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THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
8621 GEORGIA AVE., SILVER SPRING, MD.
Operating Under Contract NOrd 7386
With the Bureau of Ordnance, U. S. Navy

SEMIANNUAL REPORT

OF

BUMBLEBEE PROJECT

JULY - DECEMBER 1949

Bumblebee Series

Report No. 123 **March 1950**

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SECRET

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July--December 1949

Bumblebee Report No. 123

THE JOHNS HOPKINS UNIVERSITY
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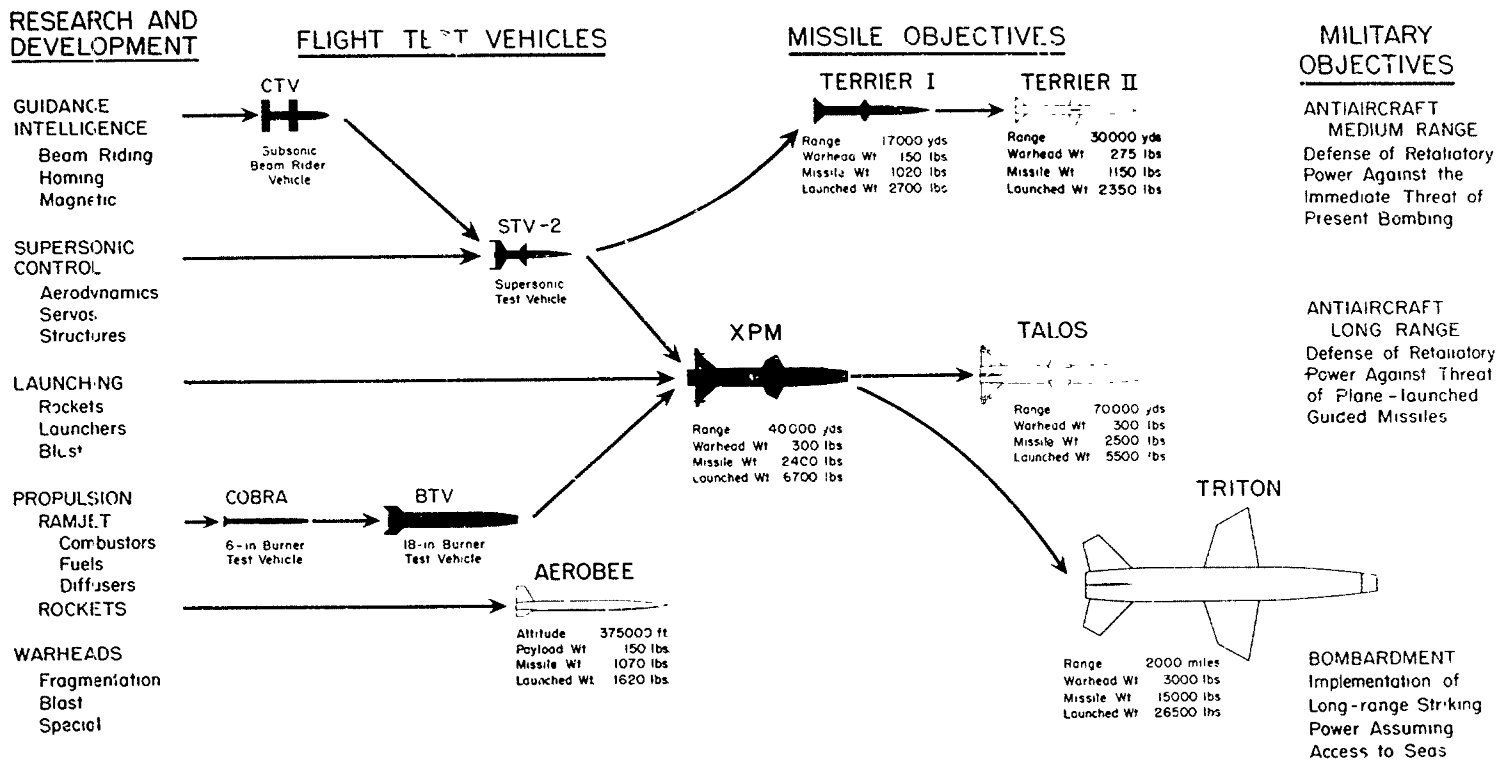
BUMBLEBEE



BUMBLEBEE TEST VEHICLES AND MISSILE OBJECTIVES
Vehicles shown in black have been flown full scale.

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INTRODUCTION

The end of 1949 marks the completion of the first five years of the BUMBLEBEE program. It is gratifying to note that the objectives originally scheduled for this five-year period have come reasonably close to realization. These were:

1945 - Demonstration that solutions existed for all the critical technical problems.

1946 - Establishment of research and development facilities.

1947 - Accumulation of basic data.

1948 - Design and development of components.

1949 - Demonstration of a missile prototype.

The Terrier missile is now in the prototype stage. It is noteworthy that the BUMBLEBEE program, which was founded on the basis of a broad research and development program in guided-missile technology, has been the first to produce a tactical, supersonic missile prototype.

Effort in the BUMBLEBEE program during the past six months has been directed primarily toward crystallization of the prototype development program for Terrier and Talos. All but two of the Terrier components have been released to Consolidated Vultee Aircraft Corporation for production engineering. and a firm program of ground and preliminary shipboard tests has been established in cooperation with other Bureau of Ordnance agencies. The Talos program has been revised in the light of experience with XPM and Terrier to move directly to development of a long-range missile (70,000 yards) with homing. A sound basis has been laid for Triton combustor design in tests at Ordnance Aerophysics Laboratory of a 48-in combustor, and for mid-course guidance by a 1200-mile aircraft flight test of an automatic magnetic navigation system.

