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THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

8621 GEORGIA AVENUE
SILVER SPRING, MARYLAND

Operating under Contract NOrd 7386
with the Bureau of Ordnance, U. S. Navy

SURVEY OF

BUMBLEBEE

ACTIVITIES

SECURITY INFORMATION

JULY
1952

[redacted]

IN REVIEW

The general objective of the **Bumblebee** project, initiated in 1945, has been the development of a radar-guided, ramjet-propelled, supersonic missile (Talos). Originally limited to antiaircraft application, **Bumblebee** has been extended to include a long-range, ship-launched, guided bombardment missile (Triton) as well as a short-range, solid-rocket-propelled antiaircraft missile (Terrier). These missile objectives have been the outgrowth of a research and development program in basic fields of science related to a guided missile technology. Achievements in the general technology as well as in specific missile developments include the following:

April 1945:	Ramjet burning in flight with 6-inch unit
June 1945:	Ramjet thrust in flight with 6-inch unit
June 1945:	Successful telemetering from burning ramjet
July 1945:	Initiation of burner experiments at APL
July 1945:	Execution of 5g turns by winged, supersonic rockets
August 1945:	Initiation of burner experiments at OAL
August 1945:	Bang-bang roll stabilization of subsonic CTV
September 1945:	Bang-bang roll stabilization of supersonic coaster
October 1945:	Ramjet acceleration in flight with 6-inch unit
November 1945:	Proportional roll stabilization of subsonic CTV
December 1945:	Burner tests of RTV (18-inch ramjet) at OAL
March 1946:	Initiation of wind tunnel tests at OAL
September 1946:	Ramjet flight to range greater than 20,000 yards with 6-inch, kerosene-fueled unit
September 1946:	Successful flight test of RTV (18-inch ramjet)
September 1946:	Twelve-channel telemetering operated successfully in burning ramjet (RTV)
January 1947:	Subsonic beam riding for 16 seconds along a fixed beam with CTV
May 1947:	Temperature telemetered from burning ramjet in flight
June 1947:	Subsonic beam riding along slowly moving beam with CTV
August 1947:	Flight of BTV (18-inch) to maximum velocity of 2520 feet per second and with maximum acceleration of 4g
August 1947:	Supersonic roll stabilization with STV
December 1947:	Cobras unmodified for altitude operation burn to heights above 35,000 feet and coast to over 50,000 feet
March 1948:	Supersonic beam riding for over 20 seconds with STV-2
July 1948:	BTV (18-inch) burned successfully to over 40,000-ft altitude and coasted to 70,000 feet
July 1948:	Jet-vane control of booster rocket
December 1948:	Successful launching of STV from "zero-length" launcher
March 1949:	Successful flight test of XPM, the 24-inch-diameter prototype
April 1949:	Successful use of capture beam with supersonic test vehicle
September 1949:	Cobra (6-inch ramjet) operation to 60,000-ft altitude
October 1949:	STV-3 beam-riding accuracy greatly increased to achieve longest beam-riding flight to date; 54 seconds of powered flight
February 1950:	Successful flight of first production pre-Terrier unit
March 1950:	Successful roll stabilization of XPM (RTV-N-6a2)
May 1950:	First test of supersonic guided missile against target drone
October 1950:	First dual-launching test of supersonic guided missile against target drone
December 1950:	Successful demonstration of accurate Terrier guidance computer
March 1951:	Demonstration of beam-guided, 28-inch, ramjet-propelled prototype Talos missiles
April 1951:	Successful target test of Terrier proximity fuze
September 1951:	Successful shipboard launching of a Terrier missile
October 1951:	First flight test of radar interferometer homing system using RTV-N-6a4a
December 1951:	Detonation of Terrier warhead causing damage to target plane
May 1952:	Destruction of two F6F target drones by Lot 3 Terrier missiles

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FOREWORD

The SURVEY OF BUMBLEBEE ACTIVITIES is issued monthly by the Applied Physics Laboratory of The Johns Hopkins University. It is one of the Section T BUMBLEBEE series of documents, which also includes technical papers and symposia reports. The Survey is intended to provide a brief summary of the month-by-month progress of the BUMBLEBEE guided-missile project which has been undertaken by a Section T group of associate and related contractors. The contractors currently engaged in this work are:

1. Aerojet Engineering Corporation
2. Applied Physics Laboratory, The Johns Hopkins University
3. Applied Science Corporation of Princeton
4. Bendix Aviation Corporation
5. Capehart-Farnsworth Corporation
6. Consolidated Vultee Aircraft Corporation
7. Cornell Aeronautical Laboratory, Inc.
8. Experiment Incorporated
9. Goodyear Aircraft Corporation
10. Hercules Powder Company
11. The Johns Hopkins University, Baltimore
12. M. W. Kellogg Company
13. McDonnell Aircraft Corporation
14. New Mexico College of Agriculture and Mechanic Arts
15. Princeton University
16. Radio Corporation of America
17. Standard Oil Development Company
18. University of Michigan
19. University of Texas
20. University of Virginia
21. University of Wisconsin

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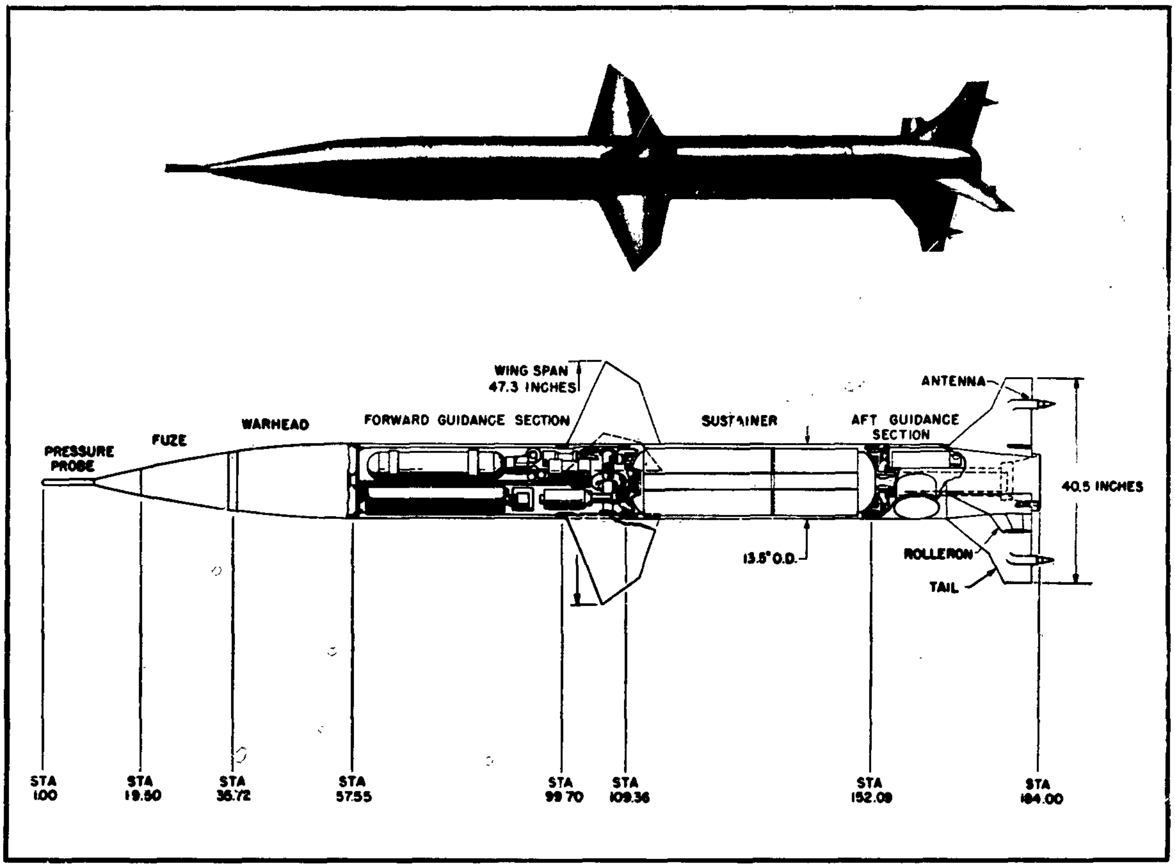


TERRIER

Description (Lot 4)

Terrier (XSAM-N-7) is a solid-rocket propelled, supersonic surface-to-air guided missile, designed to provide antiaircraft protection for ships to a horizontal range of 20,000 yards, against targets approaching at speeds up to 800 feet per second and at altitudes up to 35,000 feet.

Configuration

The Terrier missile has a diameter of 13.5 inches, a length of 183 inches, a wing span of 47.3 inches, a tail span of 40.5 inches, and a weight of approximately 1100 pounds, including sustainer rocket fuel. The four steering wings, oriented in a cruciform configuration, are located near the center of gravity. The four fixed tail surfaces are oriented 45 degrees with respect to the wings.

The launching configuration of missile and booster has a total length of approximately 28 feet and a weight of approximately 2300 pounds.

Launcher and Booster

Terrier is launched to a speed of 2000 feet per second by means of a solid-propellant booster rocket (JATO, 2.5-DS-59000) which provides 59,000 pounds of thrust for 2.5 seconds. A shipboard, zero-length dual launcher, trainable in azimuth and elevation, is used to direct the missile initially along a radar beam which tracks the target.

Propulsion

Terrier is propelled by a solid-rocket sustainer which produces a thrust of approximately 2350 pounds for a period of 20 seconds. The sustainer maintains the velocity of the missile at about 1200 miles per hour until burnout occurs.

Guidance

The Terrier missile is guided to intercept the target by being constrained to ride the axis of the radar beam which is tracking the target. The initial launching direction is controlled so that the missile with normal dispersion during the boost period will intersect a wide, low-power, auxiliary radar capture beam and recover into the center of this beam. The basic beam-rider intelligence is furnished from a conically-scanned, pulsed radar whose repetition rate is frequency-modulated to supply a reference signal in the scan cycle. The missile will select guidance intelligence from the narrow guidance beam rather than from the capture beam as determined by the pulse coding present and the setting of the decoding circuits controlled by a timing mechanism of the missile.

Stability and Control

The Terrier missile is roll stabilized for coordination of the missile axis with that of the guidance radar. Roll stabilization about the longitudinal axis is obtained from differential motion of rollerons on two opposite tail fins.

Roll and steering intelligence is processed by missile-borne computers to produce control signals which in turn feed electromechanical servo systems driving the rollerons and steering wings.

The steering computer provides path damping, converts angular error to linear displacement error, limits wing angle as a function of altitude and speed, and compensates for any persistent lag in following the radar beam.

Telemetering

A simple three-channel FM/FM telemetering system is included in Terrier for evaluation purposes.

Warhead and Fuze

An ultra-high velocity fragmentation warhead weighing 220 pounds will be used with a microwave proximity fuze.

Status

The Terrier missile (XSAM-N-7), which is in an advanced prototype development stage, has been developed from a guidance test vehicle, the STV, designed to test supersonic control and beam-rider guidance for the Talos missile. These development vehicles have been guided successfully since March 1948. Engineering design of a Terrier prototype based on the STV-3 and incorporating warhead and fuze, was completed early in 1949, and was followed by the production of an initial lot of 15 missiles (designated Lot 0) by the Consolidated Vultee Aircraft Corporation. Fourteen missiles of this lot have been flown at the Naval Ordnance Test Station, Inyokern, California, where equipment simulating the shipboard installation was installed for tests prior to shipboard use.

The first actual Terrier missiles manufactured in accordance with production specifications were designated Lot 1. The first units of this lot became available in October 1950. Lot 1 was followed by the production of Lots 2 and 3 consisting of 10 to 15 units each which incorporate improvements suggested by flight and development tests. A larger quantity of Lot 4 missiles, which will include all of the military features required for Service evaluation, will be produced. The missiles in this lot are expected to be the development prototypes of the first tactical Terrier missile. The first Lot 4 missile to be fired (Serial No. 42) was tested at NOTS in April 1952.

TABLE I

Flight Tests of Production Lot Missiles in Terrier Program

Production Lot	Fuze; Warhead; Smoke Puffs	Missiles Flown at NOTS		Missiles Flown from Aboard AVM-1	
		Against F6F Target Drone	Without Target Drone	Against F6F Target Drone	Without Target Drone
Lot 0	Fuze	Serial Nos. 6, 5, 8, 7, 9			
	Fuze and Smoke Puffs	Serial No. 11			
	None	Serial Nos. 3, 10, 12	Serial Nos. 1, 2, 13, 14, 15		
Lot 1	Fuze	Serial Nos. 1, 15			
	Fuze and Warhead	Serial Nos. 2, 4, 5			
	Fuze and Smoke Puffs	Serial Nos. 12, 14, 11, 3			
	None	Serial Nos. 7, 10, 8	Serial Nos. 6, 9		
Lot 2	Fuze and Warhead	Serial No. 19		Serial No. 25	
	Fuze and Smoke Puffs	Serial Nos. 17, 18		Serial Nos. 24, 23	
	None	Serial No. 22			
Lot 3	Fuze and Warhead	Serial No. 36, 37		Serial Nos. 28, 30	
	Fuze and Smoke Puffs	Serial No. 29		Serial No. 27	
Lot 4	Fuze	Serial No. 42			

The two most recent Terrier flight tests were held on May 16 using Serial Nos. 36 and 37 of Lot 3. These missiles, flown to demonstrate the effectiveness of the missile fuze-warhead combination against F6F target drones, were extremely successful. Both drones suffered immediate and conclusive kills and fell to the ground in flames. A listing of the forty-two missiles from Lots 0, 1, 2, 3, and 4 which have been flown at NOTS and from aboard the USS *Norton Sound* since February 1950 is given in Table I. The flight tests of all of these missiles have been reported in previous issues of the *Survey*.

The AVM-1 went to the San Francisco Navy Yard in January 1952, where the Terrier shipboard equipment used in firing missiles of Lots 2 and 3 has been modified to permit testing of Lot 4 missiles.

The USS *Mississippi* went to the Norfolk shipyard on February 1, 1952 for modification to adapt it for the firing of Terrier missiles. This modification is due to be completed on August 8 when the *Mississippi* will leave the shipyard. A preliminary BuOrd evaluation program of missiles fired from the *Mississippi* will be conducted this fall, after which the ship will go into a program of OPDEVFOR evaluation of the Terrier weapon.

Concurrently with the engineering and test program, development effort is continuing at APL and at Convair toward producing a considerably improved version of Terrier, designated Lot 6. The primary goal is to increase missile maneuverability, particularly at high altitudes, in order to improve accuracy and effectiveness against maneuvering targets. In addition, the maximum range is being increased to 30,000 yards by improvement of the sustainer rocket and the use of a larger booster; greater lethality is being accomplished by use of a heavier warhead; and considerable improvement is being sought in performance at very low altitudes.

Two Navy Guided Missile Training Units and one Marine Corps Unit were trained at APL, and later at Convair and NOTS, to become indoctrinated in the checkout, handling, preflight, and flight tests of the pre-Terrier and Terrier missiles. All three units have participated in the flight tests of the proof firings at NOTS in cooperation with Convair and APL. The first Navy Unit, designated GMU No. 21, has reported aboard the USS *Mississippi* (EAG-128) and will participate in the OPDEVFOR evaluation of Terrier missiles. The second Navy Unit, designated GMU No. 23, has replaced GMTU No. 21 aboard the *Norton Sound*. A third Navy Unit, to be designated GMSU No. 211, recently completed training at APL and at Convair. This unit, acting as a service and logistics group, is operating at Naval Mine Depot, Yorktown, Virginia. Another service unit, GMSU No. 213, will enter training at Convair in July, and will report later to the Naval Ammunition Depot, Crane, Ind. and the Naval Ordnance Plant at Indianapolis.

Functional Test Equipment for Terrier

ABSTRACT—A testing device, known as the Bureau of Ordnance Functional Test Equipment, for the pre-flight testing of Terrier missiles, has been devised at the Applied Physics Laboratory and the Vitro Corporation, and is being constructed by the Hycon Manufacturing Company. The test is of the open-loop type, in which the equipment automatically controls the missile and programs the test inputs. A signal generator feeds a microwave signal to the missile to test the "A" and "B" channels; simulated gyro signals test the roll system. Wing and rolleron transducers mounted on the missile measure control-surface motion to determine missile response to the programmed inputs and feed this information back to "Go, No-Go" indicators and a recorder. Determination of missile flight-readiness is made by examination of the "Go, No-Go" indicators, supplemented by a simple analysis of the recordings.

When it became evident in the fall of 1951 that the ruggedized factory-type test equipment for pre-flight checking of the Terrier missile, for use on the U.S.S. *Mississippi*, would not be ready as early as planned, the Bureau of Ordnance requested the Applied Physics Laboratory, the Vitro Corporation of America, and the Consolidated Vultee Aircraft Corporation to recommend a suitable testing facility which could be built on an emergency basis. The recommendations of APL and the Vitro Corporation[1] were combined into a proposed design, known as the Bureau of Ordnance Functional Test Equipment, which is now being constructed by the Hycon Manufacturing Company, Pasadena, California, under a contract with the U. S. Navy Bureau of Ordnance.

