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ABSTRACT

A summary of the R&D Flight Test performance of Bell Aircraft's Rascal (GAM-63A) air-to-surface missile, including the objectives and accomplishments, is presented in this report. The program was concerned primarily with the in-flight evaluation of the missile and the director aircraft, the basic purpose being to evaluate the design and performance of Weapon System 112A, and to demonstrate its performance and capabilities according to contractual requirements. By the completion of the program in October 1957, 62 missiles had been launched, and weapon system performance in terms of missile range, speed, and accuracy exceeded contractual requirements. Performance in terms of reliability showed improvement, although further development is needed.

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58R02-21098

I. INTRODUCTION

The Rascal Guided Aircraft Missile (GAM-63A), as well as other elements of Weapon System 112A, was designed and developed by the Bell Aircraft Corporation under cognizance of the Air Research and Development Command. This work was accomplished within the provisions of prime Contracts W33(038)-14169 and AF33(600)-31948. Flight testing of System 112A was conducted by Bell Aircraft at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico. Summarized in this report are the objectives and accomplishments of the Rascal flight test program from its inception in September 1951 until its completion in October of 1957.

Section I includes a brief history of the research and development program, a description of the operational configuration of System 112A, and an explanation of a typical Rascal mission. These data will provide the reader with an adequate insight into the Rascal program before reviewing the goals and results of the flight test effort.

Section II, the flight test summary, covers the entire Rascal R&D program separated for each group of missiles of similar configuration and miscellaneous supporting flight test programs. The flight test summary for each missile group includes a description of the missile and the director aircraft, the flight test objectives and plans, a discussion of the test results, and conclusions. Supporting programs include the flight testing of gravity bomb vehicles and the use of auxiliary piloted aircraft as simulated missiles and director aircraft.

The conclusions contained in Section III were fomulated from the results of the entire flight test program.

A. HISTORY OF SYSTEM 112A PROJECT

The Weapon System 112A (Rascal) Project, formerly referred to as Project MX-776, was initiated by the Air Materiel Command on 29 April 1946 as a study program for the conception of a subsonic air-to-surface missile. The study program was later amended to include a supersonic missile and eventually the subsonic missile phase was discontinued.

ILLUSTRATIONS

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SPACE FLIGHT AND MISSILES DIVISION

BY D. Zoeckler
D. ZOECKLER
FLIGHT TEST ANALYSIS
WEAPON SYSTEM REQUIREMENTS AND ANALYSIS
SPACE FLIGHT AND MISSILES DIVISION

CHECK: J. B. Friedenberg
J. B. FRIEDENBERG
ASS'T PROJECT ENGINEER
WEAPON SYSTEM REQUIREMENTS AND ANALYSIS
SPACE FLIGHT AND MISSILES DIVISION

APPROVED: R. C. Rogers
R. C. ROGERS
PROJECT ENGINEER
WEAPON SYSTEM REQUIREMENTS AND ANALYSIS
SPACE FLIGHT AND MISSILES DIVISION

APPROVED: R. A. Howland
R. A. HOWLAND
PROJECT ENGINEER - WS-112A
SPACE FLIGHT AND MISSILES DIVISION

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From the beginning of the program, it was apparent that development of the Rascal guidance system would be the most difficult task and thus would set the pace for development of the entire weapon system. Consequently, the program was expanded in the early stages to include the development of various items of guidance equipment and the flight testing of existing radars for adaptability to the Rascal weapon. In January of 1948, the project was divided into two concurrent efforts: the X-9 Shrike Test Vehicle Program, and the GAM-63A Rascal Guidance System Development Program.

The Shrike missile was a liquid-rocket-powered supersonic test vehicle (small-scale version of Rascal) with a 50-mile range and capable of carrying a 1000-pound warhead. On 17 May 1950, the first powered Shrike missile was launched successfully from a modified B-50 director aircraft. In January 1953, the Shrike program, which included the flight testing of 28 powered missiles, was successfully completed.

Meanwhile, in the Spring of 1950, the Air Force authorized Bell Aircraft to proceed with detail design and fabrication of Rascal missiles.

The first powered flight of Rascal (XGAM-63 No. 0307B*) took place at the Air Force Missile Development Center on 30 September 1952 with satisfactory results. This flight test had been preceded by two glide tests of unpowered missiles (Model A) during 1951. By the end of 1953, four Model B missiles (with high-pressure propulsion systems) had been launched successfully. In January 1954, the last of these missiles was flight-tested.

During the remainder of 1954, the capabilities of the Rascal Weapon System were demonstrated with the flight testing of 14 Model B missiles containing low-pressure propulsion systems. Capabilities were demonstrated in search radar and microwave link operation, propulsion system performance and control, missile performance at high altitudes, and remote control of the missile during the terminal guidance phase. Pinpoint accuracy was demonstrated by missile 1626B which, under full guidance control, scored the first target bull's-eye of the flight test program.

---

*The first two digits of the missile number indicate firing order; the last two digits indicate USAF airframe delivery number; the letter designates the model. Thus, 0307B is the 3rd missile to be launched, the 7th airframe delivered to the USAF, and is a B-series missile.

In the first quarter of 1955, six Model D missiles were launched. Two missiles scored satisfactory target hits.

Up to the this point, the DB-50 was used exclusively to launch and to direct the Rascal missile. After completion of the D-series missile program, the DB-50 was no longer used as a director aircraft.

The first operational prototype of the Model F Rascal, missile 2849F, was launched on 5 May 1955 from a DB-36 director aircraft. The first missile launched from a DB-47 director aircraft was missile 3054F on 14 July 1955.

Late in 1955, after nine unsatisfactory flight tests of Model F missiles, the program was reoriented to emphasize reliability. A comprehensive test program was established to determine the components which required improvement to provide an over-all increase in operational reliability. Repetitive acceptance and life tests, hot ground firings, and captive flight tests provided a measure of attained reliability. Missile 4075F, launched on 11 June 1956, was the first Model F Rascal to be flown after ground and captive testing under the revised concepts.

Between 1 January 1956 and 31 October 1957, 26 R&D missiles were launched. This part of the flight test program was highlighted by four successive missiles impacting within the desired target area during September and October 1957. The flight testing of missile 6296F on 31 October 1957 concluded the research and development phase of the GAM-63A flight test program.

During the second quarter of 1957, the successful launching of three Gravity Bomb Test Vehicles comprised another phase of the flight test program. These tests were made to evaluate the flight characteristics of a free-falling missile and thus to establish a gravity bomb capability for the weapon system.

Prior to and concurrent with the Rascal flight test program, many airborne tests were conducted with simulated missile/director aircraft teams. Various aircraft combinations were used primarily to evaluate missile and director aircraft guidance system operation. From 1946 through 1950, two B-17's and a B-25 were used extensively in this program. In 1950, tests were begun with an F-80/B-17 combination modified to simulate the Rascal and its director aircraft. An F-89 replaced the F-80 in June of 1954. The F-89 missile simulator was also tested in conjunction with DB-36 director aircraft during 1956 and 1957.

The R&D flight test program at the AFMDC, from the arrival of the first Shrike on 13 April 1950 to the launching of the final R&D Rascal on 31 October 1957, was completed with

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a perfect flying safety record. During this time, field flight operations used a total of 14 support airplanes. Five B-50's, two B-36's, and three DB-47's were used as director aircraft; two F-80's and one F-89 as simulated missiles; and one B-17 as a simulated director airplane. More than 1500 missions were flown in these airplanes to accumulate approximately 4000 hours of flying time. Air Force and Army support aircraft included L-19 liaison airplanes and helicopters; F-80, F-89, and F-94 fighters; and B-47 bombers. These aircraft, used for recovery and as chase aircraft, flew approximately 600 missions, accumulating more than 1400 flying hours.

B. DESCRIPTION OF SYSTEM 112A

The Rascal Weapon System comprises four major elements: GAM-63A missiles, DB-47 director aircraft, ground support equipment, and training aids. The flight test program was concerned primarily with the in-flight evaluation of the GAM-63A and the director aircraft. These elements of the weapon are described in the following paragraphs.

1. GAM-63A MISSILE

The GAM-63A missile consists of five major systems. These are the airframe, the propulsion, the guidance, the servo-control, and the warhead and fuzing systems. During the R&D phase of the Rascal program, an instrumentation system was also an essential part of the missile configuration.

a. Airframe

The GAM-63A missile (shown in Figure 1) has an over-all length of 32 feet, a maximum body diameter of 4 feet, and a gross weight of approximately 18,500 pounds. Structurally, the airframe consists of five sections: the radome, forward body, warhead section, center or tank section, and aft body.

The radome, a fiberglass-reinforced plastic ogive, encloses the search radar antenna and is attached to the forward body by a splice ring. The forward body section includes the rudders, forward wing and elevators, and houses electronic and mechanical units of the guidance and servo-control systems. Two large structural doors provide access to the upper compartment of the forward body. The lower compartment is accessible by removing the lower door of the warhead section.

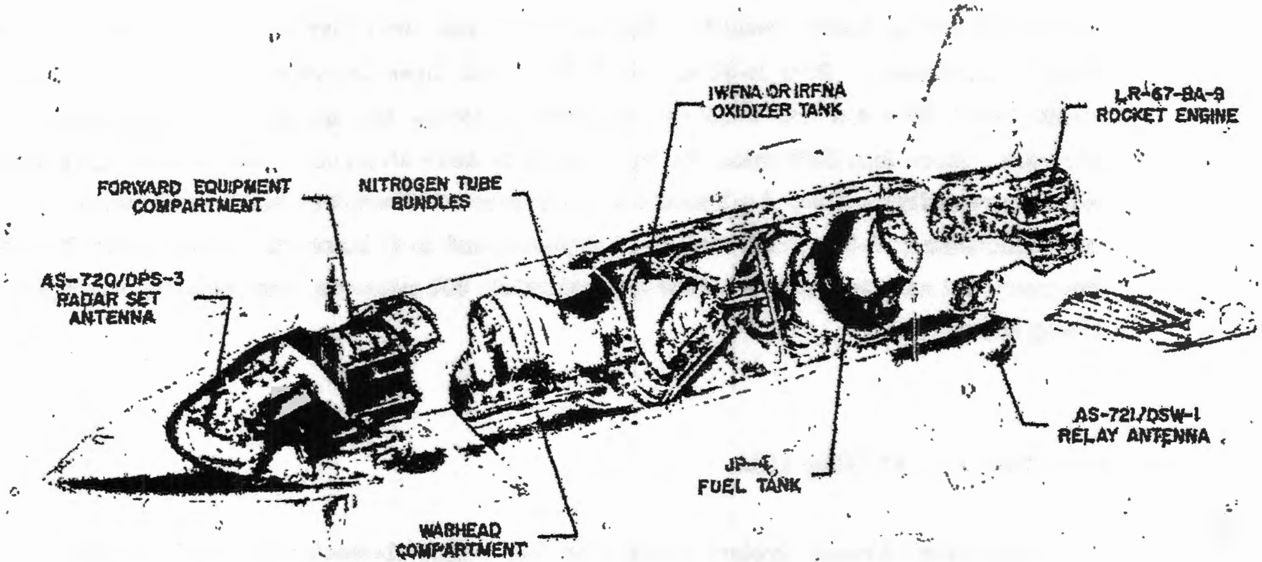

Figure 1. GAM-63A Missile

The warhead section consists of a fixed upper half-shell, and a removable structural lower door to facilitate installation of the warhead. In addition to the warhead and fuzing components, this section contains a series of stainless steel tubes that are curved to fit the inside contour of the body shell. These tube bundles store high-pressure nitrogen gas used for pressurizing the propellant tanks. A small access door, located on the right-hand side of the missile, permits installation of warhead batteries while the missile is mated to the DB-47.

The center body section is a ring-stiffened cylindrical shell of aluminum alloy with integral oxidizer and fuel tanks compartmented to maintain center-of-gravity control. Additional tube bundles for storage of nitrogen gas are located between the tanks. Nonstructural tunnels running fore and aft on top and bottom of the body enclose electrical cordages, and propellant, nitrogen, and hydraulic lines.

The aft body section includes the vertical and horizontal tail surfaces and ailerons, guidance and hydraulic equipment compartment, rocket engine, and a removable aft cowling. The rocket engine is mounted on a truss attached to, and supported by, the carry-through structure of the aft horizontal wing. The relay antenna is mounted on the lower vertical fin.

Launching provisions consist of three forged steel fittings used to attach the GAM-63A to the director aircraft by means of standard bomb shackles. One fitting is located at the forward end of the warhead section and the other two are located in the center body between the propellant tanks.

b. Propulsion System

The GAM-63A is powered by a liquid-propellant rocket propulsion system incorporating a turbine pump unit. Thrust is provided by three identical chambers that together develop 12,000 pounds thrust at an altitude of 40,000 feet. The liquid propellants, inhibited red fuming nitric acid oxidizer and JP-4 fuel, are pumped to the thrust chambers by the gas-driven turbine pump. The turbine, which incorporates a gas generator that operates on the engine propellants, develops sufficient power to drive a hydraulic pump and an alternator in addition to the propellant pumps. The turbine pump may be operated independently of the thrust chambers by passing the pumped propellants back to the tanks. Thus, the turbine continues to furnish electric and hydraulic power for the missile during the periods when thrust chamber operation is not required. A two-stage nitrogen gas regulator reduces high-pressure nitrogen to operating pressures for regulator valves, actuating valves, and propellant tank pressurization.

c. Guidance System

The Rascal guidance scheme consists of two basic units: an inertial range computing system (IRCS) and a radar guidance system. The IRCS, in conjunction with the servo-control system, provides inertial guidance of the missile to the point of terminal dive. The radar guidance system enables the guidance operator in the director aircraft to view the position of the target relative to the missile and to send missile flight corrections as necessary to hit the target.

