

(2) Propulsion System: The probability of no failure during a simulated or actual mission.

(3) Director Aircraft Guidance System: The probability of no failure during 115 minutes of field operation.

(4) Director Aircraft Miscellaneous System: The probability of no failure during 150 minutes of field operation.

An analysis of the 165 components included in Appendix D has shown the following observed performance on tactical Rascal components throughout the reliability program:

Components in	No. of Components Which Equaled or Exceeded Established Reliability Goals for a 70% Weapon System		No. of Components Which Equaled or Exceeded Established Reliability Goals for a 45% Weapon System		No. of Components On Which No Failures Were Experienced at Missile or Director Aircraft System Test Level in the Factory or in the Field
	Factory	Field	Factory	Field	
Missile	76 (66%)	67 (58%)	89 (77%)	74 (64%)	34 (29%)
Director Aircraft	---	28 (57%)	---	39 (80%)	18 (37%)
Weapon System	---	95 (58%)	---	113 (68%)	52 (32%)

Note: The numbers in parenthesis indicate the percentage of components out of the total of 116 for the missile, 49 for the director aircraft, and 165 for the over-all weapon system.

SECTION III SUMMARY OF FACTORY TESTS AT NIAGARA FRONTIER FACILITIES

This section of the report includes significant results of factory tests conducted during the fourth quarter of 1958 and reviews the results of factory tests from February 1956 to the end of the program in December 1958.

A. FACTORY TESTING OF MISSILES - FOURTH QUARTER OF 1958

Tables II and III contain reliability information on the last eight missiles, GAM Nos. 214-221, which completed factory testing during this quarter.

The observed reliability of a missile was calculated for the last portion of factory testing only, during which time the entire missile was operated and formal countdowns were conducted. The formal composite system tests or countdowns consisted of:

Phase I - Simulating takeoff-to-launch equipment operation

Phase II - Simulating launch-to-target equipment operation

This last portion of missile testing has been designated as "Composite System Test Phase". The reliability observed during the composite system testing of the Rascal missile was a measure of the inherent reliability of that portion of the missile which was tested during this period.

Analysis of the data contained in Tables II and III shows the following:

(1) The cumulative reliability for the group of missiles tested in the factory during this quarter was 89.9%, which compares favorably with the 86..% missile goal necessary to obtain a 70% airborne weapon system reliability. This 89.9% observed reliability figure was for the missile less the propulsion system and less those propulsion-associated components not normally operated with the complete missile, except during static ground firings or during airborne launching operations.

(2) Seventy-one percent of all valid composite system tests were successful.

(3) An average of 7.8 composite system tests was conducted per missile this quarter as compared to the average of 19 composite system tests conducted per missile on the R&D missiles, GAM Nos. 87 through 101, during the factory testing phase.

(4) The minimum time requirements for all major circuits were met in every case.

TABLE II

FACTORY OBSERVED RELIABILITY AND COMPOSITE SYSTEM TESTS
(During Composite System Test Phase Only)

Item	Missile Numbers								GAM Nos. 214-221	Goal*
	214	215	216	217	218	219	220	221		
Observed Reliability** of Missile, Less Propulsion System and Less Propulsion-Associated GAM Auxiliary Components	92.9%	89.7%	89.9%	90.6%	93.1%	95.2%	92.8%	83.4%	89.9%	86.5%
Composite System Tests:										
Number Conducted	9	9	5	6	10	7	7	9	7.8 Average	5 Minimum
Number Successful	7	5	5	5	6	5	5	6	5.5 Average	-
Per Cent Successful	78%	56%	100%	83%	60%	71%	71%	67%	71%	50%

* A reliability goal of 86.5% was established for the missile less the propulsion system and less the propulsion-associated GAM auxiliary components, to meet the requirements of a 70% airborne weapon system.

** This observed reliability is a probability of one hour of failure-free operation during the factory testing phase.

NOTE: (1) A successful composite system test is defined as one during which no reliability-type failures are experienced in the missile systems.

(2) No ground firings were conducted on the above missiles. All rocket engines were fired during engine acceptance tests prior to installation in missiles.

TABLE III

FACTORY OPERATING TIME (IN HOURS)
(During Composite System Test Phase Only)

Missile Number	Master Power	Non-Emanating Power (Servo B+)	Hydraulic and Servo	Antenna Spin Drive	IRCS	Radar Low Voltage (Unattended Search Radar)	Radio Low Voltage (Relay and Command)
214	112	93	71	38	70	78	77
215	108	79	70	41	77	65	65
216	82	70	62	50	52	57	65
217	75	68	61	45	52	67	67
218	108	98	74	44	62	80	76
219	59	55	49	42	42	51	51
220	76	72	59	38	57	61	56
221	91	78	52	44	66	79	74
Average Time	89	77	64	43	60	67	66
Minimum Requirement	None	None	40	20	20	40	40

B. FACTORY TESTING OF MISSILES - FEBRUARY 1956 TO DECEMBER 1958

A comparison of the reliabilities of missiles at the time of shipment from the factory (by blocks of R&D, E&ST, and Operational Squadron missiles, since February 1956) is shown in Figures 2 and 3 on factory observed reliability and percent of successful composite tests conducted on missiles during factory testing. The observed reliability shown in Figure 2 is the probability of one hour of failure-free operation during the factory testing phase and is a measure of the inherent reliability of the Rascal missile, less the propulsion system. The total factory operating time accumulated on major missile circuits is shown in Table IV for all missiles tested since February 1956. The total factory operating time includes the time of operation of the missile in the subsystem test phase plus the composite system test phase.

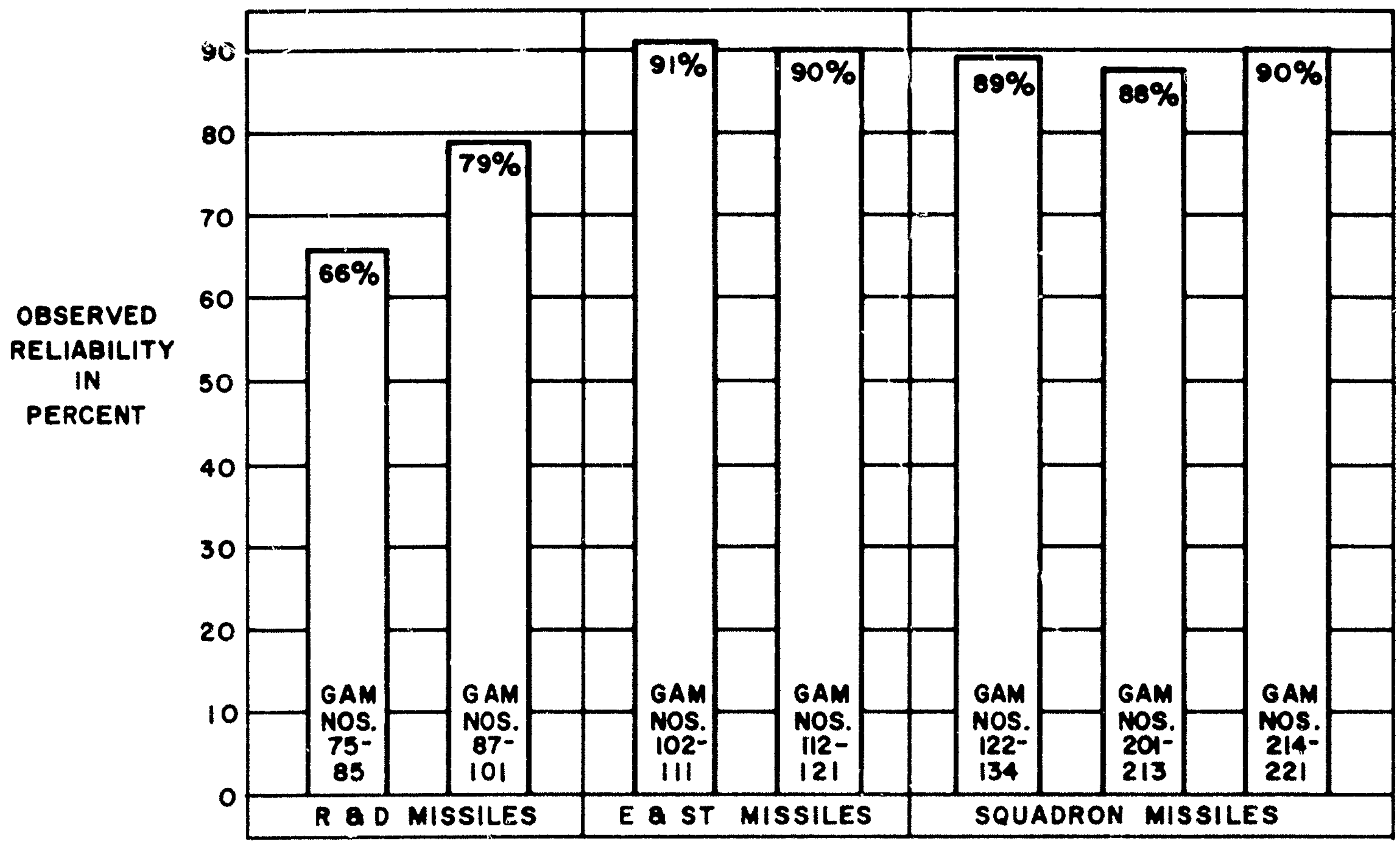


Figure 2. Factory Observed Reliability of Missiles (less Propulsion System)

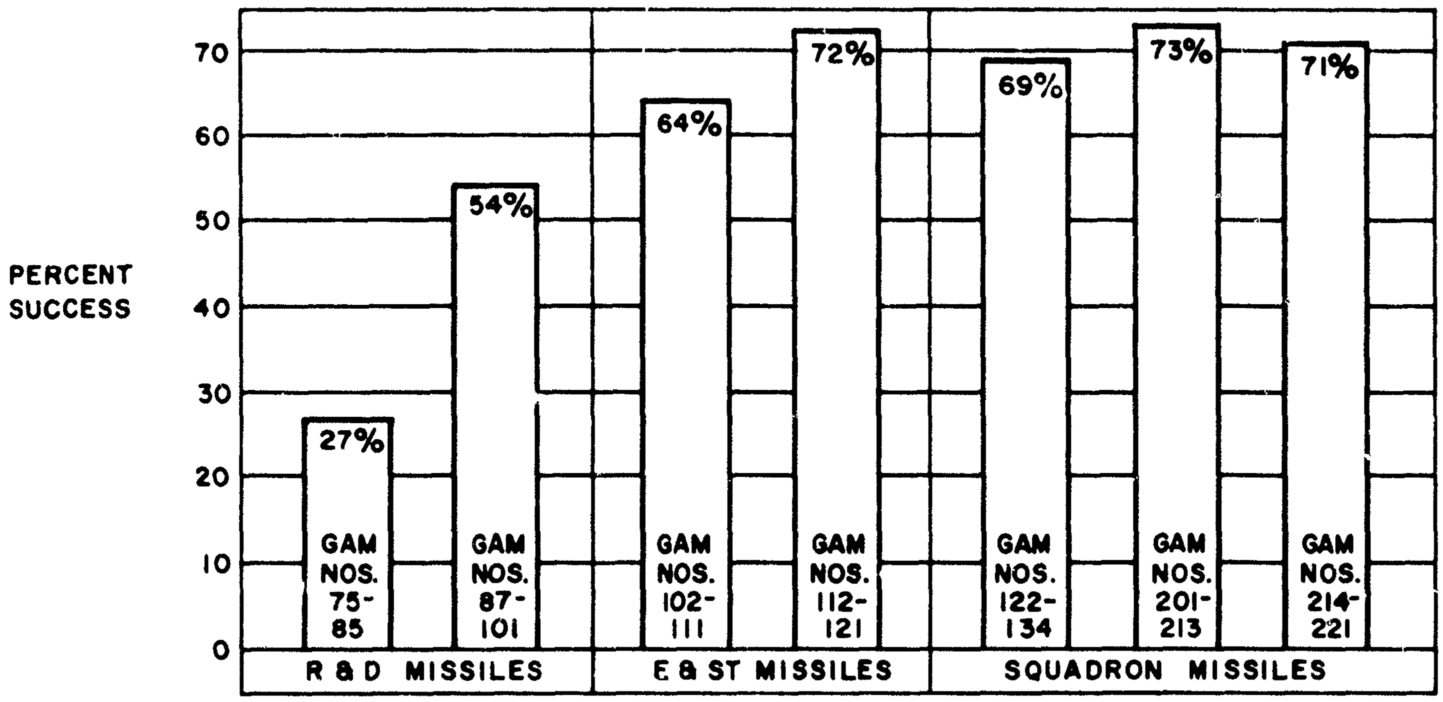


Figure 3. Success of Composite System Tests on Missiles During Factory Test

TABLE IV

TOTAL FACTORY OPERATING TIME BY MISSILE BLOCKS
(In Average Hours Per Missile)

	R & D		E & ST		Operational Squadron		
Major Circuit	GAM Nos. 75-85	GAM Nos. 87-101	GAM Nos. 102-111	GAM Nos. 112-121	GAM Nos. 122-134	GAM Nos. 201-213	GAM Nos. 214-221
Master Power	572	436	333	275	251	256	274
Non-Emanating Power (Servo B+)	334	280	238	201	178	177	179
Hydraulic & Servo	214	204	178	146	134	135	137
Antenna Spin Drive	40	47	39	60	57	50	49
IRCS	83	89	85	106	115	116	120
Radar Low Voltage	88	128	99	99	94	86	85
Radio Low Voltage	98	101	97	93	94	86	82

C. ANALYSIS OF MISSILE RELIABILITY AND DELIVERY SCHEDULES

During the period September 1957 to December 1958, this Contractor fulfilled all monthly missile delivery schedules established by the Air Force. This fulfillment of delivery schedules was accomplished without jeopardizing the reliability of missiles delivered during this period.

Effective with the delivery of GAM No. 104, new reliability requirements for (1) observed reliability, (2) percent successful composite system tests, and (3) minimum system operating hours, were established to ensure that the most economical reliability-assurance tests would be conducted during the manufacturing process which would be compatible with delivering a reliable missile on schedule.

It had been determined previously that the 15 composite system tests which were a requirement for GAM Nos. 87-103 could be reduced to a minimum of five composite system tests for GAM Nos. 104 and subsequent without sacrificing the reliability of the delivered missiles. Analyses had proven that the configuration of missiles effective with GAM No. 96 was definitely of a higher order of reliability than previous missiles and, hence, required less reliability testing in the factory (considered here as missile debugging tests) to provide assurance of delivering a satisfactory product.

Figure 4 shows that the later R&D missiles, GAM Nos. 96 through 101, were of a much higher reliability configuration than the earlier R&D missiles, GAM Nos. 75-95. Also in Figure 4 there can be observed the fact that an acceptable cumulative percentage of successful tests was reached after an average of only eight tests on GAM Nos. 102 and subsequent as compared to an average of 19 tests on the earlier R&D missiles.

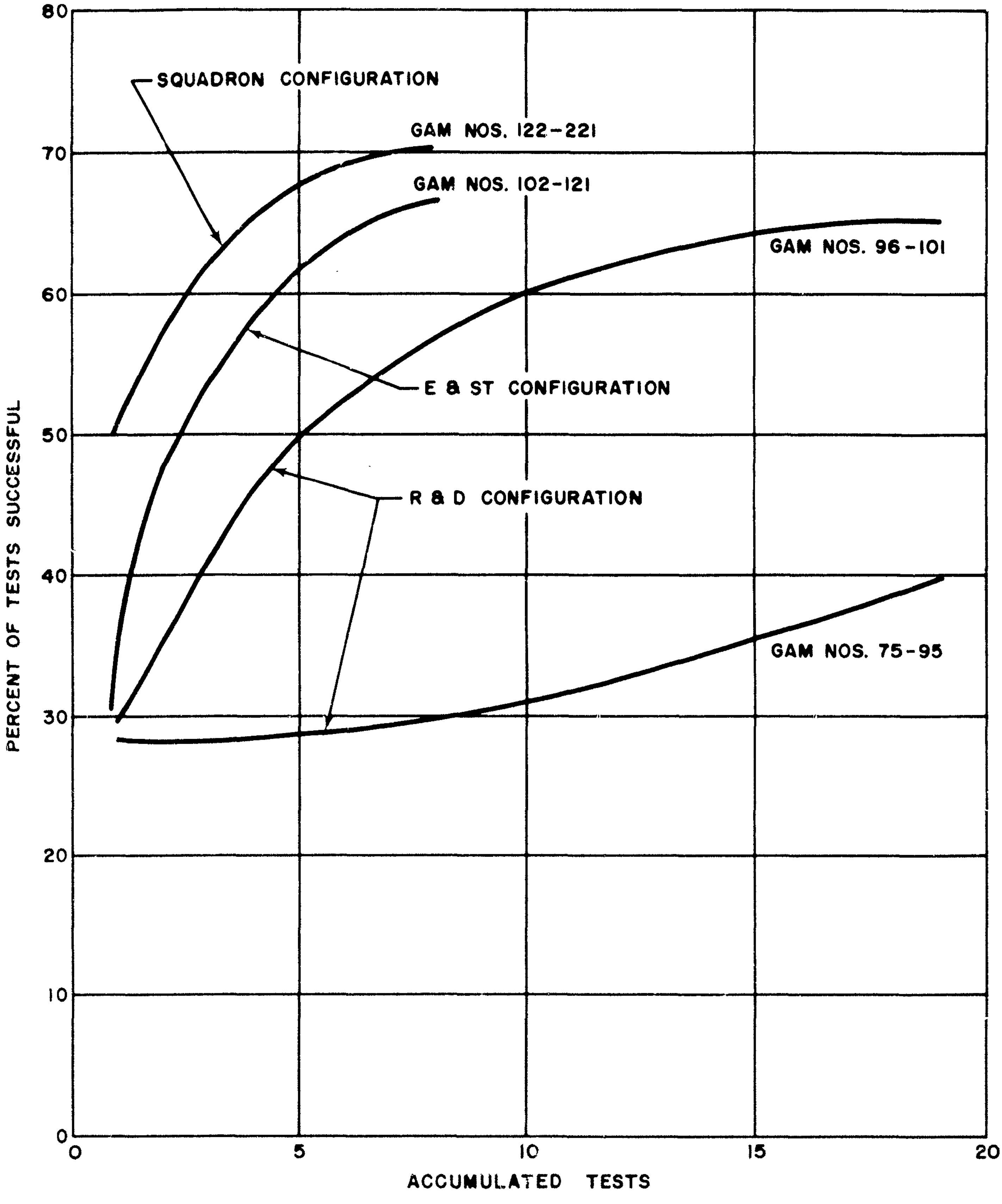


Figure 4. Cumulative Percentage of Success of Composite System Tests on Rascal Missiles During Factory Tests

D. FACTORY TESTING OF ROCKET ENGINES

A comparison of the results of acceptance testing of LR-67BA-9 rocket engines for R&D missiles, E&ST missiles and squadron missiles is contained in Table V.

TABLE V

ANALYSIS OF ROCKET ENGINE ACCEPTANCE TESTS

	R&D Missiles GAM Nos. 75-101	E&ST Missiles GAM Nos. 102-121	Squadron Missiles GAM Nos. 122-134, 201-222
Number Tested	33	24**	35
Total Tests Conducted	89	51	58
Tests Per Engine	2.7	2.1	1.7
Shutdowns Caused by Engine Failures*	13	2	5
Probability of No Shutdown Due to Engine Failure	0.85	0.96	0.91

*Engine shutdowns caused by test equipment failures or by testing errors were not included.