The first direct measure of the charge on the primary cosmic-ray particles has been obtained during the course of Aerobee flights. The result appears to confirm beyond question the earlier theoretical predictions that the primary radiation consists largely of protons.

BUMBLEBEE PROGRAM

Five Years of Progress

The objectives of the BUMBLEBEE program include (a) collecting and assessing background information from which a class of guided missiles can be designed, and (b) development of actual prototypes of proven performance. The status of the prototype missiles under development in this program is indicated in the Frontispiece and by the following statements.

TERRIER - The Terrier missile has been declared to be in the prototype stage except for two components, the beam-rider receiver and computer, which require further development. Specifications have been written and a production contract let by the Bureau of Ordnance which will provide missiles for the first shipboard firings from the USS NORTON SOUND (AV-11) in October 1950.

TALOS - Two units of the XPM, the pre-Talos prototype, have been flight tested. The design and specification for this missile are scheduled for completion in September 1950.

TRITON - The long-range, bombardment, offensive guided missile, Triton, is still in the research stage. Plans call for the production of the first Triton test vehicles around July 1952.

Many of the achievements of the program are listed in the monthly Survey of BUMBLEBEE activities. The chronological list of achievements appearing in the December 1949[1] issue indicates some of the important contributions of the BUMBLEBEE program during this five year period.

(January 1, 1945:	Initiation of Bumblebee Program)
April 1945:	Ramjet burning in flight - with 6-in unit.
June 1945:	Ramjet thrust in flight - with 6-in 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 CTV (subsonic).
September 1945:	Bang-bang roll stabilization of supersonic coaster.
October 1945:	Ramjet acceleration in flight - with 6-in unit.

[1]BUMBLEBEE Report No. 114.

November 1945:	Proportional roll stabilization of CTV (subsonic).
December 1945:	Burner tests of RTV (18-in 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-in kerosene-fueled unit.
September 1946:	Successful flight test of RTV (18 in ramjet).
September 1946:	Twelve-channel telemetering operated successfully in burning ramjet (RTV).
January 1947:	Subsonic beam riding for 16 seconds along 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 in) to maximum velocity of 2520 ft/sec 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 and coast to over 50,000 ft.
March 1948:	Supersonic beam riding for over 20 seconds - with STV-2.
July 1948:	BTV (18 in) burned successfully to over 40,000-ft altitude and coasted on to 70,000 ft.
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-in prototype.
April 1949:	Successful use of capture beam with supersonic test vehicle.
October 1949:	STV-3 beam-riding accuracy greatly increased to achieve longest beam-riding flight to date - 54 seconds of powered flight.