The performance of the Terrier missile is checked by an open-loop test in which the intelligence input to the missile is programmed

[1] The Convair-recommended equipment, known as the "Flight-Ready Indicator," is not discussed in this article.

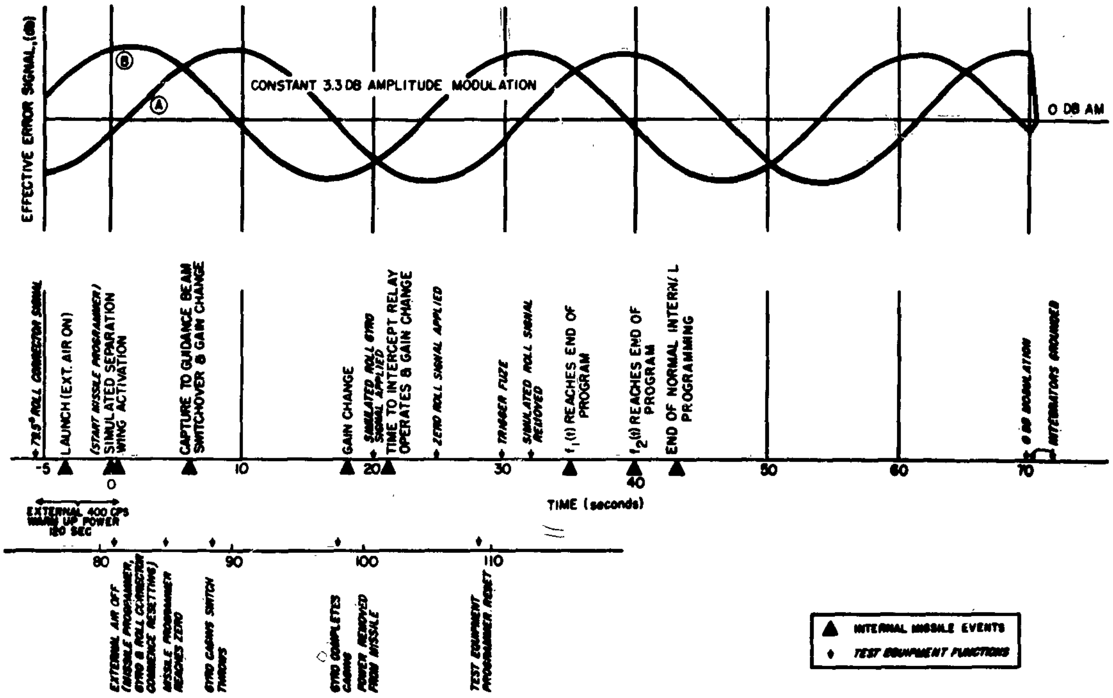


FIG. 1. INTELLIGENCE INPUT SIGNAL TO MISSILE AND SEQUENCE OF TEST EVENTS

automatically, and the response of the control surfaces to this program is measured to determine satisfactory performance. This test subjects the missile to a functional dynamic check without monitoring any internal voltages. The intelligence fed into the missile is a microwave signal of constant power level and constant-amplitude modulation. The intelligence program is obtained by continuously advancing the phase of the amplitude modulation with respect to the pulse-repetition-rate modulation at a rate of twelve degrees per second. This effectively results in a sinusoidal intelligence input to each channel of the computer, with the signals in the "A" and "B" channels ninety degrees out of phase, as illustrated diagrammatically in Fig. 1. The test is programmed so that at simulated wing activation, the "A" channel control signal after the lead network is zero, while that in the "B" channel is maximum.

The actual motion of the wings is effected by the action of the various limiters and by changes in internal gain in the missile, and follows a program such as that illustrated graphically in Fig. 2. The amplitude of the error signal and the period of the phase rotation were selected to accentuate the effects of the various limiters and gain changes. The roll system is tested by applying a roll-corrector signal to the missile in a fashion to produce a twelve-degree negative rolleron deflection, as illustrated graphically in Fig. 3. Subsequently, a simulated gyro signal is applied to the roll-test input to effect a twelve-degree rolleron deflection in a positive direction. The roll-test input is then shorted for several seconds, after which the roll-corrector signal is restored and the missile rolleron assumes its original condition.

Wing and rolleron transducers, mounted on the missile, measure the response of the control surfaces to the test signals described above. Each transducer includes contact sectors which

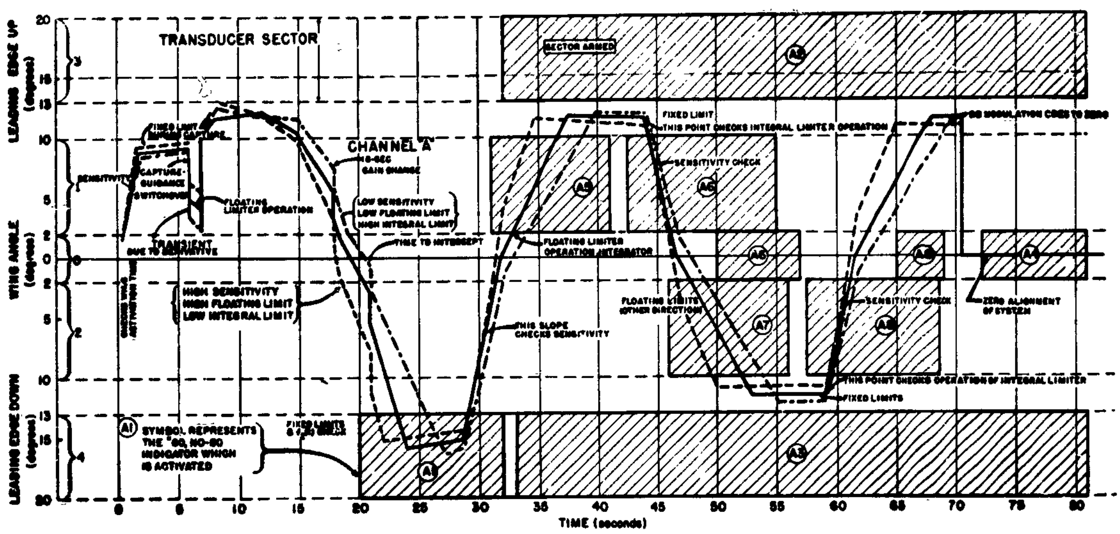


FIG. 2. MOTION OF WING "A" INDUCED BY TESTING PROGRAM

actuate the "Go, No-Go" indicators for certain control-surface deflection angles, and potentiometers which supply voltages to direct-writing recorders proportional to wing deflection.

Data presentation is, therefore, on a "Go, No-Go" basis, implemented by red and green indicators on the operating panel, and by recordings of the response of the "A" and "B" channels, and the roll-control surface motion.

The "Go, No-Go" indicators reflect the action of a selected group of functions, chosen because they should present most missile troubles. The recordings, however, are necessary to delineate the presence of the more unlikely troubles, which include such ills as intermittent faults, noise, and oscillations.

A microwave signal generator, operating at a fixed X-band frequency identical to that of the shipboard radar, furnishes pulses similar to those generated by the guidance radar, and is incorporated in the design as shown schematically in Fig. 4. The tolerances of the signal generator are sufficiently narrow to cause malfunctions of receivers which have such errors as incorrect de-

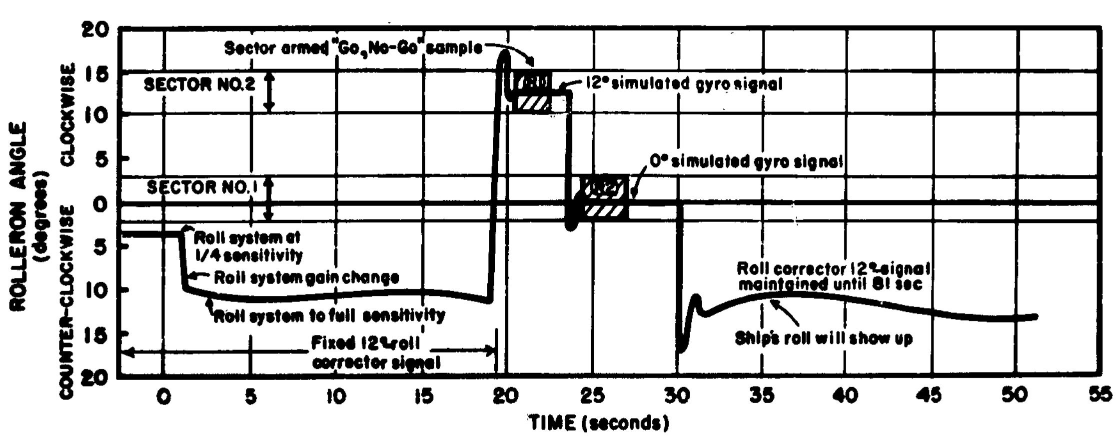


FIG. 3. ROLLERON MOTION INDUCED BY TESTING PROGRAM

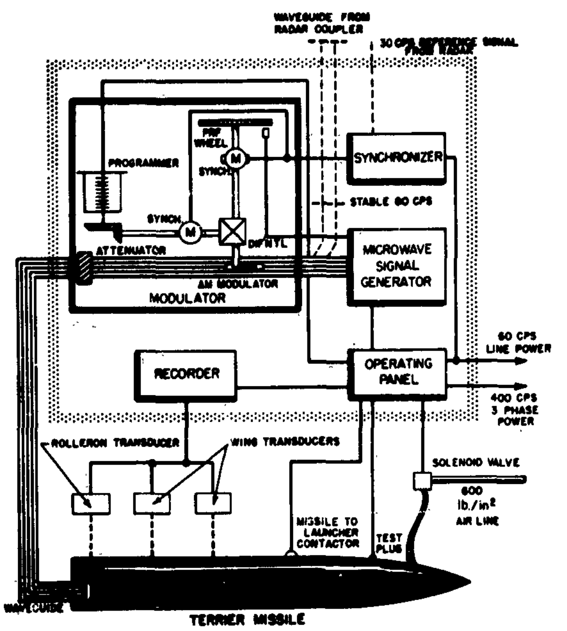


Fig. 4. Block Diagram of Bureau of Ordnance Functional Test Equipment for Terrier

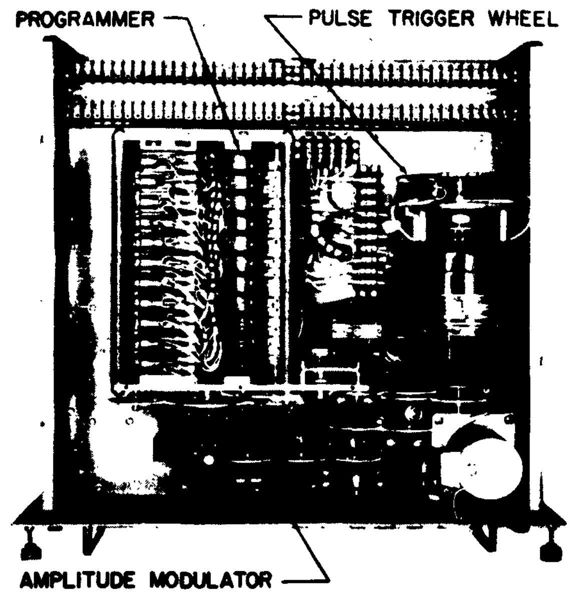


Fig. 5. Microwave Modulator for Terrier Test Equipment

coder settings. The output signal of the generator, consisting of pulsed microwave energy, is fed to the microwave modulator, illustrated photographically in Fig. 5, which uses a dipping waveguide attenuator, motor-driven at 30 cps, to impose the amplitude modulation, whose magnitude is 3.3 db, on the microwave energy. The input shaft of a mechanical differential is driven at the rate of one revolution per 30 seconds by an auxiliary motor to cause the relative angular position of the amplitude modulator to change with respect to the position of the pulse trigger wheel at the rate of 12 degrees per second. A low signal level, approximately −20 dbm, is used, so that a receiver with poor range characteristics performs improperly.

A master programmer of approximately 40 cam-operated microswitches, driven on the same low-speed shaft as the differential, takes the missile through the simulated launching procedure, activates the various "Go, No-Go" indicators, restores the missile to its shutdown position, and deactivates the test equipment.

An operating panel, illustrated photographically in Fig. 6, contains all circuits and manual controls required to control the test equipment and to provide the signals to the missile which simulate launch and which reset the missile and test equipment after the run. The "Go, No-Go" data display consists of pilot lights, motor-driven disks, and zero-center meters.

Thirteen functions are checked by means of pilot lights. There are independent red "No-Go" lights for each function and the common green "Go" light, which is illuminated when all thirteen functions are performed properly.

Eight motor-driven disk indicators are provided, four for each guidance channel. These act as clocks and measure the time taken by a wing in traversing specific angular ranges. The angular ranges over which the clocks operate are fixed in the transducer design, therefore the disk indicators essentially measure wing velocity. A red or green portion of the disk, when it stops, is visible through a window engraved with a reference line. If green, the disk indicates that the missile is within tolerance for that particular function. If the wing is moving too fast or too slow, for instance, the disk indicator will stop with the red signal visible through the aperture.

Four zero-centered vacuum-tube voltmeters monitor the fuze voltages. The center portion of the meter scales are marked green to indicate the tolerances for acceptable fuze performance. Unacceptable fuze voltages cause the meter to indicate red.

The operating panel, in conjunction with the master programmer, comprises circuitry to perform roll-corrector activation; to provide time-to-intercept to the missile; to provide a series of contactors, connected in series with contacts of the missile-to-launcher contactor, which open at simulated missile launch so that it is unnecessary to actually remove the missile-to-launcher contactor from the missile; and to feed the capture-to-guidance switch-over signals from the missile to the signal generator causing that unit to switch codes. The operating panel provides the power for the wing and rolleron transducers, and for the recorders. Circuitry is provided so that external power is applied to recage the gyro in the event that the internal power of the missile fails.

A six-channel, direct-writing recorder is employed. Although it is presently intended that only three channels be recorded, that is, "A" wing motion, "B" wing motion, and rolleron motion, six channels are available to provide for any future development.

In conducting a test, the missile is assembled to the test stand, the 600-lb/in² air line is connected, the missile-to-launcher contactor is connected, the cable to the test plug on the missile is attached, and the wing and rolleron transducers are installed. The waveguide, run from the test equipment, is connected to the waveguide input on the missile. When all such links have been made, the operator depresses the "Test-Start" button. Approximately two minutes later, the action of the master programmer is initiated, and the phase rotation begins. The recorder drive motor starts immediately thereafter, and five seconds later the first operation in the test of the missile occurs with the application of the roll-corrector signal to the missile.

Zero-time reference is placed at the simulated booster-missile separation. The various programmed events of arming the "Go, No-Go" indicators continue to occur sequentially. The various red pilot lights either remain red or go out as missile functions are checked. The disk

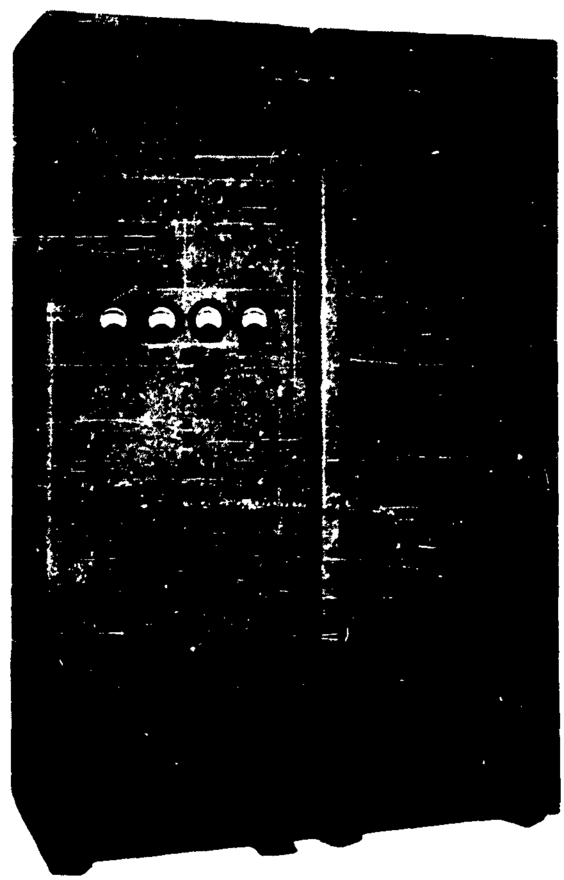


FIG. 6. OPERATING PANEL FOR TERRIER TEST EQUIPMENT
On the left is shown the test rack including, from top to bottom, the modulator, operating panel with "Go, No-Go" indicators, coder, the synchronizer (60-cps supply for modulator), and the power supplies. On the right is shown the recorder rack.

indicators rotate as they are energized and stop on "Go" or "No-Go" indications. At 69 seconds after simulated separation, the amplitude modulation from the beam simulator is reduced to zero and the missile integrators are momentarily grounded, causing the wings to assume a zero position so that unbalance and drift may be checked. After this, the re-set operations on the missile commence and voltages are applied to return the cam timer to a zero position. At 120 seconds after it begins to run, the master programmer reaches the re-set point and stops operation. Caging of the gyro automatically removes power from the missile. The missile is then in the initial condition ready for return to storage, or for flight, or for another test.