**Includes four spare engines.

Further analysis of acceptance test data, with respect to the probability of successful operation of the rocket engine, has shown the following information:

	R&D Missiles (Holloman)	E&ST Missiles (Eglin)	Squadron Missiles (McCoy)
Probability of no shutdown of the rocket engine during acceptance tests after "simulated launch"	100%	100%	98%

This analysis indicates, for example, that the inherent reliability of the rocket engines installed in E&ST missiles was observed to be 96% and that after successfully passing simulated launch the reliability of the engines for the remainder of the firing approached 100%.

SECTION IV SUMMARY OF OPERATIONS AT LOGISTICS DEPOT

A. MISSILES

1. Testing in Fourth Quarter

Eight missiles were received at the Depot, during the fourth quarter of 1958, after the completion of factory testing. The missiles were put into storage following a complete visual inspection.

In accordance with Air Force policy, which states that "missiles in storage for more than six months are required to undergo composite system test prior to shipment from the Depot", GAM Nos. 117 and 121 were subjected to composite system testing during October 1958. Table VI shows the reliability results of composite system tests conducted on these missiles. The operating time accumulated on major circuits during Depot testing is also included. GAM No. 117 was shipped to Eglin AFB, but GAM No. 121 was held at the Depot for later shipment to McCoy AFB.

2. Summary of Missile Tests

During the entire period of operations at the Logistics Depot, ten missiles satisfactorily completed one or more composite system tests. GAM No. 104 had considerable damage from an acid leak which occurred during an attempted launch at Eglin AFB, so it was completely reconditioned by Depot personnel prior to composite system test. Eight of the ten missiles given composite system tests were shipped to Eglin AFB for flight testing in the E&ST program (GAM Nos. 118 and 121 were not shipped).

3. Missile Modification Program

All missiles at the Logistics Depot required some modifications, through the installation of service kits, to make them conform to the latest configuration. Since much of the composite system testing would have been duplicated after the installation of the service kits, all missile testing was temporarily halted on 21 October 1958, pending completion of the modifications. Prior to the termination of the Rascal contract on 2 December 1958, modifications had been completed on thirteen missiles, including GAM No. 104. Termination of the Rascal program precluded completion of the missile modification program.

TABLE VI

MISSILE TESTS IN LOGISTICS DEPOT

ITEM	GAM NO. 117	GAM NO. 121
Composite System Tests Conducted	1	2
Observed Reliability of Missile, Less Propulsion System and Less Propulsion-Associated GAM Auxiliary Components	98.4%	91.2%
Reliability-Type Failures	1	1
Total Discrepancies	4	1
Mean-Time-Between-Failures	63.7 Hours	10.8 Hours
Operating Time:		
Master Power	64 Hours	35 Hours
Non-Emanating Power (Servo B+)	32 Hours	23 Hours
Hydraulic and Servo	26 Hours	17 Hours
Antenna Spin Drive	8 Hours	5 Hours
Inertial Range Computing System	9 Hours	9 Hours
Radar Low Voltage	17 Hours	11 Hours
Radio Low Voltage	15 Hours	14 Hours

B. DIRECTOR AIRCRAFT GUIDANCE (AN/APW-17) SYSTEMS

1. Testing in Fourth Quarter

Testing of thirteen Director Aircraft Guidance (AN/APW-17) Systems for operational use was continued at the Air Force Logistics Depot during October 1958. Five systems, Nos. 132 to 136, scheduled for installation in DB-47 operational squadron aircraft, satisfactorily completed testing at the Depot and were shipped to McCoy AFB.

The testing of AN/APW-17 System No. 132 revealed four discrepancies. No discrepancies were observed during the testing of System Nos. 133 to 136.

2. The AN/APW-17 System Test Program

During the AN/APW-17 test program on thirteen systems, forty-one discrepancies were discovered. Only nine of the forty-one discrepancies were due to part failures; the remainder were inspection-type items. Twenty-three (56%) of the discrepancies occurred in the first three systems tested. The number of discrepancies decreased considerably during the middle of the program and the testing was brought to a successful conclusion when the last four systems were tested without the occurrence or observation of a single discrepancy.

C. EVALUATION OF DISCREPANT COMPONENTS

Personnel at the Logistics Depot evaluated two hundred and eleven components which were reported or suspected to be discrepant during field testing at Eglin AFB and testing at the Depot. During evaluation, 88% of the components were confirmed as defective. No discrepancies could be found in the remaining 12%. In the latter group, test equipment discrepancies, tester errors, test procedure errors, or component incompatibilities at Eglin and in the Depot were concluded to be the causes of these apparent discrepancies.

One hundred sixty-one of the confirmed discrepant components were repaired or readjusted by Depot personnel to put them back into serviceable condition. The remaining twenty-five were scrapped because of the high cost of reconditioning the units. Nine of the scrapped units were taken from GAM No. 104 after an acid leak occurred during an attempted launch.

SECTION V SUMMARY OF TESTING AT EGLIN AIR FORCE BASE

This section on the testing program at Eglin Air Force Base covers the entire period from October 1957 to December 1958. In making reliability analyses of the Eglin testing, comparisons will be made before and after 30 June 1958, at which time added Contractor support became effective on the E&ST program.

A. ANALYSES BASED ON USE OF INERTIAL GUIDANCE SYSTEM

In September 1958, a decision was made by the Air Force to continue to check out the emanating guidance equipment in the missile and in the director aircraft prior to every attempted launch. Then, in case the emanating guidance equipment in the missile or director aircraft would not be operating properly, the missile would be launched on the non-emanating guidance system (Inertial Range Computing System) and autopilot system alone.

As a result, for emanating guidance failures of this type, the failure of the emanating guidance equipment was charged to Phase I (takeoff-to-launch). Also, when the missile was guided to the target on inertial guidance and autopilot, Phase II (launch-to-target) was considered a success with respect to the new objective of "guidance by inertial system alone".

B. WEAPON SYSTEM AIRBORNE TESTS

A complete description of all airborne missions conducted at Eglin AFB, during the period October 1957 to December 1958, is given in Appendix B.

1. Phase I (Takeoff-To-Launch) Tests

Table VII shows the results of Phase I (takeoff-to-launch) tests at Eglin Air Force Base for the periods prior to and after 30 June 1958. Of significance here is the eight-to-one reduction in the number of aborts per missile launched during the period after 30 June 1958, based on failures in tactical equipment of the weapon system.

The improvement in Phase I operations after 30 June 1958 was attributed mainly to the effects of using more Contractor support during this period, combined with the decision to launch several missiles on the back-up inertial guidance and autopilot systems (i.e., without the emanating guidance system).

TABLE VII

PHASE I (TAKEOFF-TO-LAUNCH) TESTS AT EGLIN AFB
ANALYSIS OF ABORTS DURING AIRBORNE WEAPON SYSTEM OPERATION

	Prior to 30 June 1958		After 30 June 1958	
Missile Number	Aborts Due to Tactical Equipment Failure	Missiles Launched	Aborts Due to Tactical Equipment Failure	Missiles Launched
102	2		1	Note (3)
103	8		0	1
104	1		0	1
105	1	1		
106	2	1		
107	1	1		
108	3		1	1
109	0	1		
110	1		0	Note (2)
111	0	Note (1)		
112			1	1
113			1	1
114			0	1
115			0	1
116			0	1
117			1	Note (3)
Totals	19	4	5	8
Number of Aborts Per Missile Launched	4.8		0.6	

Note (1): GAM No. 111 was jettisoned for safety reasons.
Note (2): GAM No. 110 was accidentally dropped because of defective missile release equipment in the B-47.
Note (3): GAM Nos. 102 and 117 did not complete field testing due to termination of the program.

2. Phase II (Launch-To-Target) Tests

Table VIII shows the Phase II (launch-to-target) test results of missiles launched during the Eglin Air Force Base operations.

TABLE VIII

PHASE II (LAUNCH-TO-TARGET) TESTS AT EGLIN AFB
ANALYSIS OF LAUNCHES DURING AIRBORNE WEAPON SYSTEM OPERATION

Date of Launch	Missile Number	Launching Aircraft No.	Results in Phase II* (Launch-to-Target)	Notes
2-17-58	105	165	Successful.	(1)
4-18-58	106	165	GAM Auxiliary System failure.	(3)
5-23-58	109	165	Rocket engine shut down at approx. 100 seconds.	(3)
6-19-58	107	165	Emanating Guidance failure; reached target area on Inertial Guidance System.	(2)
7-25-58	114	346	Emanating Guidance failure; reached target area on Inertial Guidance System. Improper warhead firing.	(2) & (4)
8-1-58	113	346	Launched on Inertial Guidance System; reached target area. Improper warhead firing.	(2) & (4)
8-22-58	115	187	Became unstable after launch.	(3)
8-29-58	112	187	Launched on Inertial Guidance System; became unstable after terminal dive; reached target area.	(3)
9-16-58	116	187	Became unstable after launch.	(3)
9-24-58	103	346	Launched on Inertial Guidance System; reached target area.	(2)
11-10-58	108	187	Missile launched off course; beacon destruct.	(4)
11-18-58	104	168	Launched on Inertial Guidance System; loss of power at 97.5 seconds.	(5)

*A complete description of all airborne missions at Eglin will be found in Appendix B.

Notes: (1) Completely successful.
(2) Successful with respect to use of the back-up inertial guidance and autopilot systems.
(3) Human error — inadequate maintenance or checkout.
(4) Non-Bell responsibility.
(5) Part failure.

It is significant to note that for seven missiles (GAM Nos. 106, 109, 112, 113, 114, 115, and 116) the conditions which caused the missions to be unsuccessful were confirmed to be present on take-off or were analyzed as most likely to have been present prior to take-off. This analysis indicated the firm need for additional checkouts to be performed prior to take-off for a launching mission or the implementation of certain precautionary maintenance procedures and policies as applicable to each missile.

C. WEAPON SYSTEM GROUND TESTS (COMPATIBILITY TESTS)

The success of compatibility tests conducted on the Rascal weapon system (missile and director aircraft) on the ground at Eglin AFB is shown in Table IX.

It was concluded that the 64% success observed on compatibility tests conducted after 30 June 1958 did not represent a degradation of hardware reliability, but instead showed an improvement in the ability to detect and correct unfavorable conditions that could result in subsequent aborts. The more critical testing was considered a direct beneficial result of increasing the technical support at Eglin AFB. This conclusion appeared justified by the large decrease in number of aborts per missile launched subsequent to 30 June 1958.

TABLE IX

COMPATIBILITY TESTS RESULTS AT EGLIN AFB

Compatibility Tests	Prior to 30 June 1958	After 30 June 1958
Total Number Conducted	54	45
Successes	38	29
Failures:	16	16
(Missile)	(14)	(14)
(Director Aircraft)	(2)	(2)
Percent Successful	70%	64%

D. MISSILE RELIABILITY

1. Reliability of Missile, Less Propulsion System and Less Propulsion-Associated Components in GAM Auxiliary System

The observed reliabilities of the E&ST missiles, less propulsion system and less propulsion-associated components in the GAM auxiliary system, as observed during ground and airborne tests, are shown in Table X. Included in Table X is a record of the composite system tests conducted on each missile at Eglin AFB. Table XI contains a summary of missile operating time by major circuits.

TABLE X

TEST RESULTS FOR MISSILES, LESS PROPULSION SYSTEM AND LESS PROPULSION-ASSOCIATED GAM AUXILIARY COMPONENTS, DURING GROUND AND AIRBORNE TESTING AT EGLIN AFB

As of December 1958

Item	MISSILE NUMBERS																	GAM Nos. 102-117
	102**	103	104*	104*	105	106	107	108	109	110	111	112	113	114	115	116	117**	
Observed Reliability of Missile, Less Propulsion System and Less Propulsion-Associated GAM Auxiliary Components***	86%	86%	87%	92%	84%	87%	86%	78%	100%	90%	86%	86%	81%	87%	73%	87%	76%	85%
Composite System Tests:																		
Number Conducted	10	9	2	3	4	1	5	5	1	3	2	5	2	1	2	2	2	59
Number Successful	5	5	1	2	1	1	1	4	1	2	2	3	2	1	1	1	1	34
Per Cent Successful	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58%

* GAM No. 104 was returned to the Logistics Depot to repair damages caused by an acid leak. The first column contain data from tests conducted on this missile prior to its return to the depot; the second column contains data from tests conducted after its return to Eglin AFB as a rebuilt missile.

** GAM Nos. 102 and 117 did not complete field testing at Eglin AFB due to cancellation of Rascal program.

*** Probability of no failure during one hour of field testing.

TABLE XI

MISSILE OPERATING TIME (IN HOURS) AT EGLIN AFB

(Cumulative As of December 1958)

Major Circuit	MISSILE NUMBERS																	GAM Nos. 102-117
	102**	103	104*	104*	105	106	107	108	109	110	111	112	113	114	115	116	117**	
Master Power	269	226	34	92	130	60	99	104	20	32	46	77	33	29	39	15	19	1324
Non-Emanating Power (Servo B+)	212	179	28	89	110	45	66	91	16	29	37	74	30	28	38	14	18	1104
Hydraulic and Servo	123	115	19	59	78	30	48	69	14	19	32	50	20	20	18	9	14	737
Antenna Spin Drive	97	99	13	45	46	22	38	55	14	17	25	48	15	20	18	9	14	595
IRCS	57	111	12	68	42	19	38	53	8	15	19	34	17	13	24	10	9	549
Radar Low Voltage	209	183	24	86	93	42	69	88	16	29	30	74	30	28	34	14	12	1061
Radio Low Voltage	210	175	20	78	67	42	62	87	16	29	30	74	30	28	34	14	12	1008

* GAM No. 104 was returned to the logistics depot to repair damages caused by an acid leak. The first column contains data from tests conducted on this missile prior to its return to the depot; the second column contains data from tests conducted after its return to Eglin AFB as a rebuilt missile.

** GAM Nos. 102 and 117 did not complete field testing at Eglin AFB due to cancellation of Rascal program.

The over-all reliability data obtained from tests on missiles at Eglin Air Force Base follow:

Equivalent Missile Operating Time During Ground and Airborne Tests	910 Hours
Number of Reliability-Type Failures	145
Observed Mean-Time-Between-Failures	6.3 Hours
Observed Reliability of Missiles, Less Propulsion System and Less Propulsion-Associated GAM Auxiliary Components, during ground and airborne tests	85.3%

(The observed reliability is the probability of no failure during one hour of field testing on the ground or in the air.)

The reliability goal for missiles, less propulsion system and less propulsion-associated GAM auxiliary components, was 86.5%, based on a 70% reliable weapon system (equivalent to a mean-time-between-failures goal of 6.9 hours).

The observed average operating time for missiles during airborne prelaunch checkout and post-launch operation was 2.2 hours based on the eleven missiles launched over the Eglin firing range. The observed average missile operating time at Eglin greatly exceeded the originally-planned one hour mission, consisting of the prelaunch airborne checkout and the post-launch missile flight.

2. Propulsion System Performance

The Rascal propulsion system consisted of the following subsystems:

Nitrogen Subsystem

Turbine Pump Subsystem

Thrust Chamber Subsystem

Engine Miscellaneous Subsystem

Missile Installation Subsystem

Propellant Storage Subsystem

A comparison of the performance of the propulsion system experienced during airborne operations prior to and after 30 June 1958 is given in Table XII.

TABLE XII

RASCAL PROPULSION SYSTEM PERFORMANCE DURING AIRBORNE OPERATIONS AT EGLIN AIR FORCE BASE

Item	Phase I (Takeoff-to-Launch)		Phase II (Launch-to-Target)	
	Prior to 30 June 1958	After 30 June 1958	Prior to 30 June 1958	After 30 June 1958
Attempts	16	14	3	8
Successes	10	14	2	7*
Per Cent Successful	62%	100%	67%	88%*

* The one unsuccessful airborne propulsion system operation during this period was caused by a procedural error in draining the fuel system, causing cavitation in the fuel tank during flight.

3. Performance of Propulsion-Associated Components in GAM Auxiliary System

The propulsion-associated GAM auxiliary components in the Rascal missile were:

Hydraulic Pump	Alternator
Delay Timer	Voltage Regulator

The percentage of successful operation for the four components in this group was calculated from the attempts and successes of missions, rather than from elapsed time of operation. The performance of this group of components during Phase I and Phase II of the airborne mission is shown in Table XIII.

TABLE XIII

AIRBORNE TEST RESULTS FOR PROPULSION-ASSOCIATED COMPONENTS OF GAM AUXILIARY SYSTEM AT EGLIN AIR FORCE BASE

Item	Phase I (Takeoff-to-Launch)		Phase II (Launch-to-Target)	
	Prior to 30 June 1958	After 30 June 1958	Prior to 30 June 1958	After 30 June 1958
Attempts	16	14	3	8
Successes	14	12	3	7
Per Cent Successful	88%	86%	100%	88%

E. DIRECTOR AIRCRAFT EQUIPMENT RELIABILITY

1. Director Aircraft Guidance System (AN/APW-17)

The observed reliabilities during ground and airborne tests for the five active Director Aircraft Guidance Systems (AN/APW-17) in use at Eglin AFB were as presented in Table XIV.

TABLE XIV

AN/APW-17 System No.	Installed In DB-47 No.	Observed Reliability*
108	346	90%
118	187	87%
120	165	91%
121	186	87%
125	168	82%

*This observed reliability is the probability of no failures occurring in the AN/APW-17 system during the 115 minutes of planned operation accumulated during a normal airborne mission or during 115 minutes of ground testing.

The over-all reliability data for the five AN/APW-17 systems follow:

System Operating Time		807 Hours
Airborne Operation	189 Hours	
Ground Operation	618 Hours	
Number of Reliability - Type Failures		52
Observed Reliability Per Planned Mission		88.4%
Mean-Time-Between-Failures		15.5 Hours

The observed mean-time-between-failures for the Director Aircraft Guidance System at Eglin AFB is compared to the Holloman observations in Table XVII.

2. Director Aircraft Miscellaneous System

The Miscellaneous System in the Director Aircraft consisted of:

(1) Missile Release Navigation Computer Subsystem

(2) Hydraulic (GAM Associated) Subsystem

(3) Electrical (GAM Associated) Subsystem

Two reliability-type failures were experienced during ground and airborne tests of the five active Director Aircraft Miscellaneous Systems in use at Eglin AFB.

The observed reliability of the five systems, based on 883 hours of operation and a 150-minute planned mission, was 99.4% for the entire Eglin ground and airborne operation.

3. Director Aircraft System

The observed reliability of the over-all Rascal Director Aircraft System, a product of the AN/APW-17 system reliability and the Director Aircraft Miscellaneous System reliability, was 87.9% for the entire ground and airborne Eglin AFB operation, based on the planned mission times. The observed mean-time-between-failures for the Director Aircraft System operation at Eglin is compared to the Holloman observations in Table XVII and Figure 5.

4. Observed Reliability Versus Goal

The reliabilities observed at Eglin AFB are compared to the respective goals established for the Director Aircraft Systems, based on an over-all weapon system airborne reliability goal of 70%, in the following summary:

OBSERVED RELIABILITY

System	Ground Tests	Captive Flights	Takeoff-to-Target	Combined Tests	Goal
Director Aircraft AN/APW-17	90.0%	93.2%	83.6%	88.4%	87.6%
Director Aircraft Miscellaneous	99.6%	97.0%	100.0%	99.4%	97.1%
Over-all Director Aircraft System	89.6%	90.4%	83.6%	87.9%	85.1%

These observed reliabilities, except for takeoff-to-target, are based on 115 minutes of planned mission time for the Director Aircraft Guidance (AN/APW-17) System and 150 minutes of planned mission time for the Director Aircraft Miscellaneous System. The takeoff-to-target figure is given in reliability per Eglin mission.