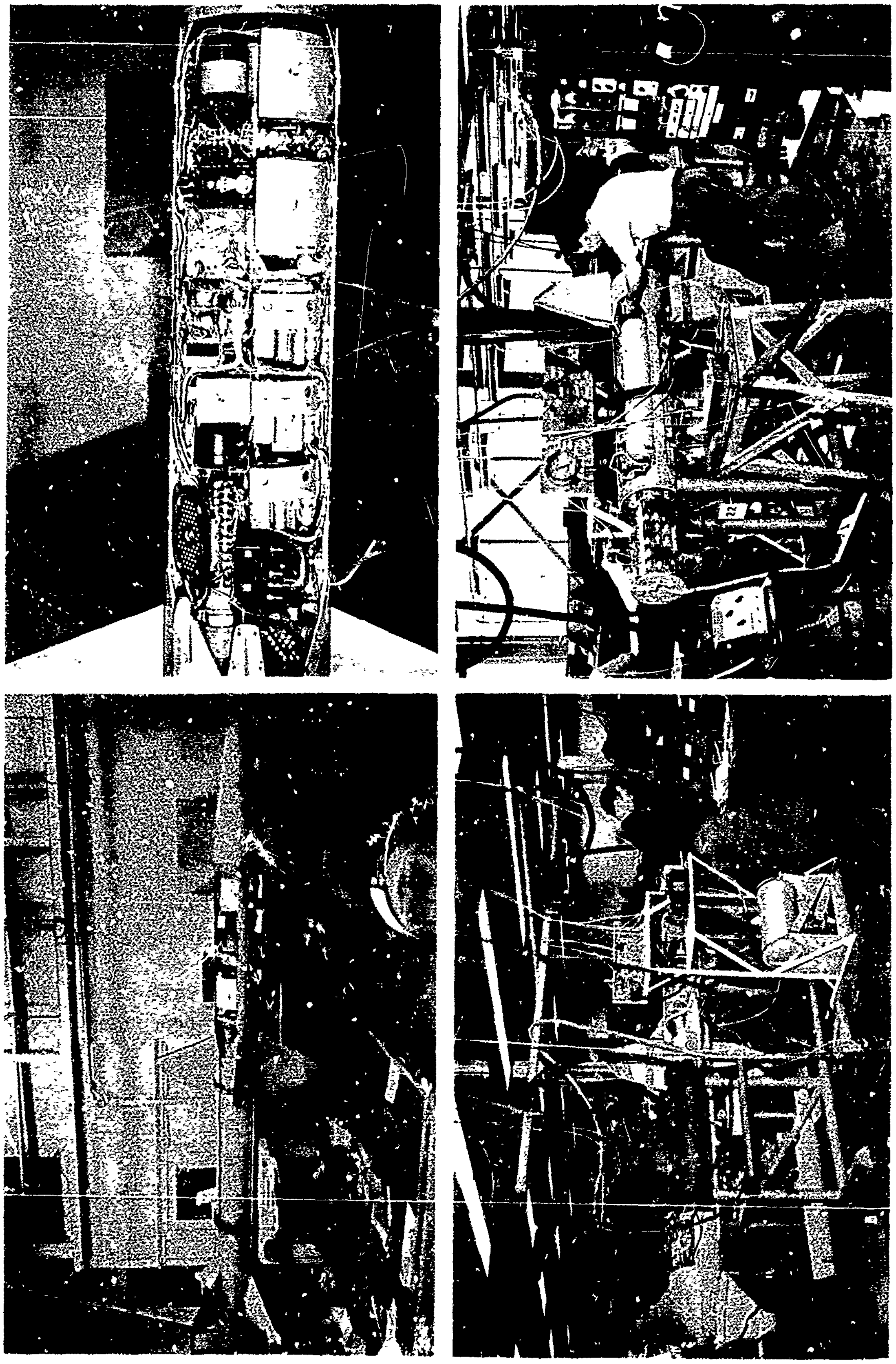

Fig. 1 STV-3B SERIAL NO. 1 UNDER CONSTRUCTION AT CONSOLIDATED VULTEE AIRCRAFT CORPORATION.
Upper left: Over-all view of STV-3B unit. Upper right: Bottom view of forward guidance compartment. Bottom views: Checkout activities for STV-3B.

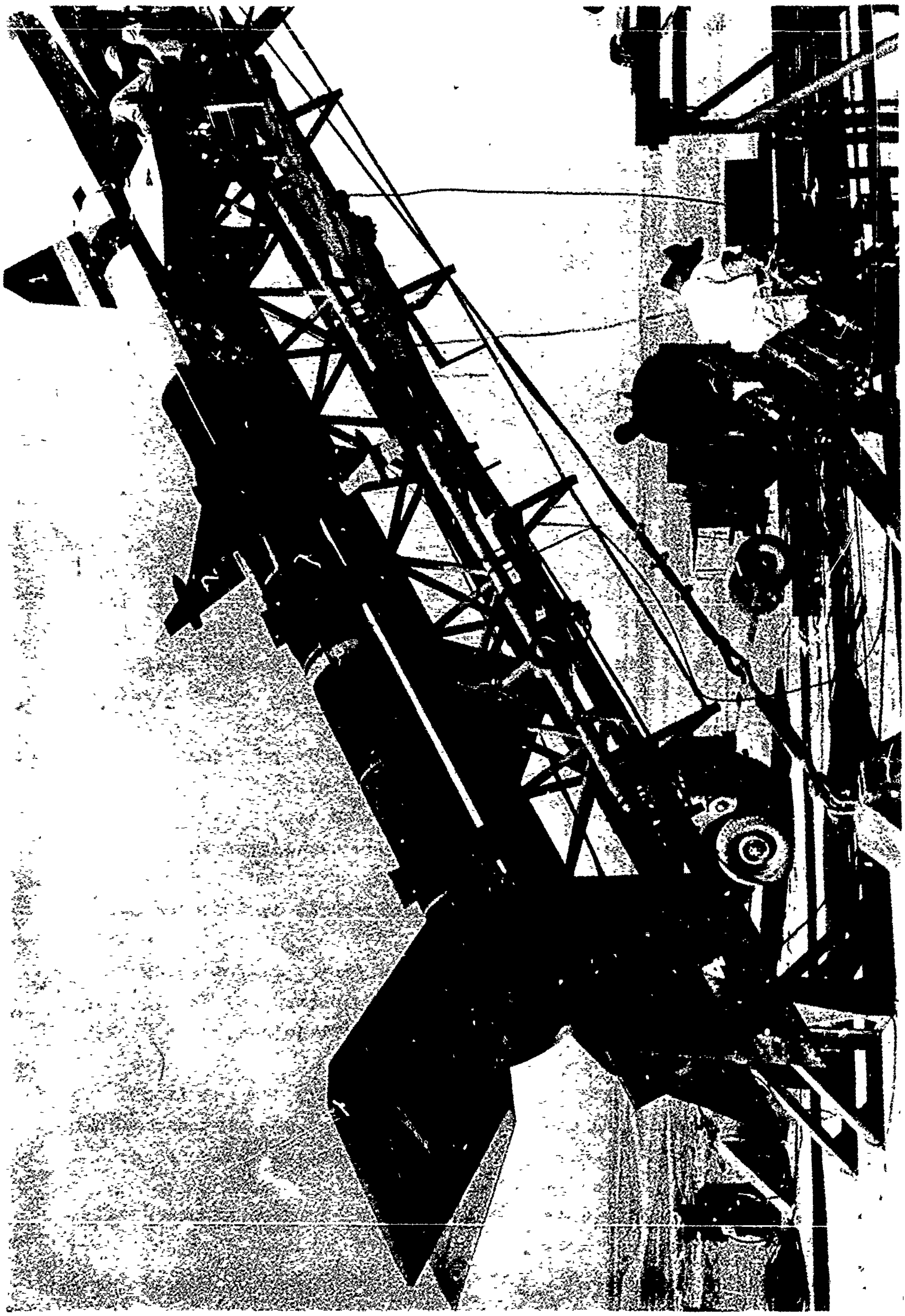

Fig. 2 LTV-3, SERIAL NO. 3 ON LAUNCHING RAMP AT NOTS, INYOKERN.

Not included in this list are a number of important contributions relating to the research program and also to complete missile prototypes. No attempt will be made to give a complete record but the following accomplishments are considered to be important enough to be added to the previous list of recognized achievements.