The indicators are arranged according to channels "A" or "B" or "Roll" or "Fuze", so that unsatisfactory missile conditions are isolated to the channel in which the trouble occurs. Each channel has several indicators so that any one of them which shows unsatisfactory test isolates the unsatisfactory condition to several items, which must then be resolved by other methods. For example, analysis by observation of the "Go, No-Go" equipment might indicate that in the "A" channel, either the floating limiter, or the fixed limiter in one direction, is not operating correctly. Further testing, or another analysis, would be required to determine the malfunction exactly.

A recording of the response of the "A" and "B" channels, and roll wing motion, is provided for use in making a more thorough analysis of the test. The recording provides all the information obtained from the "Go, No-Go" test, and in addition, registers the more unlikely failures that may occur which would not be detected by the "Go, No-Go" test. Information obtainable from the recordings not gained from the "Go, No-Go" test includes the "A" and "B" wing activation time, fixed limits during capture phase, "A" and "B" derivative action, operation of each gain-change switching operation, noise characteristics of the "A", "B", and roll channels, "A", "B", and roll wing speed, "A" and "B" channel gain during early portion of flight, "A" and "B" channel receiver phasing, rolleron quarter-gain, rolleron stability characteristics, intermittent malfunction condition in any channel, check of time-to-intercept relay operation, $f_1(t)$ gain change, and wing zero during boost.

In order to keep the test reasonably simple, it was necessary to make compromises in testing. However, those items not tested are least likely to cause trouble, provided that a thorough test has been made at the shore depot. Those items not checked by the equipment include the roll gyro (except "cage-uncage" and signal continuity), asymmetrical limiter, self-destructor, fuze arming or firing, sustainer ignition, separation switch, booster warm-up wiring, pressure-potentiometer functioning at altitude, telemeter operation, and igniter safety switch.

Future improvements in the equipment should include the elimination of the four meters which monitor voltages in the fuze. Once the proper circuitry is available to provide a functional test of the fuze, a pilot light should be adequate to indicate proper fuze functioning. When these four meters have been eliminated, it will then be desirable to have additional cams and microswitches on the disk indicators so that the green "Go" pilot light may indicate proper functioning of all "Go, No-Go" tests, whether they be pilot light or disk indicator display.

Sustainer Unit for Lot 4 Terrier Missiles

ABSTRACT—The Lot 4 Terrier sustainer is the end result of a research and development program conducted at the Allegany Ballistics Laboratory for solid-propellant propulsion of a Type I Terrier missile subsequent to its boost phase. The unit produces an average thrust of 2350 pounds while burning for 20.1 seconds at an ambient temperature of 77°F. The igniter is of the "quick-arming" type recently developed for the Lot 4 Terrier sustainer and booster. This newly-designed component may be armed only by means of a special tool provided to minimize the possibility of accidental arming. In the event of accidental ignition while in the unarmed position, the igniter assembly is blown out of the chamber head-cap, rendering the sustainer non-propulsive.

The sustainer for the Lot 4 Terrier missile, officially designated Mk 1 Mod 0 (JATO 20-DS-2350, X213 C1), has been developed from the sustainers used in the STV-1,-2,-3, and Terrier Lot 1, 2, and 3 missiles by the Allegany Ballistics Laboratory. The sustainer is a solid-propellant rocket employing a cylindrical propellant grain of OGK composition weighing 247 pounds. A single central perforation runs through its entire length, with three radial slots approximately one foot in length in the after end.

The sustainer unit burns for 20.1 seconds at an ambient temperature of 77°F, producing an average thrust of 2350 pounds and a total impulse of 47,650 lb-sec. The angle of the nozzle-expansion cone is 25 degrees. An immobilizer assembly maintains the propellant grain in position against its seat in the after end of the chamber before and during flight. The assembly incorporates four coil springs to overcome normal handling forces, as well as a boost-actuated immobilizer mechanism which is effective against the more severe loads encountered during the period of deceleration immediately following the boost phase of flight.

An inhibitor of cellulose acetate is bonded to the external cylindrical portion of the propellant grain, and a flat disk of this material separates the slotted and perforated sections of the grain. The inhibitor serves to prevent burning on the external cylindrical surface of the propellant grain and also provides a measure of insulation for the chamber walls. The internal inhibitor, or restriction plate, is necessary to provide the neutral burning characteristic of this sustainer.

The sustainer, which weighs 435 pounds, is 71.891 inches in length and has an outside diameter of 13.50 inches, as illustrated diagrammatically in Fig. 7. Its position within the missile is shown in the sketch on page 1.

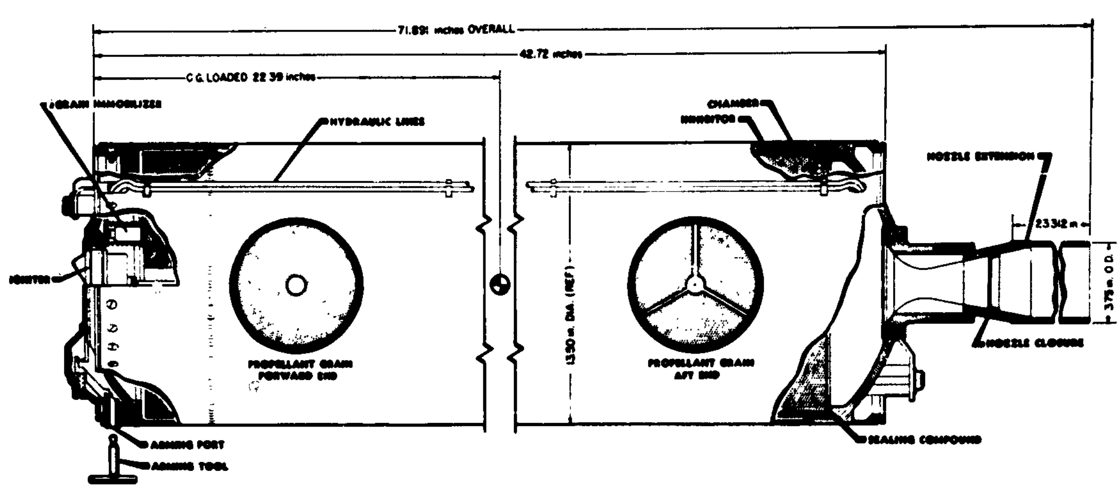


Fig. 7. Sustainer Unit for Lot 4 Terrier (Mk 1 Mod 0)

The chamber body is a steel shell with a removable head. The nozzle is threaded into position in the tail cap. Its extension is approximately two feet in length and 3¾ inches in diameter. A stator ring for attaching the unit to the missile is located at each end of the sustainer. A pressure take-off is provided for static testing and may be used in telemetering. The unit is temperature-conditioned between the limits of 0°F and 120°F for firing and −10°F and 140°F for storage. Pertinent performance data are enumerated in Table I, and a typical thrust-time record is illustrated graphically in Fig. 8.

TABLE I

Terrier Sustainer Performance (at 77°F)

Burning Time	20.1	seconds
Action Time	21.4	seconds
Maximum Pressure	1180	lb/in²
Average Pressure	1150	lb/in²
Maximum Thrust	2395	lb
Average Thrust	2350	lb
Total Impulse	47,650	lb-sec

The sustainer employs a "quick-arming" igniter of the type specifically developed for use with the tactical Lot 4 Terrier missile.[2] This is ocated within the forward head closure as an integral part of the sustainer. The igniter comprises 65 grams of FFFG black powder and 65 grams of 0.031-inch JPM booster sheet in quarter-inch squares. Ignition delay is 0.030 second, and the minimum igniter current is 4 amperes, applied to four electric squibs wired in a series-parallel circuit.

In order to minimize accidental arming of the sustainer, the igniter may be armed only by a special tool. When unarmed, the squib leads are shorted together and grounded, and only a shear washer prevents the igniter closure from rising out of position. In the event of accidental ignition, a pressure of 100 to 200 lb/in² in the rocket chamber causes the igniter closure to fracture the shear ring and blow out, creating a vent area sufficiently large to render the sustainer non-propulsive.

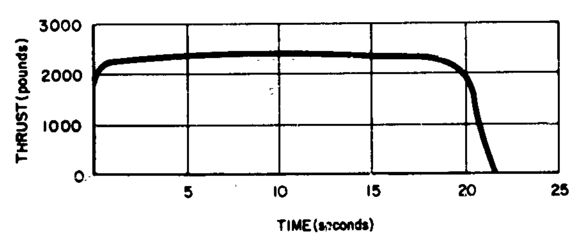
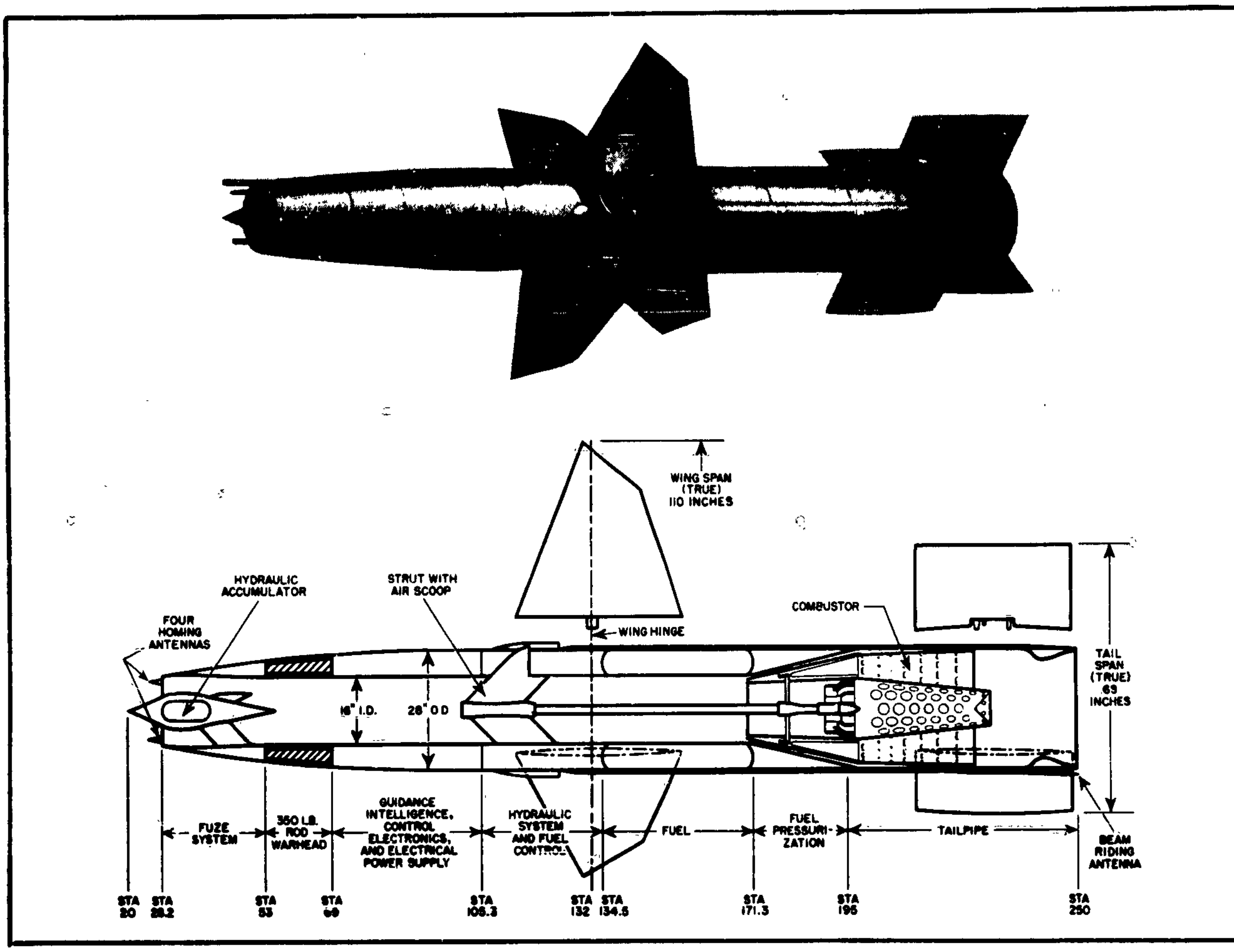


FIG. 8. TYPICAL THRUST-TIME RECORD FOR LOT 4 TERRIER SUSTAINER

[2] The igniter is described in detail in BUMBLEBEE Report No. 154, pages 12–13 (May 1951 Survey).



TALOS

Description

Talos (XSAM-N-6) is a ramjet-propelled, supersonic, surface-to-air guided missile designed to intercept and destroy aircraft carrying guided missiles at horizontal ranges from 10,000 to 100,000 yards, at altitudes up to 60,000 feet and at elevation angles as low as one degree.

Configuration

The Talos missile will have a diameter of 28 inches, a length of 19 feet, a wing span of 110 inches, a tail span of 68 inches, and a weight of approximately 2700 pounds in fueled condition. The cruciform wings and tails will be positioned in line on the missile.

The launching configuration of missile and booster will have a total length of 27.5 feet and an approximate weight with fuel of 5700 pounds.

Launcher and Booster

A solid-fuel rocket, providing approximately 370,000 pound-seconds of impulse for over four seconds will be used to launch Talos to a nominal separation velocity of 2000 feet per second from a zero-length, trainable, dual launcher built for shipboard use.

Stabilization through the boost period will be accomplished by attitude control achieved by the employment of movable vanes in the booster exhaust jet. Missiles will be launched directly into a programmed auxiliary beam (not the tracking radar beam) for capture and midcourse guidance.

Propulsion

Talos will be ramjet-propelled at a velocity of 2000 feet per second. Fuel weight will be 400 pounds. A near-isentropic diffuser and an exit constrictor will be employed. Missile velocity will be held constant by the fuel metering system.

Guidance

Beam-rider guidance will be provided for the midcourse phase by means of an auxiliary beam of approximately five degrees half-width, which acts solely as a transmitter. The beam elevation and azimuth will be programmed so as to approach coincidence with the target tracking beam prior to transition to terminal guidance. The elevation program will permit "up-and-over" trajectories favorable from the standpoint of fuel economy; the azimuth program will avoid restrictions in firing direction arising from launching interferences.

Semiactive radar interferometric homing will be employed during the terminal phase of flight, target illumination being provided by the tracking radar. Target discrimination will be accomplished by the homing equipment through range gating. An alternate dish-type homer is also under development.

Aerodynamics and Control

Talos employs wing control for both steering and roll systems; separate actuators are used for each wing. The steering system is basically an accelerometer feedback servo loop with auxiliary rate gyro and wing position feedbacks. The roll system employs roll position as the primary feedback loop during beam riding and switches to rate during homing. The acceleration response to a 10g command is a function of both Mach number and altitude, providing approximately 10g in the combined plane up to 40,000 feet at design speed, with increasing accelerations at lower speeds.

Warhead and Fuze

A rod-type warhead weighing 350 pounds will be used with a microwave proximity fuze.

Talos System

Each Talos battery will include one dual launcher, three guidance transmitters (AN/SPW-1), and one illuminating radar (AN/SPG-49) whose action will be coordinated by a Talos Battery Computer. After target evaluation and designation, the output of the search and height finding radar (AN/SPS-2) will be entered into a track-while-scan system for use by the Talos Battery Computer in determining position orders, assignment times and firing orders.

STATUS

The first phase of the Talos missile (XSAM-N-6) development program had as its objective the development of the prototype missile RTV-N-6a3 (XPM). Only seven of these vehicles were flown, since the aerodynamics and control systems were basically identical to those already extensively tested in the series of flights leading to the introduction of the Terrier missile. The launching and propulsion systems had likewise been established by separate flight-test programs.

The first five flight tests of the XPM prototype missile were conducted at the Naval Ordnance Test Station (NOTS), Inyokern, California. XPM Nos. 1 and 2, both without forward wings, were flown in March and June 1949, respectively, to test the propulsion system and to determine roll control characteristics. XPM No. 4, the third vehicle in this series to be tested, was launched in March 1950 as a programmed yaw test unit. XPM Nos. 3 and 5 were successfully tested as beam riders in March 1951. The last two flight tests of RTV-N-6a3 units were conducted at White Sands Proving Ground (WSPG), Las Cruces, New Mexico, where equipment for Talos flight tests was established. XPM No. 7 was launched as a "cold" unit in July 1951, and XPM No. 6 was flown as a successful beam rider in August 1951. All of these flights have been reported in previous issues of the *Survey*.