The observed average operating time for each system, for completed missions on the Eglin firing range, was:

Director Aircraft Guidance System	141 Minutes
Director Aircraft Miscellaneous System	141 Minutes

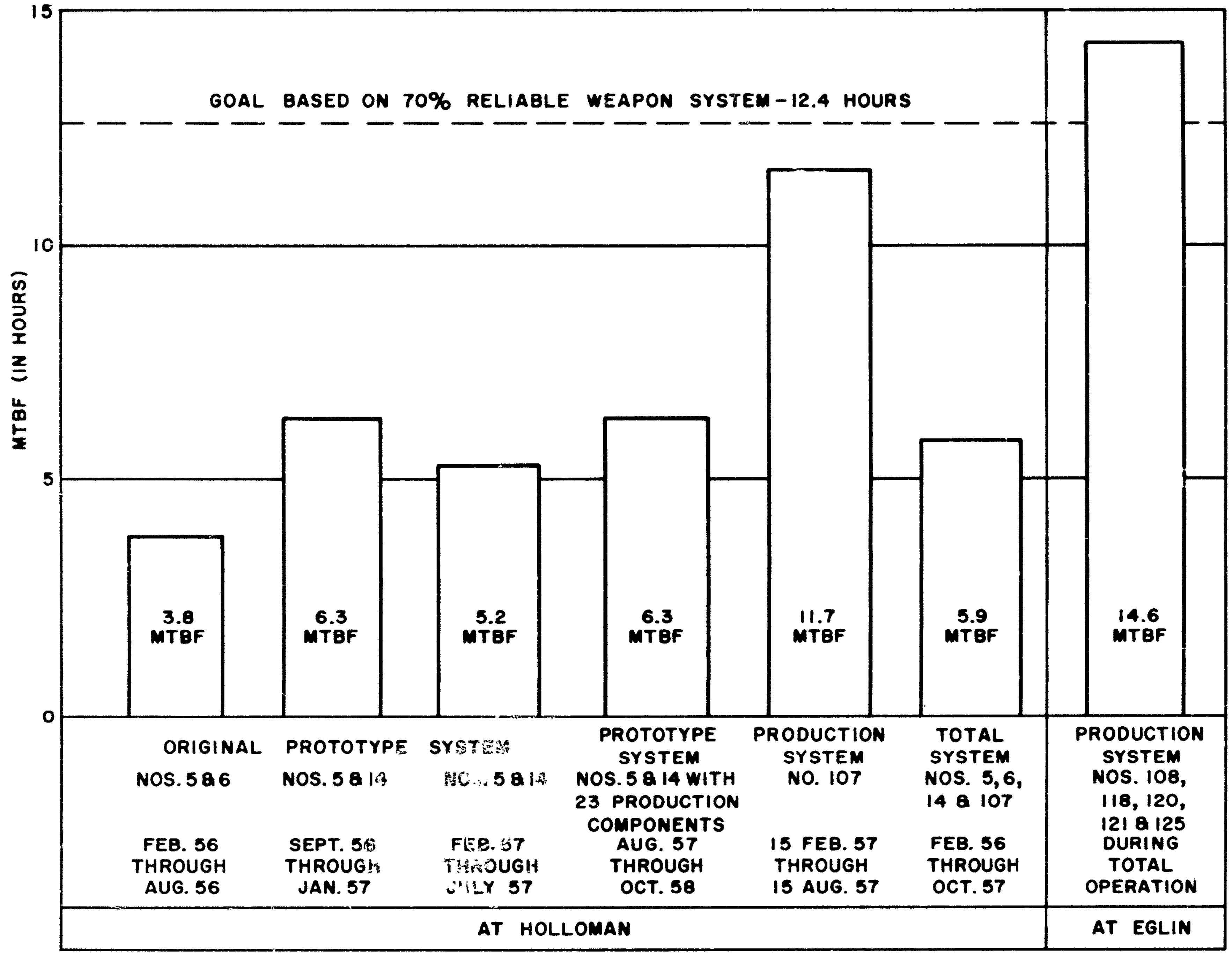


Figure 5. Total Director Aircraft System Mean-Time-Between-Failures Observed During Field Tests

The 141 minutes consumed at Eglin to check out the director equipment prior to launching a missile, plus the time required to guide the missile in flight, were far in excess of the originally-planned 115 minutes for this function.

F. DETERMINATION OF USE RELIABILITY

1. Missile Analysis

The most rigorous and statistically-valid tests on the Rascal weapon system which produced data from which to calculate Use Reliability at Eglin AFB were those conducted on the missile, less the propulsion system and less the propulsion-associated components of the GAM auxiliary system. GAM Nos. 102 and 103 were not considered for this purpose because they were utilized at Eglin to a large degree for Air Force training purposes.

a. Analysis Based on Observed Reliability

The observed reliability (this is the probability of no failures during one hour of operation) of the E&ST missiles, less propulsion system and less propulsion-associated GAM auxiliary components follows:

Observed Reliability in Factory on GAM Nos. 104-117 (Inherent Reliability)	90.9%
Observed Reliability at Eglin AFB, based on ground and airborne tests on GAM Nos. 104-117 (Total Field Operational Reliability)	84.9%

$$\text{Use Reliability} = \frac{\text{Operational Reliability}}{\text{Inherent Reliability}} = \frac{84.9}{90.9} = 93.4\%$$

b. Analysis Based on Success of Composite System Tests

The observed percent of successful composite system tests on the E&ST missiles (GAM Nos. 104-117), less propulsion system and less propulsion-associated GAM auxiliary components, follows:

Observed Percent Successful Composite System Tests in the Factory (Inherent Reliability)	66%
Observed Percent Successful Composite System Tests at Eglin AFB (Field Ground Operational Reliability)	60%

$$\text{Use Reliability} = \frac{\text{Operational Reliability}}{\text{Inherent Reliability}} = \frac{60}{66} = 91\%$$

2. Propulsion Engine Analysis

Engine acceptance tests in the factory and observed performance of the rocket engine at Eglin AFB are considered the most valid sources of data from which to calculate the use reliability of the Bell Aircraft rocket engine. It should be noted that the remaining components of the propulsion system (tanks, etc.) are excluded from this analysis.

	Observed Reliability In Percent of Successful Tests	
Factory Engine Acceptance Tests (Inherent Reliability)	96%	
Airborne Results of Rocket Engine Tests observed at Eglin AFB (Operational Reliability)	Before 30 June 58 81.2%	After 30 June 58 100%
Observed Use Reliability for the number of attempts shown	84.6% Based on 16 attempts.	100% Based on 14 attempts.

3. Director Aircraft System Analysis

The most rigorous tests on the Director Aircraft System were those extensive tests conducted at Eglin AFB on the ground and in the air.

Observed reliability during ground tests (this is a measure of inherent reliability)	89.6%
Observed reliability during airborne tests (this is a true measure of the airborne operational reliability)	83.6%

$$\text{Use Reliability} = \frac{\text{Operational Reliability}}{\text{Inherent Reliability}} = \frac{83.6}{89.6} = 93.3\%$$

SECTION VI SUMMARY OF OPERATIONS AT McCOY AFB

A. DIRECTOR AIRCRAFT SYSTEM RELIABILITY

The installation of Director Aircraft Guidance (AN/APW-17) Systems in B-47 aircraft was completed on schedule as part of the over-all program of converting these aircraft to Rascal-carrying DB-47's.

Thirteen AN/APW-17 systems (Serial Nos. 125, 126, 128 - 138) were bench checked and installed in B-47 aircraft which had undergone modifications to the airframes to permit the carrying and launching of GAM-63A Rascal missiles. One additional system (Spare No. 1) was bench checked and kept at McCoy Air Force Base as a bench set for use in troubleshooting.

Since this program was essentially an installation program and not an extended testing program, tests were conducted only to ensure proper installation of the AN/APW-17 systems.

Table XV shows the failures observed on the major subsystems during the initial installation tests. The failure rates derived from these data do not represent the true reliability of the AN/APW-17 system in that the systems were not completely debugged after installation and captive flights (airborne tests using a Rascal missile or an airborne missile simulator) were not conducted on the thirteen systems.

TABLE XV

AN/APW-17 SYSTEM TESTS AT McCOY AIR FORCE BASE

Subsystem Item	Terminal Guidance Control Subsystem	Relay & Command Subsystem	Automatic Checkout Subsystem	Auxiliary Subsystem	Automatic Tracking Relay Antenna Subsystem
Subsystem Failures	5	3	1	3	0
Total Discrepancies, Including Inspection-Type Items	25	11	4	8	0
Operating Time (Hours) in B-47 Aircraft	121.5	85.9	83.0	187.5	20.8
Total Operating Time (Hours) on Bench and in B-47 Aircraft	245.7	158.9	298.9	426.3	34.9

B. MISSILE RELIABILITY

No Rascal missiles were tested at McCoy Air Force Base during this quarter.

SECTION VII RASCAL RELIABILITY IMPROVEMENT PROGRAM

This section of the report summarizes the basic methods and results of taking corrective action on problems experienced on the Rascal Weapon System.

A. RASCAL CORRECTIVE ACTION PROGRAM

The original corrective action program for the Rascal Weapon System utilized Discrepancy Analysis Teams (described in Section III-A, Bell Aircraft Corporation Report No. 56-989-109) to investigate failures and specify necessary corrective actions. Approximately 650 teams were formed in the period October 1955 to November 1957 to analyze and solve individual problems.

As the reliability program progressed and as large quantities of valid data became available, a more effective method was established for taking corrective action on Rascal problems. Problem definition sheets were established for all known repetitive problems and a priority of importance was assigned to each problem (described in Section II, Bell Aircraft Corporation Report No. 56-989-117). By this method, over two hundred problems were analyzed.

The importance of the two hundred repetitive problems is shown by the fact that, in the various factory and field test areas, these repetitive problems constituted from 75 to 90% of all discrepancies in the missile and from 40 to 60% of all discrepancies in the Director Aircraft System. Because of time and funding limitations, during the latter part of the R&D phase and during the E&ST phase, only 36% of the documented repetitive problems were eliminated by effective corrective action.

B. VERIFIED RELIABILITY IMPROVEMENTS IN THE MISSILE

1. Observed Reliability

A significant increase in the level of observed reliability of missiles tested in the factory after the inception of the expanded reliability program has been verified. Table XVI compares the observed reliability of missiles as measured in the last phase of factory testing at significant points in the program:

TABLE XVI

OBSERVED RELIABILITY OF MISSILES AT THE COMPLETION OF FACTORY TESTING

	Total Tactical Missile, Including Propulsion System	Tactical Missile, Less Propulsion System
Prior to Expanded Reliability Program, October 1955 GAM Nos. 47, 49-56 (R&D)	30%***	45%***
After Expanded Reliability Program, October 1955		
GAM Nos. 75-85 (R&D)	53%*	66%
GAM Nos. 87-101 (R&D)	69%**	79%
GAM Nos. 102-111 (E&ST)	-	91%
GAM Nos. 112-121 (E&ST)	-	90%
GAM Nos. 122-134 (Squadron)	-	89%
GAM Nos. 201-213 (Squadron)	-	88%
GAM Nos. 214-221 (Squadron)	-	90%

*One-half of these missiles were given ground-firing tests.

**One-third of these missiles were given ground-firing tests.

***Approximate. Reporting system was not fully effective.

2. Success of Composite System Tests

Effective with GAM No. 87, reliability requirements for conducting at least 15 composite system tests in the factory were established. This decision was based on the debugging characteristic observed on the life test missile, GAM No. 78. As the reliability of production missiles increased during the Rascal program, the need for the factory debugging tests diminished and, effective with GAM No. 104, the requirement for composite system tests was reduced from 15 (minimum) to 5 (minimum). The following tabulation shows the average number of composite system tests conducted on the various configurations of the Rascal misile, effective with GAM No. 75.

Groups of Missiles	Average Number of Composite System Tests Conducted on Missiles Before Being Considered Acceptable for Delivery to the Customer
R&D Missiles:	
GAM Nos. 75-85, 95	6
GAM Nos. 87-101, less 95	19
E&ST Missiles:	
GAM Nos. 102-103	19 (Average of 8)
GAM Nos. 104-121	7
Squadron Missiles:	
GAM Nos. 122-134, and 201-221	8

The growth of reliability of the Rascal missile is graphically shown in Figure 4. The E&ST missiles required an average of only eight composite system tests before acceptance and, in addition, reached a higher degree of successful performance earlier in the test phase than previous missiles. The squadron missiles reflected even a higher reliability, still earlier in the test phase.

C. VERIFIED IMPROVEMENTS IN THE DIRECTOR AIRCRAFT

1. Director Aircraft Guidance (AN/APW-17) System

Table XVII shows the improvements observed on the Director Aircraft Guidance System during ground and airborne tests in the field. The first significant improvement can be seen after the introduction of production system No. 107, used to launch two of the R&D missiles. The production systems used at Eglin to launch E&ST missiles demonstrated a 2.4-to-1 improvement over the prototype systems used to launch the last eight missiles at Holloman (these prototype systems contained 23 production components). The later production systems, System No. 126 and subsequent, which were installed in B-47 aircraft to launch squadron missiles, were expected to give a significantly higher reliability than earlier systems because of the incorporation of worthwhile design improvements.

2. Director Aircraft Miscellaneous System

Table XVII shows that the Director Miscellaneous systems at Eglin demonstrated a 2.5-to-1 improvement over the equipment in use at Holloman at the end of the R&D program.

TABLE XVII

DIRECTOR AIRCRAFT SYSTEM OBSERVED MEAN-TIME-BETWEEN-FAILURES (IN HOURS) DURING FIELD TESTS

		Holloman						Eglin
		Original Prototype Systems			Prototype Systems Nos. 5 & 14 with 23 Production Components Aug. 57-Oct. 57	Production System No. 107 15 Feb. 57 to 15 Aug. 57	Total Feb. 56 through Oct. 57	Production System Nos. 108, 118, 120, 121 & 125 During Total Operation
System	Goal (In Hours)	Nos. 5&6 Feb. 56 through Aug. 56	Nos. 5&14 Sept. 56 through Jan. 57	Nos. 5&14 Feb. 57 through July 57				
Director Aircraft Guidance (AN/APW-17)	14.5	4.5	7.2	5.6	6.5	11.7	6.4	15.5
Director Aircraft Miscellaneous	85.0	23.8	48.5	230.0	180.0	Greater than 125.0	72.5	441.2
Director Aircraft Over-all	12.4	3.8	6.3	5.2	6.3	11.7	5.9	14.6

3. Total Director Aircraft

The reliability trend of the Director Aircraft System, consisting of the AN/APW-17 System and the Director Aircraft Miscellaneous System, is shown graphically in Figure 5 for ground and airborne operations. The AN/APW-17 System, because of its very great complexity provided the main effect on the over-all reliability of the Director Aircraft System as can be seen by comparing the values of the AN/APW-17 System to the over-all Director Aircraft in Table XVII. The Director Aircraft System at Eglin demonstrated a 2.3-to-1 improvement over prototype equipment used to launch the last eight R&D missiles at Holloman.

D. VERIFIED IMPROVEMENTS IN MAJOR MISSILE SYSTEMS

An analysis of test data for the six major systems of the Rascal missiles, recorded during the final test phase in the factory, is shown in Table XVIII. It will be observed that the improvements between major systems installed in R&D missiles and production missiles (E&ST and Squadron missiles) ranged from 1.6-to-1 up to 2.9-to-1.

TABLE XVIII

IMPROVEMENTS IN SIX MAJOR SYSTEMS IN THE RASCAL MISSILE
(Expressed in Mean-Time-Between-Failures in Hours, as Measured During Factory Tests)

Major System	R&D Missiles (GAM Nos. 75-101)	Production Missiles (GAM Nos. 102-221)	Reliability Improvement
Flight Control	18.9	35.2	1.9-to-1
Non-Emanating Guidance (Inertial Range Computing System)	45.2	70.9	1.6-to-1
Emanating Guidance	10.4	20.4	2.0-to-1
Propulsion (Engine Only)	6.8*	15.6*	2.3-to-1
GAM Auxiliary (Less Hydraulic Pump and Delay Timer)	15.4	44.2	2.9-to-1
Fuzing	No Failures Observed		---

*Based on engine acceptance test data.

E. VERIFIED RELIABILITY IMPROVEMENTS IN ELECTRONIC COMPONENTS

Four of the most complex electronic components, representing 25% of the complexity of the entire missile, demonstrated the most significant improvement in the reliability of electronic components. An analysis made of the total discrepancies observed during missile testing shows, in Table XIX, the very large improvements obtained on the four components during the Rascal reliability program.

The increase in reliability of the Radar R-T Unit and Radar Modulator was attributed to the following actions taken by the vendor:

(1) Incorporation of design improvements and better parts.

(2) Application of safety factors and derating factors in the use of parts.

(3) Use of standardized Bell Aircraft workmanship techniques.

(4) Subjecting of all components to limited-environmental tests.

Similar improvements were incorporated into the Relay Transmitter and the Command Unit at Bell Aircraft Corporation.

TABLE XIX

IMPROVEMENTS IN FOUR COMPLEX ELECTRONIC COMPONENTS
(During Factory and Field Tests)

Electronic Component	Mean-Time-Between-Discrepancies, in Subsystem Operating Hours					
	GAM Nos. 75-85	GAM Nos. 87-101	GAM Nos. 102-111	GAM Nos. 112-121	GAM Nos. 122-134	GAM Nos. 201-222
Radar Modulator	50	37	82	130	174	372
Radar R-T Unit	15	22	40	100	101	133
Relay Transmitter	11	14	36	72	42	74
Command Unit	17	34	42	42	41	77

F. VERIFIED IMPROVEMENTS OF INDIVIDUAL PARTS

This subsection shows some of the specific problems for which quantitative improvements have been documented. The observed failure rates, shown in Table XX, are given for the missile test phase (i.e., the components , parts were operated in a missile), unless otherwise noted. The failure rate is expressed as the number of failures observed divided by the number of part-hours of operation (such as 50/6760), or the number of failures divided by the total cycles of operation, depending on the nature of the equipment being analyzed.

To provide a measure of statistical significance, these failure rate data are shown in the form of the minimum 90% confidence limit for each mean-time-between-failures (MTBF). These data are of greater usefulness than the observed MTBF since it can be stated, with 90% confidence, that the actual MTBF for this equipment is no less than that presented in Table XX. It can be further stated, with 90% confidence, that the actual improvement ratio for each part is no less than the figures contained in the improvement ratio column.