In a typical mission (see Figure 2), the DB-47 carrying the GAM-63A is navigated to the launch area by means of the MA-8 bombing-navigation system. Immediately before launch, director aircraft velocity and range-to-target data are supplied to the IRCS of the missile. The GAM-63A is automatically launched following the orientation of the directional gyro along the proper heading. The IRCS measures range in a horizontal plane in the direction of the longitudinal axis of the missile. During the midcourse phase, the autopilot maintains control in azimuth and altitude and the IRCS computes range to go to the target. At a preset range-to-go, the dive signal is automatically initiated by the IRCS and the missile dives toward the target at a nominal 35° angle from the horizontal.

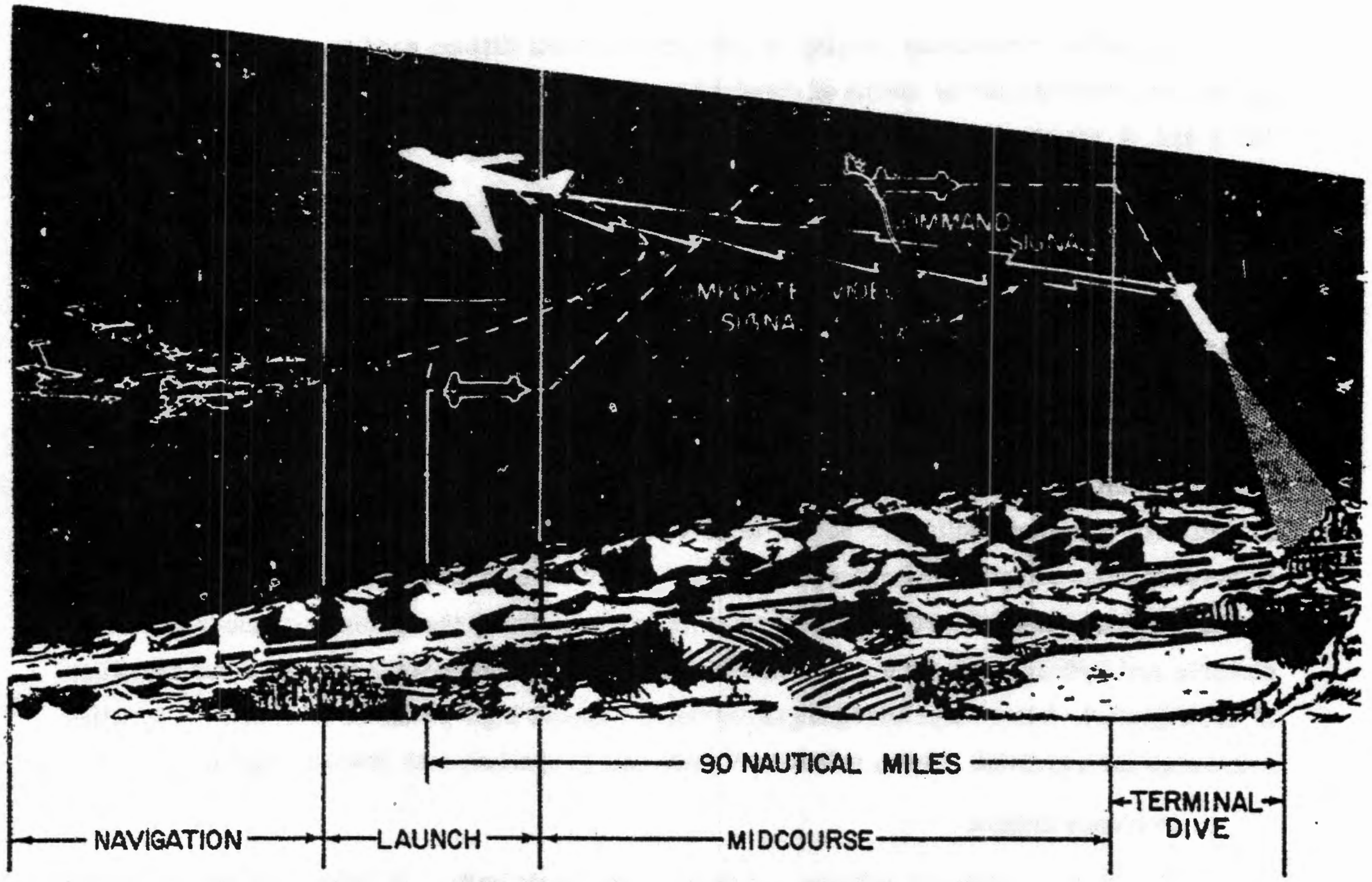

Figure 2. System 112A Guidance Scheme

The dive signal energizes the radar system and the target area is scanned by an unattended X-band search radar in the nose of the missile. Radar video of the target area is transmitted to the director aircraft by means of an X-band relay link. The guidance operator accomplishes guidance by means of a tracking stick that positions range and azimuth cursors over the target video return on a radar scope. Displacement of the tracking stick by the operator determines the magnitude of the command signals that are automatically computed, coded, and transmitted to the missile. As the missile approaches the target, expansion of the target video enables the operator to send command signals with increasing accuracy. Security of the relay and command link is provided by directional antennas, coded signals, and the use of different frequencies in opposite directions. Once the relay link is established during the midcourse phase, a command can be transmitted to energize the search radar set. Thus, the guidance operator can observe the progress of the missile prior to terminal dive. It is then possible to override the autopilot control and to change the missile direction in azimuth or initiate the dive, if desirable, prior to the IRCS dive signal.

d. Servo-Control System

The primary function of the servo-control system is to stabilize and control the missile during its flight to the target. Pitch, roll, and yaw attitude are independently stabilized to gyroscopic references. Separate aerodynamic control surfaces for each degree-of-freedom are positioned by hydraulic actuators. Hydraulic power is provided by a pump mounted directly on a power take-off pad of the turbine pump unit in the propulsion system.

After launch, a barometric altitude controller programs the missile into a climb to a preset level flight cruise altitude. Upon receipt of a command from the IRCS, the missile is placed in a 35° dive to the target. During the dive, pitch and yaw command signals can be sent to direct the missile to the target.

e. Warhead and Fuzing Systems

The GAM-63A is designed to accommodate a 2800-pound special warhead mounted on a removable structural door that is located in the lower portion of the warhead section just aft of the forward wing.

The fuzing system that arms and detonates the warhead consists of batteries, a lanyard switch, arming and firing baroswitches, a low-voltage arm-safe switch, and a network of impact fuzes. This system provides for either altitude detonation initiated by closure of a barometric switch, or ground detonation by self-powered impact fuzes. Safety is provided by several protective elements in series, while reliability is provided by the use of redundant circuits. A standard T-249 control panel in the DB-47 enables the guidance operator to select the burst mode during the prelaunch phase, as well as to perform the required arming functions. A warning light on the panel provides a means of warhead monitoring.

f. Instrumentation

The basic telemetering system utilized during R&D flight testing was an FM/FM telemetering system. During the flight testing of the Model B and D missiles and through the first half of the F-series flight tests, the number of telemetering channels was varied between six and twenty. By commutating as many as four of the channels, data transmission totaling 94 functions was obtained. Typical instrumentation included accelerometers, angle of attack and sideslip angle vanes, pressure pickups, rate gyros, position potentiometers, a-c and d-c voltage units, vibration and temperature pickups, flowmeters, and strain gages. Power for operating the telemetering package was supplied by batteries or from missile power sources.

In later Model F missiles (No. 4684F and subsequent), the telemetering system utilized four subcarrier channels, three of which were continuous and one commutated. This system operated on a regulated power supply with input from the 467-cps 115-volt source of the missile.

For R&D flight testing, an S-band and an L-band radar beacon were installed in the missile. Each beacon received and retransmitted radio frequency pulses within a specific frequency range and pulse repetition rate. They were used to facilitate tracking by the ground-based radar used as part of the range instrumentation. The S-band beacon was normally powered by a 28-volt battery in the GAM-63A, while the L-band beacon used 115-volt ac from the missile alternator. In addition to facilitating tracking, both beacons were designed to trigger the missile destruct system when the PRF of the tracking radar was changed to 854 cps if flight termination was required for range safety.

The destruction system was also a part of the instrumentation systems providing a means of terminating missile flight upon the decision of the range safety officer. When a destruct command is transmitted to the S-band or the L-band beacon, the destructor system is activated. Activation of this system ignites two primer charges thus detonating a boost charge which, in turn, ignites a ring of explosive primacord located beneath the missile skin at the aft end of the tank section. The explosion severs the missile at this point and the missile sections fall to the ground. The system incorporates safety devices which preclude the possibility of destructing the missile until approximately 16 seconds after launch.

2. DB-47 DIRECTOR AIRCRAFT

The director aircraft are modified B-47 strategic bombardment airplanes, redesignated as DB-47. Their primary mission is to carry the GAM-63A missile to an area approximately 90 nautical miles from the target and to provide for its proper launching and guidance after launch. In addition to an MA-8 bombing-navigational system, director aircraft are equipped with (1) automatic equipment to check the GAM-63A before launch and to release the missile automatically; (2) a relay link system to establish and maintain microwave contact with the missile; (3) a guidance system, with a control station, that permits a guidance operator to monitor the flight path of the missile relative to the target and, if necessary, to initiate course corrections during the midcourse and terminal dive phases of flight.

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C. TYPICAL RASCAL MISSION

The mission of the Rascal Weapon System is to destroy strategic targets without exposing the director aircraft to local target defenses. This mission is accomplished by combining a high-performance DB-47 with a supersonic GAM-63A missile.

Weapon system requirements were established to accomplish the basic mission. These requirements were based upon the following mode of operation. The DB-47 carrying a fully located GAM-63A is navigated to a prescribed launch area. During the flight, performance of components in the DB-47 and GAM-63A are monitored and checked. When within 50 nautical miles of the launch aimpoint, corrected ground velocity and range-to-target data from the MA-8 system is fed to the missile.

After final checkout of the missile is accomplished by the automatic checkout system, the turbine is automatically fired. When the DB-47 achieves the desired heading, the directional gyro in the missile is uncaged to establish the proper heading reference and the missile is launched. Separation occurs at an altitude of about 35,000 feet MSL and at Mach 0.75. The range to target at launch is 70 to 90 nautical miles based upon zero wind and an NACA standard atmosphere. Within 3 seconds after launch, full rocket engine thrust is attained and the programmed climb begins to the level flight altitude of 65,000 feet. The autopilot maintains stabilized flight along the predetermined flight path. Full-thrust duration is timed and the propulsion system is transitioned into bypass operation. When the desired range to target is attained, the IRCS initiates dive which in turn activates the emanating guidance system. During the dive, the guidance operator can make corrections to the missile flight path. The missile intersects the horizontal target plane within a CEP* of 1500 feet from the intended target. The vertical accuracy of the fuzing system has a standard deviation** of not greater than ±405 feet. Missile speed is supersonic during the dive phase down to at least an altitude of 5000 feet MSL.

After the missile is launched, the director aircraft executes a procedural turn to a predetermined heading and maintains this heading until the relay link is established with the missile. After the link is established, DB-47 maneuvers can be performed within vision-angle limits of the DB-47 relay antenna.

*CIRCULAR PROBABLE ERROR: The limiting value, as the number of flights becomes greater, of the radius of a right circular cylinder whose axis is a vertical line through the target and within which 50% of the detonations occur.

**VERTICAL STANDARD DEVIATION: The limiting value, as the number of flights becomes greater, of the root-mean-squared distance between the actual and intended detonation altitude.

II. FLIGHT TEST PROGRAM

The Rascal flight test program was conducted between September 1951 and October 1957. In keeping with the dual mission of "test vehicle" and "tactical weapon", the Rascal flight test program was set up to provide an evaluation of the various missile systems and to develop launching and ground handling techniques peculiar to an air-to-surface weapon system of this size. Flight testing began with the evaluation of a simple glide test vehicle and continued through the evolution of the operational weapon system which demonstrated capabilities and met established requirements. A total of 65 missiles were expended in the flight test program, including three missiles used to demonstrate the gravity bomb capability.

The test program was segregated into test phases based upon missile model designations: Models A, B, D, and F. The Model A Rascal flight test consisted of glide tests of the basic airframe. The Model B missiles were separated into two configurations. The first five missiles utilized a high-pressure thrust chamber feed system. All remaining missiles incorporated the low-pressure turbine-fed propulsion system. Elements of the propulsion, servo-control, guidance, and warhead systems were flight-tested during the Model B tests. The Model D missiles were essentially the same configuration with minor system modifications. Emphasis was placed on the guidance aspect during this phase of flight test. The Model F missiles were essentially prototype operational missiles. The DB-47 and DB-36 aircraft were utilized as director aircraft replacing the DB-50 used on the Model A, B, and D tests. The inertial range-computing system was installed and several missiles contained inert warheads. The Model F missiles are treated in two groups: those flown before the reoriented .ability program (Nos. 3247 through 3964) and those flown after the reorientation (Nos. 4075 through 61101).

The detailed review of the flight test program which follows treats separately the six groups of missiles: (1) Model A, (2) Model B, high-pressure, (3) Model B, low-pressure, (4) Model D, (5) Early Model F, and (6) Later Model F.

Concurrent with the flight testing of Model F missiles, three modified airframes were utilized to evaluate a gravity bomb capability which could be used operationally. Results of this program are discussed separately.

Throughout the Rascal design and development, various aircraft were used primarily to aid in the development and evaluation of Rascal guidance equipment. These aircraft, simulating director aircraft and recoverable missiles, provided significant guidance performance data in support of the missile flight test program. A review of these programs is also included.

A. FLIGHT TEST CONCEPT

The basic purpose of the flight test program was to evaluate the design and performance of the Rascal Weapon System and to demonstrate its performance and capability in accordance with contractual requirements. This was to be accomplished by evaluating system performance under flight conditions and, finally, by attaining a satisfactory operational flight path with a prototype weapon system. In addition, flight testing furnished a means of establishing environmental limitations, launching techniques, accuracy, and reliability.

Aerodynamic data were required early in the program to establish satisfactory operation of the servo-control system and adequacy of the airframe. The first two Model A missiles were unpowered glide vehicles dropped to evaluate separation from the launch gear, to test the recovery system, and to obtain aerodynamic data. Flight testing of the high-pressure Model B missiles was concerned basically with aerodynamic and servo-control performance under dynamic conditions. The missile attitude was programmed to provide dynamic flight conditions. An interim high-pressure propulsion system was utilized so that aerodynamic and servo-control testing could begin while the low-pressure power plant was undergoing acceptance-testing. The guidance system was also flight tested for the first time.