1. Completion of specifications and initiation of procurement for Terrier, the first prototype BUMBLEBEE missile.
2. Preparation of specifications for the pre-Talos prototype, a ramjet-propelled, long-range anti-aircraft missile.
3. Development of the standardized "Telepac", six-band, and ten-band telemetering systems for guided missile application.
4. Establishment of a large scale ground test ramjet burner and wind tunnel facility at OAL.
5. Construction and use of a high-altitude, ramjet test facility at APL.
6. Acquisition of hitherto lacking supersonic, aerodynamic data sufficient for the design of Talos and Terrier along with significant data on the surface-to-surface Triton missile.
7. Development of a series of solid-propellant booster rockets now used by a number of other guided-missile projects in the United States.
8. Development of simulators for laboratory demonstration and study on BUMBLEBEE guidance systems.
9. Development of a hypersonic wind tunnel at APL.
10. Demonstration of high-altitude combustion in a 6-in ramjet (Cobra) to an altitude of 57,000 feet with combustion chamber pressures as low as 5 pounds per square inch.
11. Initial experimentation on a 48-in, ramjet motor for Triton which demonstrates the adequacy of the OAL facility for ground testing this surface-to-surface missile application.
12. Acquisition of facilities, and of personnel trained in the design and fabrication of test missiles and guided missile prototypes, which are now available for missile engineering and production.
13. Development of high-altitude, liquid-rocket-propelled sounding rocket.
14. Demonstration of the feasibility of long-range guidance based on use by means of the earth's magnetic field.

15. Demonstration of feasibility of radar interferometric homing for antiaircraft missiles.

The remainder of this report will concern the details of BUMBLEBEE progress during the period July - December 1949.

Flight Test Program

Four of the five flight tests conducted during the last six months of 1949 resulted in significant advances in the program; these were:

1. STV-3 Type 73 - most successful beam-riding flight; demonstrated elimination of sustainer ignition shock problem, and feasibility of maintaining constant accuracy by increasing control sensitivity with range.[2]
2. STV-3 Type 77 (Terrier configuration) - Demonstrated Terrier control system and aerodynamic response.[3]
3. LTV-3 (XPM launching configuration) - Demonstrated successful elimination of aerodynamic misalignments at transonic speeds which had led to flight failures of the first two LTV's.[4]
4. Cobra (6 in burner test vehicle) - Demonstrated combustion up to 57,000 feet altitude.[5]

The flight-test program may be summarized as follows:

The sustainer rocket ignition shock problem which plagued the STV-3 flight tests of early 1949 was eliminated.[6] A spring compression device sandwiched between the forward end of the sustainer rocket charge and the case now prevents shifting and consequent hammering effect of the charge. Flight proof of the effectiveness of the cure was demonstrated in the two STV-3 flights conducted during this period. Unintelligible signals usually found in the telemetering records just after the end of boost completely disappeared.

Successful roll stabilization of both the STV-3 and STV-3A airframes has been demonstrated. The STV-3A airframe (Type 77), using a roll servo improved both with regard to dead space and speed of response, showed excellent roll stabilization. The roll recovery was critically damped to a steady state oscillation with less than one-half degree amplitude. Mention should be made that this occurred on a flight test in which the yaw and pitch wings were not moving rapidly. Such motion may produce coupling roll torques and hence a more severe oscillation.

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[2]See BUMBLEBEE Report No. 112, pages 9-11 (October 1949 Survey).

[3]See BUMBLEBEE Reports No. 107, page 1 (July 1949 Survey), No. 113, page 1 (November 1949 Survey) and No. 114, pages 12-15 (December 1949 Survey). It should be noted that the STV-3 Type 77 has a Type 72 airframe and it is under the latter designation that it is discussed in the Survey references.

[4]See BUMBLEBEE Reports No. 107, page 14 (July 1949 Survey) and No. 111, page 15 (September 1949 Survey).

[5]See BUMBLEBEE Reports No. 112, pages 12-13 (October 1949 Survey) and No. 113, pages 4-5 (November 1949 Survey).

[6]See BUMBLEBEE Report No. 104, pages 3-4 (June 1949 Survey).