In the current phase of the Talos program, six vehicles in the RTV-N-6a4 prototype series are being equipped for homing tests and will be devoted to establishing a prove-in of the interferometer terminal guidance system and a correlation of flight performance with homing simulator predictions. These units are almost identical to the XPM except that they are 20 inches longer, thus providing additional space for the homing equipment. Four of these units have been fired at WSPG. RTV-N-6a4a, -6a4b, and -6a4c were flown during October 1951, January 1952, and June 1952, respectively. The results of these tests have been reported in previous issues of the *Survey*. **The fourth flight test in this series, using RTV-N-6a4d, was held on July 3, 1952. A preliminary report on this flight is contained in this issue of the *Survey*.** Talos proof tests began in June 1952. The first flight test is now scheduled for August, following the completion of the RTV-N-6a4 series of flights.

The Bendix Aviation Corporation is the prime contractor for the production of the first lot of thirty Talos missiles, with assembly and testing of the missiles centering at the Products Division, Mishawaka, Indiana. Participating with Bendix as subcontractors on major missile engineering and production tasks are the McDonnell Aircraft Corporation, the Capehart-Farnsworth Corporation, and the Federal Telecommunication Laboratories. Booster rocket grains are being supplied by the Hercules Powder Company, with the M. W. Kellogg Company furnishing the metal parts.

Delivery of the first Talos airframe to Bendix was made in June. Type tests of the first production unit of the complete fuel system with a Talos combustor have been completed at the Ordnance Aerophysics Laboratory. The control system is now being repackaged from the breadboard circuits to a flight unit assembly, after extensive tests of the breadboard on a missile simulator. The power supply system details have been frozen and flight packaging is underway. The homing system (initially at X-band) is in the stage of final prototyping. Delivery of C-band systems is scheduled for February 1953. **Ten full-scale booster grains have been tested at the Allegany Ballistics Laboratory. In eight of these firings, including two incorporating jet vanes, the heavy-wall chambers were used. Satisfactory prove-ins of both the igniter and the propellant were achieved. Two static firings with the lightweight chambers have been completed with satisfactory results.** Fuzes will be available for each flight of Talos after Serial No. 1

Work is in progress on all portions of the Talos Weapon System and it is expected that land-based prototypes of all of the critical components will be available for simulated shipboard installation at WSPG during 1953. Tactical units including the modifications required for shipboard stabilization will be available later. The initial installation at WSPG will include one AN/SPG-49 illuminating radar, two AN/SPW-1 guidance transmitters, a Talos Battery Computer, an AN/SPS-6C search radar, an AN/SPS-8 height-finding radar, a four channel track-while-scan system, and miscellaneous simulator and control equipment. The Talos Battery Computer, designed by the Applied Physics Laboratory, is being fabricated by the Reeves Instrument Company. The other components are being procured by the Bureau of Ordnance as modifications of production equipment designed for other programs. This installation will permit firing a two-missile salvo at a single target or one missile at each of two targets. In addition, the use of the target simulators will permit the exercise of the system, for non-firing tests, under any type of tactical attack.

Flight Test of RTV-N-6a4d Homing Test Missile

The fourth flight test of an RTV-N-6a4, ramjet-propelled, homing test missile was held at White Sands Proving Ground on July 3, 1952, when the RTV-N-6a4d unit was fired at an approaching B-17 target drone.[3] Preliminary information indicates that launching, boost, roll stabilization, ramjet ignition, capture, and beam riding were satisfactory. No test of the homing system was possible due to a cutout of the local oscillator of the homing superheterodyne receiver, which records show occurred on the ramp, a few seconds prior to launch.

The RTV-N-6a4d missile was practically identical to RTV-N-6a4c, except for two changes which were made because of the ignition difficulties encountered during the flight test of the latter unit. The fuel-air ratio was set for 0.040 at launching and then programmed to a rich limit of 0.0606. This provided a leaner starting sequence than was used in RTV-N-6a4c. Because of this leaner rich limit, the fuel load was reduced by about 150 pounds to provide a higher launching Mach number and a reduced thrust requirement.

The missile was fired from the Talos interim launcher, raised to a quadrant elevation of about 28 degrees, while the B-17 target drone was approaching the launcher at a speed of approximately 200 knots and at an altitude of 19,000 feet above terrain. Launching and the boost phase appeared to be normal. Missile position at separation (which occurred at about 4.23 seconds) was 1.6 degrees above and 1.9 degrees left of beam center, and roll attitude was of the order of 100 degrees from the flight-stabilized position. Roll stabilization was completed by 5.05 seconds. Capture was effected by about 13 seconds, and beam riding was satisfactory from this time until the end of flight. Acquisition of the target and switchover from beam riding to homing were not accomplished because the component failure of the front-end local oscillator of the homing system blocked all homing signals. The missile was within 2 degrees of beam center at self destruction which occurred at 42 seconds, even though the power output of the tail-end local oscillator of the beam-rider receiver dropped steadily during flight and gave intermittent operation between 34.5 seconds and self

[3] Results of the first flight test in the RTV-N-6a4 series (with RTV-N-6a4a) are contained in Bumblebee Reports No. 164, pages 6–8 (October 1951 Survey) and No. 173, pages 7–8 (February 1952 Survey); preliminary results of the second test using RTV-N-6a4b are contained in Bumblebee Report No. 171, pages 12–13 (January 1952 Survey); and preliminary results of the third test with RTV-N-6a4c are contained in Bumblebee Report No. 179, pages 6–7 (June 1952 Survey).

destruction. At the intercept time of about 27.5 seconds, the missile was 132 feet up-left of the target drone in the "A" plane and 22 feet down-left in the "B" plane.

The starting phase, which was the source of difficulty in the preceding test in this series, was entirely normal. Ignition was smooth, and the restrictor was ejected at 1.8 seconds after separation.

The final two units in the series, RTV-N-6a4e and -6a4f, will be flown as exact duplicates of the RTV-N-6a4d.

Breadboard Layout for Talos Control System

ABSTRACT—As an aid in the development of the control section of the Talos missile, a breadboard model has been constructed at the Applied Physics Laboratory. Both open- and closed-loop tests have been made to assure that the control system satisfies specification requirements and to verify theoretical studies. The open-loop tests included measurements of network transfer characteristics, phase shift, dynamic range, limiting level, zero stability, linearity, and signal mixing. The closed-loop tests, representing the first three-dimensional closed-loop tests ever made on an APL control system, were conducted in conjunction with the Reeves Electronic Analog Computer (REAC) which simulated the aerodynamic and kinematic functions relating to the closure of the various feedback loops, representing a typical missile flight against a moving target. The model was constructed in breadboard form and is arranged to furnish a high degree of flexibility and to permit easy access to all components. Approximately 100 performance checks were made as part of the open-loop tests. More than 1000 REAC runs were made during the closed-loop tests.

An experimental working model of the Talos control system has been constructed at the Applied Physics Laboratory, in the form of a breadboard layout, as an aid in the development of the control section of the missile. Such control systems are notably complex, and this breadboard has been effective in laboratory investigations of the practical aspects of the problem. Also, to assure that the Talos control system satisfies specification requirements and to verify theoretical studies, a comprehensive series of open- and closed-loop tests is required and made possible by the experimental model.[4]

The open-loop tests were made on the breadboard and have included measurements of network-transfer characteristics, phase shift, dynamic range, limiting level, zero stability, linearity, and signal mixing. The results have been documented to serve as a guide for the preparation of a simplified flight-package test procedure. In addition, the breadboard has made possible, for the first time, complete three-dimensional closed-loop tests of an APL control system. These investigations were conducted in conjunction with the Reeves Electronic Analog Computer (REAC) which simulated the aerodynamic and kinematic functions relating to the closure of the various feedback loops, representing a typical missile flight and a moving target. Since sensing elements, such as gyros, accelerometers and ram-pressure pickoffs, cannot function during the breadboard test, these signals were also supplied by REAC steering-intelligence inputs. Control system performance with respect to loop stability, weathercock damping and acceleration transients were observed. The roll stabilization system was also checked and, in some runs, roll-steering interaction was roughly simulated.

In addition to the performance of open- and closed-loop tests, the breadboard has aided in the evaluation of proposed modifications to the system and has disclosed design factors which require further consideration. Finally, the breadboard has served to demonstrate the reliability of the control system in general.

The construction of the breadboard involved the preparation of a working model of the con-

[4] A discussion of the design of the Talos wing-control system, and evaluations based on analytical studies made with the REAC, are given in Bumblebee Report No. 157, pages 16–20 (July 1951 Survey). Typical studies in which the bread-board assembly was used with the REAC are reported in Bumblebee Report No. 175, pages 13–18 (March 1952 Survey).

trol system which is arranged to furnish a high degree of flexibility and to permit a thorough and complete investigation of the problem. The primary design objectives in the construction of the breadboard were maximum access to all circuits and components, the introduction of test signals, and monitoring and recording throughout the system. These objectives were achieved by the use of an open type of construction in a breadboard layout which comprises three major sections. These are the control-circuit electronics, a servo-amplifier rack, and a hydraulic bench, supplemented by a hydraulic power system, regulated power supplies, power distribution wiring and test equipment. Provisions were made to vary the outputs of the regulated power supplies over a range sufficiently large to allow analysis of system performance under conditions of diminishing supply potentials.

The electronics section of the breadboard is composed of sub-chassis which were fabricated and wired as separate units. The individual units are mounted on two large horizontally placed angle frames, as shown photographically in Fig. 9. One frame contains the roll-stabilization system, the channel "A" and channel "B" mixer-limiters, and the four demodulators. The other frame contains the acceleration follow-up unit and the airborne guidance-computer unit with associated modulators and amplifiers.[5] The components of each individual sub-chassis are mounted so that tube sockets, transformer terminals, resistor-mounting strips and tie points are all above the base for easy access.

Electrical power and signal inputs are applied through connectors which allow the electronics section to be quickly disconnected from the rest of the system for repair or modification. A volt box furnishes accurately-measured positive and

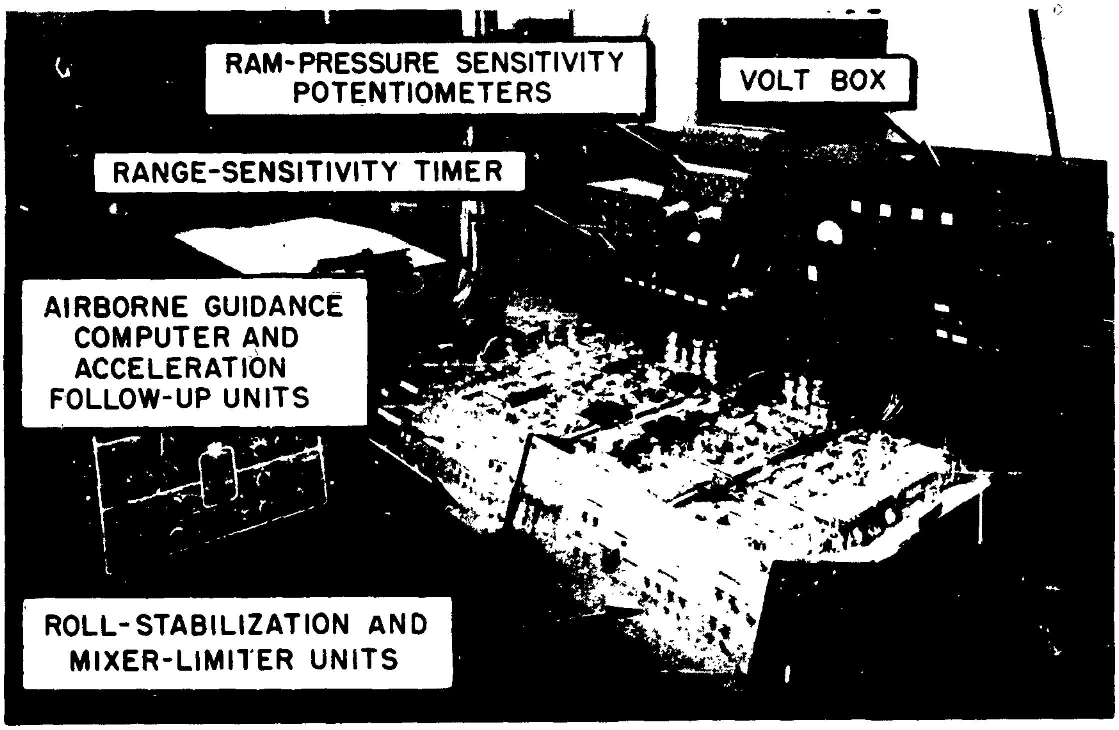


FIG. 9. ELECTRONICS SECTION OF TALOS CONTROL-SYSTEM BREADBOARD LAYOUT

[5] The functions of these various sub-sections of the Talos control system are described in detail in BUMBLEBEE Report No. 157, pages 16–20 (July 1951 Survey).

negative d-c potentials through a large range of values. The introduction of test signals, and monitoring or recording, is facilitated by means of jacks on the front panel. Ground-loop difficulties between the various units, and between the widely separated portions of the breadboard, were minimized by use of a separate ground circuit, carried completely through the system and maintained electrically apart from the chassis.

The wing-control servo-amplifier section of the breadboard, illustrated photographically in Fig. 10, consists of four rack-mounted units. These amplify the wing commands from the electronic section after which they are applied to the electro-hydraulic servo units which actuate the wings. The servo-amplifiers are connected to the electronic section through jacks to permit testing and adjustment. Individual current meters are connected in the plate circuits of each of the servo-amplifier vacuum tubes so that their operation may be balanced.

The hydraulic bench, shown in Fig. 10, contains the transfer valves, torque motors, hydraulic accumulators and oil lines, and the hydraulic actuators for moving the wings. Each of the actuators is equipped with four rectilinear potentiometers. In each case, only one potentiometer in the feedback circuit is part of the control system proper. The remaining three develop signals proportional to some function of wing position as required during simulated tests. Input and output circuits of the various sections of the breadboard are connected through closed-circuit jacks, wired in such a manner that when the plugs are removed, normal operating conditions are effected. Connections between REAC and breadboard are also made by plug and jack, and provide a great degree of flexibility of interconnection.

During the development of the Talos control system, approximately 100 performance checks were made as a part of the open-loop tests and over 1000 REAC runs were carried out during the closed-loop tests. The breadboard has accumulated approximately 400 operational hours during which failures were minor.

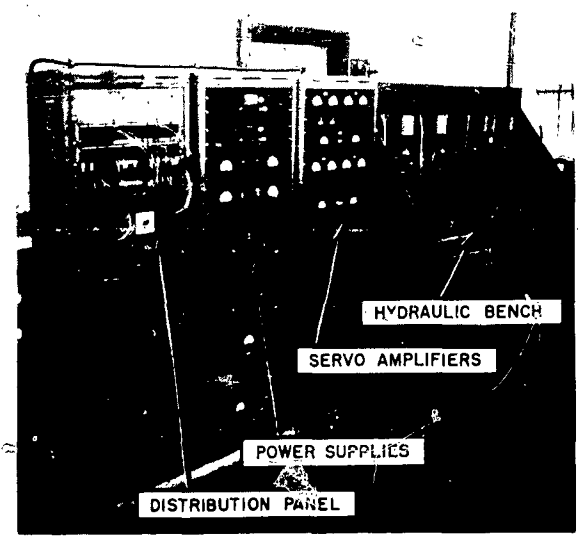
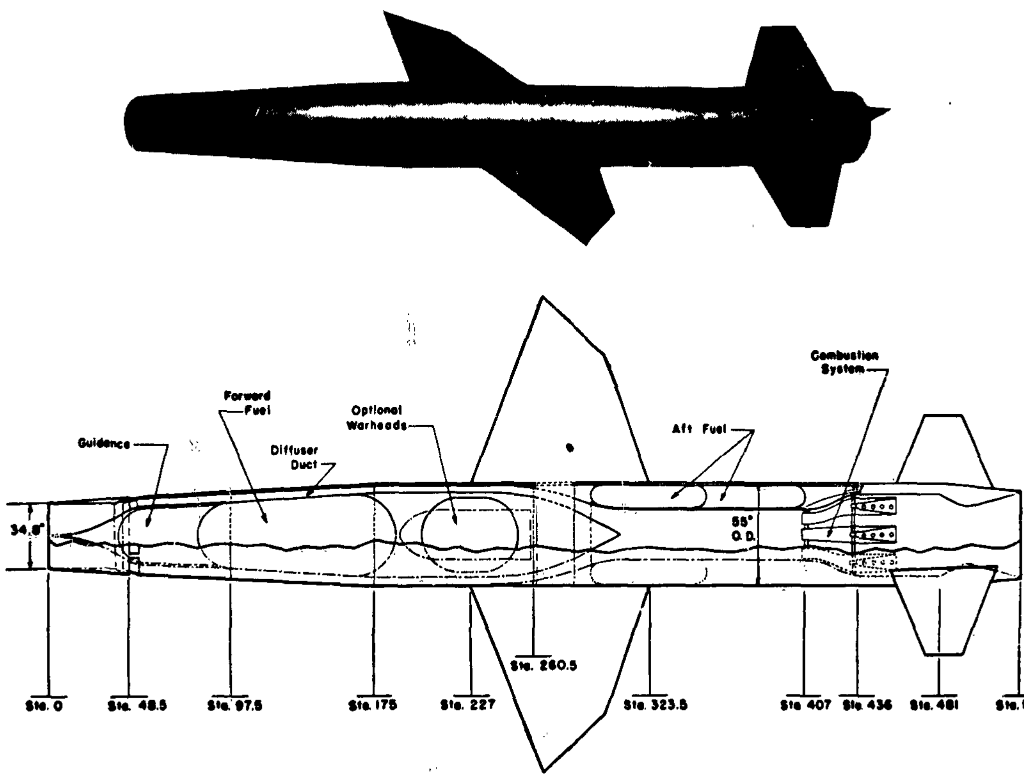


Fig. 10. Servo Section and Auxiliary Equipment



PROPOSED DESIGN FOR TRITON

TRITON

Description

Triton (XSSM-N-2) is a ramjet-propelled, supersonic, ship-to-surface guided missile intended to increase the range at which Naval offensive power can be brought to bear against shore targets. Current requirements specify a range of 1200 nautical miles or greater.