The next step was to add the originally planned low-pressure propulsion system. Flight tests of the low-pressure Model B missiles were mainly concerned with obtaining aerodynamic data and evaluation of the propulsion and servo systems. Guidance tests were conducted during this phase and guidance evaluation was a major objective during the Model D flight tests. These early flights were of limited range, speed, and altitude. However, since the tests were for system evaluation, the limitations were of minor concern.

With the advent of the Model F Rascal, flight testing emphasized the accuracy of guidance and fuzing and evaluation of the warhead installation. The Model F missiles were essentially the operational configuration and launching from a DB-47 permitted the achievement of performance levels necessary to accomplish the required flight profile. These missiles were used to demonstrate guidance and fuzing accuracy, range, and warhead installation, thereby completing the flight test phase of the Rascal R&D program.

B. MODEL A MISSILES

Model A missiles were simple glide test vehicles launched in the latter half of 1951. The group consisted of two missiles, Nos. 0104A and 0205A, containing only destruction, recovery, and instrumentation systems. These Rascals were used to evaluate missile launch and performance prior to powered flight; all test objectives were accomplished successfully.

The following paragraphs discuss the Model A flight test vehicle and the test objectives. Table I summarizes the test results in terms of configuration, objectives, and results. A discussion of the test phase is then presented with conclusions based upon the test results.

TABLE I SUMMARY OF RASCAL FLIGHT TESTS — MODEL A GLIDE MISSILES

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	Remarks
0104A	DB-50	9-27-51	a, b, j	0	■	■	■	▨	■	Satisfactory test; recovery partly effective.
0205A	DB-50	12-18-51	a, b, j	0	▩	■	■	▩	■	Satisfactory test; recovery partly effective; 4-point release did not function properly.

SYSTEMS INSTALLED

a. Recovery
b. Destruction
c. Propulsion system (high-pressure)
d. Servo control
e. Relay-command guidance system (two operators)
f. Inertial guidance
g. Flight programmer
h. Inert warhead
j. Telemetry instrumentation (battery-powered)
k. Propulsion system (low-pressure) vendor turbine pump
l. Relay-command guidance system (one operator)
m. Telemetry instrumentation (missile generator-powered)
n. Propulsion system (low-pressure) Bell Aircraft turbine pump

■ Accomplished
▨ Not accomplished
▩ Partly accomplished
☐ No chance

OBJECTIVES

1. Test the missile launch gear.
2. Obtain aerodynamic data.
3. Test the destruct system.
4. Test the recovery system.
5. Evaluate instrumentation.

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems or Rascal Weapon System equipment installed in the director aircraft.

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1. CONFIGURATION

The carrier airplane for Model A missiles was a modified B-50 equipped with a four-point-suspension missile release system. Equipment for checking out missile components prior to launch was installed in the waist compartment of the B-50.

Configuration details of Model A missiles were quite simple. Each missile contained a destruction system controlled by a barometric switch. At a preset altitude, blasting caps ignited a ring of explosive primacord which separated the missile into two sections. On missiles 0205A through 2535D, an additional explosive ring separated the tank section from the aft body section. The second ring was added to induce instability in the aft section and thus enhance deployment of the aft recovery chute. A recovery system, using a 5-10-100 foot parachute arrangement, was used to recover the forward and aft missile sections. This system was being evaluated as a means of recovering missile hardware, in cases of missile failure, for purposes of analysis. In missile 0205A, provisions were added so that destruction could be accomplished at the discretion of the range safety officer by means of a command received in the missile radar beacon. Telemetry consisted of a simple 217.55-mc FM/FM system with five continuous channels and one commutated channel. To ensure missile stability during the glide tests, the airframes were ballasted with concrete (0104A) or water (0205A) for weight control and center-of-gravity location.

2. OBJECTIVES

The basic objectives included verification of aerodynamic data obtained from wind tunnel testing, evaluation of the destruction and recovery systems, evaluation of separation characteristics of the missile emergency release system, and evaluation of the telemetering system.

3. TEST PHASE

The Model A flights were characterized by launching the missiles from the modified B-50 at 30,000 feet MSL, followed by a planned missile glide to approximately 18,000 feet where the destructor system was activated. Missile speed increased during flight from Mach 0.45 (initial) to 0.87 (break-up); range from launch to break-up was approximately 2.0 nautical miles.

Ballasting the missiles for static stability proved successful; a near-zero lift trajectory was obtained. The qualitative aerodynamic data from these flights, in conjunction with the wind tunnel test results, indicated that missile drag and stability parameters were satisfactory. Basic pressure measurements were obtained and various coefficients were determined from the telemetered data. The coefficient of drag obtained along the missile axis provided the first information for compilation of drag data.

The destruction system worked successfully in both cases and the break-up between the two sections was clean and effective. On 0205A, the aft secondary ring of expolsive primacord detonated but failed to sever completely the skin of the missile between the propellant tanks and the aft body.

The recovery system was only partly effective. On missile 0104A, the forward and aft sections were not recovered because the parachutes failed to deploy as planned. On missile 0205A, the forward section was recovered successfully, but the aft section parachutes failed to deploy. Both flights resulted in the loss of, or damage to, the 5-foot parachute.

A third glide missile (06A) was scheduled to be launched at the AFMDC during this test phase. However, this missile was accidently dropped from the B-50 over New York State while conducting a captive flight test. As a result of this accident, the launch gear was modified before launching missiles 0104A and 0205A. The four-point-suspension release system was effective in launching 0104A with a clean flat drop from the B-50. On 0205A, the left side of the launch gear failed to release immediately. This caused the right side of the missile to drop, imparting a rolling motion to the missile.

Telemetry functioned successfully on both flights. The units transmitted continuous signals from X-90 seconds to impact. Noise interference was considered to be well within the desired limitations.

4. CONCLUSIONS

The Model A missiles provided the first complete information for study of the subsonic performance and stability of the Rascal missiles. Aerodynamic data essentially substantiated predicted performance.

While the destruction system was adequate, the recovery system was unsatisfactory. Flight data anlysis resulted in adding a simplified recovery system in subsequent missiles.

The first flight evaluation of the missile emergency release system with four-point suspension did not meet the required reliability of a safe release system. The mechanical support hardware was modified to assure proper release capabilities for the powered vehicles.

The Model A missiles accomplished the intended objectives and provided information and assurance required for launching "hot" missiles.

C. MODEL B MISSILES WITH HIGH-PRESSURE FUEL-FEED SYSTEMS

Five Model B missiles, incorporating the high-pressure propulsion system, were flight-tested between September 1952 and January 1954. The high-pressure propulsion system was substituted for the low-pressure turbine-pump-fed propulsion system because of considerable difficulty in obtaining delivery of satisfactory vendor-supplied turbine pumps. Substitution of the high-pressure propulsion system provided a rocket-powered vehicle with similar thrust characteristics so that flight testing of other missile systems could be accomplished without delaying the program. Originally, only three missiles were to be flight-tested during this phase (Nos. 0307B, 0409B, and 0510B); primary objective was to provide data for aerodynamic and servo-control evaluation. However, two missiles were added to the program (Nos. 0615B and 0713B) to test emanating guidance equipment, while completing the acceptance-testing of the low-pressure propulsion system. The aerodynamic and servo-control evaluation flights provided flight performance data, but guidance evaluation was limited on the last two flights because of servo-control malfunctions.

The following paragraphs describe these five Model B flight test vehicles and the test objectives. Table II summarizes the flight tests in terms of configuration, objectives, and results. A discussion of the test phase is then presented with conclusions based upon the test results.

1. CONFIGURATION

The DB-50 served as the director aircraft throughout these Model B missile tests. Configuration of the DB-50 was modified by incorporating elements of the dual-operator guidance system including midcourse guidance, terminal guidance, and relay and command components. A four-point-suspension (zero-rail) launch technique was used during these flight tests.

The Rascal missile for the first three of the five flight tests consisted of the basic airframe with the high-pressure propulsion system, the three-axis servo-control system, and the destruction and recovery systems. Telemetering instrumentation was also installed to obtain performance data.

The high-pressure propulsion system was a deviation from the low-pressure system originally planned. With the high-pressure system, the propellant tanks were pressurized with regulated nitrogen gas from the 6000-psi source. This pressure was sufficient for supplying propellants at the required feed pressures, to the three thrust chambers. The high-pressure system provided the desired thrust level, but over a shortened time interval.

TABLE II

SUMMARY OF RASCAL FLIGHT TESTS — MODEL B MISSILES WITH HIGH-PRESSURE PROPULSION SYSTEMS

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	6	7	8	Remarks
0307B	DB-50	9-30-52	a,b,c,d,j	0	■	■	■	■	■	■			Satisfactory test.
0409B	DB-50	1-15-53	a,b,c,d,g,j	0	■		▨	■	■	■			Satisfactory test.
0510B	DB-50	3-13-53	a,b,c,d,g,j	1	■	■	■		■	■			Satisfactory test.
0615B	DB-50	10-5-53	a,b,c,d,e,g,j	2	■			■	■	▩	▩	□	Servo-control failure shortly after dive entry.
0713B	DB-50	1-12-54	a,b,c,d,e,g,j	2	■			■	▩	▩	□	□	Servo-control failure shortly after launch.

■ Accomplished
▨ Not accomplished
▩ Partly accomplished
□ No chance

SYSTEMS INSTALLED

a. Recovery
b. Destruction
c. Propulsion system (high pressure)
d. Servo-control
e. Relay-command guidance system (two operators)
f. Inertial guidance
g. Flight programmer
h. Inert warhead
j. Telemetry instrumentation (battery-powered)
k. Propulsion system (low pressure) vendor turbine pump
l. Relay-command guidance system (one operator)
m. Telemetry instrumentation (missile generator-powered)
n. Propulsion system (low-pressure) Bell Aircraft turbine pump

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems or Rascal Weapon System equipment installed in the director aircraft.

OBJECTIVES

1. Demonstrate satisfactory prelaunch procedures and separation of missile from the director airplane.
2. Obtain aerodynamic data.
3. Obtain successful recovery of the forward equipment section.
4. Obtain environmental, vibration, and temperature data.
5. Obtain satisfactory operation of the pressurized propulsion system.
6. Test operation of the servo-control system.
7. Test midcourse guidance.
8. Test terminal guidance.

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The thrust chamber assemblies were the same as those used in the low-pressure system. Considering the purposes of the modified program, any undesirable aspects such as shorter range, additional weight, and the use of batteries for deriving electrical and hydraulic power were considered negligible.

The servo-control system was to be tested by programmed maneuvers during the flight testing of Nos. 0409B and 0510B. Pitch programming was incorporated in one missile and both pitch and yaw programming in the other. These programmers provided a series of brief step-function commands to the pitch and yaw systems of the autopilot, thereby providing a means of evaluating performance and response under dynamic conditions.

The recovery system was modified to provide for recovery of the forward equipment section only; the aft recovery parachute compartment was utilized for additional tube bundles for the storage of nitrogen gas. However, the destruction system was the same as that in missile 0205A.

The configuration of missiles 0615B and 0713B differed somewhat from the first three Model B missiles. In addition to the high-pressure propulsion system, the three-axis stabilization system, and the modified recovery system, these two missiles carried a radar guidance system. A pitch-attitude programmer was used to achieve the desired flight path and the aneroid switch in the destruction system was disconnected to allow flight to impact. The capability for beacon destruction of the missile was maintained for range safety.

The dual-operator guidance system utilized on the two guidance evaluation flights functioned in the following manner: After launch, the search radar of the DB-50 tracked a radar beacon in the missile and fed this information to a midcourse computer in the DB-50 which determined the position of the Rascal missile relative to a target. The midcourse guidance operator transmitted azimuth corrections to the missile through a microwave relay link. In this manner, the missile was guided to the dive point at a predetermined distance from the target. The search radar of the missile was energized at launch and a video return signal was received in the director aircraft. This return was displayed on an azimuth tracking indicator and a dive-angle tracking indicator. The dive was initiated remotely by the terminal dive operator or as programmed by the range computer in the missile. During the dive phase, a guidance operator at each indicator tracked the missile's course and ininitiated pitch and azimuth corrections as required to hit the target.

2. OBJECTIVES

The flight test objectives were similar for the first three Model B missiles. Objectives common to all three were (1) to demonstrate satisfactory prelaunch procedures and separation of the missile from the director aircraft, (2) to obtain satisfactory operation of the high-pressure propulsion system, (3) to obtain aerodynamic and servo-control performance data, and (4) to recover the forward equipment section of the missile. Secondary objectives differed from missile to missile depending upon the nature of the flight and the special instrumentation installed. In all cases, vibration data and additional aerodynamic data were obtained.

For the two missiles containing emanating guidance (Nos. 0615B and 0713B), the flight test objectives emphasized evaluation of the different phases of guidance control, in addition to the four objectives mentioned in the preceding paragraph. Guidance systems in both the missile and the director aircraft were to be tested. During the dive phase, operation of the terminal guidance equipment was to be tested, as well as missile response to transmitted commands. Guidance, servo, and telemetering systems were instrumented to obtain internal temperature data as a secondary objective.

3. TEST PHASE

Flight profiles for the five missiles were varied according to the missile configuration and the test objectives. The missiles were launched from a DB-50 director aircraft at an altitude of 30,000 feet MSL and at Mach 0.42. Flight range was 20 to 30 nautical miles. A prescribed missile flight altitude was reached by programming the pitch angle. Maximum speed between Mach 1.4 and 1.7 was to be attained. The first three tests were to be terminated in flight by actuation of the destruction system at the planned altitude. The last two missiles were to impact on the target and were controlled by the two guidance operators in the DB-50 following the dive maneuver. The midcourse guidance operator was to track the missiles, but no commands were to be sent prior to dive. The director was to track the missiles, but no commands were to be sent prior to dive. The director aircraft was to continue on the release heading for 10 seconds after launch and then to turn upwind at 2° per second until a 50° turn was completed. The new heading was to be maintained until the end of the missile flight.