TABLE XX

VERIFIED IMPROVEMENTS OF PARTS

Item	Improvement Made	Observed Failure Rate (During Missile Testing)		Minimum MTBF (90% Confidence)		Minimum Improvement Ratio (90% Confidence)
		Before Improvement	After Improvement	Before Improvement	After Improvement	
OC3, OD3 Tubes in Servo Power Supply	Circuit modification; replaced OC3 and OD3 tubes with OA3 tubes.	50/6,760	1/14,000	110	3,600	22:1
Tantalum capacitors in Pitch and Yaw Command Modulators	Manufacturer provided improved capacitors from a new production run.	16/33,600	11/92,800	1,500	5,590	2:1
	Replaced improved tantalum capacitors with paper capacitors in a redesigned circuit.	16/33,600 (Original Capacitor)	0/40,000	1,500	17,400	6:1
Stable Platform	A nylon brake was used, pitch potentiometer was replaced with synchro transducer.	67/4,000	69/16 770	50	210	3:1
Arcing and nitrogen leakage in search antenna feedhorn cover unit	Larger cover developed, with better adhesive to feedhorn.	13/1,250	0/3,680	66	1,600	11:1
Resistor R-803 in USR Modulator	R-803 was changed from a 2-watt 5% carbon composition to a 5-watt 3% wire-wound resistor. During Functional Test:	13/1,740	0/3,760	92	1,630	8:1
CR-1601, CR-1602 Crystals in USR R-T Unit	Filters were added to crystal monitoring circuit; test leads used in monitoring crystal current were shortened; improvements were made in test box to monitor crystal current.	62/5,760	14/14,140	79	700	6:1
Blower Motors in Emanating Guidance	Installed improved type blower motor.	44/31,250	4/29,750	580	3,720	4:1
CR-501 Crystal in Relay Transmitter	a. Test leads were shortened. b. Improvements were made in the test box used to monitor crystal current.	23/2,720	3/6,820	89	1,020	6:1
PS-1701 Transpac in Dive Angle Computer	PS-1701 transpac was replaced with a Bell Aircraft designed D-C filament supply using silicon diode rectifiers in place of selenium type rectifiers.	10/2,240	0/7,175	145	3,120	9:1
IRCS Accelerometer	Special shipping containers. Noise filter capacitor. Bell Aircraft sealing technique.	40/17,300	7/12,600	350	1,070	2:1
Missile Voltage Regulator	Use of derating and safety factors, improved relay, selected tubes, and improved workmanship and packaging techniques.	22/248	8/646	8 (Based on cycles of operation)	50	3:1
Gas Generator Package Leakage	Replaced gasket made of blue African asbestos with one made of Canadian asbestos.	39/34	1/58	.7	15	14:1
		(Based on number of engines tested and number of leaks observed).				

SECTION VIII RELIABILITY ANALYSES OF HOLLOMAN AIRBORNE OPERATIONS

A. DESCRIPTION OF TACTICAL EQUIPMENT

Twenty-three R&D missiles, in the block GAM Nos. 75-101, were flown during the period May 1956 through October 1957. The last eight of the R&D missiles were of a higher-reliability configuration, containing substantial improvements over previously-flown missiles. Further, the director aircraft guidance systems used to launch these eight missiles each contained twenty-three production components which were significantly more dependable than the well-worn prototype components previously used at AFMDC. As further substantiation of the higher reliability of the last eight R&D missiles and the associated director systems, five of the eight missiles demonstrated 100% reliability after launch and were guided within a 1500-foot radial miss-distance.

Between October 1955, the start of the expanded reliability program, and May 1956, three missiles (GAM Nos. 58, 63, and 64) were flight tested solely to acquire additional data for Sandia. The three missiles were not included in the reliability program missiles because they were of a lower-reliability configuration and did not include the Bell Aircraft rocket engine which became effective on GAM No. 75. The test results of the three missiles are not included in this analysis.

B. METHOD OF ANALYSIS

The reliability analysis of the last twenty-three R&D missiles flown at AFMDC, as contained in this section, includes the following four aspects:

1. Success of Missions

The percent success of the airborne missions is expressed as the ratio of observed successful missions to the attempted airborne missions.

2. Phases of Flight

The airborne mission of the Rascal weapon system is analyzed by each of the two flight phases:

Phase I - Takeoff-to-Launch

Phase II - Launch-to-Target

3. Groups of Missiles

The analysis is based on three groupings of the R&D missiles and associated director aircraft systems:

(1) First 15 missiles.

(2) Last 8 missiles.

(3) Total of 23 missiles.

4. Basic Causes of Unsuccessful Missions

The analysis of all unsuccessful airborne missions has been made according to the following basic causes:

Category	Definition of Category
A	(1) Inadequate field maintenance by Contractor personnel.
	(2) Inadequate range support by Air Force.
	(3) Inadequate weapon system supporting equipment such as K-4 systems, Sandia equipment, B-47 aircraft, and ground tracking stations.
B	(1) Inadequate Contractor maintenance procedures and test procedures.
	(2) Inadequate Contractor technical support.
C	(1) Part failu es.
	(2) Equipment failures.
	(3) Possible equipment failures.

Note: The items in Category C constitute a measure of inherent unreliability of equipment.

C. RECORD OF HOLLOMAN AIRBORNE FLIGHTS

During the flight test program at Holloman, 74 weapon system (missile plus director aircraft) take-offs were necessary to launch the last 23 R&D missiles. The mission with GAM No. 76, on 2 August 1956, which was aborted due to poor weather was not included in this analysis. A complete record of the 74 airborne flights, together with the previously-defined categories of causes of unsuccessful missions, is given in Appendix A.

D. ANALYSIS OF UNSUCCESSFUL FLIGHTS BY SYSTEMS

Table XXI shows the contribution of each system of the tactical weapon system to the unsuccessful airborne missions experienced at

TABLE XXI

ANALYSIS OF HOLLOMAN AIRBORNE MISSIONS

This analysis shows the breakdown of the weapon system into the various equipments in which malfunctions* were observed during unsuccessful missions.

Equipment	GAM NOS. 75-101 (23 Missiles)				LAST EIGHT MISSILES			
	Based On Missions		Based On Failures		Based On Missions		Based On Failures	
	No.	%	No.	%	No.	%	No.	%
Unsuccessful Missions:								
Missile Tactical Equipment	33-1/2	45.3	39	48.75	11	52.3	14	73.6
Propulsion System	8-1/2	11.5	9	11.25	3	14.3	3	15.8
Flight Control System	4-1/2	6.1	6	7.5	1	4.8	2	10.5
Non-Emanating Guidance System	1	1.4	1	1.25	1	4.8	1	5.3
Emanating Guidance System	11	14.8	14	17.5	4-1/2	21.3	6	1.5
GAM Auxiliary System	8-1/2	11.5	9	11.25	1-1/2	7.1	2	10.5
Fuzing System	0	0	0	0	0	0	0	0
Carrier Tactical Equipment	15-5/6	21.4	20	25.0	2	9.5	2	10.5
AN/APW-17 System	13-1/3	18.0	17	21.25	2	9.5	2	10.5
Miscellaneous System	1-1/2	2.0	2	2.5	0	0	0	0
Operator	1	1.4	1	1.25	0	0	0	0
Telemetering	2	2.7	2	2.5	0	0	0	0
Beacons	3	4.1	4	5.0	1	4.8	1	5.3
S-Band	1	1.4	1	1.25	0	0	0	0
L-Band	2	2.7	3	3.75	1	4.8	1	5.3
Range Support Equipment	5	6.7	6	7.5	1	4.8	1	5.3
Sandia Equipment	1-1/2	2.0	2	2.5	0	0	0	0
B-47 Aircraft	5-1/6	7.0	7	8.75	1	4.8	1	5.3
Successful Missions	8	10.8	-	-	5	23.8	-	-
Totals	74	100.0	80	100.0	21	100.0	19	100.0

*Note: Either failures occurred in these equipments during the airborne operation or the equipments were not operable prior to take-off.

Holloman. Also included are the contributions of other items such as beacons, telemetering, range support equipment, B-47 aircraft, and Sandia equipment.

E. ANALYSIS OF FLIGHTS BY BASIC CAUSES OF FAILURE

The flights recorded in Appendix A were analyzed with respect to the three categories of causes for unsuccessful missions given in paragraph VIII-B-4.

Table XXII shows the distribution of causes for unsuccessful missions for Phase I (takeoff-to-launch) of the airborne operation for the first 15 missiles, the last eight missiles, and the entire group of 23 missiles. During this phase there is shown an increase in the number of successful missions for the last eight missiles as compared to the first 15 missiles.

Table XXIII shows the distribution of causes for unsuccessful missions for Phase II (launch-to-target) of the airborne operation for the first 15 missiles, the last eight missiles, and the 23 missiles. During this phase there is shown a very significant improvement in

TABLE XXII

ANALYSIS OF PHASE I (TAKEOFF-TO-LAUNCH)

Distribution of Causes for Unsuccessful Missions on GAM Nos. 75-101* at AFMDC (Holloman)

Category	First 15 Missiles	Last 8 Missiles	Total of 23 Missiles
Unsuccessful Missions:			
A - Inadequate field equipment, maintenance, and support.	20.1%	9.5%	17.1%
B - Inadequate Contractor procedures and technical support.	8.5%	0%	6.1%
C - Equipment failures and possible equipment failures. (Inherent Unreliability)	43.1%	52.4%	45.7%
Successful Missions	28.3%	38.1%	31.1%

*GAM Nos. 78, 86, 92 and 95 were not tested at Holloman.

TABLE XXIII

ANALYSIS OF PHASE II (LAUNCH-TO-TARGET)

Distribution of Causes for Unsuccessful Missions on GAM Nos. 75-101*
at AFMDC (Holloman)

Category	First 15 Missiles	Last 8 Missiles	Total of 23 Missiles
Unsuccessful Missions:			
A - Inadequate field equipment, maintenance, and support.	20.0%	12.5%	17.4%
B - Inadequate Contractor procedures and technical support.	13.3%	12.5%	13.0%
C - Equipment failures and possible equipment failures. (Inherent Unreliability)	46.7%	12.5%	34.8%
Successful Missions	20.0%	62.5%	34.8%

*GAM Nos. 78, 86, 92 and 95 were not tested at Holloman.

the weapon system performance using the last eight missiles as compared to the first 15 missiles.

Using the results of the last eight missiles launched at Holloman, the observed successes were:

	Percent Mission Success
Phase I (Takeoff-to-Launch)	38.1
Phase II (Launch-to-Target)	62.5
Over-all Weapon System Success	23.8

SECTION IX RELIABILITY ANALYSIS OF EGLIN AIRBORNE OPERATIONS

A. DESCRIPTION OF TACTICAL EQUIPMENT

During the employment and suitability testing (E&ST) program at Eglin AFB, tests were conducted on 16 missiles during the period October 1957 to December 1958. All missiles were of a higher reliability configuration than the missiles used during the R&D flight test program at Holloman, as evidenced by factory tests. The Director Aircraft Guidance (AN/APW-17) Systems were of a production configuration which was of a higher reliability than the prototype AN/APW-17 systems used at Holloman.

B. METHOD OF ANALYSIS

In a manner similar to the analysis made in Section VIII, the reliability analysis of the 16 missiles tested at Eglin AFB, as contained in this section, includes the following three aspects:

1. Success of Missions

The percent success of the airborne missions is expressed as the ratio of observed successful missions to the attempted airborne missions.

2. Phases of Flight

The airborne mission of the Rascal weapon system is analyzed by each of the two flight phases:

Phase I - Takeoff-to-Launch

Phase II - Launch-to-Target

3. Basic Causes of Unsuccessful Missions

The analysis of all airborne missions has been made according to the following basic causes of unsuccessful missions:

Category	Definition of Category
A	(1) Inadequate field maintenance by military personnel.
	(2) Inadequate range support by Air Force.
	(3) Inadequate weapon system supporting equipment such as K-4 systems, Sandia equipment, B-47 aircraft, and ground tracking stations.
	(4) Inadequate design of military-furnished S-band beacon and destruct system.
B	(1) Inadequate Contractor maintenance procedures and test procedures.
	(2) Inadequate Contractor technical support.
C	(1) Part failures.
	(2) Equipment failures.
	(3) Possible equipment failures.

Note: The items in Category C constitute a measure of the inherent unreliability of equipment.

As will be noted, items in Category A were generally the basic responsibility of the Air Force. Items in Category B and C were basically the responsibility of the Bell Aircraft Corporation.

C. RECORD OF EGLIN AIRBORNE FLIGHTS

During the flight test program at Eglin AFB, 41 weapon system (missile and director aircraft) take-offs were necessary to launch 12 E&ST missiles. A complete record of the 41 airborne flights, together with the previously-defined categories of causes of unsuccessful missions, is given in Appendix B.

D. ANALYSIS OF UNSUCCESSFUL FLIGHTS BY SYSTEMS

Table XXIV shows the breakdown of the tactical weapon system into the various equipments in which malfunctions were observed during unsuccessful missions at Eglin AFB. Included also are the contributions to unsuccessful missions by other items such as beacons, telemetering, range support equipment, B-47 aircraft, and Sandia equipment.

TABLE XXIV

ANALYSIS OF EGLIN AIRBORNE MISSIONS

This analysis shows the breakdown of the weapon system into the various equipments in which malfunctions* were observed during unsuccessful missions.

Equipment	GAM Nos. 102-117				Tests Conducted After 30 June 1958			
	Based On Missions		Based On Failures		Based On Missions		Based On Failures	
	No.	%	No.	%	No.	%	No.	%
Unsuccessful Missions:								
Missile Tactical Equipment	20-11/12	51.0	26	41.9	8-1/3	52.1	11	47.8
Propulsion System	7	17.1	8	12.9	1/2	3.1	1	4.4
Flight Control System	2	4.9	2	3.2	2	12.5	2	8.7
Non-Emanating Guidance System	0	0	0	0	0	0	0	0
Emanating Guidance System	3-5/12	8.3	7	11.3	1-1/3	8.3	3	13.0
GAM Auxiliary System	8-1/2	20.7	9	14.5	4-1/2	28.2	5	21.7
Fuzing System	0	0	0	0	0	0	0	0
Carrier Tactical Equipment	7-1/3	17.9	15	24.2	1-1/3	8.3	3	13.0
AN/APW-17 System	6-5/6	16.7	14	22.6	1-1/3	8.3	3	13.0
Miscellaneous System	0	0	0	0	0	0	0	0
Operator	1/2	1.2	1	1.6	0	0	0	0
Telemetering	0	0	0	0	0	0	0	0
Beacons	1-5/6	4.5	5	8.1	1/2	3.1	1	4.4
S-Band	1-7/12	3.9	4	6.5	1/2	3.1	1	4.4
L-Band	1/4	0.6	1	1.6	0	0	0	0
Range Support Equipment	2-7/12	6.3	5	8.1	1-1/2	9.4	2	8.7
Sandia Equipment	5/6	2.0	2	3.2	5/6	5.2	2	8.7
B-47 Aircraft	6-1/2	15.9	9	14.5	3-1/2	21.9	4	17.4
Successful Missions:	1**	2.4	-	-	0***	0	-	-
Total	41	100.0	62	100.0	16	100.0	23	100.0

Notes on Successful Missions:	**	***
Completely Successful Flight	1	0
Successful Inertial Flights, in which 2 had improper warhead firing.	4	3

*Note: Either failures occurred in these equipments during the airborne operation or the equipments were not operable prior to take-off.

An analysis of the weapon system improvement made at Eglin AFB after 30 June 1958 is shown below on equipment with which the Contractor was primarily concerned:

Equipment in Which Malfunctions* Were Observed During Unsuccessful Missions	Percent of Unsuccessful Missions	
	Before 30 June 58	After 30 June 58
Missile Tactical Equipment (Beacons and Telemetering not included).	50.3%	52.1%
Director Aircraft Tactical System (B-47 aircraft not included).	24.0%	8.3%
Total Tactical Equipment in the Weapon System	74.3%	60.4%

*Note: Either failures occurred in this equipment during the airborne operation or the equipment was not operable prior to take-off.

E. ANALYSIS OF FLIGHTS BY BASIC CAUSES OF FAILURE

The flights recorded in Appendix B were analyzed with respect to the three categories of causes for unsuccessful missions which were defined in paragraph IX-B-3.

Table XXV shows the distribution of unsuccessful operation during Phase I (takeoff-to-launch) and Phase II (launch-to-target) of the airborne missions.

Using the results of the entire test period at Eglin AFB, the following successes were observed:

	Percent Mission Success
Phase I (Takeoff-to-Launch)	19.5%
Phase II (Launch-to-Target)*	25.0%
Over-all Weapon System Success	4.9%

*The Phase II success included one successful flight on emanating guidance and two successful flights on inertial guidance. Two additional flights which were successful with respect to inertial guidance had improper warhead firing and were not included in the above successes.

TABLE XXV

ANALYSIS OF AIRBORNE MISSIONS AT EGLIN AIR FORCE BASE

Distribution of Causes for Unsuccessful Missions on GAM Nos. 102-117

Category	Phase I (Takeoff-to-Launch)	Phase II* (Launch-to-Target)
Unsuccessful Missions:		
A - Inadequate field equipment, maintenance, and support	48.0%	52.8%
B - Inadequate contractor procedures and technical support	21.9%	11.1%
C - Equipment failures and possible equipment failures (Inherent Unreliability)	10.6%	11.1%
Successful Missions	19.5%	25.0%**

*GAM Nos. 102, 110, 111, and 117 were not launched during the E&ST program.

**The Phase II successes included one successful flight on emanating guidance and two successful flights on inertial guidance.

SECTION X COMPARISON OF HOLLOMAN AND EGLIN AIRBORNE OPERATIONS

A. COMPARISON OF EQUIPMENT RELIABILITY

1. Director Aircraft Systems

The relative reliabilities, expressed in mean-time-between-failures, of the Director Aircraft Guidance (AN/APW-17) Systems used at Holloman and Eglin are shown in Table XVII. The data, in all cases, include both ground and airborne tests. The improvement in reliability between the AN/APW-17 systems used to launch the last eight R&D missiles and the systems used at Eglin AFB was observed to be 2.4-to-one.

The relative reliability of the entire Director Aircraft System, consisting of the AN/APW-17 System and the Director Aircraft Miscellaneous System, is shown in Table XVII and Figure 5 for both Holloman and Eglin operations. The Director Aircraft Miscellaneous System used at Eglin AFB consisted of production-type components as compared to the prototype components used at Holloman. The Eglin systems were observed to be 2.3-to-one better than the Holloman systems used to launch the last eight R&D missiles.

2. Missile Systems

a. Missiles, Less Propulsion Systems

Based on factory tests the relative reliability of the Eglin and Holloman missiles is shown in Table XXVI.

TABLE XXVI

RELIABILITY COMPARISON OF EGLIN & HOLLOMAN MISSILES, LESS PROPULSION SYSTEM

Comparison Parameter	Holloman R&D Missiles	Eglin E&ST Missiles	Reliability Improvement
Observed Reliability of Missiles during Factory Tests	69.8% (84.2%)	90.5%	3.6-to-1 (1.7-to-1)
Per Cent Successful Composite System Tests Conducted in Factory	49% (57%)	67%	2.2-to-1 (1.3-to-1)

Note: Figures in parenthesis are for the last eight R&D missiles launched at Holloman.

b. Propulsion System

The propulsion system, less the rocket engine, was assumed to have the same improvement of 3.6-to-one as the remainder of the missile (see Table XXVI).

The rocket engine acceptance tests in the factory provide a means for comparison of the reliability of the engines used at Holloman and Eglin, as shown in Table XXVII.

B. COMPARISON OF MAINTENANCE SUPPORT

The major factors which were concerned with performing the maintenance function at Holloman and Eglin AFB included personnel, organization, training, ground support equipment, handbooks, test procedures, and inspection.

1. Maintenance Organization and Personnel

At Holloman and at Eglin, the principal types of personnel to be considered in the maintenance function were management, maintenance, maintenance control, and inspection personnel.