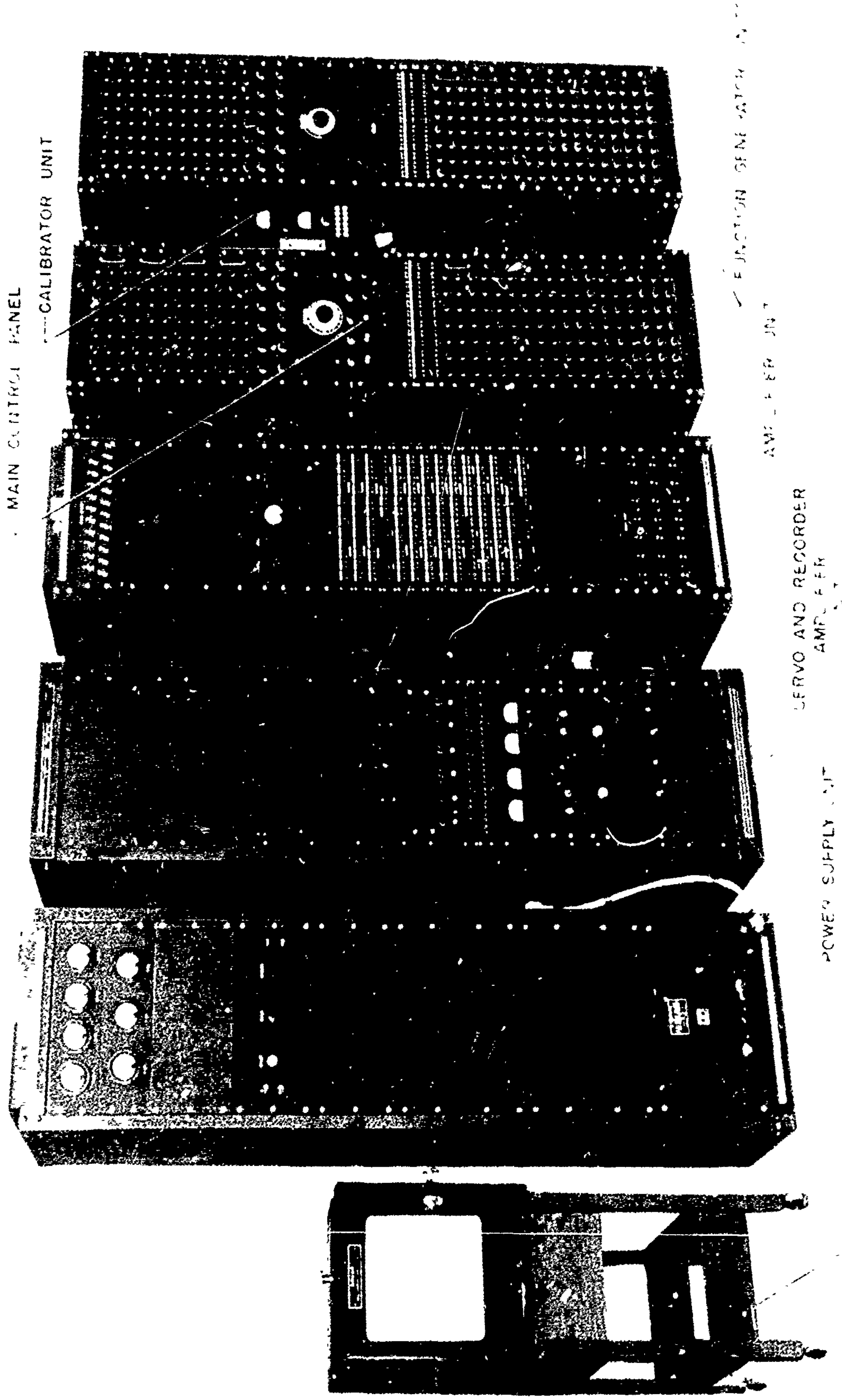
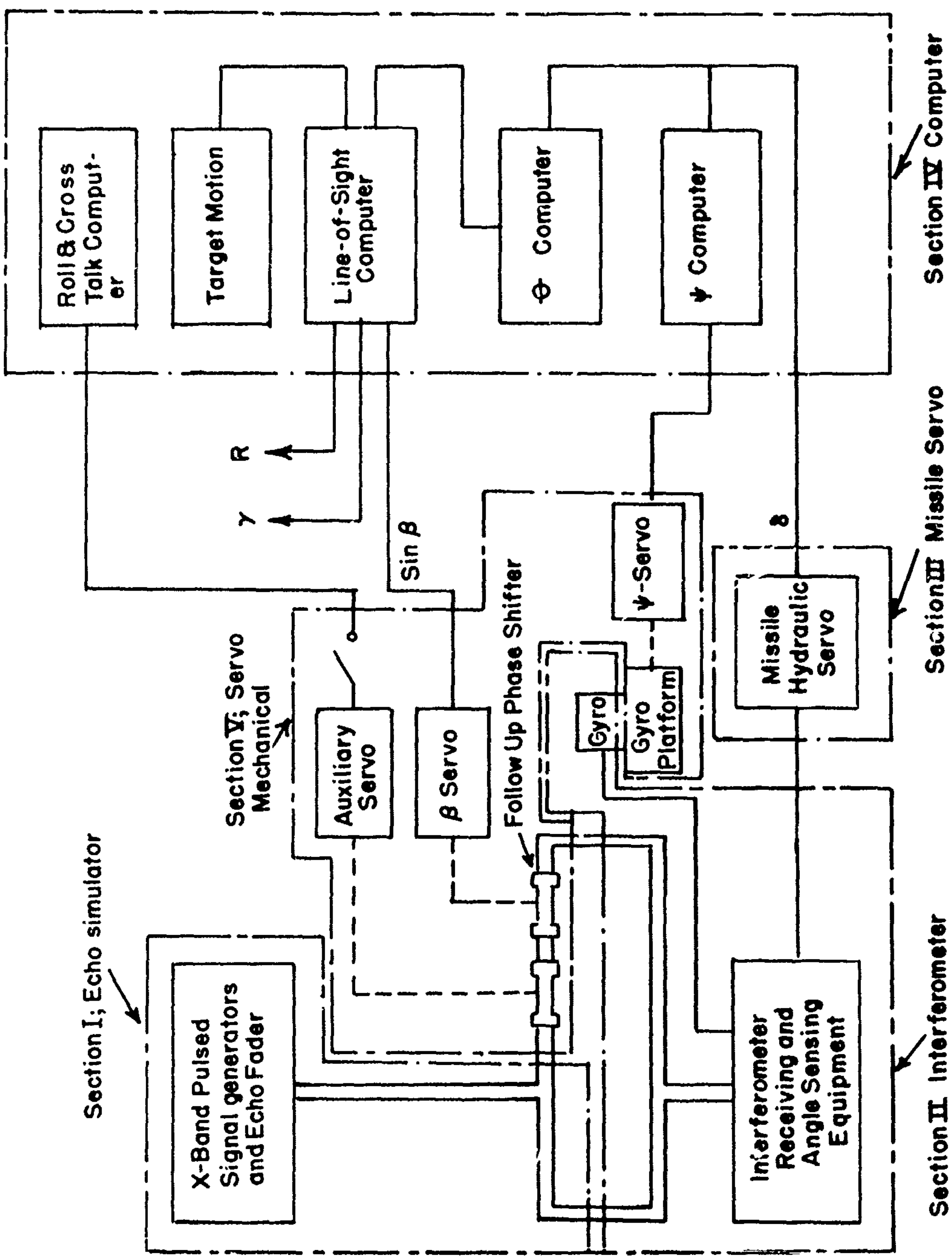