Configuration

The currently proposed Triton missile is of conventional design, having two main horizontal supporting wings located close to the center of gravity. Four cruciform tail surfaces are located at the rear of the cylindrical body. The intake duct of the ramjet engine is located at the nose of the missile; and the air is ducted through a diverging subsonic diffuser to the combustion chamber, which is located in the aft section of the body. The burned gases are ejected at the rear of the body through a converging-diverging exit nozzle.

Launcher and Booster

Triton will be launched to the design velocity by the use of a cluster arrangement of four solid-fuel booster rockets of somewhat higher unit impulse than those used for RTV-N-6a4 launchings.

Propulsion

Triton will be ramjet-propelled at a Mach number of 2.4 during the cruise portion of flight. Kerosene or an equivalent hydrocarbon fuel will be burned. A near-isentropic diffuser will be used for supersonic compression, followed by a divergent duct for final subsonic compression. Combustion will be initiated at a near-stoichiometric ratio, with air from the duct added in the combustion chamber downstream to bring the resulting air-fuel ratio to about 70:1.

Guidance

An Automatic Magnetic Guidance (AMG) system will be used for guidance throughout the cruise portion of flight, with a homing system controlling the terminal phase to achieve desired target accuracies.

Stability and Control

Triton will be a roll-stabilized missile and will obtain its attitude intelligence from gyros so that it will fly a constant-speed cruising trajectory with position information supplied by a magnetometer and an altimeter. Aerodynamic control of the vehicle will probably be achieved by means of a combination of wing and tail incidence changes producing conventional bank and turn-type maneuvers.

Status

The Triton project is at present in a research and design study stage. Aerodynamic, propulsion, and launching principles established through extensive wind-tunnel and flight-test programs with RTV-N-6a and XSAM-N-7 are basic to the Triton study. Detailed studies, based on these principles and on conservative assumptions where test data are lacking, have resulted in design data for three potential Triton configurations which have about the same dimensions and weights for equivalent performance. One configuration (illustrated at the head of this section) is characterized by a symmetrical annular air duct which permits passage of the air from the supersonic diffuser in the forward end of the fuselage to the ramjet engine in the aft section. With this type of internal configuration, the volume contained within the geometrical outlines of the missile is utilized effectively and the problem of securing symmetrical air velocity distribution at the entrance to the combustion chamber is minimized. However, it presents accessibility problems in the installation, servicing and checkout of missile-borne equipment.

In developing the second configuration, an attempt was made to ease some of these access difficulties by re-routing the subsonic diffuser duct. In this arrangement, the air is carried through a kidney-shaped duct around the warhead in the upper half of the missile until it reaches the vicinity of the combustion chamber. The duct then returns to the center of the missile and becomes circular in cross section as it enters the combustion chamber.

The third configuration employs external scoops as air intake ducts for the jet engine. These scoops are diametrically opposed on the upper and lower sides of the missile and, with their associated fairings, extend along the aft third of the missile body. This configuration possesses packaging advantages over the first two and would permit a somewhat lighter and simpler airframe construction.

The structural feasibility of these three configurations has been investigated by the Cornell Aeronautical Laboratory (CAL) and the conclusion has been reached that the structural weight of the missiles will be between 20 and 25 per cent of the initial gross weight. Detailed wind-tunnel data have not been taken on the performance of the diffusers of all these arrangements. However, for design purposes a diffuser efficiency at flight Mach number 2.4 of 87 per cent in the supersonic regime and 80 per cent in the subsonic regime have been assumed in the performance calculations of the missile. It has been estimated that the efficiency of the subsonic diffusion process in the symmetric and eccentric diffuser ducts is approximately 76 per cent, while the corresponding efficiency for the aft scoop intake type is approximately 90 per cent.

Wind-tunnel tests have been made on models of five different supersonic diffusers under identical conditions at the Ordnance Aerophysics Laboratory. The diffusers tested were: (a) Streamline cowled Oswatitsch diffuser, (b) perforated cowl diffuser, (c) single shock Ferri inlet diffuser, (d) modified single shock Ferri inlet diffuser, and (e) double shock Ferri inlet diffuser.

Although designed for operation at Mach number 2.23, the five diffusers were tested at Mach numbers 2.00, 2.23, and 2.50. Experimental data on diffuser drag and pressure recovery characteristics were obtained for angles of attack of 0, 2, 4, 6, and 8 degrees. These data are being studied to select a diffuser inlet for the Triton missile which will be optimized for pressure recovery, drag, and width of stable operating regime.

As part of the general ramjet development program, combustion has been accomplished in the laboratory and in flight at pressures between one-half and one-third atmosphere. A combustion efficiency of 90 per cent has been obtained on a Triton scale in a 48-inch diameter combustor. A conservative value of 80 per cent has been used for Triton design studies.

Work is continuing at the Consolidated Vultee Aircraft Corporation on the design of test sections of alternate Triton combustors. This design work supplements theoretical studies at APL directed toward the development of high-efficiency burners suitable for operation at low pressures. It is expected that the burner test sections resulting from these efforts will be tested at San Diego under conditions simulating low-altitude flight.

The practicality of the magnetic midcourse guidance system has been demonstrated by Convair with satisfactory terminal accuracies in flights of subsonic aircraft extending over distances of approximately 1000 miles. Since these demonstrations in 1949 of the practicality of magnetic guidance, Convair has continued development of the component parts of the system. The stability of the magnetometer and associated circuits is now adequate for missile use and plans for further subsonic airplane tests have been made. Studies of the prediction of the magnetic field, and the extrapolation of the field to missile altitude are continuing. Work is also in progress on the evaluation of all sources of error which may affect midcourse guidance accuracy.

Preliminary studies of a homing system, as proposed by the Applied Science Corporation of Princeton, are being continued by the Capehart-Farnsworth Corporation, which will produce plans and specifications for a complete homing system.

Studies have been completed at CAL on the details of the equipment required for the refrigerating, pressurizing, power supply, and fuel-flow functions aboard the missile. These studies have resulted in a preliminary design of the air-conditioning system together with the estimated performance of the various items of equipment. This system consists of two turbines and an intercooler which operate so as to extract heat from the compartment charge air and subsequently reject this heat to the atmosphere. Performance studies indicate that the system will maintain the compartment temperature below 160°F at a pressure of 5.0 lb/in² or greater.

Power to operate various components will be required aboard the missile. Current plans utilize one of the air-conditioning system turbines which drives the electrical generator, the hydraulic pump, and the fuel pump. The generator, driven at constant speed through a speed reduction coupling, supplies alternating current at 400 cycles, 110 volts, with two kilowatts output for the main power supply.

A stored nitrogen fuel tank pressurization system is planned for Triton. A pressure of 30 lb/in^2 (absolute) will be maintained in the space above the fuel to prevent evaporation of the fuel and vapor lock in the fuel distribution system. A spherical tank fifteen inches in diameter holding about 11 lb of nitrogen at 4000 lb/in^2 is sufficient for this purpose.

Detailed investigation of the fuel-distribution system has been suspended pending establishment of more precise specifications of the missile propulsion system. It is expected that developments in the Talos fuel-metering system will be applicable to Triton. In addition, the studies indicate that selective pumping from the various fuel cells will be required to maintain the proper distribution of weight about the missile center of gravity.

Fiberglas laminate has been investigated by CAL as a structural material for use in fabricating fuel cells and the outer skin of the Triton missile. Its non-magnetic property makes it attractive for use as a fabrication material for a magnetically-guided missile. Its physical properties at elevated temperatures, up to 400°F, have been found suitable for high-speed missile use.

RESEARCH AND DEVELOPMENT

SECRET

PROPULSION

Ordnance Aerophysics Laboratory Burner Tests

June 2 to June 21, 1952

According to current procedure, a preliminary data report is published by the Ordnance Aerophysics Laboratory, Daingerfield, Texas, on tests conducted in the burner laboratory. This report presents corrected data, and includes the computations of performance parameters; however analysis of test results is not included. Because of its preliminary nature, distribution of the report is limited, in general, to one copy for the test conductor, one file copy for the Applied Physics Laboratory, and four copies for use at OAL. Inquiries from authorized organizations relative to such reports should be directed to the test conductor concerned.

The test conductor is responsible for compiling a final report on each test or series of tests under his direction. Bumblebee test reports are distributed by the Applied Physics Laboratory as CF or CM reports. Non-Bumblebee test reports are distributed in the same manner or according to the Joint Army-Navy-Air Force Mailing List for the Distribution of Guided Missile Technical Information.

Copies of such CF and CM reports may be obtained by properly authorized agencies from the Supervisor of Technical Reports, Applied Physics Laboratory, The Johns Hopkins University, 8621 Georgia Avenue, Silver Spring, Maryland.

OAL TEST No. 276–5 *Tests of the XRJ-43-MA-3 Engine*

Test Sponsor, Marquardt Aircraft Company
USAF Test

Test Conductor, C. L. Dunsmore (Marquardt)
June 2–3

A total of nineteen runs was made in the high-altitude facility on the Marquardt Aircraft Company's ramjet test engine XRJ-43-MA-3, Model 5B3. The Marquardt Model FM9A1, Serial No. 2 fuel metering control was installed externally. The primary objective of the test was to determine the steady state and dynamic behavior of the Mach number control input pressure and to evaluate this pressure at as many simulated trajectory points as possible. The tests were made with fuel-air ratios from 0.035 to 0.055 at conditions simulating Mach number 2.50 at an altitude of 50,000 feet. In addition, one cold flow run was made as a check of the test conditions of the exit nozzle.

OAL Test 276–6 *Tests of the XRJ-43-MA-3 Engine*

Test Sponsor, Marquardt Aircraft Company
USAF Test

Test Conductor, P. Dnistran (Marquardt)
June 16–21

A total of fifty-two runs was made in the high-altitude facility with the XRJ-43-MA-3, Model 5B4, test engine. The purpose of the first thirty-eight runs was to determine the burning characteristics of eight new configurations. The variations were in the flameholder, the pilot, and the diameter of the fuel injector. Configurations 46 and 48 appeared to demonstrate the best performance. Gas samples were taken at two simulated altitudes to determine the effect of altitude changes on combustion efficiency.

OAL Test No. 312–1 *Tests of the Talos Model H Combustor*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BuOrd Test (Ma)

Test Conductor, R. S. Wentink (Convair)
June 4–7

Forty-nine runs were made with the Talos Model G-A and H combustors in the high-altitude facility. The purpose of the testing of the G-A combustor was to determine the effect of altitude pressure on burning-limit fuel-air ratios and burner efficiency. Since the pilot shrouds were cut back from Station 171 to 173, an investigation was also made of fuel overflow from the pilot into the outer annulus. Several pilot optimization runs were made with the Model G-A combustor. It was found to operate best at a pilot fuel-air equivalence ratio of 1.8 (based on twenty per cent airflow to pilot). With an inlet total temperature of 150°F, ignition was not attainable at airflows of 28 pps or less. However, burning was sustained at 20 pps with inlet total temperature of 250°F. No appreciable fuel was indicated in the outer annulus. Documentation was made of the burning performance of the Model H combustor which had the best performance in a sea-level cell during the previous test week. Airflows were varied from 40 pps to 18 pps and the inlet total temperatures were 150°F, 250°F, and 350°F. The pilot fuel-air equivalence ratio was varied from 1.0 to 1.8. The Model H combustor maintained combustion at an airflow of 25 pps and an inlet total temperature of 250°F when the pilot fuel-air equivalence ratio was 1.2. Lowering the pilot fuel-air equivalence ratio was necessary to sustain combustion at an airflow of 30 pps when the inlet total temperature was 150°F.

AERODYNAMICS

Ordnance Aerophysics Laboratory Wind Tunnel Tests

May 26 to June 28, 1952

Under current procedure, the Ordnance Aerophysics Laboratory publishes a preliminary data report on tests conducted in the wind tunnel at Daingerfield, Texas, approximately two weeks after completion of the tests. This report presents corrected data and includes the computations of performance parameters; however analysis of test results is not included Distribution of the preliminary data report is limited, in general, to two copies for the test conductor, one file copy for the Applied Physics Laboratory, The Johns Hopkins University and four copies for retention and use at OAL. Because of the preliminary nature of this report, a wider distribution is not deemed appropriate.

Inquiries from authorized organizations relative to obtaining copies of the preliminary data reports, as well as inquiries about data not covered in reports, must be directed to the test conductor concerned. The test conductor is also responsible for compiling a final report on each test or series of tests under his cognizance, and for distributing this report in a suitable manner. Bumblebee test conductors submit a final report on OAL wind tunnel tests, as soon as possible after each test, for distribution as a CF or CM report. Non-Bumblebee test conductors submit a final report, either as a CF or CM report through APL, or as a report distributed according to the Joint Army-Navy-Air Force Mailing List for the Distribution of Guided Missile Technical Information.

A list of OAL wind tunnel tests is currently being issued as a TG-69 series report. This report is reissued in up-to-date form every two months, listing all wind tunnel test runs at OAL, together with a listing of the data reports that have been published by OAL.

A complete list of OAL wind tunnel tests and a list of all reports on OAL wind tunnel tests is published periodically in the TG-43 report series, *Status Report on* Bumblebee *Aerodynamics*.

Copies of the CF, CM and TG reports may be obtained by properly authorized agencies from the Supervisor of Technical Reports, Applied Physics Laboratory, The Johns Hopkins University, 8621 Georgia Avenue, Silver Spring Maryland.

OAL Test No. 37–2 *Calibration Tests of the Mach Number 2.50 Nozzle*

Test Sponsor, Ordnance Aerophysics Laboratory Tunnel Development

Test Conductor, M. G. Wade (OAL)
June 9, 14

Sixteen data runs were made in the Mach number 2.50 nozzle for calibration purposes. Contour modifications were made on the contraction section in an attempt to eliminate the oblique shock waves from the test section, but had no visible effect. Runs were also made without the modifications, using a rake of nine conical probes mounted on the OAL −27 linear actuator support to determine flow inclination. Data were recorded between stations which were 40 and 63 inches forward of the crossarm. Tunnel and model static pressures were recorded.

OAL Test No. 38–3 *Investigation of Flow in the Mach Number 2.23 Nozzle*

Test Sponsor, Ordnance Aerophysics Laboratory Tunnel Development

Test Conductor, H. M. Fitch (OAL)
June 23

Four data runs were made in continuation of the investigation of flow inclination and Mach number distribution of the Mach number 2.23 nozzle (see Bumblebee Report No. 162, September 1951 *Survey*). A nine-probe cone rake was mounted on the OAL −27 axial-drive strut to record angles of attack and yaw of the airflow between stations which were 53 and 63 inches forward of the crossarm in 0.5-inch increments. The 10-inch distance was surveyed with the model at 0-, ±90-, and 180-degree roll attitudes. In order to calibrate the effects of angle of attack on the cone pressures, the model was tested between ±1.5 degrees angle of attack in 0.5-degree increments.