TABLE XXVII

RELIABILITY COMPARISON OF ROCKET ENGINES USED AT HOLLOMAN AND AT EGLIN AFB

Comparison Parameter	Holloman Engines	Eglin Engines	Reliability Improvement
Per Cent Successful Engine Acceptance Tests in Factory	85%	96%	3.8-to-1

A comparison of the number, or experience, of maintenance personnel utilized at Holloman and Eglin is as follows:

Personnel	Holloman	Eglin
Management	The top men had an average of 7 years experience on Rascal.	Limited Experience on Rascal.
	All System Engineers had engineering degrees and 3 years experience on Rascal.	Minority of supervisors had engineering degrees and all had limited experience on Rascal.
Maintenance	Adequate number.	Inadequate number.
	Adequate technical capability.	Limited technical capability.
	Average experience of technicians on Rascal was five years.	Majority of men had less than two years of missile experience.
	Majority of personnell were well-trained on Rascal.	Majority of personnel did not get formal factory training on Rascal (original trainees were lost by attrition).
Maintenance Control	Adequate number.	Limited number.
Inspection	18 used by Contractor.	3 used prior to 30 June 1958.

A detailed analysis of this problem has shown that the education and experience of the Contractor maintenance personnel at Holloman were significantly superior to those of the Air Force personnel at Eglin.

2. Ground Support Equipment

The ground support equipment problems at Eglin AFB caused excessive delays in the early part of the E&ST program. However, as can be seen in Tables XVI and XXIV, neither at Holloman nor at Eglin was an unsuccessful airborne mission directly attributed to deficient ground support equipment. Since it was observed that the effect of ground support equipment on the reliability of the airborne Rascal mission was negligible, the factor of ground support equipment cannot be used for comparison purposes with respect to the analysis of the airborne tests.

3. The Maintenance Function

a. Test Procedures, Handbooks and Technical Orders

(1) R&D Program at Holloman

Extensive Rascal preventive maintenance instructions were written, most of which became effective before completion of the R&D flight test program. The AN/APW-17 system, in particular, was found to be greatly benefited by the use of preventive maintenance procedures.

(2) E&ST Program at Eglin AFB

At the inception of the program, the handbooks and technical publications were found to be inadequate for use by a military maintenance organization. Inadequacies in the handbooks contributed greatly to the lack of proper ground testing and maintenance. As of 30 June 1958, the handbooks were still not completely adequate.

Applicable military Technical Orders did not provide the proper maintenance forms required by the Rascal program and the requirements of the TO's prevented the preparation of adequate work cards and check lists. This contributed to the inability to accomplish the Rascal maintenance function satisfactorily.

b. Inspection

Performance of the inspection function at Eglin AFB was hampered by the lack of adequate personnel. As a result of adequate inspection personnel at Holloman, maintenance discipline was enforced more effectively.

c. Work Cards and Check Lists

(1) Work Cards

Work cards were not used at Holloman.

Inspection work cards used at Eglin prior to 30 June 1958 were inadequate for use on the Rascal weapon system. As of October and November 1958, the new, improved work cards were just in the process of being checked out in field evaluations.

(2) Check Lists

Check lists for maintenance procedures and for testing and checkout of equipment were prepared by Air Force and Contractor personnel at Eglin. Check lists had to be prepared to check out missile systems equipment because the Technical Orders were not suitable for use in directly checking out systems. By comparison, the Holloman procedures were usable in making direct step-by-step checkouts of equipment.

As of 30 June 1958, all of the maintenance, servicing, and testing procedures which had to be performed were not yet in the form of completely acceptable, detailed check lists.

d. Comparison of Holloman and Eglin Procedures

Some of the major differences between the Holloman R&D Test Procedures and the Eglin Handbooks (TO's) are given in the following comparison:

Holloman Test Procedures	Eglin Handbooks (TO's)
Designed for R&D operation	Designed for SAC operation.
Designed to provide quantitative test data. Detailed tests were fairly complete.	Tests were simplified too much; additional testing needed.
Contained little information on how to make a repair (repairs were performed by factory-experienced personnel using Contractor drawings).	Step-by-step instructions were given for replacement of parts.
Contained little information on troubleshooting instructions (Contractor personnel had extensive training and experience in troubleshooting).	Inadequate troubleshooting information.
Procedures were technically very accurate.	Technical inaccuracies were numerous.
Procedures were complete in themselves and could be used as check lists, with each step-by-step operation verified as accomplished.	TO's were not complete or practical for checking out a missile directly; were useful to compile check lists.

4. Performance of the Maintenance Function

By June 1958, the Air Force took steps to increase the effectiveness of the maintenance function at Eglin AFB. Stricter maintenance discipline was imposed, additional maintenance control personnel were acquired, additional inspection personnel were used, additional Contractor maintenance personnel were obtained, and better work cards and check lists were compiled. Efforts were continuing to reduce the number of personnel and management errors made in performing the maintenance tasks.

C. COMPARISON OF HOLLOMAN AND EGLIN AIRBORNE RESULTS

From Sections V, VIII, and IX certain comparison parameters were obtained which most clearly show, in this section, the outstanding differences between the observed results of the airborne tests conducted at AFMDC (Holloman) and at Eglin Air Force Base.

1. Analysis of Successful Airborne Operations

A comparison of the success of the tactical weapon system and of all of the supporting functions during airborne missions, as experienced at Holloman and Eglin, is shown in the following:

Flight Phase	Success During Testing of Last Eight R&D Missiles	Success During All Tests at Eglin
Phase I (takeoff-to-launch)	38.1%	19.5%
Phase II (launch-to-target)	62.5%	25.0%
Weapon System, plus supporting functions (Phases I and II)	23.8%*	4.9%*

*Not to be compared to the 70% goal for tactical systems during the airborne mission.

Note: Success is defined as the ratio of successful missions over total attempts (per phase) expressed in percent.

The above comparison is based on the tactical equipment plus all supporting elements for the Rascal weapon system.

The tactical weapon system (for which Bell Aircraft Corporation was responsible and for which a reliability goal was established) has been defined as consisting of the following major systems:

GAM Propulsion System

GAM Flight Control System

GAM Non-Emanating Guidance System (IRCS)

GAM Emanating Guidance System

GAM Auxiliary System

GAM Fuzing System

Director Aircraft Guidance (AN/APW-17) System

Director Aircraft Miscellaneous System

The goal which was established by Bell Aircraft Corporation for the tactical weapon system for the operational-use (squadron-use) phase was 70% for a normal mission. During a planned normal mission the missile tactical equipment (less propulsion system) would have been operated for one hour, the Director Aircraft AN/APW-17 System would have been operated 115 minutes, and the Director Aircraft Miscellaneous System would have been operated 150 minutes.

A comparison of the success (observed reliability) of the tactical weapon system alone, as experienced during airborne missions at Holloman and Eglin, is shown in the following:

Flight Phase	Success During Testing Last 8 R&D Missiles	Success During All Eglin Tests	Tactical Weapon System Goals	
			R&D	Operational
Tactical Weapon System (Phase I times Phase II)	32.8%	15.5%*	45%	70%

Note: Success is defined as the ratio of successful missions to total attempts, expressed in percent.

*This figure includes four launches which resulted in missiles successfully reaching the target area by means of inertial guidance, despite other operational failures.

2. Comparison of Unsuccessful Airborne Missions by Systems

Figure 6 graphically shows the breakdown of the flight test program into the various systems in which malfunctions were observed during attempts to launch the last eight R&D missiles at Holloman and all missiles at Eglin. The breakdown in Figure 6 is based on the following categories:

Tactical Systems:

- Missile - Six major systems.
- Director Aircraft - Two major systems and the operator.

Non-Tactical Systems:

- Telemetering
- Beacons
- Basic B-47 aircraft, including normal K-system equipment.
- Sandia equipment
- Range support equipment and operations.

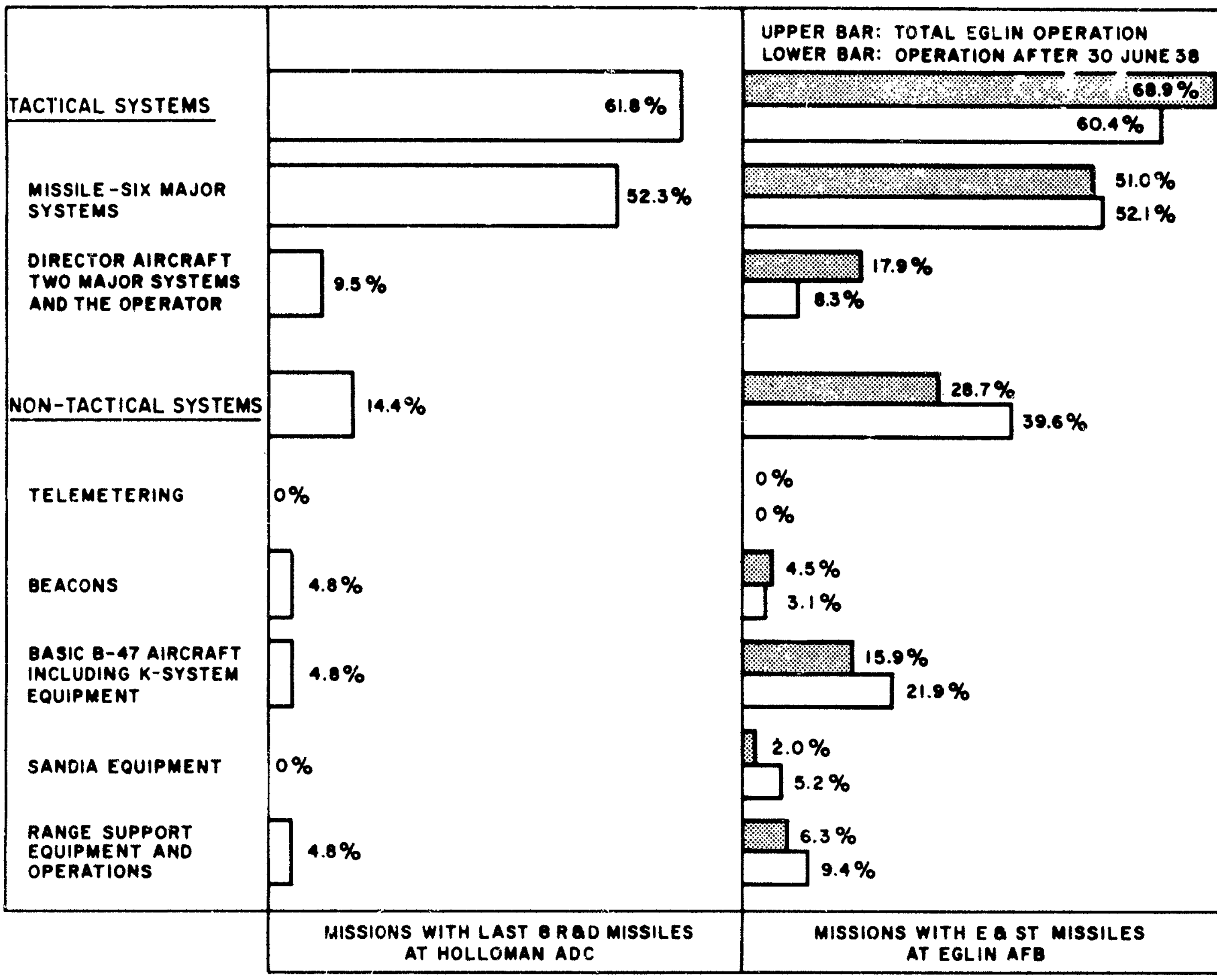


Figure 6. Comparison of Unsuccessful Missions by Systems in Which Malfunctions Were Observed

It will be noted in Figure 6 that the percent of unsuccessful missions at Eglin caused by non-tactical system failures was greater by a factor of 2-to-1 than that observed during the launching of the last eight R&D missiles at Holloman. The basic B-47 aircraft, which was not the responsibility of the Contractor, demonstrated a particularly significant decrease in reliability at Eglin AFB.

3. Effect of Field Equipment, Maintenance, and Support on Airborne Missions

The effect of field equipment, field maintenance, and field support (Category A) on the success or operational reliability of the Rascal weapon system during airborne operations is shown in Figures 7 and 8. Figure 8 shows that during Phase I (takeoff-to-launch) at Eglin this category was five times as great as that observed at Holloman. During Phase II (launch-to-target) at Eglin the effect of Category A items was 4.2 times as great as that observed at Holloman.

Figure 7 shows that the over-all level of the effect of Category A items observed at Eglin was 4.3 times that observed at Holloman during airborne missions. This analysis is based on the effect of Category A items on the tactical weapon system plus all of the supporting functions of the weapon system and test base, as described in paragraph C-2 of this section.

4. Effect of Procedures and Contractor Support on Airborne Missions

The effect of Contractor maintenance procedures, test procedures and technical support (Category B) on the operational reliability of the weapon system at Eglin and at Holloman is shown in Figures 7 and 8. Figure 8 indicates that 21.9% of the Phase I (Takeoff-to-Launch) missions at Eglin were unsuccessful due to Category B type of failures as compared to the absence of this type of failure on the airborne missions of the last eight R&D missiles at Holloman. The effect of Category B items during Phase II (Launch-to-Target) was approximately the same for Holloman and Eglin.

From Figure 7, it will be observed that the effect of Category B items (procedures and technical support) at Eglin was five times the effect of these items at Holloman.

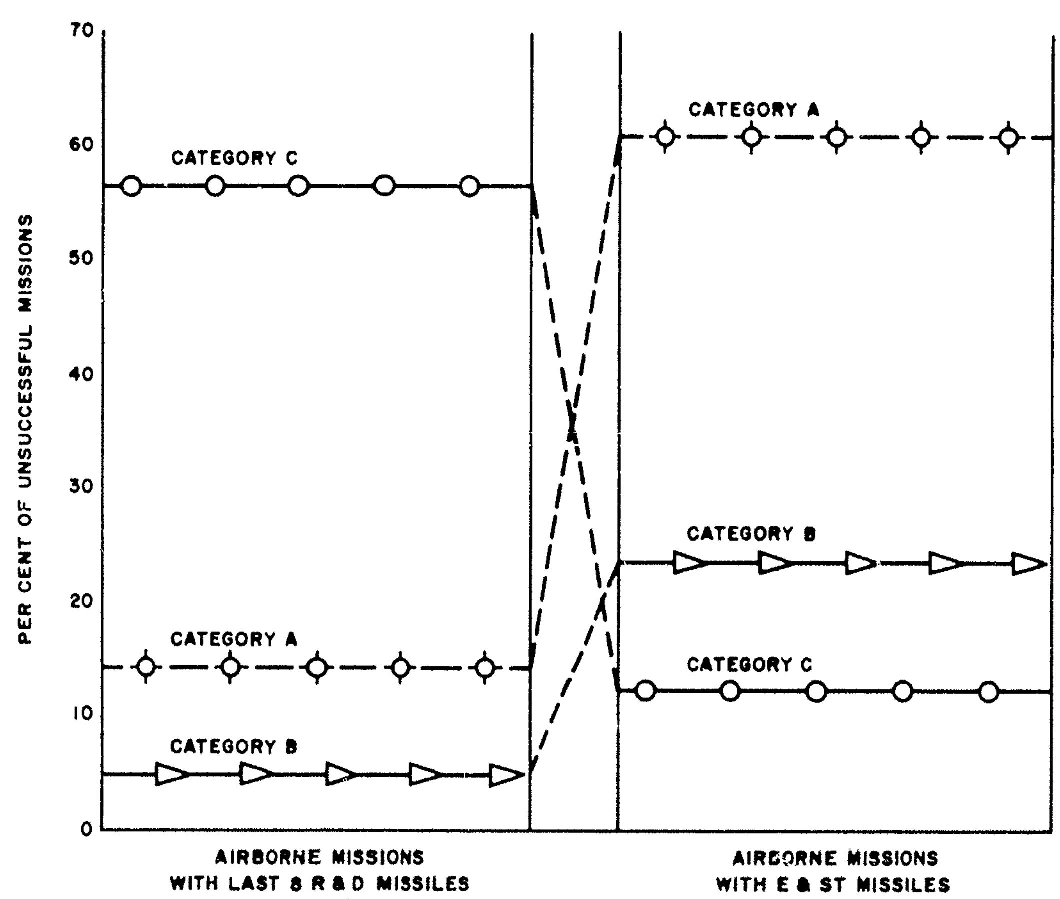
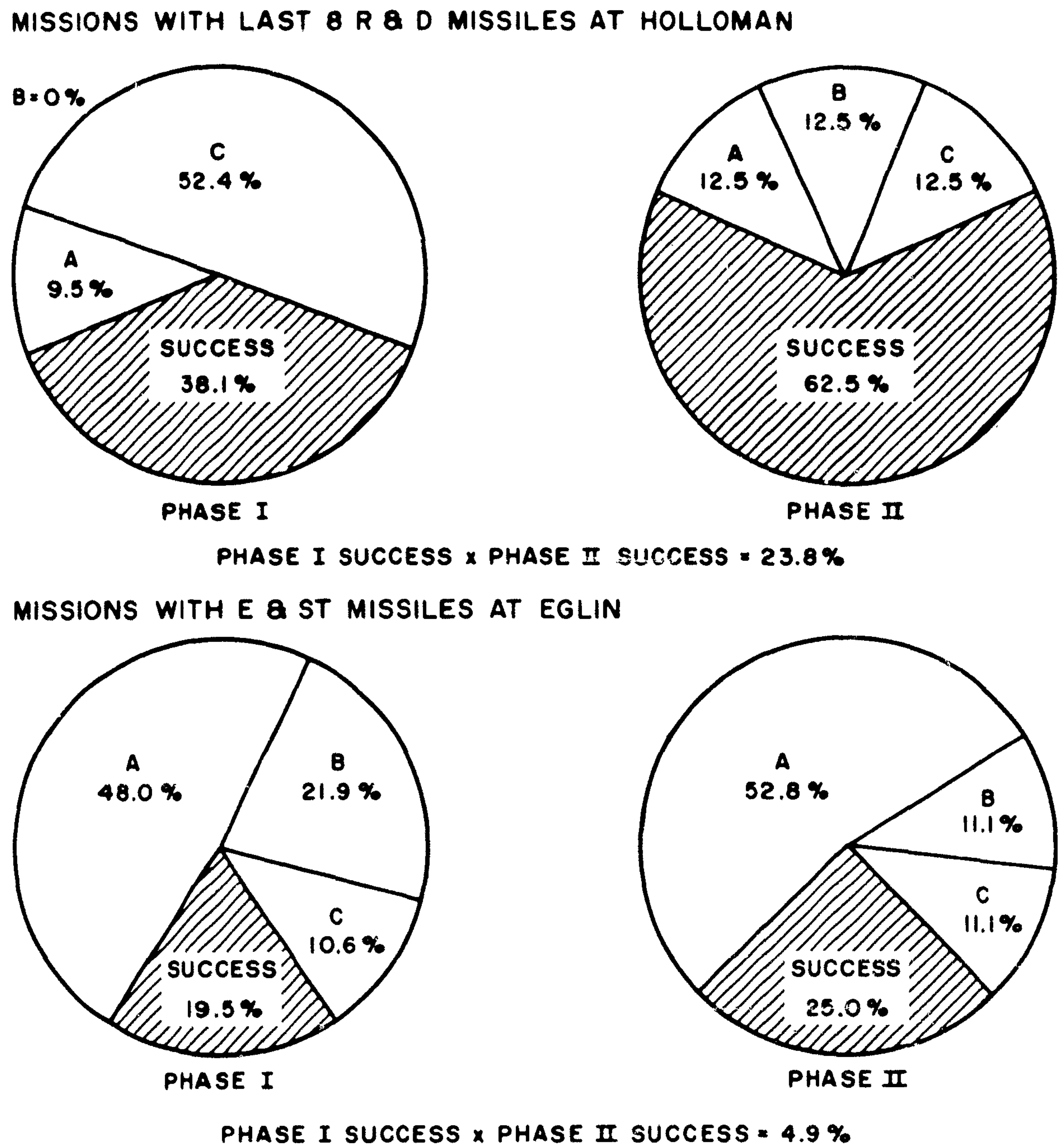


Figure 7. Relative Magnitudes of Causes for Unsuccessful Airborne Missions at Holloman and Eglin



Causes for Unsuccessful Missions:

Category A - Inadequate field equipment, maintenance, and support.