The first three flights were accomplished with satisfactory results. The first powered flight of a Rascal missile, No. 0307B, was conducted on 30 September 1952. All three missiles were launched cleanly and the flight paths were essentially as planned. The high-pressure

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propulsion system maintained the desired thrust level; the servo-control system maintained stability; and the destruction and recovery systems operated satisfactorily on two of the three flights. Except for the one failure in the recovery system, all test objectives were achieved.

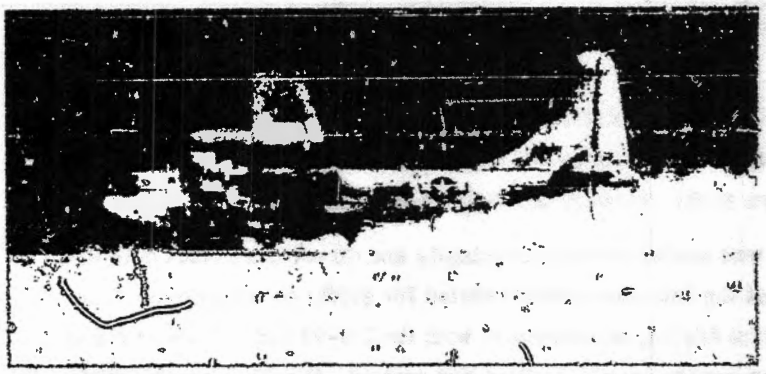
Considerable preflight testing was performed on the missile and director aircraft combination before the launch attempts of the two missiles scheduled for guidance evaluation. Since these were the first guidance control flights, equipment in both the DB-50 and the missile was functionally checked and adjusted to ensure proper contact and control. Nineteen captive flight tests were flown with missile 0713B and the DB-50 to complete this checkout and to establish operating procedures.

Owing to missile instability during the flight testing of the last two missiles with the high-pressure propulsion system, there was no opportunity to demonstrate the effectiveness of guidance control. Missile 0615B became unstable shortly after dive entry; missile 0713B became unstable shortly after launch. The directional gyro in 0615B was misoriented 90° causing severe cross-coupling effects during dive. In the case of 0713B, the directional gyro tumbled. As a result of these discrepancies, an improved directional gyro unit was incorporated in subsequent missiles. The last flight test (0713B) employing the high-pressure propulsion system occurred on 12 January 1954.

Test objectives of these two guidance evaluation flights were only partly accomplished. Satisfactory launch and missile separation from the DB-50 were demonstrated during both missions. The high-pressure propulsion system functioned properly and three-axis stabilization was maintained prior to the malfunctions. Guidance equipment testing was limited to the prelaunch and midcourse phases.

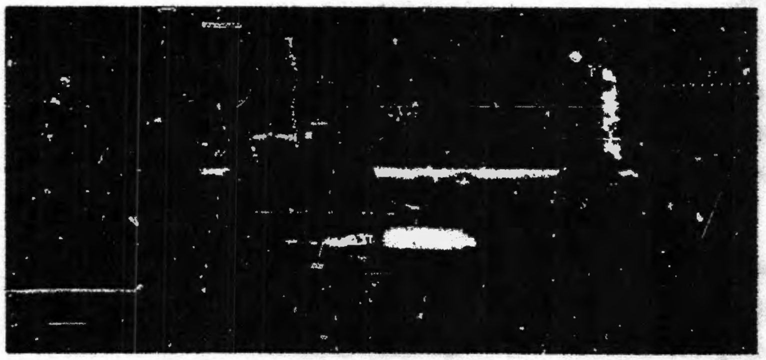
Of some significance is the number of attempts to achieve the launch of the five missiles containing the high-pressure propulsion system. Although the first two missiles were launched on the initial attempt, a total of eight attempts were necessary to achieve the successful launching of the three remaining missiles. Three of the five aborted flight tests were due to problems in the guidance system and two were due to propulsion system malfunctions.

Figure 3 illustrates the zero-rail launch technique used during this phase of flight testing. The figure shows the acid vapor trail from the thrust chambers upon receipt of the rocket-fire signal, ignition of the Boost No. 2 and cruise thrust chambers, and complete ignition of all three thrust chambers.



Acid Vapor Trail Prior to Thrust Chamber Ignition

Ignition of Boost No. 2 Chamber



All Three Thrust Chambers Ignited

Separation from the Director Aircraft

Figure 3. Launching Sequence — Rascal Missile 0409B

4. CONCLUSIONS

The high-pressure Model B missiles fulfilled the primary purpose of providing early flight tests of powered Rascal vehicles for evaluation of aerodynamic and stabilization characteristics. Use of the high-pressure propulsion system proved worthwhile as data were obtained on missile systems operation. The missiles demonstrated the ability to maintain stability and to perform required maneuvers. Evaluation of the guidance-control system was precluded by premature termination of the two guidance evaluation flights. However, some insight into the nature of guidance system performance was provided during the captive tests, during the prelaunch checks, and, to a limited extent, during the final flight testing. Performance data indicated that the Rascal missile and DB-50 director aircraft would ultimately perform as expected.

In addition to these accomplishments, some indirect benefits were derived from the high-pressure Model B missile tests. Ground handling and servicing techniques were evaluated; field test personnel received experience in handling the over-all operation; and instrumentation and data-processing techniques were developed and improved.

D. MODEL B MISSILES WITH LOW-PRESSURE FUEL-FEED SYSTEMS

The remaining 15 Model B missiles were flight-tested between May and December of 1954. The planned program called for testing the operation of the newly incorporated low-pressure propulsion system during the initial flights. Subsequent tests were to be conducted to evaluate all systems of the missile and director aircraft, with emphasis on guidance evaluation and warhead fuzing operation. Evaluation of the weapon system was precluded on 11 flight tests by malfunctions during prelaunch, launch, or midcourse. However, the guidance control technique was demonstrated on four flights. One missile (No. 1626B) impacted 290 feet from the designated target.

The following paragraphs describe the low-pressure Model B missiles and the test objectives. Table III summarizes the flight test results in terms of missile configuration, test objectives, and results. A discussion of the test phase is then presented with conclusions based upon test results.

TABLE III

SUMMARY OF RASCAL FLIGHT TESTS – MODEL B MISSILES WITH LOW-PRESSURE PROPULSION SYSTEMS

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	6	7	8	9	Remarks
0011B	--	3-16-54	a,b,d,g,j,k	1					▨	□				Propulsion system failure in ground test.
0812B	DB-50	5-12-54	a,b,d,g,j,k	0					▨	□				Propulsion system failure; missile jettisoned prior to launch.
0914B	DB-50	6-22-54	a,b,d,g,j,k	0		■			■	▩				Servo-control failure near end of flight.
1016B	DB-50	7-27-54	b,d,e,g,j,k	0			□		▨	□	□	□		Propulsion system failure at launch.
1117B	DB-50	8-9-54	b,d,e,g,j,k	0			□		▨	□	□			Propulsion system failure at launch.
1221B	DB-50	10-18-54	b,d,e,g,j,k	0	■	▩	□		□	▨	□			Servo-control failure shortly after launch.
1319B	DB-50	10-14-54	b,d,e,g,j,k	2	■		▩	■		▩	▩			Servo-control failure shortly after dive entry.
1424B	DB-50	10-22-54	b,d,e,g,j,k	1	■		□			▩	□			Propulsion system failure during midcourse phase.
1522B	DB-50	10-28-54	b,d,e,g,j,k	0	■		▩			▩	▩			Propulsion system failure prior to dive entry.
1626B	DB-50	11-4-54	b,d,e,g,j,k	0	■		■	▨		■	■		■	Satisfactory flight; impact 290 feet from target; range 35 N.M.
1728B	DB-50	11-10-54	b,d,e,g,j,k	0	■		■			▩	■		■	Servo-control failure near end of flight.
1825B	DB-50	11-29-54	b,d,e,g,j,k	0	■	▩	▩			▩	□			Servo-control failure shortly after launch.
1923B	DB-50	12-3-54	b,d,e,g,j,k	3			■	■		■	■			Satisfactory test; guidance operator error caused missile to miss target region.
2027B	DB-50	12-8-54	b,d,e,g,j,k	0			□			▩	▩		■	Propulsion system failure and premature initiation of destruct system during midcourse.
2120B	DB-50	12-17-54	b,d,e,g,j,k	0			□	■		▩	□			

■	Accomplished	▨	Not accomplished
▩	Partly accomplished	□	No chance

SYSTEMS INSTALLED

a. Recovery
b. Destruction
c. Propulsion system (high-pressure)
d. Servo control
e. Relay-command guidance system (two operators)
f. Inertial guidance
g. Flight programmer
h. Inert warhead
j. Telemetry instrumentation (battery-powered)
k. Propulsion system (low-pressure) vendor turbine pump
l. Relay-command guidance system (one operator)
m. Telemetry instrumentation (missile generator-powered)
n. Propulsion system (low-pressure) Bell Aircraft turbine pump

OBJECTIVES

1. Demonstrate free-drop launch procedures.
2. Obtain structural load data.
3. Evaluation of pressure-sensing system.
4. Obtain environmental data.
5. Test the operation of the propulsion system.
6. Test the operation of the servo control system.
7. Test the guidance system.
8. Obtain aerodynamic data.
9. Obtain environmental data in the warhead compartment (Sandia Corporation)

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems or Rascal Weapon System equipment installed in the director aircraft.

1. CONFIGURATION

The DB-50 equipped with elements of the dual-operator guidance system and the four-point launch gear served as the director aircraft for the Model B missiles with the low-pressure propulsion system.

Except for the propulsion system, the low-pressure missile configuration was essentially the same as the last two Model B high-pressure missiles.

The low-pressure propulsion system consisted of three thrust chamber assemblies, propellant tanks, tube bundles for nitrogen gas storage, a nitrogen pressure-regulating system, and a vendor-supplied turbine pump assembly. An alternator and hydraulic pump were driven by the turbine to provide internal electrical and hydraulic power for the missile. Following a failure of the nitrogen storage tube bundles on missile -- 11B during preparation for flight, all subsequent Model B and D missiles were modified, as an interim measure, to incorporate nitrogen storage bottles while improved tube bundles were being developed. On missiles without guidance equipment, the bottles were mounted in the nose section. In the missiles carrying guidance equipment, the recovery parachutes were removed from the aft section and this compartment was used to house the nitrogen storage bottles.

The servo-control system in these 15 missiles was the same as that used in the Model B high-pressure missiles. Pitch and yaw programmers were used to vary the attitude on the six missiles that were flown with no guidance operator control. Pitch attitude was programmed on all flights to achieve a satisfactory flight path.

The emanating guidance system was incorporated in the last 12 of the 15 Model B low-pressure missiles. However, the guidance system was disconnected from the servo-control system in three of the missiles and programmers were used to provide flight maneuvers for structural load measurements. During these three tests, the emanating system was energized and its operation was monitored by instrumentation, but the guidance operator had no control of the missile flight path. Full in-flight control of the missile by the guidance operator was exercised with the remaining nine missiles.

For range safety, the missile destruction capability was maintained throughout the Model B flight tests. Both S-band and L-band beacons were installed in the missiles to facilitate tracking, as well as to permit the emergency destruction circuitry to be energized. Recovery of the forward equipment section was to be achieved on the six flights with no guidance control. On the nine flights with guidance control, the aneroid switches were disconnected to permit guidance to impact.

Instrumentation was included in 12 to 15 missiles to obtain fuzing pressure-sensing data. Three of these missiles contained fuzing baroswitches.

Telemetering instrumentation was incorporated in all missiles to obtain data on systems operation. A battery-powered FM/FM transmitter, employing from 14 to 18 subcarrier channels, was used.

2. OBJECTIVES

The initial flight test objective for the 15 low-pressure missiles was to establish satisfactory operation of the propulsion system. Three missiles were scheduled to evaluate propulsion system performance, including the efficiency of propellant tank expulsion during climb and dive and during pitch and yaw maneuvers.

For the remaining 12 flights, evaluation of the dual-operator relay and command guidance system, the fuzing baroswitches, and the pressure-sensing system were of prime concern. During three of these flights, the guidance system was operated as an open loop without servo response to guidance control. A new free-drop launch technique was evaluated on the sixth and all subsequent low-pressure missiles.

Evaluation of the servo-control system was a secondary objective on all 15 missiles. This was to be accomplished on six missiles by programmed pitch and yaw maneuvers. On the missiles to be controlled by the guidance operator, stabilization data during the terminal guidance phase were desired.

Additional secondary objectives involved special instrumentation to obtain structural, aerodynamic, and environmental data. Three missiles were flown to obtain warhead structural load information. One missile was tested to obtain zero lift-drag data. Vibration instrumentation was installed in various positions on two missiles and three missiles were instrumented to record temperature data in the radome and in guidance and servo equipment. Three missiles were instrumented by the Sandia Corporation, the prime warhead contractor, to obtain environmental data from the warhead compartment.

3. TEST PHASE

Flight testing consisted of launching from a DB-50 director aircraft at an altitude of 30,000 feet and at Mach 0.45. The missile entered a climb and leveled off at a predetermined flight altitude (varied between 40,000 and 60,000 feet). The midcourse phase of flight was monitored by the guidance operators and the terminal dive was initiated either by the guidance operators or by the programmer in the missile.

weapon system was accomplished during four Model B flights which entered terminal dive. The capability of the weapon system was satisfactorily demonstrated by the flight test of missile 1626B. Following the dive maneuver, the guidance operators successfully controlled 1626B to impact 290 feet from the prescribed ground target. Guidance control was demonstrated on the other three flights until various malfunctions precluded a completely accurate evaluation. In one case, guidance operator error caused a missile to impact six nautical miles from the target. Servopilot malfunctions occurred late in the dive phase on the other two tests causing loss of missile control.

Two of the three flights to test fuzing baroswitch operation provided useful vertical accuracy data. During the flight tests of missiles 1626B and 1728B, all of the baroswitches actuated within 80 and 304 feet of the planned altitude.