OAL Test 142–5 — *Pressure Distribution Tests to Investigate Wing-Body Interference at Mach Number 2.00*

Test Sponsor, Cornell Aeronautical Laboratory
Basic Research

Test Conductor, F. D. Dye (CAL)
May 26–28, 31

Twenty-five data runs were made to continue the investigation of wing-body interference at Mach number 2.00 (see BUMBLEBEE Report No. 164, October 1951 *Survey*). Pressure data were recorded from 3-inch-diameter bodies with ogival noses and 3- and 4.5-inch-diameter bodies with double-cone noses. The wings tested in conjunction with the bodies were of rectangular planform with aspect ratios of 4.29, 3.33, and 0.500, and of delta planform with an aspect ratio of 1.36. All wings had double-wedge cross-sections. The models were mounted on a special pressure adapter and the OAL −26 pressure-model support to record data through angle-of-attack ranges of −12 to +12, and −4 to +22 degrees. Data were recorded at roll attitudes of −135, 0, 45, and 180 degrees, and wing incidence angles of 0, ±4, ±6, ±8, ±15, and ±20 degrees.

OAL Test No. 238–8 — *The Effects of Decreased Wing Size on the Stability and Control Characteristics of a 1/15-Scale Talos Re-design Model at Mach Number 2.23*

Test Sponsor, Applied Physics Laboratory
BUMBLEBEE Development

Test Conductor, M. G. Wade (OAL)
June 28

One data run was made at Mach number 2.23 to determine the effects of smaller wings on the stability and control characteristics of a 1/15-scale Talos model. The wings of the 1/15-scale XPM model were used. The model was mounted on adapter G-227 and the OAL −10 roll-indexing balance to record five-component data through an indicated angle-of-attack range of −6 to +14 degrees at 0- and −45-degree roll attitudes. All surfaces were tested at 0-degree incidence.

OAL Test No. 243–1 — *Throttle Calibration of the OAL −22 Force and Pressure Balance at Mach Numbers 2.00 and 2.23*

Test Sponsor, Ordnance Aerophysics Laboratory
Tunnel Development

Test Conductor, M. G. Wade (OAL)
June 27

One data run was made at Mach number 2.23 with the United Aircraft Corporation diffuser calibration inlet mounted on the OAL −22 force and pressure balance to calibrate exit areas near open throttle.

OAL Test No. 257 *Instrumentation Studies*

Test Sponsor, Ordnance Aerophysics Laboratory
Jet Engine Facility Development

Test Conductor, John Gluch (OAL)
June 20

Four runs were made in a sea-level cell to determine the effect of a flow straightener on the velocity profile from a straight, 24-inch-diameter pipe. The honeycomb type flow straightener with three-inch-square openings was located in a thirty-inch-diameter pipe section. The velocity profile was not changed by the flow straightener, which was placed 115 inches upstream of the exit. The only change observed when the straightener was removed, was a slight increase in total pressure.

OAL Test No. 259–4 *General Investigation of Static Pressure Probes for Terrier I (Lot V) at Mach Number 1.25*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BUMBLEBEE Development

Test Conductor, N. E. Maxwell (Convair)
June 25

Five data runs were made at Mach number 1.25 to obtain an angle-of-attack calibration of a static pressure probe for the Type I Terrier (Lot V). The probe, which has four manifolded 0.040-inch diameter orifices, was mounted on a conical nose. The model was mounted on the OAL −21 roll-indexing pressure support to record data between −8 and +2 degrees at roll attitudes of 0, 22.5, and 45 degrees. The variable between runs was the distance between the conical nose and the probe orifice, which was tested at 6, 2, 1, 0.5, and 0.25 inches.

OAL Test No. 263–12 *The Effect of an Alternate Nose and Increased Tail Span on the Stability and Control Characteristics of a 1/15-Scale Talos Model with Rectangular Tails at Mach Number 1.73*

Test Sponsor, Applied Physics Laboratory
BUMBLEBEE Development

Test Conductor, W. G. McMullen (OAL)
June 4

Eight data runs were made at Mach number 1.73 to determine the effect of an alternate nose and of ten per cent, over-sized, rectangular tails on the stability and control characteristics of a 1/15-scale Talos model. The model was mounted on adapter G-257 and the OAL −10 roll-indexing balance to record five-component data through an angle-of-attack range of −6 to +14 degrees at roll attitudes of 0, −22.5, −45, and −67.5 degrees. Continuous rolling-moment data were recorded at angles of attack of −6 and +14 degrees through the roll-angle range of −135 to +45 degrees. Tests were made with horizontal and vertical wing incidences of 0 and 15 degrees and differential wing incidences of 0 and 5 degrees.

OAL Test No. 263–13 *The Effect of Wings with Camber on the Wing-Hinge-Moment Characteristics of a 1/15-Scale Talos Model at Mach Number 2.23*

Test Sponsor, McDonnell Aircraft Corp.
BUMBLEBEE Development

Test Conductor, W. T. Jarrett (McDonnell)
June 24, 28

Ten data runs were made at Mach number 2.23 to determine the effects of wings with camber on the wing-hinge-moment characteristics of a 1/15-scale Talos model. One run was made without camber or incidence on any of the four wing surfaces. The remaining runs were made without camber in the vertical wings, 1.5 per cent camber in the left wing, and 0.75 per cent camber in the right wing. Incidence variables were 0, 10, and 20 degrees on the horizontal wings, and −20, −10, 0, 10, and 20 degrees on the vertical wings. Hinge moments were recorded at two stations from cantilever beams which were attached to the horizontal wings. The model was mounted on adapter G-257 and the OAL −10 roll-indexing balance to record data between −6 and +14 degrees angle of attack in two-degree increments at trim-roll attitudes.

OAL Test No. 264–8 *Generalized Investigation of Downwash behind Wings of Rectangular Planform at Mach Number 2.50*

Test Sponsor, Applied Physics Laboratory
Basic Research

Test Conductor, G. M. Edelman (APL)
June 10–11

Twenty-one data runs were made at Mach number 2.50 to continue the investigation of downwash behind rectangular wings and tails on a generalized missile with a cone-cylinder body (see Bumblebee Report No. 179, June 1952 *Survey*). The tails were tested both in line and interdigitated with the wings. Sixteen of the runs were made to obtain five-component stability and control data using body-alone, body-tail, body-wing, and body-wing-tail configurations. The remaining runs were made to record wing and tail panel loads and hinge moments, using body-tail and body-wing-tail configurations. Continuous rolling-moment data were recorded at indicated angles of attack of 0, 16, and 23 degrees through a roll-angle range of −45 to +135 degrees. The model was mounted on the OAL −20 roll-indexing support to obtain data from −4 to +23 degrees indicated angle of attack. Wing incidence angles of 0, +10, and −10 degrees were the only incidence variables.

OAL Test No. 293–4 *Stability and Control Tests of a 0.017-Scale Model of the XF2Y-1 Airplane at Mach Number 1.25*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BuAer Test

Test Conductor, B. V. Voorhees (Convair)
June 26

Fifteen data runs were made at Mach number 1.25 to continue the stability and control investigation of the XF2Y-1 airplane using 0.017-scale models (see Bumblebee Report No. 179, June 1952 *Survey*). The first two runs were made with a body-canopy model mounted on the G-271 offset adapter to investigate the effects of dive brakes canted 10 degrees with respect to the waterline and deflected 30 degrees. Three-component data were recorded during the investigation of the dive brakes. The remaining runs were made using the complete 0.017-scale model mounted on adapter G-241 and the OAL −19A roll-indexing balance. Six-component data were recorded on the complete model to determine the effects of external stores, such as bombs, on its stability, control, and drag characteristics. Elevon deflections of 0 and −7.5 degrees were tested. The body-canopy model was tested between −2 and +10 degrees indicated angle of attack at 0-degree roll attitude, and the complete model was tested between −6 and +6 degrees indicated angle of attack at 0- and 90-degree roll attitudes.

OAL Test 303–1

Stability and Drag Tests of a 1/10-Scale Type II Terrier ***Model with*** *an Alternate Hemispherical Nose at Mach Number 2.00*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BUMBLEBEE Development

Test Conductor, N. E. Maxwell (Convair)
May 31

Nine data runs were made at Mach number 2.00 to continue the investigation of the effects of an alternate hemispherical nose on the stability and drag characteristics of a 1/10-scale Type II Terrier Model (see BUMBLEBEE Report No. 179, June 1952 *Survey*). The body-wing-tail configurations were tested with nose radii of 0.136, 0.6 and 0.4 inches. In conjunction with the 0.6- and 0.4-inch-radius noses, nose probes with 40-degree conical tips were tested using three probe lengths. The first two runs were made using the OAL −20 roll-indexing support, adapter G-246, and the G-244 internal roll arm to record five-component data through an indicated angle-of-attack range of −3 to +23 degrees at 0- and 45-degree roll attitudes. Continuous rolling-moment data were also recorded at 23-degrees angle of attack through a roll-angle range of −45 to +135 degrees. The remaining runs were made using the OAL −24 roll-indexing balance to record drag. Six-component data were recorded through an indicated angle-of-attack range of −3 to ±14 degrees. All surfaces were tested at 0-degree incidence.

OAL Test No. 304

Investigation of Wing ***Loads,*** *Wing* ***Hinge Moments,*** *and* ***Spanwise Center-of-Pressure Locations*** *of a 0.091-Scale Type II* ***Terrier at Mach*** *Number 2.00*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BUMBLEBEE Development

Test Conductor, N. E. Maxwell (Convair)
May 31

Two data runs were made at Mach number 2.00 with a 0.091-scale body-wing configuration of the Type II Terrier, to record six-component wing hinge moment data. Two hinge moments and one bending moment were recorded on each horizontal wing from which spanwise and chordwise centers of pressure may be determined. The model was mounted on adapter G-276 and the OAL −20 roll-indexing support to record data through an indicated angle-of-attack range of −3 to +23 degrees at roll attitudes of 0, 15, 30, 45, and 180 degrees. Continuous bending moment data for the right wing panel were recorded at angles of attack of 0, 8, 16, and 23 degrees through a roll-angle range of 0 to 180 degrees. All surfaces were tested at 0-degree incidence.

OAL Test No. 304–1

Investigation of Wing Loads, Wing Hinge Moments, and Spanwise Center-of-Pressure Locations of a 0.091-Scale Type II Terrier at Mach Number 2.50

Test Sponsor, Consolidated Vultee Aircraft Corp.
BUMBLEBEE Development

Test Conductor, C. B. Shufford (Convair)
June 11-12

Three data runs were made at Mach number 2.50 using a 0.091-scale body-wing configuration of the Type II Terrier to record six-component wing-hinge-moment data. Hinge moments at two stations, and one bending moment were recorded on each horizontal wing, from which panel loads and spanwise and chordwise centers of pressure may be determined. The model was mounted on adapter G-276 and the OAL −20 roll-indexing support to record data through an indicated angle-of-attack range of −3 to +23 degrees at roll attitudes of −45, 0, 15, 30, 45, and 180 degrees. Continuous hinge-moment and bending-moment data for the right wing panel were recorded at angles of attack of 0, 8, 16, and 23 degrees through a roll-angle range of 0 to 180 degrees. All surfaces were tested at 0-degree incidence.

OAL Test No. 304–2 *Investigation of Wing Loads, Wing Hinge Moments, and Spanwise Center-of-Pressure Locations of a 0.091-Scale Type II Terrier at Mach Number 1.50*

Test Sponsor, Consolidated Vultee Aircraft Corp.
BUMBLEBEE Development

Test Conductor, C. B. Shufford (Convair)
June 12

One data run was made at Mach number 1.50 using a 0.091-scale body-wing configuration of the Type II Terrier to continue the investigation of wing loads and centers of pressure (see above). The test equipment and procedure were the same as those used in OAL No. 304–1.

OAL Test No. 305 *Axial-Force and Pressure-Recovery Tests of a Seven-Unit Perforated Diffuser Model at Mach Number 2.00*

Test Sponsor, United Aircraft Corp.
BuAer Test

Test Conductor, G. McLafferty (United Aircraft)
May 29

Seven data runs were made with various seven-unit perforated diffusers, mounted on the OAL −22 force and pressure balance, to obtain their capture area ratio, pressure recovery, and axial-force characteristics at Mach number 2.00. Models "A", "B", and "C" are similar except for differences in the angle of incidence between diffuser units, and in perforation distributions. Model "B" was tested with and without a shroud over the perforations. Model "D" is an unperforated calibration inlet. Data were recorded from 58 pressure taps with the model at angles of attack of 0, 3, 5, 7, and 10 degrees at roll attitudes of 0 and −30 degrees. Little buzz was noted.

OAL Test No. 305–1 *Axial-Force and Pressure-Recovery Tests of Seven-Unit Perforated Diffuser Models at Mach Number 2.23*

Test Sponsor, United Aircraft Corp.
BuAer Test

Test Conductor, G. McLafferty (United Aircraft)
June 23, 27

Six data runs were made at Mach number 2.23 to continue an investigation of axial force, pressure recovery, the mass-flow characteristics of three seven-unit perforated diffuser models and a calibration inlet (see above). The difference between the three models was the amount of perforation area and the incidence angle between the diffuser units. The diffuser inlets were mounted on the OAL −22 force and pressure balance which is equipped with a rake for measuring pressure recovery, a calibrated throttle for varying mass flow, and a drag link to record force in the axial direction. Data were recorded at 0, 3, 5, 7, and 10 degrees angle of attack for Model "B", and at 0 degrees angle of attack for the remaining inlets. All data were recorded at 0-degree roll attitude. During one run, motion pictures were taken of a buzz condition where the shock did not expel from the lip. The shock appeared to buzz in the perforated converging section. Oscillograph data of internal static pressure were recorded to study buzz conditions.

OAL Test No. 306 *Wing-Hinge-Moment Tests of 0.17-Scale Sparrow I and III (XAAM-N-2 and XAAM-N-6) Models at Mach Number 1.50*

Test Sponsor, Douglas Aircraft Company
BuAer Test

Test Conductor, R. R. Beal (Douglas)
June 12–13

Thirteen runs were made at Mach number 1.50 on one Sparrow III and two Sparrow I bodies, with sixty-degree-sweptback delta wings. The hinge moments and normal forces of four wing panels were recorded for the purpose of determining wing-to-wing interference. The models were mounted on the OAL −21 roll-indexing support to record data between ±12 degrees at roll attitudes between 0 and 180 degrees in 22.5-degree increments. Wing incidences and differential wing incidences of 0, ±4, and ±8 degrees were tested. During several of the runs, aeroelastic effects on wing hinge moments were determined by replacing the standard steel wing with a magnesium wing. In several cases, the wing cantilevers grounded at high angles of attack.

OAL Test No. 307 *Axial Force and Pressure Recovery of a Triton Integrated Wing-Diffuser Model at Mach Number 2.23*

Test Sponsor, Applied Physics Laboratory
Basic Research

Test Conductor, W. W. Hawley (APL)
June 27

Eight data runs were made at Mach number 2.23 to evaluate an integrated wing-diffuser configuration, from the standpoint of pressure recovery and axial force, at various angles of attack and roll. The first three runs were made using the compromise design diffuser, without the wing attached, to determine the best tip projection. The wing-diffuser combination was tested during the remaining runs at angles of attack between −6 and +6 in 2-degree increments at 0, 45, and 90-degree roll attitudes. One pressure orifice was located on the under surface of the wing, six orifices were located on the split-wedge strut which supported the wing, and fifty orifices were located in the OAL −22 force and pressure balance. Oscillograph data of buzz conditions were recorded.

OAL Test No. 308 *Stability and Control Tests of a 0.060-Scale Type II Terrier Model without Booster at Mach Number 1.25*

Test Sponsor, Consolidated Vultee Aircraft Corp.
Bumblebee Development

Test Conductor, P. H. Miller (Convair)
June 25–26

Twenty-three data runs were made at Mach number 1.25 to determine the stability and control characteristics of a 0.06-scale Type II Terrier model at or near trim-roll attitudes for the maximum angle-of-attack range. The model was mounted on adapter G-273 and the OAL −19A roll-indexing balance during the first nine runs to record five-component data through an indicated angle-of-attack range of −6 to +6 degrees. The OAL −33 offset roll-indexing balance was used during the remaining runs to record five-component data between +10 and +17 degrees indicated angle of attack. Data were recorded during two runs using a dummy −33 balance which would not record rolling moment. Tail incidence angles of 0, −5, and −9 degrees were used with 0 and 9 degrees differential incidences.

OAL Test No. 316

Stability and Control Tests of a 0.11-Scale Complete Model and Wing-Hinge-Moment Tests of a 0.17-Scale Model of the Sparrow II (XAAM-N-3) at Mach Number 1.50

Test Sponsor, Douglas Aircraft Company
BuAer Test

Test Conductor, M. S. Mixon (Douglas)
June 13

Nine data runs were made at Mach number 1.50 to obtain the aerodynamic characteristics of the Sparrow II model. The first two runs were made using a 0.17-scale Sparrow II model to record hinge moments and normal forces of four wing panels. The testing procedure and equipment for this model were the same as that used in OAL Test No. 306. The remaining runs were made using a 0.11-scale Sparrow II model with blunt-tipped, 45-degree-sweptback delta wings, and 57-degree-sweptback delta tails, to record five-component stability and control data. The 0.11-scale model was mounted on adapter G-277 and the OAL −24 roll-indexing balance to record data between ±10 degrees angle of attack at roll attitudes between 0 and 135 degrees in 22.5-degree increments. Incidence settings of 0, 4, 8, and 10 degrees, and differential incidences on the vertical wings of 0, 4, 8, and 12 degrees were used. The model grounded at high angles of attack.