Category B - Inadequate Contractor procedures and technical support.

Category C - Equipment failures and possible equipment failures (Inherent Unreliability).

Phases of Flight:

Phase I - Takeoff-to-Launch

Phase II - Launch-to-Target

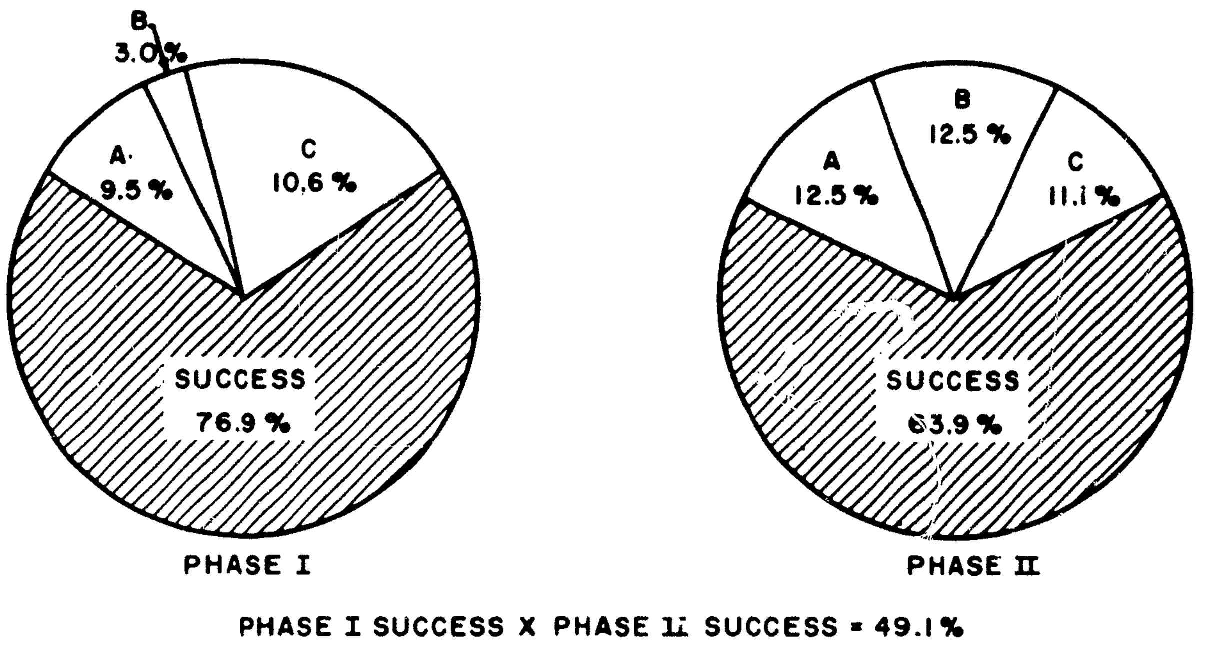
NOTE: This analysis includes the tactical weapon system plus all associated and supporting functions.

Figure 8. Analysis of the Causes of Unsuccessful Airborne Missions by Flight Phases

5. Effect of Inherent Reliability of Equipment

The effect of inherent reliability (Category C) on the operational reliability of the weapon system at Eglin and at Holloman is shown in Figures 7 and 8. Figure 8 shows that in the Phase I (Takeoff-to-Launch) portion of the airborne mission, the inherent unreliability observed on the weapon systems at Eglin was smaller by a factor of 5 than that observed on the last eight weapon systems at Holloman. The same comparison for the Phase II (Launch-to-Target) portion of the airborne mission shows the inherent unreliability of equipment to be approximately the same.

Figure 7 shows a 4.5-to-1 decrease, from Holloman to Eglin, in the over-all level of inherent unreliability of the equipment for which Bell Aircraft was responsible; namely, the tactical weapon system plus telemetering and beacons (except for S-band beacons at Eglin).



Causes for Unsuccessful Missions:

Category A - Inadequate field equipment, maintenance, and support.

Category B - Inadequate Contractor procedures and technical support.

Category C - Equipment failures and possible equipment failures (Inherent Unreliability).

Phases of Flight:

Phase I - Takeoff-to-Launch

Phase II - Launch-to-Target

NOTE: This analysis includes the tactical weapon system plus all associated and supporting functions.

Figure 9. Analysis of Predicted Rascal Airborne Success Using Eglin Hardware and Holloman-Type of Maintenance Support

D. PREDICTION OF RELIABILITY OF E&ST HARDWARE, USING CONTRACTOR-FURNISHED MAINTENANCE

An analysis has been made of the airborne success which could have been realized on the Rascal E&ST hardware, using the same level of maintenance support (Categories A and B) which was furnished by the Contractor at Holloman on the R&D flight test program. The prediction is based on the observed effects of Category A and B items on the airborne missions as experienced during tests on the last eight R&D missiles at Holloman, and on the effect of Category C items as experienced on the physical E&ST hardware used at Eglin AFB. Since there were no unsuccessful Phase I missions at Holloman due to inadequate procedures or technical support, a realistic value of three percent was assumed in making the analysis.

Figure 9 shows graphically the breakdown of the prediction analysis. The predicted reliability for E&ST program hardware, plus Holloman-type of maintenance support, is 49 percent for over-all airborne success of the tactical weapon system plus all supporting functions of the weapon system and of the test base.

A similar analysis of only the tactical equipment used on the E&ST program (the telemetering, beacon, B-47 aircraft, Sandia, and range support equipment were excluded) shows a predicted airborne reliability of 52% for the tactical Rascal weapon system as defined in paragraph C-1 of this section. This predicted airborne reliability of 52% for the tactical weapon system is approximately the same as shown in the reliability growth curve contained in Figure 5, page 33, of Bell Aircraft Corporation Report No. 56-989-117 for the same group of missiles and for the same Director Aircraft Systems which were used on the E&ST program at Eglin AFB.

SECTION XI CONCLUSIONS

A. FACTORY TESTING

The establishment of a reliability requirement for conducting at least 15 formal composite system tests on missiles during the final factory test phase provided an effective method of debugging missiles of the earlier configurations. Missiles of the lastest configurations did not require a lengthy debugging operation during the final factory test phase.

The limited-environment tests conducted on Rascal components before assembly into missiles were particularly effective in debugging the components and in providing a realistic operational-type of component test.

It was repeatedly demonstrated on the Rascal program that, except for a relatively small group of known limited-life items, a missile system can be given many repetitive tests (to provide reliability assurance at a specified confidence level, for example) without wear-out of the missile.

The reliability observed during the final factory test of the missile, less the propulsion system, provided a realistic measure of the inherent reliability of the components subjected to these tests.

It was demonstrated on the Rascal program that production delivery schedules could be met without sacrificing reliability or quality in missiles manufactured for a complex weapon system.

B. FIELD TESTING

The contractor-furnished field maintenance support at Holloman, which include technically trained and experienced personnel (both test and service maintenance personnel) together with the application of unwritten precautionary maintenance procedures and techniques and the application of effective troubleshooting techniques, was far more effective in producing successful operational flights than was the military-furnished field maintenance support at Eglin AFB.

The contribution of failures from non-tactical and non-Rascal equipment at Eglin AFB was far higher than that experienced at Holloman during tests on the last 23 R&D missiles and particularly so with respect to the last 8 R&D missile tests. The equipment included in this non-tactical and non-Rascal equipment category covers beacons, range support equipment, Sandia equipment, and the B-47 aircraft.

The fact that the director aircraft equipment was operated 23% longer and the missile equipment was operated 120% longer than the respective planned airborne mission times was a contributing factor to the low airborne reliability experienced at Eglin AFB.

As has been established in several sections of this report, the reliability of the tactical hardware of the missile systems and of the director aircraft systems used at Eglin AFB was higher than that of the tactical hardware used during the R&D flight test program at AFMDC (Holloman).

The ground support equipment had a negligible direct effect on the reliability of Rascal equipment during airborne missions, both at Holloman and at Eglin.

An analysis of the Eglin operations has proven the need for accurate and comprehensive contractor-furnished field manuals for use by the military service when it performs evaluation tests on a military weapon system. The Eglin Technical Orders were less effective in the conduct of the E&ST operation than were the Holloman procedures in the conduct of the R&D program. Inadequacies in the handbooks contributed to the lack of proper ground preparation and maintenance at Eglin AFB.

In a similar vein, the need for complete and effective maintenance procedures during military use of a complex weapon system was verified during the Eglin operations. These maintenance procedures include correct and effective service (repair) maintenance instructions, preventive maintenance procedures, precautionary maintenance procedures, troubleshooting techniques, standard check lists, and military or inspection work cards used by the individual maintenance personnel.

It has been concluded that for a very large sample of missiles in use in field operations, a fairly accurate human-error factor (part of Use Reliability) can be determined for a complex weapon system. It was observed, however, on the Rascal field test program at Eglin AFB, that the incidence of serious human errors was far greater than had been predicted. They were caused primarily by inadequate technical training, inadequate quality control, and inadequate maintenance control.

For other weapon systems of the complexity of Rascal, missiles of the E&ST programs should be as fully instrumented (with telemetry and direct recording) as the missiles of the R&D flight test program in order to provide the utmost information on environments and operational performance.

The reliability of Air Force guidance operators during airborne phases of the Rascal weapon system was very high, both at Eglin and at AFMDC (Holloman).

C. RELIABILITY CONTROL

The reliability data reporting system established at Bell Aircraft Corporation on a corporate-wide basis, in February 1956, has proven to be a most effective method of reporting raw data for use on a comprehensive reliability program for a complex weapon system. With only slight modification, the Bell Aircraft reporting system can be adapted to any other weapon system.

The utilization of the Bell Aircraft reliability data reporting system at Eglin AFB proved the feasibility of using a Contractor reporting system on a military test base to effectively report all reliability data required for a comprehensive reliability program. Further, it proved the need for stationing Contractor reliability representatives on the military base to collect such reliability information. The same advantages were observed while using the Contractor's reporting system and reliability representatives in the Air Force Logistics Depot.

The establishment of the "idea-for-improvement" program for the Rascal weapon system was an effective method of getting voluntary employee participation in producing a better product. This "idea-for-improvement" program was similar to "suggestion-box" plans in effect throughout industry.

The method of establishing formal definitions of repetitive problems, as detected by machine-processed reliability data, is an extremely effective method of initiating corrective action on problem areas experienced during the R&D test phase and the production phase of a complex weapon system.

D. DESIGN

It was established that the Rascal missile and Director Aircraft guidance equipment required a high level of competence and experience in the personnel who performed the maintenance, test, and inspection functions on this equipment during all test operations. The basic design of the Rascal weapon system used at Eglin could be called "modified R&D equipment" since a production design was never accomplished on the Rascal equipment. As a result, implementation of certain high-reliability design techniques, such as provision for optimum serviceability, maintainability, interchangeability, stability, and human engineering, did not become effective on this weapon system.

A number of airborne flights were unsuccessful because the design of the emanating guidance system did not provide for successful operation over an ocean water firing range when adjusted for use over a land firing range.

Depot tests on AN/APW-17 systems showed that of the thirteen systems tested the last systems built showed the highest reliability, thus reflecting a higher level of basic design. The AN/APW-17 systems which would have been used by the operational squadrons would thus have been more reliable than the five systems used at Eglin on the E&ST program (see Table XVII).

The reliability growth curve of the Rascal system was such that there was a slow but constant improvement in the potential inherent design from the start of the reliability program until the termination of the program. Since corrective actions for numerous problems never became effective on the system, the full inherent reliability of the Rascal weapon system was never realized.

The reliability technique of specifying rigorous design criteria to vendors was proven especially effective in the case of electronic components such as the Radar modulator, Radar R-T unit, and the voltage regulator.

Engineering qualification and life tests, to be valid and meaningful, must be conducted under the environments which simulate the actual operational conditions of system-installation environment, physical environment, and miliatry-use environment.

E. MANAGEMENT

As has since been recognized by senior Air Force weapon system management personnel and Contractor management personnel, the Rascal weapon system was transferred too abruptly from a contractor-operated flight test (R&D) program to a military-operated flight test (E&ST) program, with resulting severe adverse effects on the operational reliability of the weapon system.

In final conclusion, although the establishment of a comprehensive reliability program on the Rascal weapon system produced many outstanding improvements in reliability, this reliability program was applied after the basic research and development design had been completed and thus the ultimate in inherent reliability was never attained. The time required for effective application of corrective measures on this reliability program was very great. For example, approximately one year was required to collect sufficient evidence of all of the problem areas that existed in the Rascal weapon system. By the time the corrective-action and product-improvement plan became firm, the concluding stages of the R&D flight test program had been reached and preparations were already in effect for initiating the E&ST program.

Consequently, limited by time and funds, the bulk of the major identified repetitive problems did not receive corrective action. Likewise, also limited by time and funds, numerous completed product-improvement designs which would have contributed enormously to inherent reliability and to performance were not made effective on this weapon system program.

This Contractor has, as a result of the Rascal Reliability Program, acquired the capability to achieve high reliability in a complex weapon system, namely, by applying effective reliability techniques beginning in the design concept stage and continuing the application of reliability program practices and techniques into the production and military-use phases of the weapon system.

Although the maximum potential reliability of the Rascal weapon system was not achieved during the R&D and E&ST phases, sufficient evidence was obtained to prove that the reliability goal of 70%, as established by the Contractor for an airborne mission, was a practicable and attainable goal, satisfactory for operational use. The reliability growth curve shown in Bell Aircraft Corporation Report No. 56-989-117 (page 33) illustrated the reliability potential of the weapon system which could have been achieved by using Contractor-type of maintenance support (i.e., as effective as that used at Holloman), by applying solutions to the known repetitive problems, and by incorporating the benefits of the product-improvement program.

APPENDICES

APPENDIX A

SUMMARY OF R&D AIRBORNE OPERATIONS AT AFMDC (HOLLOMAN)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
75	6-6-56	710	Abort	Bell	B	Loss of telemetered data.	T/M Dynamotor burn-out due to carbon collecting between commutator segments. Inadequate maintenance.
75	6-11-56	710	Launch	-	-	Successful.	
76	8-2-56	710	Abort	Non-Bell	(a)	Poor weather.	Note (a): This abort was not included in the final analysis.
76	8-6-56	710	Launch	-	-	Successful.	
77	9-11-56	220	Launch	Non-Bell	A	Beacon destruct via unauthorized ground signal at X+14.8 seconds.	Unauthorized GAM beacon destruct signal caused by unwanted radiation from a ground transmitter. Beacons were found to be susceptible to stray signals; design changes were made.
79	10-23-56	220	Abort	Bell	C	No surface center light.	Defective 6021 tube (V706) in missile pitch amplifier.
79	10-24-56	220	Abort	Non-Bell (b)	B	Incorrect solution in Inertial Range Computing System.	Improperly seated fuse in Director MRNC System. Note (b): In one of 6 AC Spark Plug components assigned to Bell Aircraft reliability responsibility. Procedure No. 205 was not adequate.
79	10-25-56	220	Abort	Non-Bell (b)	C	(1) Early turbine fire.	Director MRNC R_{ts} loop out of step; design problem. Checkout procedure inadequate.
				Non-Bell	A	(2) Unwanted destruct condition.	Unauthorized GAM beacon destruct signal caused by uncontrolled ground signal (See GAM No. 77 launch).
79	11-2-56	220	Abort	Bell	C	No video relay signal or command contact.	Improper operation of A1016 magnetron. High failure rate on this tube.
79	11-5-56	220	Launch	Bell	B	Power plant shutdown 4.5 sec. after dive. Impact 5 miles short of target.	Improper fuel loading procedure.
80	11-8-56	220	Abort	Bell	C	(1) Turbine shutdown.	Missile gas generator sequence valve leaked internally. Preventive maintenance test procedures were revised. New valve effective on GAM No. 122.
				Bell	C	(2) Unstable synchronization on azimuth and elevation indicator.	Frozen bearing in indicator.
80	11-15-56	220	Abort	Bell	C	No command contact at at altitude.	Open filaments on 4PR60 tube in Director Aircraft command transmitter. This was an old-design tube.
80	11-19-56	220	Abort	Bell	C	Marginal command contact.	Defective low voltage power supply in missile relay and command subsystem.
80	11-26-56	220	Abort	Bell	C	No command contact at altitude.	Open filaments on 4PR60 tube in Director Aircraft command transmitter. Filament voltage too high. Filament dropping resistor added.
80	11-29-56	220	Abort	Bell	C	(1) USR synchronization problem.	Missile search antenna failed to synchronize. Also, hydraulic system required filtering.
				Bell	C	(2) Azimuth and elevation indicator display failed.	Resonances set up by blower were picked up by microphonic tube in the Director Aircraft voltage regulator. Unit was changed from variable line frequency to fixed line frequency to avoid a self-resonant condition in the blower motor.
80	2-20-57	219	Abort	Bell	B	Azimuth and elevation indicator display failed.	Mispositioning of the reluctance wheel and excessive carbon particles in commutator in the azimuth and elevation indicator. Inadequate preventive maintenance procedures.
80	2-25-57	219	Abort	Bell	A	Turbine failed to start.	Moisture in nitrogen system tube bundles caused check valve to freeze in closed position, precluding turbine fire. Inadequate maintenance.
80	2-28-57	219	Abort	Bell	B	Loss of N_2 source pressure.	A clogged filter due to moisture in nitrogen system tube bundles caused loss of N_2 pressure, precluding turbine fire. Procedures and technical support considered inadequate.