Twenty-one attempts were required to achieve the 13 launchings. One missile was destroyed on the ground and another was jettisoned prior to launch due to propulsion system failures. Of the six remaining aborted flight tests, four were due to servo-control problems and two were due to guidance system failures.

4. CONCLUSIONS

The 15 missiles scheduled to be flown during this phase met with only limited success in terms of satisfactory completion of individual flight tests. Since proper operation of the propulsion system was a prerequisite for satisfactory evaluation of other missile performance aspects, the seven failures involving the propulsion system contributed to the fact that the desired test objectives were not accomplished satisfactorily. Design changes eliminated the propulsion system problems; especially noteworthy is the free-drop launch technique which was used on the last 10 Model B flight tests, as well as all subsequent launchings.

The seven failures on the remaining eight flights, in addition to the eight aborted attempts, varied in nature and involved components of the director aircraft equipment and the missile servo, guidance, and beacon components. Failures of this nature were not completely unexpected since the Model B flight test phase was clearly a research and development stage in the Rascal program. The problems encountered led to additional developmental work and eventual system modification.

Adequate evaluation of missile systems was not accomplished during the Model B low-pressure missile flight tests. However, the flight test of missile 1626B, in particular, and the three other guidance controlled flights, demonstrated the capability and the feasibility of the Rascal weapon system.

During the terminal dive phase, the missiles were either programmed in pitch and yaw or controlled remotely by the guidance operator. The missile flights were terminated by actuation of the destruction system, or by impacting in the target area. Planned flight ranges varied between 40 and 60 nautical miles. The director aircraft continued on the launch heading for 5 seconds after launch, then turned upwind at 2° per second until a 65° turn was completed. This heading was maintained until the conclusion of the missile flight. A similar postlaunch procedure was used for the DB-50 during the remaining Model B and D missile flights.

The first two missiles scheduled to be launched were rendered unserviceable owing to propulsion system discrepancies. Missile -- 11B was destroyed on the ground by an explosion of the nitrogen storage bundles. The second missile, 0812B, was jettisoned from the DB-50 on 12 May 1954 when an explosion occurred in the turbine pump case during the turbine firing sequence. The next missile, 0914B, launched on 22 June 1954, was successfully flown for 130 seconds before becoming unstable due to a failure in the servo-control system.

After the flight test of 0914B, the rocket engine shut down immediately after launch during two successive missile flights. Malfunctions in the thrust chamber safety circuitry shut down the propulsion system as the missile separated from the DB-50. This safety circuitry had been incorporated as a protective measure for the aircrew while the missile was either attached to the DB-50 or was in close proximity to the airplane. With proper operation of the circuitry, failure of any one of the thrust chambers to ignite caused immediate shutdown of the propulsion system. As a result of the two successive failures in this circuitry, the sixth missile (1121B), as well as all later missiles, incorporated provisions for the free-drop launch technique that had been developed for Model D and subsequent missiles. In the new launch procedure, rocket fire was initiated by a timer after the missile was released from the DB-50; thus, the need for the thrust chamber safety circuitry was eliminated. During the flight test of missile 1221B, separation from the launch gear was clean and the release operation was completely successful. The free-drop launch technique was used without failure for all remaining R&D missiles. Following launch, the flight of 1221B was terminated when servo instability was caused by failure of the roll-rate gyro.

Of the remaining nine missiles, five flight tests were terminated prior to dive entry and four flights were guidance controlled during the terminal dive phase. Of the five flights terminating prior to dive, three were directly attributable to propulsion system malfunction, one was a flight-control problem, and one flight was terminated by premature initiation of the destruct system. Limited performance data were obtained on the servopilot and propulsion system during the midcourse phase of operation. Evaluation of the guidance control aspect of the [illegible] as

E. MODEL D MISSILES

During the first quarter of 1955, six Model D missiles were flight tested. Early flight planning called for the installation of the single-operator guidance system in the Model D missiles. The free-drop launch technique was also to be evaluated. Later planning rescheduled the single-operator guidance system for incorporation in the Model F missiles, and the free-drop launch technique was successfully demonstrated on the later group of Model B missiles. Consequently, the Model D missiles maintained the configuration, test objectives, and flight plans of the later Model B missiles, and can be considered a continuation of the earlier group. Test objectives emphasized continued evaluation of the guidance system and pressure-sensing components of the fuzing system. Two missiles completely satisfied the planned flight objectives and scored "bull's-eye" hits on the target. Limited evaluation was possible on four missiles which experienced propulsion failures during flight.

The following paragraphs describe the Model D flight test vehicle and the test objectives. Table IV summarizes the flight test results in terms of missile configuration and test objectives and results. A discussion of the test phase is then presented, followed by conclusions based upon test results.

1. CONFIGURATION

The DB-50 director aircraft containing dual-operator guidance components and the four-point launch gear was used throughout the flight testing of the Model D missiles.

The configuration of Model D missiles was similar to the later Model B missiles except for minor modifications of some components. The dual-operator guidance system was maintained, with azimuth control capability for the complete flight and pitch control capability for the terminal dive phase. Timers were used for propulsion system and other controlled functions, and programmers provided pitch control. The parachute recovery system was retained for the forward missile section. However, the aneroid switches were disconnected (except on missile 2634D) and recovery was attempted only in cases of missile malfunction. One change was made in the propulsion system: the 65 L* thrust chambers were replaced by 75 L* chambers using modified injector heads (L* = characteristic thrust chamber length in inches). An addition to the telemetry system included an R-F transmitter for telemetering impact fuze data for which receiving station facilities were established in the target area. Special instrumentation was also provided to measure and record structural load data during the flight of 2634D.

TABLE IV

SUMMARY OF RASCAL FLIGHT TESTS – MODEL D MISSILES

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	Remarks
2231D	B-50	1-13-55	a,b,d,e,g,j,k	1	■	■	■	▦		Impact 320 feet from target; range 38 N.M.
2332D	B-50	1-28-55	a,b,d,e,g,j,k	2	▦	▦	▦	☐		Propulsion system failure during midcourse.
2430D	B-50	2-12-55	a,b,d,e,g,j,k	0	■	■	■	▦		Impact 1160 feet from target; range 39 N.M.
2535D	B-50	2-16-55	a,b,d,e,g,j,k	0	▦		▦	☐		Propulsion system failure shortly after dive entry.
2634D	B-50	3-1-55	a,b,d,e,g,j,k	0			▦	☐	▦	Propulsion system failure during midcourse.
2733D	B-50	3-29-55	a,b,d,e,g,j,k	3	☐	▨	☐	☐		Propulsion system failure shortly after launch.

■ Accomplished
▦ Partly accomplished
▨ Not accomplished
☐ No chance

SYSTEMS INSTALLED

- a. Recovery
- b. Destruction
- c. Propulsion system (high pressure)
- d. Servo-control
- e. Relay-command guidance system (two operators)
- f. Inertial guidance
- g. Flight programmer
- h. Inert warhead
- i. Telemetry instrumentation (battery-powered)
- k. Propulsion system (low-pressure) vendor turbine pump
- l. Relay-command guidance system (one operator)
- m. Telemetry instrumentation (missile generator-powered)
- n. Propulsion system (low-pressure) Bell Aircraft turbine pump

OBJECTIVES

1. Test airframe-autopilot response to commands from director aircraft.
2. Obtain warhead environmental data.
3. Test operation of dual-operator guidance system.
4. Test pressure-sensing system, baro-switches, and impact fuzes.
5. Obtain structural load data.

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems and Rascal Weapon System equipment installed in the director aircraft.

2. OBJECTIVES

The flight test objectives for the Model D missiles were a continuation of those for the Model B missiles, with emphasis remaining on additional flight evaluation of the dual-operator guidance system during the midcourse and terminal dive phases. Evaluation continued on the pressure-sensing system, barometric pressure switches, and impact fuzes that were intended for use in the warhead fuzing system. Missile 2634D was instrumented to obtain in-flight structural load data under programmed guidance commands during the terminal dive. Secondary flight test objectives were (1) to obtain environmental data in the warhead compartment using Sandia instrumentation and (2) to evaluate further the servo-control and propulsion systems and to obtain aerodynamic performance data.

3. TEST PHASE

The typical flight plan used for the Model D missiles can be generally described as follows: The missiles were free-drop launched from 30,000 feet MSL at Mach 0.45, and at a range-to-target of about 38 nautical miles. Following launch, the missiles were programmed to climb and attain a level flight altitude of approximately 47,000 feet MSL. At approximately 14 nautical miles from the target, a 30° dive was to be initiated either by the guidance operator or by the midcourse computer. The missiles were guidance-controlled during the midcourse and terminal dive phases.

Favorable test results were obtained from two of the Model D flight tests, and these satisfied the test objectives. Missile 2231D, the first of this series, was launched successfully on 13 January 1955. During the midcourse flight, the missile demonstrated good airframe/servopilot response to programmed commands. The guidance operators clearly identified the target during the latter part of the midcourse phase and, with minor flight path corrections immediately after dive, the missile was directed to a point 320 feet from the center of the target. This event marked the second bull's-eye of the Rascal flight test program. Successful performance was again realized on 12 February 1955 when the third Model D missile (2430D) was guided to impact 1160 feet from the target center. These two missiles demonstrated complete achievement of all flight objectives except for limited data obtained from the components of the pressure-sensing system. The flight test of missile 2430D provided information on pressure-sensing errors in the region of altitude and Mach number of interest to fuzing. The baroswitches actuated between 230 and 263 feet lower than planned. Impact fuze data indicated that performance was satisfactory.

Evaluation was limited on the remaining four flights because of discrepancies in the propulsion system. Flight data established that the failures were due to the following conditions: (1) Suspended solids in the oxidizer clogged the inlet-line filter of the oxidizer pump causing a gradual decay of performance until the engine malfunctioned; (2) the gas generator ceased to operate either because of an interruption in the propellant flow caused by the pitch attitude unporting the suction line in the propellant tanks, or because of a failure in the propellant valve actuating system of the gas generator; (3) failure of the aft bearing of the alternator gear resulted in loss of electrical power; and (4) two thrust chambers failed to fire and, as a result, a flight was made with one thrust chamber firing. This last difficulty was traced to a faulty electrical connection in the propulsion system timer.

The guidance operator transmitted minor flight path corrections prior to failure on two of the four failed flights and missile response was satisfactory. The flight of missile 2634D represented the third attempt to obtain structural load data under programmed guidance commands during the terminal dive phase.

During the Model D flight test effort, there were six aborted flights attributable to equipment of the Rascal Weapon System; four were guidance system problems, one was a descrepancy in the servo-control system, and one was a failure in the propulsion system.

4. CONCLUSIONS

Propulsion system malfunctions with Model D missiles proved costly since the apparent low-reliability of the system limited the evaluation of other missile systems, particularly in the terminal dive phase.

Enough pressure-sensing and baroswitch data were collected to begin complete fuzing system evaluation with the Model F missiles.

Results of the Model D flights, in combination with data from the previous missile flights (now numbering 27), were not sufficient to evaluate completely all missile systems. However, additional data were provided for verifying performance of existing designs with respect to the airframe and the servo-control, guidance, and propulsion systems. The two target hits showed that System 112A was fundamentally sound and that the required accuracy could be achieved.

F. EARLY MODEL F MISSILES

The twelve Model F missiles in this group were flight-tested between May 1955 and May 1956. The original objective of the Model F missile program was to demonstrate performance and capability of the operational Rascal weapon. However, after nine unsuccessful flights, the program was halted temporarily to reorient the testing effort by placing greater emphasis on individual system reliability both in the factory test area and in the field test area. While the test program was being reoriented, three interim missiles were approved for flight testing, primarily to obtain environmental data. One of these missiles was successfully guided to the target region. The other two missiles did not attain a satisfactory flight path, but useful environmental data were obtained.

The following paragraphs describe the configuration and the flight test objectives of these first twelve Model F missiles. Table V summarizes the flight tests in terms of missile configuration and flight test objectives and results. A discussion of the test phase is then presented and this is followed by conclusions based upon the test results.

1. CONFIGURATION

Both the DB-36 and DB-47 were scheduled for use as director aircraft during the testing of Model F missiles. The DB-36 was originally designated the first priority operational director aircraft, with the DB-47 as the second priority airplane. Later, however, the DB-36 was dropped from the program and the DB-47 was used exclusively.

The Rascal missile was carried differently by these two director airplanes. The missile, in the DB-36, was carried partly within the bomb bay and was mounted with the longitudinal axis of the missile parallel to that of the airplane. Roll angle of the Rascal was zero degrees with respect to the airplane. On the DB-47, the missile was attached to a pylon protruding from the fuselage below the right wing. The longitudinal axis of the Rascal was parallel to that of the DB-47 and the missile was mounted with a 13° angle of counterclockwise roll. A two-point suspension launch gear was utilized on both the DB-36 and the DB-47, rather than the four-point launch gear used on the DB-50.

The AN/APW-17 guidance system installed in the director aircraft featured a single-operator guidance scheme to control the missile flightpath instead of the dual-operator system used with the Model B and D missiles. Use of radar guidance in midcourse was eliminated; the Model F missiles were guided in midcourse by the servo-control system and were placed in terminal dive by the new inertial range-computing system. Radar guidance was used only

TABLE V

SUMMARY OF RASCAL FLIGHT TESTS — EARLY MODEL F MISSILES

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	6	Remarks
2849F	DB-36	5-5-55	b,d,f,h,j,k,l	0	■	□	□		□	□	Servo-control failure shortly after launch.
2960F	DB-36	6-11-55	b,d,f,j,k,l	1	■	□	□		□	▩	Propulsion system failure during midcourse.
3054F	DB-47	7-14-55	b,d,f,h,j,k,l	2		■	□		■	▩	Propulsion system failure shortly after dive entry.
3155F	DB-47	7-19-55	b,d,f,j,k,l	0		□	▩		■	▩	Propulsion system failure during terminal dive.
3247F	DB-36	8-5-55	b,d,f,h,j,k,l	9	■	□	□			□	Servo-control failure during midcourse.
3356F	DB-36	8-16-55	b,d,f,j,k,l	3	□	□	□		□	□	Servo-control failure during midcourse.
3451F	DB-36	8-30-55	b,d,f,h,i k,l	5	■	■	□		■	▩	Propulsion system failure shortly after dive entry.
3552F	DB-36	9-2-55	b,d,f,j,k,l	1	■	□	□			□	Servo-control failure shortly after launch.
3653F	DB-47	9-29-55	b,d,f,h,j,k,l	4	■	■	□			▩	Propulsion system failure during midcourse.
3758F	DB-47	3-7-56	b,d,f,h,j,k,l	1		■					Satisfactory flight; owing to tracking error, radial miss distance in target plane was 3014 feet; range 53 N.M.
3863F	DB-47	4-24-56	b,d,f,j,k,l	1				■			Guidance failure; no relay contact during flight; missed target by 4 N.M.
3964F	DB-47	5-3-56	b,d,f,j,k,l	1				□			Propulsion system failure; missile jettisoned prior to launch.