OAL Test No. 319

Stability and Control Tests of a 1/15-Scale Talos Model With an Alternate Nose at Mach Number 2.23

Test Sponsor, McDonnell Aircraft Corp.
BUMBLEBEE Development

Test Conductor, W. T. Jarrett (McDonnell)
June 24, 28

Twenty-five data runs were made at Mach number 2.23 with a 1/15-scale Talos model to determine the effects of an alternate nose on its stability and control characteristics, and to determine the effects of various mass-flow conditions. The model was mounted on adapter G-280 and the OAL −10 roll-indexing balance to record five-component data between −6 and +14 degrees indicated angle of attack at or near trim-roll attitudes. The model was tested with low-aspect-ratio tails and tails with increased span. An internal restriction area of 76 per cent of the inlet area existed during most of the runs. The restriction was increased during three runs to determine the effects of additional spillover. Buzz conditions were noted to be present throughout the test. Several motion pictures were taken of the oscillating shock waves.

GUIDANCE

Multiple-Target Simulator

ABSTRACT—The multiple-target tracking and guidance problem, in which the radar information becomes confused when more than one target is illuminated within the radar range gate, is being analyzed at the Applied Physics Laboratory with a newly-devised simulator. A simultaneous lobe-comparison (SLC) radar receiver and the signals from one, two, or three targets are simulated. Each of the target signals is produced by an independent random-noise generator and appears at the input of the receiver as a narrow band of random noise having a center frequency of approximately 175 kc. Sum and difference signals from the various targets are added in appropriate circuits and passed through the simulated monopulse receiver where the outputs of sum and difference amplifiers are combined to produce an error signal. The balanced outputs of the amplifiers are applied to a target-position potentiometer from which a difference signal proportional to the angular position of the simulated target with respect to the axis of a radar beam is obtained. The phase relationship between the sum and difference signals from each target is the same as in an SLC radar receiver. The next step in the simulator program is planned in the construction of additonal equipment to simulate proposed modifications, or additions, to the monopulse radar circuitry which have been suggested as solutions to the multiple-target problem.

The information derived from a tracking radar becomes confused if more than one target is illuminated within the radar range gate, and the data pertaining to the azimuth or elevation and the number of the targets are consequently deranged. This obstacle has been the subject of an investigation at the Applied Physics Laboratory, where a simulator has been devised which permits statistical analyses of the problem. The simulator, illustrated photographically in Fig. 11, reproduces the behavior of a simultaneous lobe-comparison (SLC) radar receiver and the signals which it receives from one, two, or three separate targets within the radar beam, if these targets are at the same range but separated in angle.[6]

An SLC radar is simulated rather than the conical-scan type because the former offers more promise in the eventual solution of the multiple-target problem. Each of the target signals is produced by an independent random-noise generator and appears at the input of the receiver as a narrow band of random noise having a center frequency of approximately 175 kc.[7] The phase and amplitude of the signals from any one target fluctuate in a random fashion which is not correlated with the corresponding fluctuations of the other target signals. Either narrow-band noise, having a bandwidth

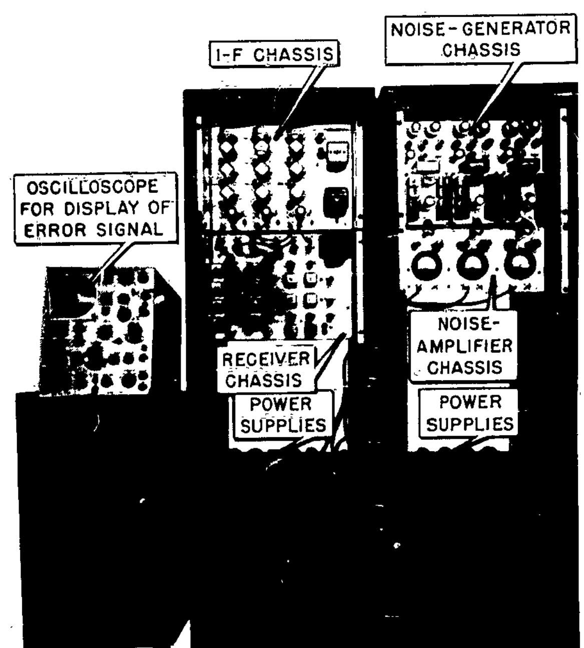


Fig. 11. Simultaneous Lobe-Comparison Radar and Target Simulator

[6] An earlier study of multiple-target discrimination with the interferometer system of guidance, conducted by the Defense Research Laboratory, The University of Texas, is described in Bumblebee Report No. 98, pages 12-13 (February 1949 Survey).

[7] The exact value of the center frequency of the target signal is of little significance in multiple-target simulation, the value of 175 kc being chosen because of circuit-design considerations.

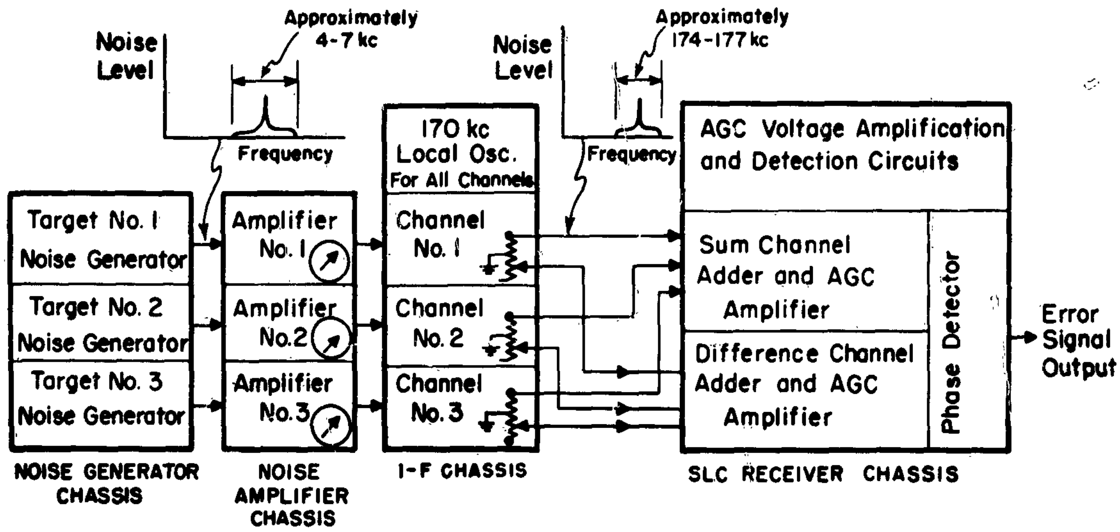


FIG. 12. BLOCK DIAGRAM OF SIMULTANEOUS LOBE-COMPARISON RADAR AND TARGET SIMULATOR

of 3 cps, or wide-band noise, having a bandwidth of approximately 3 kc, may be obtained from the noise generators, and the two bandwidths may be mixed in any desired fashion. The signals are CW rather than pulsed for reasons of simplification since the mechanism of the multiple-target confusion is believed to be the same for CW and pulsed radar systems.

The noise of each target is generated and filtered to produce the desired bandwidth and shape of the spectrum in the individual noise-generator chassis which are incorporated in the complete design of the simulator as shown in the block diagram of Fig. 12. The output in each case is a band of noise having a center frequency of approximately 5500 cps. At the output of each noise tube (a Type 6D4 thyratron), the wide-band signal may follow two paths in proportions determined by a selector switch and mixing controls, as indicated in Fig. 13. One path contains a narrow-band filter consisting of a high-Q resonant circuit and a Q-multiplier which produces an effective Q of 2000 in the resonant circuit and a half-power bandwidth in the filter of about 3 cps. The latter value is believed to be near the bandwidth of the sharp central spike in the Doppler spectrum of the actual target signal. The filtered and unfiltered signals are recombined in an "adder" and the combined signals are then passed through a filter which restricts the bandwidth of the total noise output to approximately 3 kc.

This signal is amplified and monitored on the noise-amplifier chassis and fed to the i-f stage which contains balanced modulators and side-band i-f amplifiers. Here, the center frequency of the noise spectrum is transformed to 175 kc and the sum and difference signals are made available at balanced outputs.

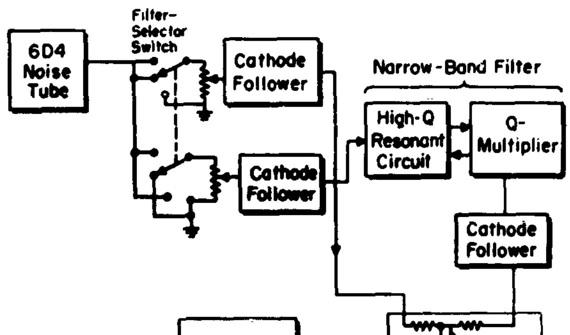


FIG. 13. BLOCK DIAGRAM OF CHANNELS ON NOISE-GENERATOR CHASSIS

The noise signal may follow two independent paths in proportions determined by the filter-selector switches and the settings of their associated potentiometers.

The sum signals from the various targets, and the difference signals, are each added in separate circuits and passed through the simulated monopulse receiver circuitry. This consists of sum- and difference-channel amplifiers having matched gain-versus-AGC-voltage characteristics and a common AGC voltage taken from the detected sum-channel output, plus a phase detector which combines the outputs of the sum and difference amplifiers to produce an error signal. For a single target, this error signal is a d-c voltage with a small amount of superimposed noise, as illustrated by the oscillogram of Fig. 14(a).

The balanced output of each i-f amplifier is applied to a target position potentiometer from which a difference signal proportional to the angular position of the simulated target with respect to the axis of the radar beam is obtained. The center of this potentiometer is at ground potential and the difference signal is obtained between the moving arm and ground, so that the center position of the control corresponds to the on-axis or null position of the simulated target. The sum signal is obtained from one end of the potentiometer. Thus, the phase relationship between the sum and difference signals for each target is the same as in the SLC receiver. That is, the signals are in-phase when the target is off-axis in one direction and 180 degrees out-of-phase if the target is off-axis in the opposite direction.

The sum and difference signals from the various targets are first combined in the adders of the receiver to produce the total sum and difference signals that would be normally present in an SLC receiver. These signals are fed through their respective AGC amplifiers and combined in the phase detector to produce the error signal. The AGC circuitry is an "instantaneous" type in which the detector circuit and filters for the AGC voltage are designed to have a wider frequency response than the noise bandwidth. Thus, the AGC should follow all fluctuations of signal amplitude including those of the highest frequency that are expected to occur in the simulator.

The error voltage output when two targets are present simultaneously is shown by the oscillogram of Fig. 14(b), and indicates the nature of the multiple-target problem that exists whenever two or more targets are present within the beam and within the range gate of a radar. The

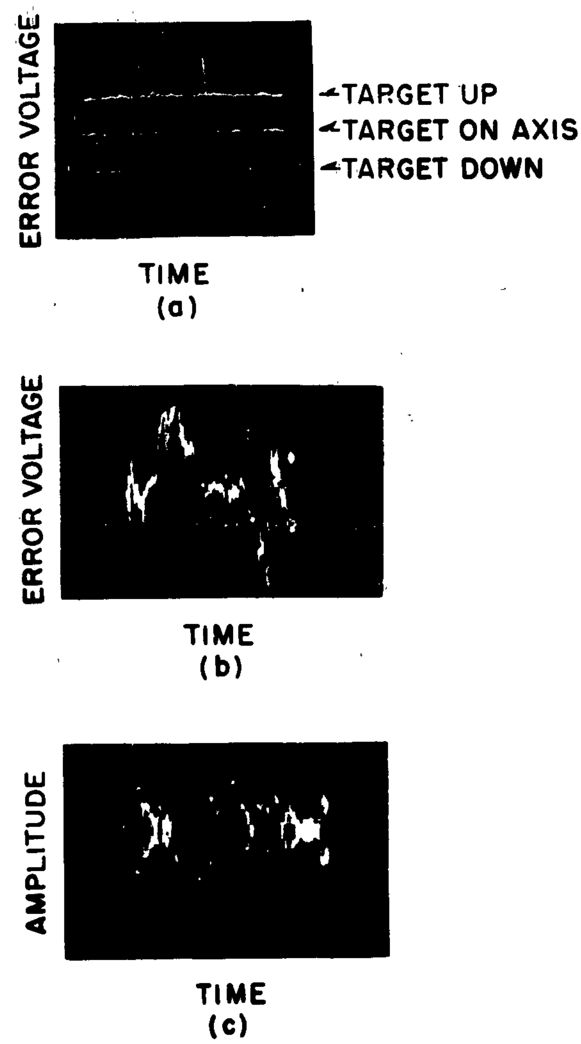


FIG. 14. TYPICAL SIMULATOR SIGNALS

A triple exposure is shown in (a) and illustrates the error signal from a single target in three positions; the error voltage for two fixed simultaneous target signals is shown in (b); the narrow-band noise input signal to the receiver is shown in (c).

noise voltage used to simulate a target signal, as it appears at the input of the simulated receiver, is illustrated by the oscillogram of Fig. 14(c).

The simulator was constructed for the purpose of testing various modifications or additions to the monopulse radar circuitry which have been proposed as solutions to the multiple-target problem. The next step in the program is the construction of the additional special circuitry to simulate each such proposal.

MISSILE FEASIBILITY STUDIES

Feasibility Study of a Small, Supersonic, Guided Missile[8]

ABSTRACT--An investigation designated Feasibility Study No. 7, undertaken by APL at the request of the Bureau of Ordnance, has been completed recently. The results of this study show that a small, supersonic, short-range guided missile used by destroyer escorts would provide an adequate convoy defense against air attacks, including those from low-altitude torpedo planes and toss bombers. The proposed missile would be less than seven feet long and would weigh under 300 pounds; with the addition of the booster, the launching configuration would be less than twelve feet in length and would weigh about 550 pounds. A single-stage missile would also be feasible but would be shorter and heavier than the two-stage missile, and would require a longer development time. The shipboard radar problem and the question of stabilization of the missile ship are of special significance and require further investigation.

The Applied Physics Laboratory has recently completed a study (designated FS-7) of the problems outlined in the Navy's Operational Requirement AD-07703, which gives the general tactical and physical requirements for a small guided missile to be used from destroyer-type ships against air attack, principally by low-flying planes. The study, assigned to APL by the Bureau of Ordnance, dealt with (a) the question of whether a guided missile would make possible a significant improvement in convoy defense over the use of air defense weapons now available or planned, (b) the general specifications of the missile and its shipboard system, should a new guided missile seem to be desirable, and (c) the determination of areas in which additional studies must be performed.

It is expected that about 80 per cent of the air attacks on convoys will be made by torpedo planes flying at altitudes below 1000 feet and by toss bombers at altitudes of less than 10,000 feet. Assuming that there is no decrease in effectiveness caused by the low altitudes of the targets, destroyer escorts, under typical conditions, can be expected to kill 0.2 plane in a 15-plane wave attack over a 90-degree sector using 5-inch, 38-caliber conventional antiaircraft guns or Loki rockets, or 0.63 plane using 5-inch, 38-caliber Angled Arrow Projectiles. Escort ships using supersonic guided missiles under the same conditions of attack will kill 3.7 targets on the average, assuming only a 50 per cent kill probability for a salvo of two guided missiles. Thus the need for a guided-missile system is evident. Type II Terrier missiles with homing show promise of meeting this threat of air attack if Terrier missile ships can be assigned to convoy duty. If smaller ships must be used, as is likely, a new, smaller, short-range, low-altitude missile, such as the FS-7 missile described, would provide an adequate means of convoy self defense against air attacks.

The investigation showed that either a conventional two-stage missile including a separate booster, or a single-stage missile in which booster and sustainer are packaged in the same case would be feasible. The single-stage missile considered for the same range would be somewhat heavier and shorter than the two-stage missile and would require a longer development time. The proposed FS-7 two-stage launching configuration, illustrated in Fig. 15, would weigh about 550 pounds, and would have an over-all length of less than twelve feet. The missile, itself would weigh less than 300 pounds, would be about seven feet long, and would have an outside diameter of 10.0 inches. It would have a horizontal range of almost 12,000 yards at sea level, or 10,000 yards at an altitude of 25,000 feet. The range could be extended easily to 15,000 yards at the expense of a slight length and weight increase. Noteworthy design fea-

[8] Copies of the original report on this study are not available for distribution.