Fig. 3 CURTISS-WRIGHT ANALOG COMPUTER; DESIGNED AND BUILT TO SOLVE THE EQUATIONS OF MOTION OF GUIDED OR CONTROLLED LAUNCHING CONFIGURATIONS.



HOMING FLIGHT SIMULATOR

Fig. 4 DIAGRAM OF THE DEFENSE RESEARCH LABORATORY (UNIVERSITY OF TEXAS) HOMING FLIGHT SIMULATOR SHOWING SEPARATE PARTS INCLUDING THE MISSILE COMPONENTS AND SIGNAL SOURCE.

The first test in which the beam-rider control sensitivity was changed during flight was made October 13 with the STV-3, Type 73, Serial 8 unit. A change in sensitivity from 8 to 40 occurred at 16 seconds flight time. The resultant improvement in beam-riding accuracy agreed well with prediction. Sensitivities as high as 200 are to be used in the next flight tests. Progressive increase in sensitivity with increasing range and altitude will maintain approximately constant off-beam distance throughout flight, insuring adequate accuracy over the effective missile range.

The STV-Terrier flight-test program is to be carried on during the next six months at the considerably-increased rate of two to three flights per month. The first tests of STV-3 beam riders will be with moving and jittering beams; target tests against drones will follow.

At the time the last semi-annual report was issued, the ramjet prototype anti-aircraft missile, the XPM, had been flown without the forward wings because a boost period instability had occurred on previous flights of dummy missiles. No additional XPM units were fired in this six-months interval although a dummy launching vehicle, LTV No. 3, simulating the XPM configuration was flight tested in September. This flight demonstrated that the cause of the instability, determined by aerodynamic wind-tunnel tests on a model, had been remedied. In wind-tunnel tests, it was found that the shoes on the booster for attachment to the launching rail changed the pressure distribution on the adjacent booster fins at transonic speeds sufficiently to produce large angles of attack during the boost period. A slight change in the position of these shoes, coupled with the addition of shoes in the symmetrical locations on the other side of the booster, appears to have eliminated this undesirable effect completely. A second factor contributing to the failure of the previous LTV's was theoretically determined to be wing torsional bending. In the later LTV flight this was overcome by wing locks which prevent wing bending during the boost phase and are retracted at separation.

In September, three 6-in ramjet test vehicles (Cobras Nos. 316, 317, and 318) were flight tested to high altitudes. One of the two burning units successfully demonstrated the adequacy of the propulsion system to 57,000 feet altitude. Achievement of combustion at combustion chamber pressures as low as 5 pounds per square inch verified the ground test data on these vehicles previously obtained at the Forest Grove Station burner laboratory.

Terrier Prototype (XSAM-N-7) [7]

The first missile of the initial experimental production lot (Lot Zero) of Terrier missiles was delivered during December, approximately a month and a half behind schedule. The delay was due to difficulties in obtaining sub-miniature vacuum tubes of the proper performance characteristics, to delays in the delivery of other components, and to the time required to build up automatic

[7] For a detailed description of Terrier see BUMBLEBEE Report No. 112, pages 1-9 (October 1949 Survey).

missile checkout instrumentation. The assembly line at Convair is now turning out these units and the fifteen airframes on this order are essentially complete. The termination of assembly of this lot is scheduled for June 1950, at which time the rate of production will be four per month.

During this period Terrier has been declared to be in a production prototype stage except for further development required on the beam-rider receiver, missile-borne computer and the tactical telemetering system. Complete performance requirements were prepared for the production of a final design, designated as Lot VII, of the Terrier missile. A production contract was awarded by the Bureau of Ordnance to Convair for the procurement of 50 Terrier units in four lots (Lots I through IV). Waivers on Lot VII specifications have led to specifications for the first lot which is now under procurement. An engineering contract covering the production engineering of this missile for service use was also awarded to Convair during this period. As various engineering designs become available, changes will be made in the specifications to incorporate them into the missile. Drawings have been released for Lot I with production already under way. The scheduled release date for the drawings for Lot II is February 15, 1950.

Planning for shipboard tests of the Terrier missile from the USS Norton Sound (AV-11) in October 1950 has necessitated the joint effort of the numerous agencies supplying equipment for tests of the complete Terrier guided-missile system. APL will continue to act in an advisory capacity on the technical aspects of these tests. A list of the agencies and contractors having responsibilities in the organization of the tests is given in the following table.