APPENDIX A (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
80	5-23-57	219	Abort	Non-Bell	A	(1) PDI marker rotating.	Defective wiring in Boeing B-47 aircraft.
				Non-Bell	A	(2) Carrier relay antenna could not be extended.	Air in the Boeing B-47 aircraft hydraulic system, due to inadequate maintenance.
				Bell	C	(3) Excessive noise on the azimuth and elevation indicator display.	Discrepant carrier relay receiver.
80	5-28-57	219	Abort	Non-Bell	A	Carrier relay antenna could not be lowered.	The sequence valve actuator on the left relay antenna door was improperly adjusted (Boeing B-47 aircraft equipment).
80	6-4-57	219	Abort	Non-Bell	A	PDI marker rotating.	Defective wiring in Boeing B-47 aircraft.
80	6-12-57	220	Abort	Non-Bell	A	Electrical failure on base.	Failure in range support. No electrical power on AF base.
80	6-17-57	220	Abort	Bell	C	Missile relay magnetron hard to start.	Improper operation of A1016 magnetron.
80	6-19-57	220	Launch	Bell	C	Range safety officer destructed missile 18 seconds after launch.	Inoperative missile S-band beacon. Procedure revised to check beacon battery 24 hours prior to launch. Range safety policy being reviewed.
81	12-12-56	219	Abort	Bell	C	Yaw gyro failed to uncage.	Missile yaw gyro caging mechanism inoperative. Improved gyro effective in GAM No. 95.
81	12-17-56	219	Abort	Bell	C	(1) No right and climb lights.	Shorted tantalum capacitor in missile pitch command modulator. Capacitor from defective vendor lot.
				Bell	B	(2) Unsatisfactory decode and lock-in.	Inadequate preflight adjustment procedure.
81	12-20-56	219	Abort	Bell	A	No video on PPI.	Pinched filament lead of V515 in the carrier azimuth and elevation indicator due to inadequate maintenance by ground crews.
81	1-7-57	219	Launch	Bell	B	Hydraulic pressure loss at 9 seconds after launch resulting in loss of stability.	Missile hydraulic system failure due to inadequate maintenance procedures. Procedure for checking accumulator precharge pressure not adequate.
82	11-27-56	219	Launch	Bell	A	Video contact lost after launch.	Improper operation of A1016 magnetron. In addition to high failure rate on this tube, precautionary maintenance instructions were inadequate.
83	12-17-56	220	Abort	Bell	C	Turbine failed to start.	Inoperative missile meletron switch. Inadequate design.
83	12-20-56	220	Abort	Bell	C	Command contact lost.	Open filament on 4PR60 tube in carrier command transmitter; operated at improper filament voltage.
83	1-4-57	220	Abort	Non-Bell	A	(1) Loss of communications on base.	Failure in range support — VHF difficulties.
				Bell	C	(2) Air pressurization problem.	Pressure leak at carrier relay antenna mount due to a cracked wave guide.
83	1-7-57	220	Abort	Bell	C	Yaw gyro failed to uncage.	Missile yaw gyro caging mechanism inoperative. Improved gyro effective on GAM No. 95.
83	1-14-57	220	Abort	Bell	C	(1) Azimuth and elevation indicator display shifting.	Excessive backlash in the gear train of the missile azimuth computer.
				Non-Bell	A	(2) No sweep on the PPI in APS-23.	Defective wiring in Boeing B-47 aircraft.
83	1-16-57	220	Abort	Bell	C	Missile internal power lost.	Short circuit in missile voltage regulator. Design inadequate.
83	1-31-57	219	Abort	Non-Bell	A	Range safety problem.	Failure in range support item.
83	2-1-57	219	Abort	Bell	C	No internal power check.	Defective relay in the missile voltage regulator.
83	2-5-57	219	Abort	Bell	C	Pressure regulator malfunction.	Missile power plant regulator package output high. Better design became effective on GAM Nos. 80, 85 and subsequent.
83	2-11-57	219	Launch	Bell	C	Loss of internal power approx. 0 seconds after launch.	Electrical voltage fluctuations caused GAM failure. Laboratory tests indicated voltage fluctuations could be duplicated by a failure in the GAM voltage regulator. Design inadequate.

APPENDIX A (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
84	1-14-57	219	Abort	Bell	C	Low N_2 source pressure.	Failure to incorporate modification in missile main junction box caused erroneous readings from an N_2 source pressure gauge.
84	1-16-57	219	Launch	Bell	A	Impact 2.9 miles west of target.	Operator error; did not follow procedure.
85	4-8-57	219	Abort	Non-Bell	A	PPI presentation erroneous in azimuth.	APS-23 synchronizer failure.
85	4-10-57	220	Launch	-	-	Successful.	----
87	5-10-57	220	Abort	Non-Bell	A	Sandia telemetering problem.	Sandia equipment failure.
87	5-14-57	220	Launch	Bell	C	Flight erratic at approx. 150 seconds after launch.	Electrical voltage fluctuations caused GAM failure. Laboratory tests after GAM 90 flight indicated voltage fluctuations could be duplicated in the GAM voltage regulator. New improved voltage regulator effective GAM Nos. 89, 94, 96, 98 and subsequent.
88	6-27-57	219	Abort	Bell	C	(1) No command contact.	Director command transmitter failure. See final flight on 7-1-57.
				Non-Bell	A	(2) Sandia warhead problem.	Sandia equipment failure.
88	7-1-57	219	Launch	Bell	C	Loss of command contact.	Carrier command transmitter failure — gear slipping on turning shaft due to a loose screw. Gears required pinning.
89	8-30-57	220	Abort	Bell	C	Loss of video.	Arcing of USR magnetron. Design inadequacy; R-1649 resistor changed from 250 to 130 ohms.
89	9-4-57	220	Launch	Bell	B	Operated satisfactorily for 126.2 seconds after which an electrical failure shut down the power plant.	Improper tube in the IRCS power supply caused a short at altitude.
90	7-10-57	345	Launch	Bell	C	Loss of power with subsequent missile shutdown at 72.9 seconds after launch.	Electrical voltage fluctuations caused GAM failure. Laboratory tests indicated voltage fluctuations could be duplicated by a failure in GAM voltage regulator. New improved voltage regulator effective GAM Nos. 89, 94, 96, 98 and subsequent.
91	3-7-57	220	Abort	Bell	C	No command contact.	Intermittent carrier ATRAS antenna control. Defective synchro T-2504.
91	3-11-57	220	Abort	Bell	C	(1) Subnormal missile L-band beacon tracking.	Improper missile L-band beacon operation; faulty antenna.
				Bell	C	(2) Intermittent magnetron current.	Intermittent magnetron current when a 42° right command was inserted in the carrier polycode driver. V104 would not cut off. Marginal circuit corrected.
91	3-13-57	220	Launch	Bell	C	Impact short of target.	Drift in director aircraft range computer. Resistors were not sufficiently stable.
93	6-20-57	345	Abort	Bell	C	(1) Marginal decode and lock-in.	Improper operation of A1016 magnetron.
				Bell	C	(2) Intermittent missile L-band beacon tracking.	Beacon noise and antenna cable shielding inadequate. Probable contribution to problem by ground tracking station.
93	6-26-57	345	Abort	Bell	C	Phase jumping on azimuth and elevation indicator.	Defective missile azimuth computer-gain potentiometer. R1101 was fully clockwise. Locknut not tight and "O" ring deteriorated.
93	7-1-57	345	Launch	Bell	C	Missile became unstable at 226 seconds after launch.	Missile hydraulic failure — air seepage from air side to oil side of accumulator piston. Inadequate design. Heaters were added to the oil and air ends of the hydraulic accumulator, effective on GAM No. 201
94	6-28-57	220	Abort	Bell	C	Heading [illegible] problem.	GAM USR antenna bubble and seal leakage and antenna out of synchronization.
94	7-9-57	220	Abort	Bell	C	L-band beacon track lost.	GAM L-band beacon triggered due to interference radiated by the Sandia equipment and picked up on the L-band beacon antenna spike. Defective beacon.
94	9-11-57	219	Launch	-	-	Successful.	
96	9-30-57	220	Abort	Non-Bell	A	Roadblock not established.	Range support problem.
96	10-2-57	220	Abort	Bell	C	Power plant shutdown.	Over-temperature condition in power plant caused by gas generator mixture ratio being at top of its spec.
96	10-17-57	219	Abort	Bell	C	Power plant shutdown approx. 1.25 seconds after turbine fire.	Fuel case pressure malfunction. Insufficient instrumentation precluded pin-pointing the discrepant component. Post-launch testing disclosed no malfunction.
96	10-28-57	219	Abort	Bell	C	Turbine failed to arm.	Fused contacts of the N_2 jettison relay caused early loss of N_2 pressure, thus preventing arm signal from reaching sequence box.

APPENDIX A (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
96	10-31-57	220	Launch	Bell	A	Missile suffered fire and engine compartment explosion at rocket fire.	Propellant by-pass valve failed to close and probable fuel leak downstream of Boost No. 1 propellant value d. s to inadequate checkout prior to flight. Investigation indicated that portions of preflight checkout were omitted since this missile was flown on last day of R&D program. This failure probably resulted from a residual failure from an earlier abort.
97	8-16-57	220	Launch	-	-	Successful.	----
98	10-4-57	220	Abort	Bell	C	No "S" meter readings.	Voltage regulator tube failed in the director relay receiver power supply.
98	10-9-57	220	Launch	-	-	Successful.	----
99	9-25-57	219	Abort	Bell	C	(1) Intermittent command contact.	Faulty AFC unit in the missile relay transmitter.
				Bell	C	(2) No response to USR "On" command.	Faulty command package in the missile command unit.
99	9-27-57	219	Abort	Non-Bell	A	K-system problem.	Faulty tube in the APS-23 modulator.
99	10-3-57	219	Abort	Bell	C	ACS failed to release missile.	A crushed and partially shorted wire in the carrier ACS power supply.
99	10-8-57	219	Abort	Bell	C	Loss of video.	A defective tube (6AL5) in the missile USR synchroniser.
99	10-16-57	220	Launch	-	-	Successful.	----
100	10-11-57	220	Launch	-	-	Successful.	----
101	10-25-57	220	Abort	Bell	C	(1) Poor video, no command contact.	Improper operation of the A1016 magnetron.
				Bell	C	(2) Both ailerons hard over.	Shorted 5687 (V-908) tube in the missile roll amplifier.
101	10-29-57	220	Launch	Bell	C	(1) Excessive climb angle.	Lack of output from the missile pitch cathode follower circuit.
				Bell	C	(2) Missile shutdown at approximately 45 sec. after launch.	Loss of missile prime electrical power. Design inadequacy. Alternator and voltage regulator problem was restudied at high altitude, under vibration.

Note: Definition of Categories of Causes for Unsuccessful Missions

Category A - Inadequate Contractor field maintenance and inadequate military range support and field supporting equipment.
Category B - Inadequate Contractor maintenance procedures, test procedures, and technical support.
Category C - Equipment failures and possible equipment failures (Inherent Unreliability).

APPENDIX B

SUMMARY OF E&ST AIRBORNE OPERATIONS AT EGLIN AFB

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
102	2-24-58	165	Abort	Non-Bell	A	(1) Blooming presentation on the azimuth and elevation indicator.	A resistor in the high-voltage supply had arced to ground, caused by inadequate maintenance control.
				Bell	C	(2) No control on the relay receiver tuning.	5Y3 tube (V-2115) open filament. Resistor R-2153 burned out. 6A57 tube (V-2119) loose base.
				Non-Bell	A	(3) Weak and intermittent interrogating signal.	Defective coaxial cable from the "L" band beacon antenna.
				Bell	C	(4) Command transmitter magnetron indication was one half of one segment.	Defective magnetron.
102	3-17-58	165	Abort	Bell	B	Loss of hydraulic pressure 62.5 seconds after turbine fire.	The hydraulic pump bound causing the pump shaft to shear (condition existed prior to launch).
102	11-7-58	168	Abort	Bell	C	Loss of video & signal strength, T/M reception & 115V phase "A" power. Phase "A" circuit breaker was open.	Alternator/voltage regulator believed to be cause of failure.
103	12-17-58	346	Abort	Non-Bell	A	(1) Beacons were mistriggering almost continuously at the range.	Design problem in Air Force equipment. S-band beacon required modification.
				Bell	C	(2) Intermittent commands.	Improper operation of A1016 magnetron.
				Bell	C	(3) Loss of command link.	Sand, from defective dummy load, was found in waveguide switch.
				Non-Bell	A	(4) Unable to pick up target in scope.	Range support problem; aimpoint target was not installed on range.
103	1-8-58	346	Abort	Non-Bell	A	(1) No "S"-band beacon tracking or destruct signal from range.	Faulty ground station equipment.
				Bell	C	(2) Intermittent loss of R_s mark on azimuth and elevation indicator.	Condition would not repeat on ground, but cause was believed to be in indicator.
103	1-10-58	346	Abort	Non-Bell	A	(1) The automatic checkout system did not give a "rocket ready" light.	Probably improper adjustments. Not a propulsion system malfunction.
				Bell	B	(2) Intermittent loss of R_s mark on azimuth and elevation indicator.	Problem was believed to be in azimuth and elevation indicator; component was replaced.
103	2-10-58	346	Abort	Non-Bell	A	No indication of turbine fire.	A wire in director capsule was broken due to improper maintenance.
103	2-17-58	346	Abort	Bell	B	(1) The R_s mark would not move as the tracking handle was moved.	Incorrect alignment of the T.G. Synchronizer due to inadequate maintenance procedure.
				Bell	B	(2) Turbine shut down after 1.5 seconds of operation.	Chromic acid frozen in system. The system had been improperly flushed after a previous abort. Tank bleed valve was replaced.
103	3-17-58	186	Abort	Non-Bell	A	(1) Director Aircraft could not retract the outrigger wheels.	Defective landing gear mechanism on DB-47.
				Bell	B	(2) No video.	The K-806 relay was open due to an inadequate procedure.
103	3-24-58	186	Abort	Bell	B	The automatic checkout system stopped on "internal-power" check.	Unknown at time of flight (see abort of 3-28-58 below). Turbine sequence control assembly was replaced because of short in P-75 connector. However, this was not considered the true cause of the failure.
103	3-28-58	[illegible]	Abort	Bell	B	The turbine would not start.	Improper pressurization due to a defective check valve.
103	9-19-58	346	Abort	Non-Bell	A	"L"-band destruct signals were not received.	Difficulties with range support equipment (Ground Station A-13).

APPENDIX B (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Result	Cause of Failure
103	9-24-58	346	Launch	Non-Bell	A	No director aircraft magnetron current during prelaunch; missile launched on inertial guidance system. Flight on "inertial guidance" was successful.	A leaking check valve (Boeing supplied in the director aircraft) permitted the pressure in the transmitter to drop causing an internal arc-over in the command transmitter. Inadequate maintenance.
104	1-8-58	165	Abort	Non-Bell	A	(1) IRCS dive time was 180 seconds instead of 120 seconds.	Operator took time from "antenna No Go" light instead of the "I.G. Start" light.
				Non-Bell	A	(2) K-system stabilizer unit appeared to tumble with any slight turn.	Failure of alternator in director aircraft.
104	11-18-58	168	Launch	Bell	B	(1) The USR AFC would not lock in during prelaunch; missile launched on inertial guidance system.	Procedures were not adequate for use of AFC on the Eglin range.
				Bell	C	(2) Loss of primary power at 97.5 seconds after launch.	Presumed to be the missile alternator or voltage regulator.
105	1-27-58	186	Abort	Non-Bell	A	(1) Sluggish surface responses.	Defective hydraulic pump in director aircraft.
				Non-Bell	A	(2) Automatic altitude track circuit would not operate properly.	Inadequate maintenance; disconnect sensitivity was misadjusted.
105	2-17-58	165	Launch	-	-	Successful.	----
106	1-16-58	165	Abort	Non-Bell	A	(1) No S-band beacon destruct signals received.	Loose plug in selector unit due to improper maintenance.
				Non-Bell	A	(2) Missile release navigation computer was 15-16 miles off.	A design problem in the missile release navigation computer system (AC Spark Plug equipment).
106	1-27-58	165	Abort	Bell	B	Turbine shutdown after 1.4 seconds of operation.	A power plant by-pass valve was in a closed position due to incorrect torque on oxidizer side retainer as a result of an inadequate Technical Order.
106	3-24-58	346	Abort	Bell	B	No internal power.	K-7 relay was open in both the energized and non-energized position due to an inadequate Technical Order.
106	4-18-58	165	Launch	Non-Bell	A	No change in missile altitude and no rocket fire after satisfactory prelaunch.	Unknown — but a major change was made in the main "J" box prior to flight and no composites were run before this flight to verify that the circuit was operating properly. K-8 relay did not actuate; roll buck-out signal was not removed.
107	5-16-58	165	Abort	Non-Bell	A	The turbine shut down after gyro uncage.	High water content in the acid (oxidizer) due to inadequate maintenance control.
107	6-19-58	165	Launch	Bell	B	No post-launch modulation (video) on the carrier frequency to the director aircraft. Flight on "inertial guidance" was successful.	Inadequate AGC in the USR due to the weapon system not having been checked out over the actual water target area. Inadequate setup procedure.
108	5-13-58	165	Abort	Non-Bell	A	No internal power check light.	Defective missile alternator; caused by improper test cable used during previous flight.
108	5-27-58	165	Abort	Non-Bell	A	Changeover from external to internal power occurred late.	A malfunction in the automatic checkout system due to inadequate maintenance control.
108	5-29-58	165	Abort	Non-Bell	A	Turbine did not fire.	Gas generator chamber pressure switch was shorted in a closed position. Post-flight evaluation indicated failure present prior to takeoff.
108	10-17-58	168	Abort	Non-Bell	A	Surface center light could not be obtained. Both ailerons were hard over.	Roll amplifier was not properly seated, probably as the result of a tube replacement 3 days earlier. Inadequate maintenance control.
108	10-24-58	187	Abort	Non-Bell	A	(1) Automatic Check-out System stopped at gyro uncage.	Failure in the basic K-system wiring.
				Non-Bell	A	(2) Intermittent indications of S-band beacon destruct signals.	Gain potentiometer R-119 in the destructor assembly was out of adjustment due to maintenance inadequacy.

APPENDIX B (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
108	11-10-58	187	Launch	Non-Bell	A	Prelaunch operation satisfactory. Immediately prior to dive, missile was reported outside the safety range limit and was destructed.	GAM launched off course probably due to an operator navigational error or a failure of the K-4 system.
109	5-23-58	165	Launch	Non-Bell	A	Prelaunch operation satisfactory; rocket engine shutdown at approximately 100 seconds after launch.	Oxidizer starvation of the gas generator due to the fact that test personnel did not change the gas generator filter as recommended by technical representatives.
110	6-6-58	165	Abort	Bell	C	(1) Loss of search antenna synchronization and a heading marker shift.	V-603 in the spin drive amplifier appeared to be inoperative. Amplifier, motor and valve were replaced.
				Non-Bell	A	(2) No S-band beacon tracking or destruct signal.	CR-27 (IN67) was found to be reversed due to failure to detect this discrepancy on previous compatibility test (6-4-58).
				Non-Bell	A	(3) Intermittent L-band beacon destruct checks.	Ground radar trouble; power output low.
110	10-6-58	346	Abort	Non-Bell	A	Missile would not release, either automatically or manually.	The rigging of the GAM release system in the director aircraft was out of adjustment. The missile accidentally released 17 seconds after turbine shutdown.
111	3-28-58	346	Abort	Non-Bell	A	Aircraft hydraulic pressure was lost.	A screwdriver was thrown into the wheel well during takeoff and punctured one of the hydraulic lines. Missile was jettisoned for crew safety.
112	8-8-58	346	Abort	Non-Bell	A	Automatic control system stopped at surfaces neutral.	Yaw command zero potentiometer and the yaw D.C. amplifier balance were out of adjustment due to inadequate maintenance.
112	8-29-58	187	Launch	Non-Bell	A	(1) Difficulty in tuning the relay receiver during prelaunch; missile launched on inertial guidance system.	The tuning meter was pegged due to a defective or damaged coaxial cable in the director aircraft.
				Bell	B	(2) The GAM became unstable 10 seconds after dive; reached target area.	Turbine pump cavitation caused by improper drainage procedure.

APPENDIX B (CONT)

GAM No.	Date	Director Aircraft Number	Type of Flight	Responsibility for Cause of Failure	Category of Cause of Failure	Observed Results	Cause of Failure
113	7-2-58	186	Abort	Bell	C	(1) Automatic checkout system stopped at the 5.4 KC check.	The time base stepper switch (K-951) in the director aircraft selector assembly would not reset; defective.
				Non-Bell	A	(2) Unsatisfactory S-band beacon destruct.	Ground radar difficulties.
113	8-1-58	346	Launch	Bell	B	(1) No video display during prelaunch; missile launched on inertial guidance system.	Automatic gain control problem in the USR system due to flight over water course.
				Non-Bell	A	(2) Airburst instead of planned groundburst. Note: Successful inertial flight.	Incorrect wiring in circuitry to warhead.
114	7-25-58	346	Launch	Bell	C	(1) Satisfactory prelaunch; no relay link established after launch.	Numerous checks were run on director aircraft without pinpointing the problem. A sticking waveguide switch was found later which may have caused the problem.
				Bell	B	(2) No video display; missile reached target area on inertial guidance system. Note: Successful inertial flight.	Automatic gain control problem in the USR subsystem due to flight over water course.
				Non-Bell	A	(3) Airburst instead of planned groundburst.	Incorrect wiring in circuitry to warhead.
115	8-22-58	187	Launch	Non-Bell	A	GAM became unstable immediately after launch following satisfactory prelaunch operation.	Hydraulic system failure suspected because of leakage observed prior to takeoff.
116	9-16-58	187	Launch	Non-Bell	A	GAM became unstable at launch.	Attributed to the loss of the roll rate gyro signal, based on computer tests conducted after the flight.
117	11-25-58	168	Abort	Bell	C	The automatic checkout system stopped at function No. 10.	Missile did not transfer to internal power or phase "A" power was lost; probably due to missile alternator or voltage regulator failure.