■ Accomplished

▩ Partly accomplished

▨ Not accomplished

□ No chance

SYSTEMS INSTALLED

a.	Recovery
b.	Destruct
c.	Propulsion system (high-pressure)
d.	Servo-control
e.	Relay-command guidance system (two operators)
f.	Inertial guidance
g.	Flight programmer
h.	Inert warhead
j.	Telemetry instrumentation (battery-powered)
k.	Power plant (low-pressure) vendor turbine pump
l.	Relay-command guidance (one operator)
m.	Telemetry instrumentation (missile generator-powered)
n.	Propulsion system (low-pressure) Bell Aircraft turbine pump

OBJECTIVES

1. Check prelaunch procedures and missile separation characteristics.
2. Test inert special warhead installation.
3. Test warhead fuzing system.
4. Obtain environmental data.
5. Test accuracy of inertial guidance system.
6. Test the single-operator guidance system.

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems or Rascal Weapon System equipment installed in the director aircraft.

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after dive entry. The target was tracked during terminal dive and both pitch and azimuth commands could be sent by the guidance operator to correct the missile flight path as required to hit the target.

An automatic checkout system (part of the AN/APW-17) was installed in the director aircraft to check various missile functions in sequence and, in conjunction with the MA-8 bombing navigation system, to launch the missile upon satisfactory completion of the checks. If a missile function failed to check out during the final countdown, the launch was halted automatically.

The Model F missile was essentially the planned operational configuration, except for an improved propulsion system that was to be phased into the program at a later date. The airframe was modified to accommodate the warhead installation and the parachute recovery system was eliminated. However, the S-band and L-band beacons and the destruction system were retained for range safety.

The propulsion system for the early Model F missiles was similar to the system installed in Model D missiles. The same engine assembly, using the vendor-supplied turbine pump, was incorporated. Reinforced tube bundles were used for high-pressure nitrogen storage instead of the storage bottles used temporarily in the Model B and D missiles.

The servo-control system, except for minor modifications and repackaging, was similar to the system used in Model B and D missiles. A barometric altitude control unit was added for programming the missile climb and for maintaining level altitude in the midcourse phase.

The addition of the inertial range-computing system (IRCS) was the major change in the guidance system of Model F missiles. The servo-control system stabilized the missile flight from launch to initiation of terminal dive; at this point, the dive signal was initiated by the IRCS and the search radar was automatically energized. The guidance operator then assumed control of the missile by means of the radar-relay link. As an added feature, the guidance operator could initiate a command to energize the emanating system any time after the relay link was established. The relayed video information could be used to check and correct the missile's progress. Also, the terminal dive could be initiated through the command link.

Six of the twelve early Model F Rascals had inert nuclear warheads. Special instrumentation was installed with the warhead so that the Sandia Corporation could obtain data for evaluation of missile/warhead compatibility and environmental conditions in the warhead compartment.

2. OBJECTIVES

The primary flight test objective was to demonstrate the ability of the Rascal missile to accomplish its assigned mission. These objectives were: (1) to evaluate the single-operator guidance system, (2) to evaluate the inertial range-computing system, (3) to test the warhead fuzing system, and (4) to test the compatibility of the warhead with the missile and its systems. Checking of prelaunch procedures, including the automatic checkout system and launch separation characteristics from both the DB-36 and the DB-47, were secondary objectives.

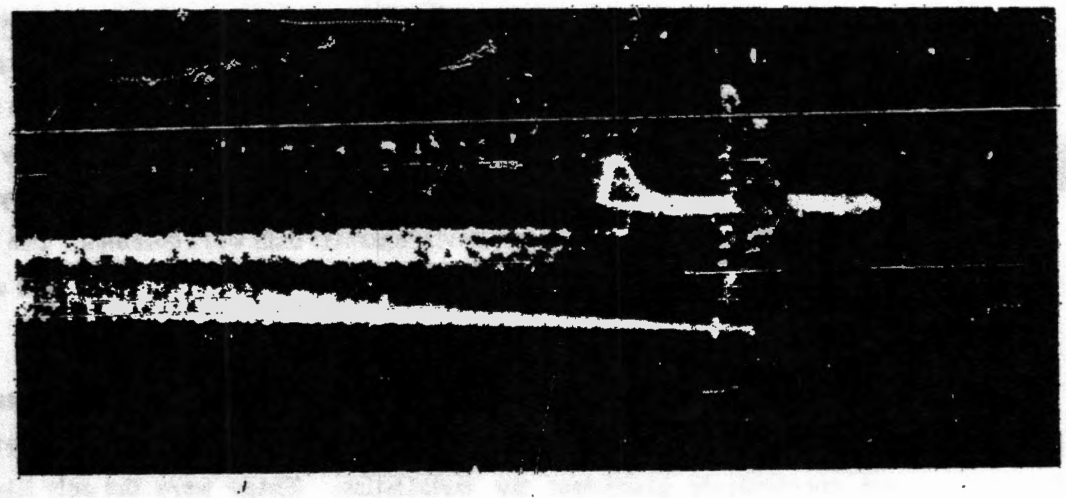
After the need for reorienting the flight test program became apparent, the flight test objectives for the last three missiles were changed. One missile was flown to test only the warhead installation. Two other missiles were launched to obtain temperature, vibration, and acceleration data under operational flight conditions.

3. TEST PHASE

Flight planning for this group of missiles included a launching from a director aircraft at an altitude of 40,000 feet MSL. Launch Mach number was to be 0.60 for a DB-36 launch and 0.75 for a DB-47 launch. Following launch, the altitude controller would initiate a climb to the desired level flight altitude (65,000 feet MSL) and maintain that altitude until terminal dive. The IRCS would automatically place the missile into a dive at the prescribed range-to-target. Terminal dive could also be initiated by the guidance operator at the desired range-to-target as indicated by the radar presentation. Stabilization of the missile was to be provided by the servopilot; pitch and azimuth control was to be provided by the altitude controller, the inertial range-computing system, and the terminal guidance operator. Missile operation was to be demonstrated at ranges up to 75 nautical miles. It was planned that the director aircraft, following launch, would turn at 2° per second until a turn angle of 180° to 205° was completed (the turn angle varied with the individual flight plane). This heading was maintained until the end of missile flight.

Nine flight tests, including five missiles with inert warheads, were completed before the program was temporarily halted. The first missile to be tested, No. 2849F, was launched on 5 May 1955 from a DB-36. The first flight to utilize a DB-47 as the director aircraft was the testing of No. 3054F on 14 July 1955. Satisfactory missile separation and launch on all nine missions indicated satisfactory performance of the ACS and the two-point launch gear. However, all nine flights were unsatisfactory owing to failures prior to, or shortly after, the missiles entered terminal dive. The prime objectives were not accomplished. Five of these flight failures were attributed to propulsion system discrepancies and four were caused by improper operation of the servo-control system. The ninth missile in the series, No. 3653F, was tested on 29 September 1955. Figure 4 illustrates the "free-drop" technique used to launch GAM-63A's from the DB-36 director aircraft. The upper photograph in Figure 4 shows No. 3356F, with the turbine running, dropping clear of the DB-36. The lower photograph shows thrust chamber ignition and the missile in free flight.

Turbine Running After Free-Drop



Thrust Chamber Ignition

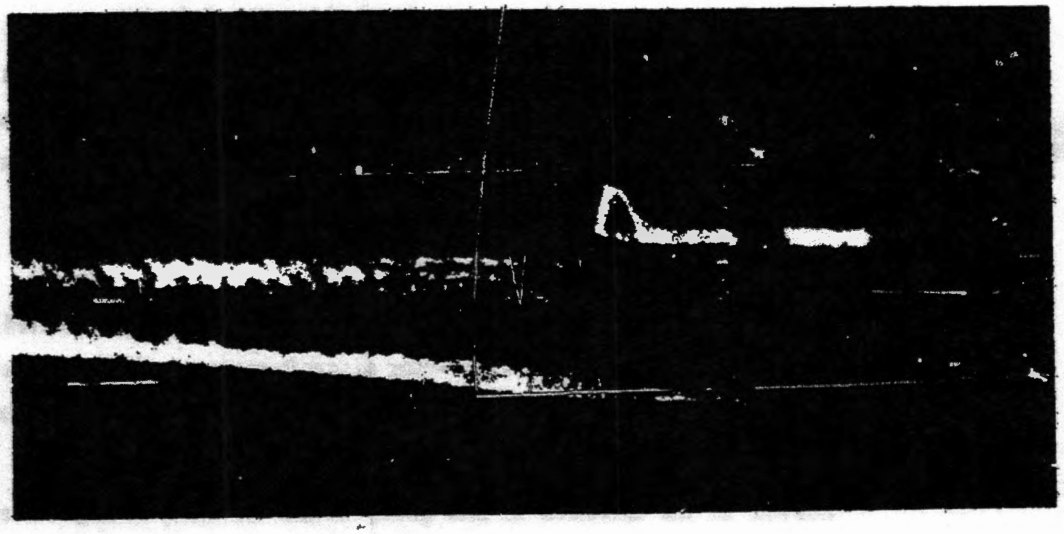


Figure 4. Free-Drop Launch of Rascal from DB-36

Although performance of the missile systems were apparently satisfactory, the number of system failures pointed out the need for a major improvement in relaibility. Consequently, the flight test program was halted temporarily while a comprehensive investigation was made. As a result of this investigation, the reliability program was greatly expanded throughout all phases of development from initial research and design through flight testing of the finished product.

While the reliability program was getting under way, three interim missile flights were scheduled to test the warhead installation and to obtain additional environmental data for use in establishing reliability test criteria. Missile 3758F, flown on 7 March 1956, again demonstrated the capability and accuracy of the Rascal weapon. The barometric fuzing system actuated within 447 feet of the planned altitude. Under full guidance control to the target, the missile flight resulted in a radial miss distance of 3014 feet. A tracking error by the guidance operator contributed to a greater-than-expected range deviation. The guidance system failed during the flight of missile 3863F; however, environmental data were obtained. The third interim missile, No. 3964F, tested on 3 May 1956, was jettisoned before launch because of a propulsion system malfunction prior to turbine fire.

Although warhead performance and environmental data were obtained on the six flights with the inert nuclear warheads installed, the Sandia Corporation reported that the results did not conclusively proof-test the installation. These were the only flights with this warhead; later missiles incorporated a new warhead of improved design.

In addition to the missile in-flight failures, launch cancellations were necessary during 28 launch attempts. The guidance system was responsible for 15 of the aborted missions, the propulsion system for four, the servo-control system for four, and miscellaneous electrical problems for five.

4. CONCLUSIONS

Results from the 12 early Model F missile flights clearly indicated the need for improving the reliability of the missile and director aircraft systems. The last three flight tests provided environmental data which helped to establish new ground test requirements for the missile systems.

Eleven of the missiles in this group failed too early in flight to accomplish the primary objectives. The secondary objective, concerning evaluation of the launch technique and missile separation characteristics, was accomplished. The flight test of No. 3758F again demonstrated the accuracy of the Rascal guidance and fuzing systems.

G. LATER MODEL F MISSILES

The last group of R&D missiles, flight-tested between June 1956 and October 1957, encompassed missiles 4075F through 61101F. Airborne flights in this group included 23 missile launchings, 21 captive flights, and 38 aborted launchings. The missile and director aircraft systems were of the planned operational configuration and the over-all testing emphasis was placed on demonstrating operational performance and improving reliability. Test objectives were accomplished throughout the entire program, in particular during the last few missile tests which demonstrated improved weapon system reliability and performance by repeated successes.

The following paragraphs describe these flight test vehicles and the test objectives. Table VI summarizes the flight test results in terms of missile configuration and test objectives and results. A discussion of the test phase is then presented, followed by conclusions based upon the test results.

1. CONFIGURATION

The missile and director aircraft were essentially of the operational configuration as described earlier in this report. However, significant changes incorporated in the later Model F missile systems are discussed briefly.

The DB-36 was discontinued as a director aircraft after the first two launchings and was replaced by the DB-47 carrier.

In the guidance system, the spin drive system for the search radar antenna was converted from an electrical to a hydraulic system operating in conjunction with the missile hydraulic system.

The propulsion system was modified considerably. A new Bell-designed turbine pump assembly, incorporating many improved design features, replaced the vendor-furnished assembly. The large-cone propellant tanks were replaced by small-cone tanks which permitted greater variations in the flight plan with increased propellant tank efficiency. Missile 4379F and subsequent GAM-63A's employed a fuel tank with a bladder-type expulsion system.

Eight missiles were equipped with inert prototypes of the new special warhead. Instrumentation was installed with the warhead so that the Sandia Corporation could gather data for evaluating warhead compatibility and environmental conditions. The missiles without warheads were ballasted for weight and center-of-gravity control.