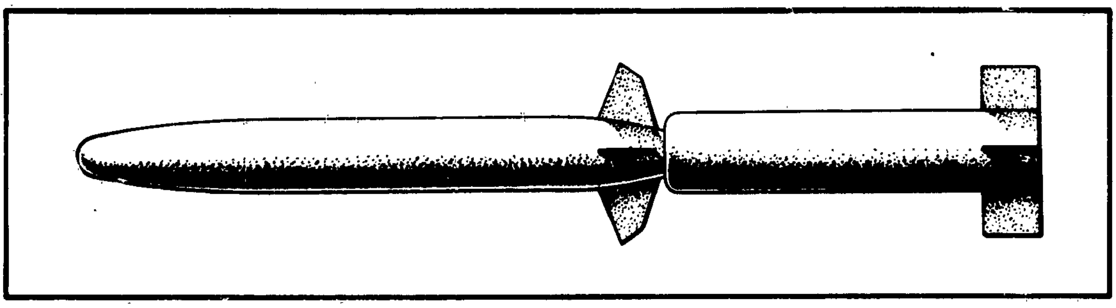


FIG. 15. TWO-STAGE LAUNCHING CONFIGURATION OF FS-7 MISSILE

tures of the missile include a wingless tail-controlled airframe, an extremely simple control system, a guidance system using a hemispherical radome, and a partially ship-based intelligence system using a range-rate discrimination of target from the image in the sea. Design features requiring minimum research and development have been stressed throughout to make it available for the earliest possible fleet use

The missile design (see Fig. 15) has a rounded-nose, body-tail configuration. The rounded-nose body is required in view of the present status of radome design, but future development might permit the use of a more advantageous aerodynamic shape. The tail-control surfaces are arranged in a cruciform configuration, each surface pivoting about a hinge line. The horizontal surfaces would be used for pitch control, with the vertical surfaces used for both yaw and roll control. Missiles were considered whose parameters vary up to 20 per cent from the values selected for weight, length, and diameter. The curves of Fig. 16 give weight, length, and downrange comparisons for sea-level flight for several such possible missiles. The slant ranges obtained vary between 8000 and 13,000 yards, depending on the type, length, weight, and flight path of the particular configuration. The maneuverability available with the missile designs considered would satisfy the Navy's requirement of 10g up to an altitude of 10,000 feet at a Mach number of 1.5.

In all cases the powerplants would be solid-fuel rockets with the rockets positioned in the missile so that the fuel center of gravity would be nearly coincident with the full and complete missile center of gravity. This would nearly eliminate center-of-gravity travel as the fuel is consumed, thereby minimizing undesirable variations in stability and control characteristics.

The proposed missile control system is extremely simple. Pitch and yaw control systems are of the position feedback type, with fixed characteristics, and requiring no accelerometers or gyros. The need for synthetic weathercock damping would be obviated by heavy filtering of input data at weathercock frequency, thus preventing excitation of the weathercock oscillation. The roll-control system is of a standard form, with gyro inputs, the control being effected by differential positioning of the vertical control surfaces.

The control of the tracking dish is designed so that frictional torques tending to drive the dish as the body rotates would be largely balanced out. The rotation of the sight line would be measured by small rate gyros attached to the dish.

Since highly-accurate guidance intelligence would be needed, the use of a tracking head furnishing intelligence for a proportional navigation homing system is indicated. A semiactive system is required in order to permit tracking from launch, and an X-band system is specified because of availability considerations. The pro-

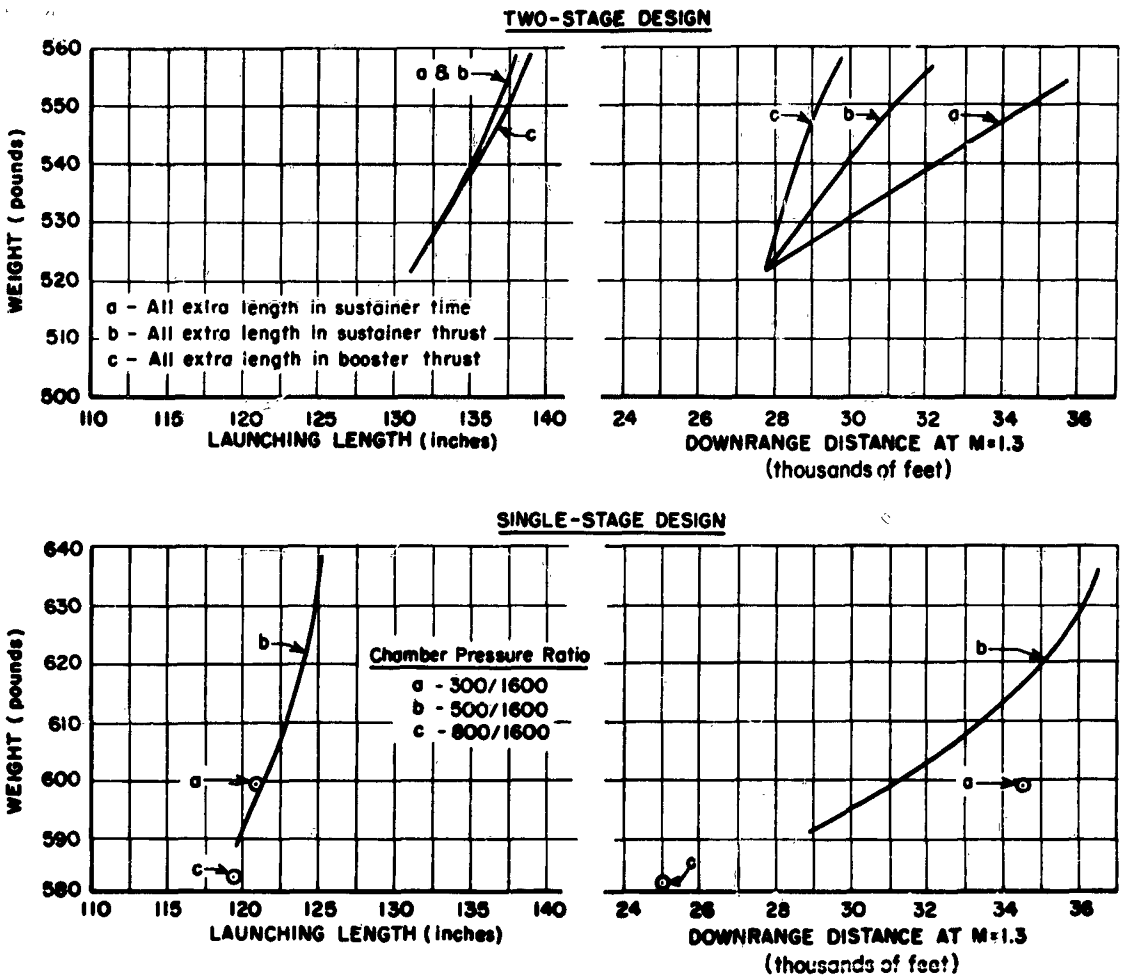


FIG. 16. WEIGHT, LENGTH, AND RANGE COMPARISONS OF FS-7 MISSILES FOR SEA-LEVEL FLIGHT

posed missile would use a hemispherical radome to reduce sharply the spurious signals frequently encountered with conical or ogival radomes, and would have a high weathercock frequency to permit large attenuation of spurious signals generated by missile weathercock. The relatively linear aerodynamic response and high maneuverability of the missile appear to meet homing guidance demands very satisfactorily. Runs made on the Reeves Electronic Analog Computer under a wide variety of conditions indicate that miss distances would rarely exceed 20 feet.

A major difficulty in the guidance of a missile against a low-flying target is that of resolving the target from its image in the sea. Range-rate resolution by means of narrow frequency gates in a CW Doppler system may be practicable, even against targets at altitudes as low as 50 feet. The risk of a missile going into the sea in response to the image signal would be eliminated by the use of an altimeter override which would prevent the missile from flying less than 50 feet above the surface of the water.

The warhead recommended is of the high-speed, controlled-size, fragmentation type. The suggested warhead weight is 40 pounds, fragment mass about 0.25 ounce, fragment speed about 6000 ft/sec, and beam center 75 degrees from the nose. A beam about 40 degrees wide is proposed because of the expected small miss distances and consequent difficulty expected in fuzing accurately.

It has been found that a fixed-angle fuze can be made small enough for this missile. The use of the rate of change of the homing signal Doppler rate appears to be marginally satisfactory for fuzing purposes and would require a negligible additional amount of components in the missile. The possibility of using an infrared fuze should be explored further. Effectiveness calculations based on the recommended warhead and a moderately good fuze indicate that a kill probability of 50 per cent can be attained with a standard aiming error as high as 20 feet.

A destroyer escort may be converted to use this missile with minimum disturbance to the ship's normal tactical functions, if sufficient radar intelligence can be achieved. Removal of the 5-inch, 38-caliber gun turret on DE-class vessels would permit a storage-loading-launching system similar to that planned for the Terrier missile ship. About 30 missiles could be stored in this installation.

The major disadvantage in the use of destroyer escorts is the large roll, which renders missile handling difficult and also reduces very significantly the effectiveness of the search radar. This situation is also intensified by the possibility of performing antisubmarine maneuvers at the time of air attack. A thorough investigation of the possibility of fin stabilization of the ship is necessary to determine the effectiveness of the missile system

PUBLICATIONS AND ADDRESSES

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SECTION T REPORTS

(The reports listed below were issued during the current month.)

Reports in the BUMBLEBEE Series:

No. 179 *Survey of BUMBLEBEE Activities* (Secret), Applied Physics Laboratory, The Johns Hopkins University, June 1952. (40 pp., 12 illus.)

An account is given of the flight test of the RTV-N-6a4c, the third of this series of beam-riding, ramjet-propelled, homing test missiles to be tested. The missile was flown at White Sands Proving Ground, on June 23, 1952. . . . The operation of a Talos battery computer, now being constructed by the Reeves Instrument Corporation, is described. This computer will be used at White Sands Proving Ground in simulated shipboard evaluation tests of the Talos Weapon System. . . . Results of the flight tests of six magnesium-fueled, ramjet test vehicles (PTV-N-4e) are evaluated. The missiles were constructed by Experiment Incorporated and flown at NOTS, in January 1952. . . . A summary is given of a flame-velocity study in which the temperature profile through the flame front of propane-air flames was determined as a function of composition and ambient pressure of the gas mixture.

CM Memoranda:

CM-725 *Study of Transient Hot-Wire Response in a Shock Tube*, by Darshan S. Dosanjh, Leslie S. G. Kovásznay, and Patricia C. Clarken, Department of Aeronautics, The Johns Hopkins University, March 12, 1952. (48 pp. + 28 illus.)

The transient response of a hot wire exposed to a sudden finite change in flow conditions in a shock tube is investigated. It is established that even for a finite step function, the hot-wire response is governed essentially by a linear differential equation of the first order. From the experiments reported here it is concluded that the hot-wire technique can be used to measure temperature and mass flow step-function transients in the shock tube.

CM-734 *Phenomena of Ignition and Flame Propagation; Final Report*, by James S. Arnold and Russell K. Sherburne, Physical Science Laboratory, New Mexico College of Agriculture and Mechanic Arts, June 30, 1952. (12 pp., 7 illus.)

A summary is given of the results that were obtained in this investigation. Since the publication of the previous report on this project (CM-698), experiments to confirm and extend the theory of a critical-radius criterion have been conducted. These are described briefly.

CM-735 *Progress Report on Study of Combustors for Supersonic Ram-Jet (ODS Project) for Period October 1, 1951–March 31, 1952* (Confidential), Esso Laboratories, Standard Oil Development Company, June 30, 1952. (77 pp., 30 illus.)

During this period experimental work was continued on four phases of this project: fuel atomization and mixing, combustor performance and development, flame spreading and stability, and pilot performance and development. Progress made in each phase is summarized.

PUBLICATIONS BY SECTION T STAFF MEMBERS

Title	*Author*	*Journal*
On the Validity of Spectroscopic Temperature Determinations in Flames	K. E. Shuler, Applied Physics Laboratory	*Journal of Chemical Physics*, **20**, 1176–1177, July 1952

ADDRESSES BY SECTION T STAFF MEMBERS

June 26—Division of Fluid Dynamics, American Physical Society, Salt Lake City, Utah, "Experimental Study of the Formation of a Vortex Ring," by F. K. Elder and N. de Haas, Applied Physics Laboratory

July 2—Colloquia of the Aeroballistic Research Department, U. S. Naval Ordnance Laboratory, White Oak, Maryland, "Hypersonic Experiments at the Applied Physics Laboratory," by F. K. Hill, Applied Physics Laboratory

REPORTS RELEASED FOR UNRESTRICTED PUBLICATION

The following Section T publications have received security review by the Bureau of Ordnance U. S. Navy, and have been released for unrestricted publication by the authors or their sponsoring agents.

CM Memoranda

CM-15 *Results of First Tests of Model Athodyds at Island Beach*, by W. H. Goss, Applied Physics Laboratory, The Johns Hopkins University, February 20, 1945.

CM-43 *Flight Test of Winged Models at Island Beach April 12–13*, by A. C. G. Mitchell and H. S. Stillwell, Applied Physics Laboratory, The Johns Hopkins University, April 30, 1945.

CM-57 *Supersonic Airfoil*, by H. H. Porter, Applied Physics Laboratory, The Johns Hopkins University, July 4, 1945.

CM-63 *Supersonic Body Drag Data*, by H. H. Porter, Applied Physics Laboratory, The Johns Hopkins University, July 12, 1945.

CM-219 *Supersonic Flow around Inclined Bodies of Revolution*, by L. L. Cronvich, Applied Physics Laboratory, The Johns Hopkins University, February 25, 1946.

CM-224 *Calculation of Pressure Distribution over an Ogive for Supersonic Axial Flow*, by L. L. Cronvich, Applied Physics Laboratory, The Johns Hopkins University, March 14, 1946.

CM-232 *On the Radiation from a Horn: I*, by C. W. Horton, Defense Research Laboratory, The University of Texas, March 13, 1946.

CM-246 *A Novel Method to Produce Damping in an Electrical Servo System*, by Walter A. Good, Applied Physics Laboratory, The Johns Hopkins University, May 2, 1946.

CM-248 *Tabular Forms for the Application of H. S. Tsien's Method to the Calculation of the Lift and Moment Coefficients for Bodies of Revolution at Supersonic Velocities*, by L. Beskin, Consolidated Vultee Aircraft Corporation, May 17, 1946.

CM-250 *Damping Forces and Moments on a Body of Revolution at Supersonic Velocities*, by L. Beskin, Consolidated Vultee Aircraft Corporation, May 31, 1946.

CM-251 *Determination of Upwash Around a Body of Revolution at S*
by L. Beskin, Consolidated Vultee Aircraft Corporation, M

CM-252 *Transition Curves in Supersonic Two-Dimensional Flow* (L
L. Beskin, Consolidated Vultee Aircraft Corporation, June

CM-255 *Supersonic Two-Dimensional Airfoil Theory*, by L. Beskin, C
Aircraft Corporation, August 14, 1946.

CM-256 *Steady Supersonic Two-Dimensional Flow*, by L. Beskin, C
Aircraft Corporation, June 14, 1946.

CM-690 *The Theory of Flame Propagation and Detonation, III*, by
Hirschfelder and D. E. Campbell, Naval Research Labora
Wisconsin, February 15, 1952.

CM-703 *Experimental and Theoretical Activities in the Gas Prope*
Date, by Ivan F. Weeks, Naval Research Laboratory, Univ
January 8, 1952.

CM-717 *A Method for the Selection of Valves and Power Pistons in H*
Fletcher C. Paddison and Walter A. Good, Applied Physi
Johns Hopkins University, January 26, 1952.

In addition to internal (Section T) distribution, the distribution of this document includes Parts A, B, and C of the ANAF-G/M Mailing List No. 18 as revised April 10, 1952.

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Johns Hopkins University, Applied Physics Lab., Silver Spring, Md. (Bumblebee Series Report No. 181)
SURVEY OF BUMBLEBEE ACTIVITIES. July '52, 40 pp. incl. photos, tables, diagrs, graphs. ~~SECRET~~

The Survey of Bumblebee Activities is issued monthly by the Applied Physics Laboratory of the Johns Hopkins University. It is one of the Section T Bumblebee series of documents which also includes technical papers and symposia reports. The Survey is intended to provide a brief summary of the month-by-month progress of the Bumblebee guided-missile (over)

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project which has been undertaken by a Section T group of associate and related contractors. The contractors currently engaged in this work are listed herein. Included in this issue are: description and status of Bumblebee prototypes Terrier, Talos, and Triton; OAL burner tests, OAL wind-tunnel tests, multiple-target simulator, and feasibility study of small supersonic guided missiles. Section T reports, publications by Section T Staff Members, Addresses by Section T Staff Members, and reports released for unrestricted publication are also included.

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