Note: Definition of Categories of Causes for Unsuccessful Missions

Category A - Inadequate military field maintenance, range support, and field supporting equipment.
Category B - Inadequate Contractor maintenance procedures, test procedures, and technical support.
Category C - Equipment failures and possible equipment failures (Inherent Unreliability).

APPENDIX C

LIST OF QUARTERLY RELIABILITY REPORTS PUBLISHED ON THE RASCAL WEAPON SYSTEM

Bell Aircraft Corporation Report Number	Name of Report	Date of Publication
56-989-101	Project MX-776 Quarterly Reliability Report	28 February 1954
56-989-102	Project MX-776 Quarterly Reliability Report	31 May 1954
56-989-103	Project MX-776 Quarterly Reliability Report	31 August 1954
56-989-104	Project MX-776 Quarterly Reliability Report	30 November 1954
56-989-105	Project MX-776 Quarterly Reliability Report	28 February 1955
56-989-106	Project MX-776 Quarterly Reliability Report	31 May 1955
56-989-107	Project MX-776 Quarterly Reliability Report	31 August 1955
56-989-108	Project MX-776 Quarterly Reliability Report	30 November 1955
56-989-109	Project MX-776 Quarterly Reliability Report	29 February 1956
56-989-110	Project MX-776 Quarterly Reliability Report	31 May 1956
56-989-111	Project MX-776 Quarterly Reliability Report	31 August 1956
56-989-112	Project MX-776 Quarterly Reliability Report	30 November 1956
56-989-113	System 112A Quarterly Reliability Report	28 February 1957
56-989-113*	System 112A Quarterly Reliability Report	15 May 1957
56-989-114	System 112A Quarterly Reliability Report	30 May 1957
56-989-115	System 112A Quarterly Reliability Report	31 August 1957
56-989-116	System 112A Quarterly Reliability Report	31 December 1957
56-989-117	System 112A Quarterly Reliability Report	31 March 1958
56-989-118	System 112A Quarterly Reliability Report	30 June 1958
56-989-119	System 112A Quarterly Reliability Report	30 September 1958
56-989-120	System 112A Quarterly Reliability Report	1 May 1959

* Supplement

APPENDIX D

COMPARISON OF OBSERVED RELIABILITIES AND ESTABLISHED RELIABILITY GOALS FOR TACTICAL RASCAL SUBSYSTEMS AND COMPONENTS

PART I MISSILE

Subsystem and Component	Observed Reliability[(1)] (In Per Cent)		Airborne Reliability Goal (In Per Cent)	
	Factory* Tests	Field** Tests	R&D*** Phase	Operational Phase****
Propulsion	82.90	75.79	90.2	95.5
Nitrogen Subsystem	100	92.59	98.27	99.22
N_2 Fill and Jettison				
Relief Valve Installation	100	100	99.91	99.96
Regulator Package Assembly	100	96.97	99.44	99.75
Tube Bundle Installation (Three)	100	95.49	99.13	99.61
Aft Bomber Compartment	100	100	99.75	99.89
Turbine Pump	82.90	92.59	97.01	98.65
Drive Assembly	93.94	98.47	99.53	99.79
Gas Generator Package	88.25	96.97	98.09	99.14
Power Control Cyl. Assy.	100	100	99.96	99.98
Cable Assembly	100	100	99.66	99.85
Turbine Pump Miscellaneous	100	96.97	99.75	99.89
Thrust Chamber	100	98.47	98.29	99.23
Thrust Chamber Assy. (Three)	100	100	98.78	99.45
By-Pass Valve	100	98.47	99.84	99.93
Thrust Chamber Miscellaneous	100	100	99.66	99.85
Engine Miscellaneous	100	96.97	98.01	99.10
Exhaust Duct	100	100	99.96	99.98
Start Tank Fill Valve (Three)	100	100	99.91	99.96
Drain Valves (10)	100	100	99.82	99.92
Sequence Control Assembly	100	100	99.37	99.72
Electrical Harness	100	98.47	99.17	99.63
Engine Miscellaneous	100	98.47	99.75	99.89
Missile Installation	100	100	99.87	99.94
Missile Installation	100	100	99.87	99.94
Propellant Storage	100	94.03	98.51	99.33
Oxidizer Tank Assembly	100	100	99.49	99.77
Fuel Tank Assembly	100	98.47	99.40	99.73
Propellant Oxidizer Miscellaneous	100	95.48	99.73	99.88
Propellant Fuel Miscellaneous	100	100	99.89	99.95
Propulsion System Miscellaneous[(2)]	100	98.47	--	--

* Factory tests based on GAM Nos. 75 to 221.

** Field tests based on GAM Nos. 75 to 117 and corresponding Director Aircraft systems.

*** Established for airborne missions using GAM Nos. 75 to 101.

**** Established for airborne missions using GAM Nos. 122-134 and 201-222.

Notes (1) Included in these reliability calculations were failures caused by human errors, inadequate maintenance, and inadequate procedures, as well as by inherent unreliability of equipment.

(2) Contains system failures which could not be pinpointed to any one component.

APPENDIX D (cont)

PART I MISSILE

Subsystem and Component	Observed Reliability(1) (In Per Cent)		Airborne Reliability Goal (In Per Cent)	
	Factory* Tests	Field** Tests	R&D*** Phase	Operational Phase****
Flight Control System	96.58	95.08	94.1	97.3
Servo Power Subsystem	99.55	99.39	98.89	99.50
Servo Power Supply	99.55	99.39	98.89	99.50
Pitch	99.12	98.86	98	99.35
Pitch Accelerometer	99.91	99.85	99.98	99.99
SV3B Valve	99.89	99.88	99.89	99.95
Pitch Command Modulator	99.72	99.76	99.64	99.84
Gyro Cathode Follower	99.93	99.96	99.80	99.91
SV Pilot Pitch Amplifier	99.87	99.68	99.44	99.75
Elevator Potentiometer	99.97	100	99.98	99.99
Elevator Actuator	99.98	99.80	99.98	99.99
Altimeter	99.92	100	99.98	99.99
Altitude Control Demodulator	99.95	100	99.87	99.94
Yaw	99.28	98.72	98.82	99.47
Rudder Potentiometer	99.95	99.66	99.96	99.99
SV5 Valve	99.93	99.88	99.89	99.95
Rudder Actuator	100	99.93	99.98	99.99
Yaw Gyro	99.72	99.89	99.93	99.97
SV Pilot Yaw Amplifier	99.91	99.96	99.42	99.74
Yaw Accelerometer	99.99	99.55	99.98	99.99
Yaw Command Modulator	99.82	99.84	99.64	99.84
Roll	99.11	98.66	98.96	99.53
Aileron Potentiometer (Two)	99.88	99.93	99.98	99.99
Aileron Actuator (L.H.)	99.93	100	99.98	99.99
Aileron Actuator (R.H.)	100	100	99.98	99.99
SV5 Valve (Two)	99.70	98.00	99.75	99.89
Roll Rate Gyro	99.91	100	99.93	99.97
SV Pilot Roll Amplifier	99.70	99.72	99.33	99.70
Stable Platform	99.46	99.36	98.76	99.44
Stable Platform Pitch Amplifier	99.96	99.80	99.51	99.78
Stable Platform	99.67	99.68	99.66	99.85
Vertical Gyro Erection Amplifier	99.83	99.88	99.57	99.81
Flight Control System Misc.(2)	99.86	99.96	- -	- -

APPENDIX D (cont)

PART I MISSILE

Subsystem and Component	Observed Reliability(1) (In Per Cent)		Airborne Reliability Goal (In Per Cent)	
	Factory* Tests	Field** Tests	R&D*** Phase	Operational Phase****
GAM Non-Emanating Guidance	98.5	98.6	98.4	99.3
Inertial Guidance Subsystem	98.46	98.62	98.38	99.27
I.G. Accelerometer	99.95	99.94	99.96	99.98
Range Integrator	99.37	99.48	99.60	99.82
Velocity Integrator	99.78	99.48	99.62	99.83
I.G. Power Supply	99.89	99.97	99.40	99.73
Dive Angle Computer	99.51	99.74	99.80	99.91
I.G. System Miscellaneous	99.95	100	- -	- -
GAM Emanating Guidance System	93.87	89.85	83.8	92.4
Unattended Search Radar Subsystem	95.98	94.42	90.60	95.69
R-T Unit	98.87	98.80	97.01	98.65
Modulator	99.61	99.35	98.29	99.23
Synchronizer	99.40	98.85	97.35	98.81
S. A. and Synchro	99.08	99.18	99.62	99.83
Directional Coupler	99.98	100	99.89	99.95
SV5D Valve	99.95	99.75	99.89	99.95
S. A. Actuator	99.98	100	99.98	99.99
SV11 Valve	99.76	99.69	99.89	99.95
Hydraulic Spin Drive Motor	99.57	99.49	99.98	99.99
Elec. Control Amp. (Pitch and Spin)	99.87	99.72	98.80	99.46
Azimuth Computer	99.92	99.80	99.57	99.81
Relay and Command Subsystem	97.79	95.16	92.40	96.53
Command Unit	99.24	98.83	95.26	97.85
Relay Transmitter	100	97.16	98.23	99.20
Relay Antenna	99.95	99.95	99.98	99.99
Waveguide and Dir. Coupler	99.95	99.95	99.84	99.93
SV5D Valve	99.94	99.50	99.89	99.95
Relay Antenna Actuator	99.98	100	99.98	99.99
R. A. Pitch Stabilizer	99.97	99.92	99.60	99.82
R. A. Pitch Controller	99.91	99.88	99.53	99.79
Relay Antenna Synchro	99.95	99.90	99.98	99.99
Relay Antenna Altimeter	100	100	99.98	99.99
Emanating Guidance System Misc.(2)	99.88	99.65	- -	- -

* Factory tests based on GAM Nos. 75 to 221.

** Field tests based on GAM Nos. 75 to 117 and corresponding Director Aircraft systems.

*** Established for airborne missions using GAM Nos. 75 to 101.

**** Established for airborne missions using GAM Nos. 122-134 and 201-222.

Notes (1) Included in these reliability calculations were failures caused by human errors, inadequate maintenance, and inadequate procedures, as well as by inherent unreliability of equipment.

(2) Contains system failures which could not be pinpointed to any one component.

APPENDIX D (cont)

PART I MISSILE

Subsystem and Component	Observed Reliability[1] (In Per Cent)		Airborne Reliability Goal (In Per Cent)	
	Factory* Tests	Field** Tests	R&D*** Phase	Operational Phase****
GAM Auxiliary System	85.10	86.13	93.0	96.8
Electrical Subsystem	90.37	88.87	94.74	97.62
Main Junction Box	99.87	99.63	99.15	99.62
Forward Junction Box	99.97	99.97	99.55	99.80
Servo Amp. Junction Box	100	100	99.89	99.95
Sequence Timer (Three)	98.75	100	99.93	99.97
Sequence Timer	99.94	99.91	99.98	99.99
I.G. Inverter	99.72	99.79	99.55	99.80
Alternator	99.89	97.55	99.98	99.99
Voltage Regulator	98.52	93.60	99.53	99.79
Umbilical Plug	100	99.82	99.93	99.97
Interconnect Cabling	99.52	98.84	98.07	99.13
Transformer Rectifier	99.94	100	99.96	99.98
Altitude Switch (Three)	100	100	99.96	99.98
Delay Timer	93.94	100	99.93	99.97
Pressurization System	99.98	99.90	99.84	99.93
Lower Fin Installation	100	100	99.87	99.94
Forward Installation	100	99.95	99.75	99.89
Warhead Installation	100	100	99.93	99.97
Center Installation	100	100	99.91	99.96
Aft Installation	99.98	99.85	99.96	99.98
Hydraulic Subsystem	94.25	97.54	98.62	99.38
Roll Stabilization Installation	100	100	99.75	99.89
Aft Accumulator Installation	99.98	99.81	99.87	99.94
Center Installation (Pump and Reservoir)	94.27	97.97	99.62	99.83
Warhead Installation	100	100	99.98	99.99
Forward Installation	100	99.81	99.57	99.81
Antenna Forward Installation	100	100	99.82	99.92
Fin Fold Subsystem	99.92	99.36	99.46	99.76
Actuators (Four)	99.95	100	99.87	99.94
Hydraulic Valves	99.98	99.63	99.84	99.93
Solenoid Shut-Off Valve	100	100	99.98	99.99
4-Way Solenoid Valve	100	100	99.96	99.98
Switch Installation	100	99.82	99.96	99.98
Switch Installation	100	99.91	99.98	99.99
Restrictor	100	100	99.98	99.99
Tubing Assembly	100	100	99.91	99.96
GAM Auxiliary System Misc.[2]	99.98	99.58	- -	- -

APPENDIX D (cont)

PART I MISSILE

Subsystem and Component	Observed Reliability(1) (In Per Cent) Factory* Tests	Field** Tests	Airborne Reliability Goal (In Per Cent) R&D*** Phase	Operational Phase****
Fuzing System	100	100	99.3	99.7
Pressure Subsystem	100	100	99.71	99.87
Pressure Manifold and Tubing	100	100	99.98	99.99
Timers	100	100	99.96	99.98
Arming Baro	100	100	99.96	99.98
Fuzing Baro	100	100	99.87	99.94
Battery Box	100	100	99.96	99.98
Impact Subsystem	100	100	99.66	99.85
Contact Switches	100	100	[illegible]	99.93
Contact Switches	100	100	99.87	99.94
Contact Switches	100	100	99.96	99.98

PART II DIRECTOR AIRCRAFT

Subsystem and Component	Factory* Tests	Field** Tests	R&D*** Phase	Operational Phase****
Director Aircraft Guidance System		81.96	74.3	87.6
Terminal Guidance Control Subsystem		92.90	87.92	94.41
Synchronizer		98.01	96.89	98.60
Synchronizer Panel		100	99.87	99.94
Range Computer		99.76	97.52	98.89
Altitude Panel		99.88	99.89	99.95
Range Calibration Panel		100	99.73	99.88
Elevation Computer		99.88	99.19	99.64
Dive Panel		100	99.82	99.92
Computer Control		99.53	99.31	99.69
Junction Box No. 1		100	99.93	99.97
Power Supply		98.94	99.53	99.79
Voltage Regulator		99.76	99.00	99.55
Azimuth and Elevation Indicator		97.54	97.98	99.09
Monitor Unit		99.88	98.82	99.47
Junction Box No. 2		99.88	99.80	99.91

* Factory tests based on GAM Nos. 75 to 221.

** Field tests based on GAM Nos. 75 to 117 and corresponding Director Aircraft systems.

*** Established for airborne missions using GAM Nos. 75 to 101.

**** Established for airborne missions using GAM Nos. 122-134 and 201-222.

Notes (1) Included in these reliability calculations were failures caused by human errors, inadequate maintenance, and inadequate procedures, as well as by inherent unreliability of equipment.

(2) Contains system failures which could not be pinpointed to any one component.

APPENDIX D (cont)

PART II DIRECTOR AIRCRAFT

Subsystem and Component	Observed Reliability(1) (In Per Cent) Field** Tests	Airborne Reliability Goal (In Per Cent) R&D*** Phase	Operational Phase****
Relay Link Subsystem	92.36	91.82	96.26
Polycode Driver	98.63	98.69	99.41
Relay Receiver	97.69	97.20	98.74
Radio Frequency Head	99.88	99.31	99.69
Command Transmitter	97.05	98.73	99.43
Relay Antenna Control Panel	100	99.78	99.90
Relay Antenna and Mount	99.58	99.57	99.81
Relay Antenna Servo Amplifier	99.86	98.38	99.27
Power Supply	100	99.91	99.96
Automatic Checkout Subsystem	97.92	96.44	98.39
Check Assembly	98.81	98.51	99.33
Control Panel	100	99.87	99.94
Function Indicator Panel	99.85	99.84	99.93
Selector Assembly	99.25	98.21	99.19
Auxiliary Subsystem	97.55	95.49	97.96
GAM Control Panel	99.76	99.91	99.96
Light Control Panel	100	99.96	99.98
Power Control Panel	100	99.87	99.94
Checkout Panel No. 1	100	99.80	99.91
Checkout Panel No. 2	100	99.89	99.95
Checkout Panel No. 3	100	99.89	99.95
Junction Box No. 3	99.88	99.71	99.87
Directional Coupler	100	99.91	99.96
Baro Adjust Panel	100	99.98	99.99
Command Zero Panel	99.52	99.84	99.93
Capsule	99.54	99.08	99.59
Guidance Power Shield	99.55	99.44	99.75
Waveguide Switch	99.86	99.98	99.99
Blowers (Two)	100	99.96	99.98
Interconnecting Cabling	99.41	98.23	99.20
Director Aircraft Guidance System Misc.(2)	99.08	- -	- -
Director Aircraft Miscellaneous System	98.21	93.6	97.1
Missile Release Navigation Computer Subsystem	98.68	93.88	97.22
Missile Release Computer	99.73	98.44	99.30
Missile Release Computer Amplifier Unit	99.06	96.24	98.30
Launch Panel	100	99.82	99.92
Offset Panel	100	99.82	99.92
Power Supply (A-1)	100	99.53	99.79
Fuse Box	99.88	99.93	99.97
Hydraulic (GAM Associated) Subsystem	99.63	99.84	99.93
Electrical (GAM Associated) Subsystem	99.89	99.93	99.97

** Field tests based on GAM Nos. 75 to 117 and corresponding Director Aircraft systems.

*** Established for airborne missions using GAM Nos. 75 to 101.

**** Established for airborne missions using GAM Nos. 122-134 and 201-222.

Notes (1) Included in these reliability calculations were failures caused by human errors, inadequate maintenance, and inadequate procedures, as well as by inherent unreliability of equipment.

(2) Contains system failures which could not be pinpointed to any one component.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS CENTER (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

29 Dec 09

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Defense Technical Information Center
Attn: Ms. Kelly Akers (DTIC-R)
8725 John J. Kingman Rd, Suite 0944
Ft Belvoir VA 22060-6218

Dear Ms. Akers

This concerns the following Technical Report:

Technical Report number: AD308118
Technical Report Title: Quarterly Reliability Report
Technical Report Date: 1 May 1959
Previous classification/distribution code: UNCLAS

Subsequent to WPAFB FOIA Control Number 2009-02510, the above record has been cleared for public release.

The review was performed by the following Air Force organization: AFRL/RB and 88 ABW/IPI.

Therefore, the above record is now fully releasable to the public. Please let my point of contact know when the record is available to the public. Email: darrin.booher@wpafb.af.mil If you have any questions, my point of contact is Darrin Booher, phone DSN 787-2719.

Sincerely,

KAREN COOK
Freedom of Information Act Manager
Base Information Management Section
Knowledge Operations

3 Attachments
1. FOIA Request # 2009-02510
2. Citation & Cover sheets of Technical Report #AD308118
3. Copy of AFMC Form 559