TABLE OF AUXILIARY TERRIER SYSTEM COMPONENTS
AND SUPPLYING AGENCIES

	Component	Agency
1.	Mk 37 Director	Bureau of Ordnance (Re4)
2.	Mk 25 Mod 6 tracking and guidance radar	Bureau of Ordnance (Re4) Reeves Instrument Co.
3.	Missile launcher a. Type X-7 for NOTS AND USMC b. Type X-5 for AV-11	Bureau of Ordnance (Re5) Puget Sound Navy Yard
4.	Computer Mk 1	Bureau of Ordnance (Re5) Ford Instrument Co.
5.	Shipboard telemetering receiving stations	Applied Physics Laboratory

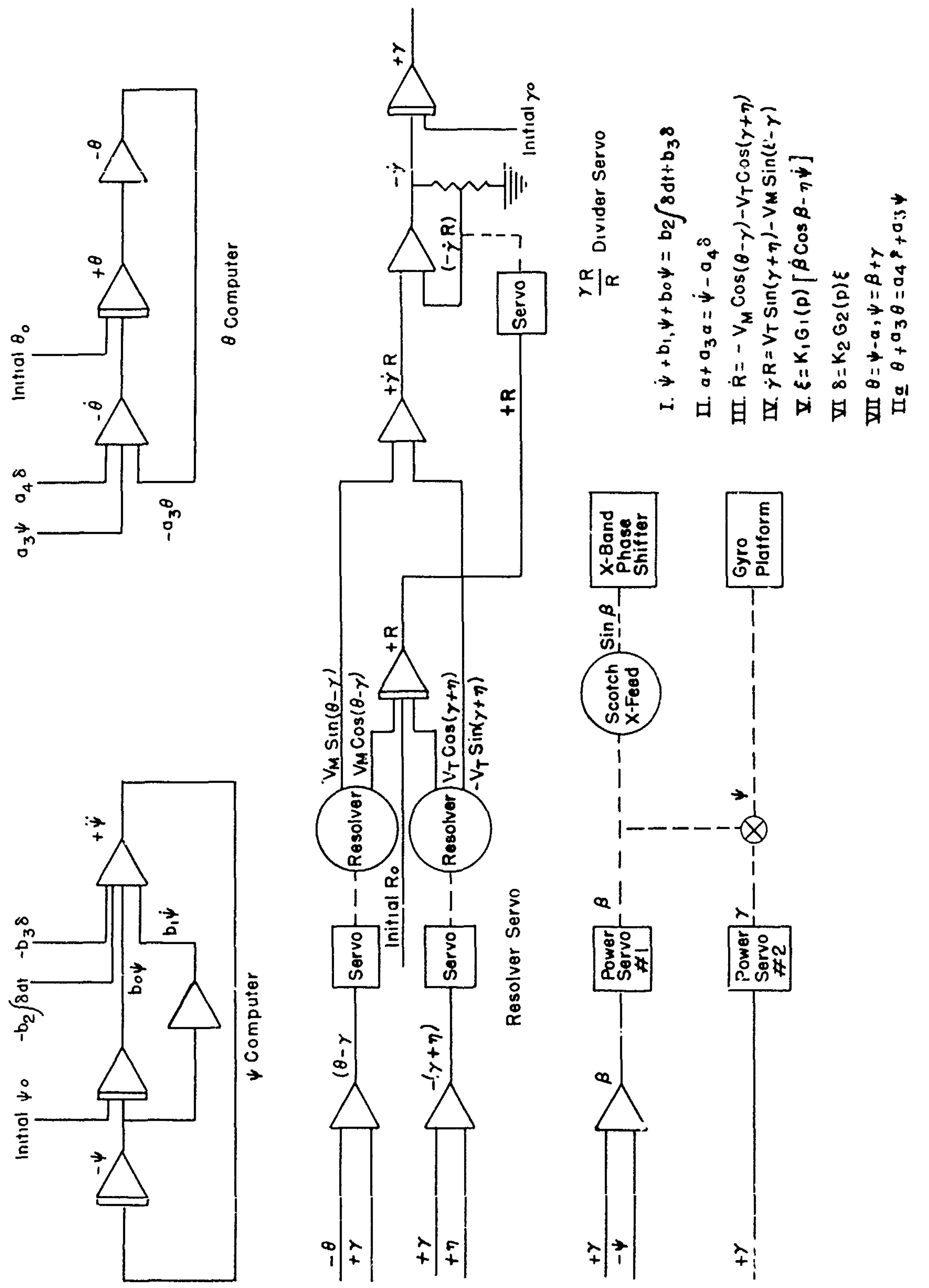


Fig 5 ELECTRONIC ANALOG COMPUTER ARRANGEMENT FOR DRL HOMING FLIGHT SIMULATOR.