TABLE VI

SUMMARY OF RASCAL FLIGHT TESTS LATER MODEL F MISSILES

GAM No.	Director Aircraft	Flight Date	Systems Installed	No. of Aborts	Objectives 1	2	3	4	5	6	7	8	9	10	11	Remarks
4075F	DB-36	6-11-56	b,d,f,j,l,m,n	0	■											Good flight to target; miss distance was 480 feet; range 68 N.M.
4176F	DB-36	8-6-56	b,d,f,j,l,m,n	0	■											Good flight to target; miss distance was 605 feet; range 66 N.M.
4277F	DB-47	9-11-56	b,d,f,j,l,m,n	0	▩											Beacon destruct by unauthorized source shortly after launch.
4378F	DB-47	11-5-56	b,d,f,j,l,m,n	4	▩	■	▩									Propulsion system malfunction after dive entry.
4482F	DB-47	11-27-56	b,d,f,j,l,m,n	0	■	■	▩	■	□	■						Impact 2.5 N.M. from target; relay link lost.
4581F	DB-47	1-7-57	b,d,f,j,l,m,n	3	▩	▩	□	□	□	▨						Servo failure at launch.
4684F	DB-47	1-16-57	b,d,f,l,m,n	0			▩				■					Impact 2.9 N.M. from target; heading and guidance operator error.
4783F	DB-47	2-11-57	b,d,f,j,l,m,n	7	▩	▩	▩	□	□	▩						Electrical failure during climb phase of midcourse.
4891F	DB-47	3-13-57	b,d,f,h,l,m,n	1			■				■	■				Good flight; impact 3790 feet; range 90 N.M.
4985F	DB-47	4-10-57	b,d,f,l,m,n	0			■				■					Good flight to target; miss distance 1495 feet; range 74 N.M.
5087F	DB-47	5-14-57	h,b,d,f,l,m,n	0			▩				▩	■				Electrical failure during midcourse.
5180F	DB-47	6-19-57	b,d,f,l,m,n	10	▩	▩	□									Intentional destruct by range safety officer shortly after launch.
5288F	DB-47	7-1-57	h,b,d,f,l,m,n	1			▩				■	■				Inertial flight; impact 8836 feet from target; range 72 N.M.
5393F	DB-47	7-1-57	h,b,d,f,l,m,n	2			▩				▩	▩				Servo failure during dive.
5490F	DB-47	7-10-57	h,b,d,f,l,m,n	0			▩				▩	▩				Electrical failure during climb phase of midcourse.
5507F	DB-47	8-16-57	b,d,f,l,m,n	0		▩	■				■					Good flight to target; miss distance 1512 feet; range 75 N.M.
5689F	DB-47	9-4-57	h,b,d,f,l,m,n	1			▩				▩	□				Electrical failure during midcourse.
5794F	DB-47	9-11-57	b,d,f,l,m,n	1			■				■					Good flight to target; miss distance 469 feet; range 89 N.M.
5898F	DB-47	10-9-57	h,b,d,f,l,m,n	1			■				■	■				Good flight to target; miss distance 730 feet; range 75 N.M.
59100F	DB-47	10-11-57	h,b,d,f,l,m,n	0			■				■	■	■			Good flight to target; miss distance 710 feet; range 75 N.M.
6089F	DB-47	10-16-57	b,d,f,l,m,n	3			■				■			■		Good flight to target; miss distance 771 feet; range 75 N.M.
61101F	DB-47	10-29-57	b,d,f,l,m,n	1							▩		▩		■	Electrical failure during climb phase of midcourse.
6296F	DB-47	10-31-57	b,d,f,l,m,n	3							▩		▩		■	Propulsion system malfunction at launch.

■ Accomplished
▩ Partly accomplished
▨ Not accomplished
□ No chance

SYSTEMS INSTALLED

a.	Recovery
b.	Destruct
c.	Propulsion system (high-pressure)
d.	Servo-control
e.	Relay-command guidance system (two operators)
f.	Inertial guidance
g.	Flight programmer
h.	Inert warhead
j.	Telemetery instrumentation (battery-powered)
k.	Propulsion system (low-pressure) vendor turbine pump
l.	Relay-command guidance (one operator)
m.	Telemetry instrumentation (missile generator-powered)
n.	Propulsion system (low-pressure) Bell Aircraft turbine pump

OBJECTIVES

1. Evaluate LR67-BA-9 Propulsion system under operational flight conditions.
2. Obtain environmental data.
3. Conduct operational-type flight.
4. Evaluate inertial range-computing system.
5. Evaluate terminal guidance system.
6. Evaluate servo system.
7. Evaluate missile systems.
8. Evaluate warhead installation.
9. Evaluate LR67-BA-9 engine using red fuming nitric acid.
10. Conduct profile mission.
11. Evaluate director aircraft capability to use point target as launch aimpoint.

NOTE: Aborted flights were cancelled launch attempts because of discrepancies in the missile tactical systems or Rascal Weapon System equipment installed in the director aircraft.

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The first eight missiles used the basic telemetering system: the 16-channel unit operated by battery power and the 4-channel unit operated by missile power. Subsequent missiles used the 4-channel unit and monitored only basic missile parameters.

2. OBJECTIVES

The primary test objective of the later Model F missiles was to demonstrate operational performance with improved reliability. Toward this end, primary flight objectives included (1) accuracy demonstrations of the guidance system in the target area, (2) an increase in missile range to 90 nautical miles, (3) flight evaluation of the propulsion system utilizing JP-4 and inhibited red fuming nitric acid as propellants, (4) evaluation of the new warhead installation, and (5) an operational profile mission.

Owing to the many changes in the propulsion unit, continued evaluation of this system was necessary. Thus, the first eight missiles were assigned for propulsion system evaluation. The last three of these eight missiles were assigned additional objectives which included obtaining environmental data and information on performance of the inertial range-computing system, terminal guidance system, and servo-control system. Instrumentation was oriented to accomplish these objectives. The remaining fifteen missiles were flown to evaluate missile systems while conducting an operational-type mission. With these objectives accomplished, the Air Force authorized the launching of the last two missiles to check out a new missile launching technique.

3. TEST PHASE

An operational flight plan was used exclusively during this test phase. A description and illustration of a typical mission are presented earlier in this report. Detailed flight plans called for variations in Mach numbers between 2.5 and 3.0, level flight altitudes between 60,000 and 70,000 feet MSL, and ranges of 75 and 90 nautical miles. The profile mission program included both prestrike and strike missions of five- to seven-hour flight durations, with the missile and director fully prepared for a "hot" mission. The strike leg also included inflight director aircraft refueling from a KC-97 tanker.

Five missiles (Nos. 4075F, 4176F, 4277F, 4379F, and 5180F) were launched primarily for propulsion system evaluation. Objectives were accomplished on the first two flights, while the remaining three provided a limited evaluation owing to missile system failures. The first two missiles were automatically checked by the ACS and launched without incident at a range-to-target of 68 and 66 nautical miles. All systems operated successfully as the missiles were guided along the planned flight path. A clear radar presentation of the target area, as well as proper guidance and servo-control, resulted in the missiles being guided to the target area with radial miss distances of 480 and 605 feet. Propulsion system operation was as planned on both flights. The three remaining missiles of the five provided limited evaluation; one failed because of a propulsion system malfunction and two were destructed shortly after launch. Missile 4379F, after a satisfactory flight through the powered phase, malfunctioned during the dive maneuver. Nitrogen gas trapped in the propellant supply from the fuel tank entered the fuel pump. The rocket engine malfunctioned owing to unloading of the fuel pump and the flight terminated. This was the first flight test of the bladder-type fuel tank; test results indicated that the fuel fill procedures were inadequate. Revised procedures were effectively used on subsequent missiles. Weapon system operation was satisfactory on the two missiles destructed and these are classified as "no-chance" missiles. The first missile was unintentionally destructed by spurious radio frequency signals external to the weapon system. Modifications to the system reduced the vulnerability of later missiles to such radio interference. The other missile was destructed as a safety measure by range personnel when the S-band tracking signal was lost at launch.

Flight objectives for the next three missiles were to evaluate the propulsion system, the IRCS, the servo-control system, and the terminal guidance system. One missile (No. 4482F) accomplished the objectives when a satisfactory flight was conducted to the target area; however, the flight was without emanating guidance because of a failure of the relay magnetron during midcourse flight. System evaluation was limited on the other two missiles: No. 4581F had a servo-control system failure at launch; the other (No. 4783F) experienced a failure in the electrical system as caused by arcing in the missile alternator.

Flight testing was mainly of a demonstration nature for the remaining 15 missiles of the flight test program. As a result of the intensified reliability program, these missiles received the benefit of more comprehensive inspection and testing at the component and composite system test level. Missile 5087F and subsequent were subjected to a minimum of 15 composite systems tests and a required amount of operating time to establish reliability of components before the missiles were released for final flight. The results of this effort were indicated by the favorable degree of success attained by the missiles and director aircraft during this final R&D test phase.

Seven of the 15 missiles completed all test objectives and demonstrated an observed reliability of 100% from launch to target. These missiles also demonstrated guidance accuracy

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instability following the dive maneuver. Four missiles experienced failures in the electrical system similar to missile 4783F. Labratory tests detected arcing when a missile alternator was tested in a combined environment of altitude and vibration. These test results were obtained too late for incorporating changes in the R&D missiles prior to flight; however, all production missiles were immediately serviced to correct the malfunction and specifications were amended to include a simultaneous altitude and vibration test at the functional test level on all production alternators.

Eight missiles contained inert warheads and utilized Sandia Corporation instrumentation for evaluation of the warhead installation. Testing began with missile 5987F and the objectives to be accomplished were: (1) to obtain additional warhead environmental data while conducting an operational mission, (2) to verify compatibility and in-flight operation of the missile/warhead combination, and (3) to obtain impact detonation data that would verify operation of the warhead for a typical ground burst. The first two objectives were accomplished with the first six warhead test missiles; five of the flights were successful. The third objective was accomplished with the remaining two missiles, both of which were successfully guided into the target area and impacted at the planned Mach number. Sandia Corporation indicated that all three test objectives had been accomplished.

The fuzing system that arms and detonates the warhead was evaluated through the Model F missile flight test phase. Objectives of these tests were to establish compatibility with the new warhead and to demonstrate fuzing accuracy. Satisfactory performance and reliability of the existing design and compatibility with the warhead were verified and the vertical accuracy of the fuzing system was demonstrated satisfactorily. Five missiles of this group (Nos. 4176F, 4982F, 4684F, 5288F, and 6099F) provided useful fuzing data. Vertical accuracy of four missiles was within 186 feet and the fifth was 625 feet, compared with a one-sigma requirement of 405 feet. Data from other flights were unsatisfactory owing to loss of telemetering, too low a Mach number, or premature flight termination.

In compliance with Air Force requests that System 112A demonstrate capabilities (1) to perform a tactical profile mission, (2) to operate the propulsion system on JP-4 and inhibited red fuming nitric acid, and (3) to increase the missile range to 90 nautical miles, special flight tests were scheduled into the program. These objectives were successfully accomplished.

The profile mission demonstration was conducted between 19 September and 16 October 1957. A series of three strike profile and four prestrike profile flights were conducted prior to the launching of missile 6099F on 16 October. The missile was launched following a captive in the target area; four were guided to within 771 feet of the target. Figure 5 shows the impact of missile 59100F in the target region.

Two additional missiles reached the target area. A guidance operator error in one case and loss of emanating guidance in the other case precluded achievement of the desired accuracy.

Six of the final 15 R&D missiles failed. One failure resulted from a propulsion system malfunction at launch; a broken wire to the by-pass propellant valve prevented the rocket engine from making a normal ignition at rocket fire. A second missile failed when a decay in hydraulic system pressure, due to accumulator gas leakage into the system, resulted in missile

Figure 5. Impact of Missile 59100 in Target Area

flight with a duration of more than five hours. All systems operated normally from launch to impact in the target area. This was the first Rascal missile flown by a SAC guidance operator. Figure 6 shows an in-flight refueling of the DB-47 from a KC-97 tanker during a strike profile mission.

Three missiles using modified rocket engines, previously ground tested for operation with red fuming nitric acid, were flown utilizing this propellant during October 1957. Satisfactory propulsion system operation with the red acid was demonstrated during all phases of flight;

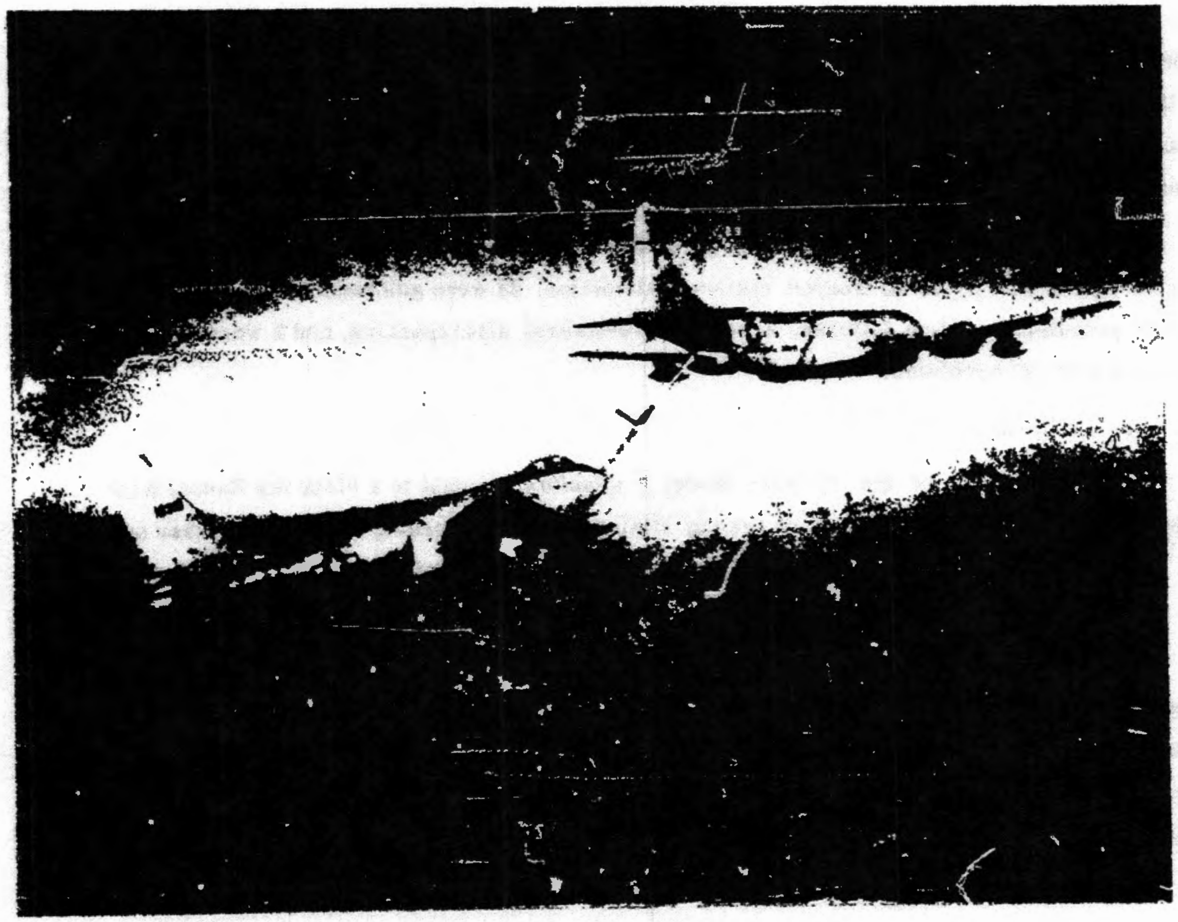

Figure 6. In-Flight Refueling of DB-47 from KC-97 Tanker

performance levels were as planned, thus satisfying this test objective. The change from white to red acid provides the advantage of a considerably lower freezing point.

To demonstrate the increased range capability, four missiles were launched at approximately 90 nautical miles from the target. One of the four missiles impacted short of the target owing to an electrical failure. Missiles 4891F and 5794F were successfully operated throughout the flight profile and provided satisfactory vertical and horizontal accuracy. Owing to a failure in the emanating guidance system during the flight of missile 4482F, no course corrections were applied during the terminal dive. All three missiles complied with the 90-nautical-mile range requirement.

Several captive flight tests were conducted to evaluate the feasibility of a new simplified launch technicque. After the results proved favorable, the Air Force authorized the launching of the last two R&D missiles, Nos. 61101F and 6296F, by this method. Both missiles were successfully launched within the required tolerance and indicated the feasibility of the new launch method. A detail discussion of the method is found in Reference 8.

Sixty-one attempts were required to launch the 23 missiles in this group. Of the 38 aborted flights attributed to weapon system malfunction, 22 were guidance system problems, 7 were propulsion system failures, 4 were servo-control discrepancies, and 5 were miscellaneous electrical problems.

4. CONCLUSIONS

The flight testing of the 23 later Model F missiles, brought to a close the Rascal R&D flight test program. This phase of testing attained a more favorable degree of success and the required operational performance of equipment in both the missile and director aircraft was demonstrated.

The improved propulsion system utilizing the Bell-developed turbine pump was successfully operated during the various flight phases with only two failures; one failure was caused by inadequate servicing procedures. All other missile systems were operated with a higher degree of success. The new warhead proved to be compatible with the missile and fuzing system and both guidance and fuzing accuracy were repeatedly demonstrated.

Flight objectives designed to evaluate various performance capabilities of the airborne weapon system were accomplished successfully. These capabilities included: conducting a tactical profile mission, propulsion system operation utilizing red acid as the oxidizer, and a missile range of 90 nautical miles.

the existing system designs and the ability of the missile and director aircraft to perform an operational flight plan, but also satisfied the required performance capabilities of System 112A.

H. SUPPORTING FLIGHT TESTS

1. SIMULATED MISSILE FLIGHT TESTS

The necessity for auxiliary flight test programs as a source of information to fill the gaps in guidance and control knowledge was established at the outset of the Rascal program in 1946. The use of manned aircraft as a proving medium provided a much closer approximation of missile flight conditions than laboratory testing. Moreover, in the flight testing effort, the Rascal missile was a one-shot vehicle which limited the amount of quantitative evaluation that could be accomplished. The basic pattern of the flight test program involving the support aircraft was first to investigate the various methods of guidance control and to develop the most feasible systems. Packaging problems were then resolved and modifications were made to fit the equipment into the space limitations of the missile. The repackaged and modified equipment was also installed in airplanes simulating the missile and carrier, and subsequent flight tests were conducted to evaluate performance and establish specifications. Seven types of airplanes were involved in this program.

a. Flight Testing

In 1946, an F-63 was utilized in preliminary evaluation of autopilots, adaptation of autopilots for radio control, and the development of radio control techniques. A B-17 and a B-25 were obtained for research work late in 1946. Early flight tests with these aircraft were concerned with evaluating various radar and television equipments, and establishing systems that were feasible for maintaining contact between a simulated missile and director aircraft, for target searching and recognition, and fcr radar tracking and guidance of a missile. The B-25 served as the missile and the B-17 as the director airplane.

Another B-17 was added to the program in July of 1947. A flight test effort was set up with the two B-17's to test guidance equipment which was in work, being modified, or being developed and built as "breadboard" units. The two B-17's, simulating the missile/carrier airplane combination, were used for more than two hundred flight tests between July 1947 and March 1950.

The failure rate of components and subsystems was reduced and a large percentage of these failures were of a repetitive type for which solutions are now known.

Increased reliability of the missile and director aircraft is evidenced by the preceding discussion of the flight test results. This is also indicated by comparing the test results from missiles prior to No. 4075F and missiles subsequent to No. 4075F. Of the 25 missile launchings (one no chance) prior to 4075F, eight were guided to the target area. Of 23 missiles launchings (two no chance) subsequent to 4075F, twelve were guided to the target area. The last eight Model F missiles launched were of a similar reliability configuration containing substantial improvements over missiles previously flown. Five of these missiles completed the planned profile with satisfactory fuzing accuracy and an observed CEP slightly over one-half the predicted 1500-foot requirement. The accuracy performance of the last eight R&D missiles is presented in Table VII.

Thus, the later Model F missiles were successful in accomplishing their intended purpose. The higher degree of success in flight performance provided an opportunity for evaluating the various missile systems so often delayed by the unfortunately poor success of the earlier phases of the flight test program. These evaluations not only substantiated the adequacy of

TABLE VII

VERTICAL AND HORIZONTAL ACCURACY PERFORMANCE — LAST EIGHT R & D MISSILES

LAUNCH CONDITIONS				TERMINAL CONDITIONS		
GAM No.	Range (N. M.)	Altitude (Feet-MSL)	Mach No.	Absolute Burst Altitude (Feet-MSL)	Radial Miss Distance (Feet)	Vertical Miss Distance (Feet)
5597	74.8	40,580	0.77	8000	1512	----
5794	89.1	39,960	0.77	8000	469	+625
5898	74.6	39,240	0.77	4804	730	+212
59100	74.9	39,427	0.75	4804	710	-225
6099	74.8	39,490	0.76	8000	771	+168
Required Accuracies: Horizontal 1500 feet, Vertical ± 405 feet						

NOTE: Two missiles failed electrically during flight and one failed at launch because of propulsion system malfunctions.

To obtain a more realistic simulation of missile performance, a jet-propelled F-80 was phased into the program in October 1948. Installed in the F-80 recoverable missile was previously tested guidance equipment that had been miniaturized to fit in the Rascal missile. An ogive radome with radar scanning equipment was installed on the nose, while wing-tip tanks housed components of the relay and command system. In addition, fins were installed on the wings to permit flat turns so that missile performance could be more closely simulated. This airplane served as an airborne platform on which missile guidance and control equipment was tested to establish the final specifications for Rascal. The first flight tests with the F-80 and B-17 were made in June of 1950. Approximately 100 flights, predominantly guidance control tests evaluating the complete Rascal guidance system, were conducted at Bell Aircraft's main plant in Wheatfield, New York. In November of . 51, the B-17 and F-80 were transferred to the Air Force Missile Development Center (AFMDC), New Mexico, to take advantage of more-favorable flying weather. More than 100 additional flights were made in New Mexico to evaluate terminal guidance accuracy and to establish a target recognition capability.

Late in 1952, a series of guidance demonstration flights was scheduled for the benefit of observers of the Strategic Air Command. To demonstrate the potential of the Rascal terminal guidance system, several simulated dives were made on complex target areas in El Paso and Amarillo, Texas, and in Alburquerque, New Mexico.

Concurrently with the program at the AFMDC, another F-80/B-17 combination was being used at Bell Aircraft's Wheatfield plant. In addition to guidance control flights, the F-80 was flown to check out the DB-50 as a director aircraft prior to actual missile launchings. The B-17 was equipped as a flying laboratory to assist in development work on guidance equipment such as automatic gain control circuitry, missile search radar with increased power, antijam devices, and K_u band radar. These developmental flights were continued until February 1957.

In mid-1954, an F-89 was modified to replace the F-80 simulated missile primarily because the F-89 was capable of operating at a higher speed and a higher altitude (50,000 feet as opposed to 30,000 feet). The F-89 was used to evaluate the guidance system configuration installed in Model F missiles; more than 100 F-89 flights were made at Wheatfield, New York. In January of 1956, the F-89 and a B-17 were flown to Whitman Air Force Base, Missouri, where 11 flights were conducted over Kansas City, Missouri. Photographic data were obtained to compare an actual in-flight scope presentation with that of the Rascal guidance operator trainer which used a metallic simulator map of the Kansas City region. Results indicated that the simulator map technique was satisfactory. In addition, the radar scope films were delivered to the Air Force for training SAC guidance operators in target recognition.

Next, the F-89 was used in the Target Acquisition Program at Phoenix, Arizona. This program was conducted to obtain a measure of the guidance operator's ability to recognize and track a target within a metropolitan complex. With a DB-36 servicing as a director aircraft, the F-89 made 18 dives on targets in the Phoenix complex. Three SAC Air Observers and one Bell Aircraft engineer participated in the program as guidance operators in the DB-36. Scorable results obtained on 11 of the 18 flights indicated that the Rascal guidance system is capable of directing the GAM-63A to within approximately 700 feet of a recognizable target. The accuracy demonstrated for a target unidentifiable by itself within a complex is within 3000 feet, where position coud be located only by reference to surrounding returns in the complex.

Following the program at Phoenix, the F-89 was used in combination with a DB-36 during the Electronics Vulnerability Testing (EVT) Program at the AFMDC. The F-89 replaced the F-80 which had served in the initial stages of vulnerability testing. The EVT program was conducted by the Air Force with Bell Aircraft support to determine the susceptibility of the Rascal weapon to interception by jamming and deception. In all, 48 flights were conducted with the F-80, 38 flights with a DB-36, and 15 flights with the F-89. A report has been published (Reference 9) by the Missile Countermeasures Laboratory of the AFMDC covering the results of this program.

b. Conclusions

Hundreds of simulated Rascal flight tests were conducted without a serious accident. These tests contributed substantially to the early development of the Rascal guidance and servo-control systems with great savings in time, man-hours, and material. The use of recoverable aircraft was invaluable in the statistical evaluation of guidance accuracy and reliability; obviously, the expenditure of missiles for this purpose was not practical. Training directly by actual flights for SAC and Bell Aircraft guidance operators, as well as indirectly by providing films and other data for the training aids such as the Rascal Guidance Operator Trainer, was a significant contribution to the over-all program.

2. GRAVITY BOMB PROGRAM

Missile modifications were evaluated in a separate flight test program to provide Rascal with an alternate gravity bombing capability for use when normal launch could not be accomplished operationally. This program included the launching of three modified full-scale Rascal airframes from a DB-47 under typical launch conditions. The program was conducted at the AFMDC between 5 April and 13 June 1957. Three Model B missiles were modified to include only telemetry, electrical, and hydraulic system; ballasting provided the same gross weight

III. CONCLUSIONS

Two primary conclusions can be drawn from the results of the Rascal R&D flight test program: (1) the weapon system, as of the completion of the program, is marginal from a reliability standpoint and (2) weapon system performance in terms of missile range, speed, and accuracy exceeds contractual requirements.

An indication of the reliability can be obtained from the test results of the last 23 missiles. Sixty-one launch attempts were required and, of the 21 missiles that had a chance, 12 succeeded in reaching the target area. Nine missiles (43%) were guided to the target with 100% success. Improvement occurred near the end of the program when five of the last eight missiles (62%) were 100% successful, while 18 launch attempts were required.

Relative to performance, seven missiles in the program demonstrated the 75-nautical-mile range capability; three missiles of four which were programmed for 90 nautical miles attained that range. Speed and altitude performance were repeatedly demonstrated. Twelve missiles with complete guidance operation achieved a CEP of 710 feet as compared with the 1500-foot requirement. Twelve missiles with useful fuzing data demonstrated a one-sigma value of 300 feet vertical error as compared with the requirement of 405 feet.

Two major factors contributed to the limited success of the Rascal flight test program:

(1) The early phases of the test program were accelerated too rapidly, in that complete guidance system testing was attempted before the missile had become a reliable flying machine. In retrospect, it can be seen that this came about through overconfidence created by success of the first few missiles and by the general urgency placed upon the program.

(2) While the intensified reliability program provided an improvement in performance repeatability, the effort was phased-in too late for the weapon system to attain the desired results by the end of the flight test program. Further development was needed and was recommended by Bell Aircraft to improve the repeatability of the performance which had been demonstrated.

Largely because of these two factors, the Rascal Weapon System, with its 90-nautical-mile standoff capability and its demonstrated pinpoint accuracy, had a marginal reliability for operational use when taken over by the Air Force at the end of the R&D program.

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and center of gravity as that of a fully loaded Model F missile. Each test vehicle also incorporated a pyrotechnic device which when actuated displaced the ailerons in a hard-over position. The induced roll served to spin-stabilize the missile throughout the free drop. The basic objectives of the program were to check a gravity bomb flight path, to obtain data on the impact fuzing system, and to evaluate the launch properties of a "dead" missile. Results obtained from the gravity bomb tests indicated satisfactory attainment of all test objectives, and these results compared favorably with the capability study predictions. Flight path data from the three tests showed good repeatability and correlation. The investigation successfully demonstrated the gravity bomb capabilities of the Rascal missile. This capability is being incorporated into all operational missiles. A report covering the results of this program (Reference 2) has been published by Bell Aircraft Corporation.

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