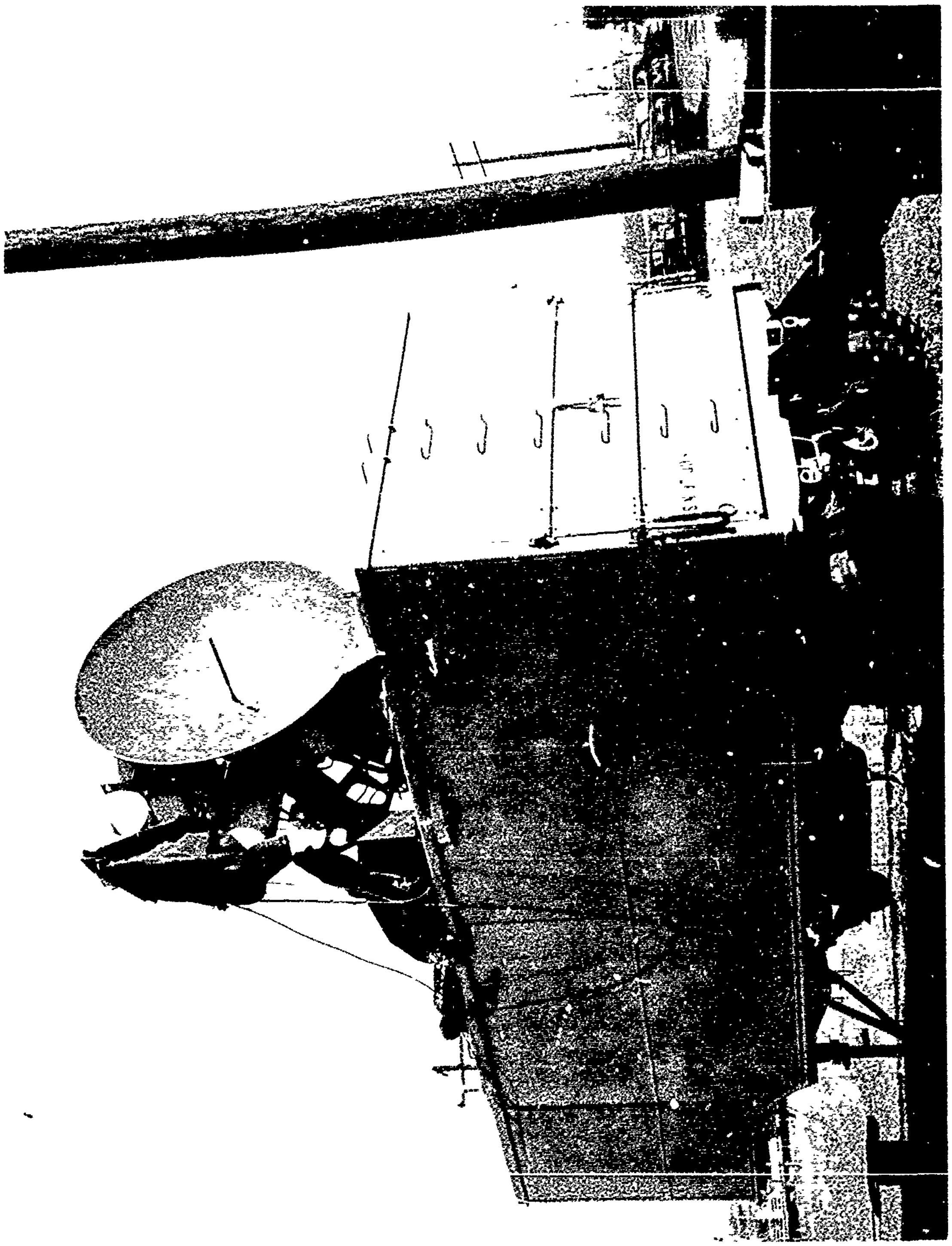


Fig. 6 SCR-584 RADAR AT INYOKERN. This radar is being constructed to include a 6-foot tracking antenna and an 18-inch capture antenna.

	Component	Agency
6.	Warhead	Bureau of Ordnance (Re3) Naval Ordnance Laboratory
7.	Proximity Fuze	Bureau of Ordnance (Re2) National Bureau of Standards
8.	Booster and Sustainer Rockets	Allegany Ballistics Laboratory
9.	Missile checkout and handling equipment	Convair
10.	Search radar	Bureau of Ships
11.	Target drones	Bureau of Aeronautics

Before being placed on shipboard the Terrier missile system will be tested against flying targets at the Naval Ordnance Test Station, Inyokern, California, to demonstrate its performance in a tactical system.[8] Equipment similar to that being installed on the Norton Sound is being set up at NOTS, including the radar, the launcher and its pointing computer, checkout equipment, and operations control stations. The first test with a live warhead against a target drone is scheduled for the Spring of 1950. All of the missiles of Lot Zero, Lot I and five missiles of Lot II are scheduled for land test. The last five units of the Lot II production are designated for shipboard trials. In order to maintain this schedule, demonstration firings must proceed at the rate of three to four missiles per month which represents a considerable increase in rate as compared with previous experience.

Talos Prototype (RTV-N-6a)[9]

The second unit of the XPM (RTV-N-6a) was flown without forward wings on June 29, 1949 just prior to the beginning of this period.[10] The flight again demonstrated adequate structural, aerodynamical and ignition properties, but the ramjet was extinguished approximately 12 seconds after separation, much as occurred in the flight of XPM No. 1. After exhaustive study it has been established that the failure of the propulsion system was due to faulty design of a component of the fuel meter.

The fabrication of XPM Nos. 3, 4, 5, 6, and 7 continues at Convair and at the Products Division of the Bendix Aviation Corporation. The next unit to be flight tested will be No. 4. It is designed as a roll stabilization and

[8] See BUMBLEBEE Report No. 112, page 8 (October 1949 Survey).

[9] For a description of the prototype Talos missile, see BUMBLEBEE Report No. 114, pages 1-3 (December 1949 Survey).

[10] See BUMBLEBEE Reports No. 104, page 1 (June 1949 Survey) and No. 109, pages 1-2 (August 1949 Survey).

program yaw unit with the forward wings on the missile locked in position during the boost phase. This flight test, previously planned for December 1949, is now scheduled for approximately March 1, 1950. The remaining four units are being fabricated as complete beam riders; two are to be flight tested before July 1 and the remaining two in the Fall. Generally the XPM program is behind the original schedule, the complexity of prototype fabrication and testing, the problems raised and solved by the LTV-3, and the flight propulsion difficulties being the principal causes of the delay. A revised schedule has been drawn up and there is reason to believe that this will be realized.

Paralleling the steps taken in the Terrier program, the Ma section of the Bureau of Ordnance is considering the procurement of additional Talos pre-prototype missiles on an Ma contract. During this period specifications have been written so that a production contract can be awarded. These units will utilize the beam rider and propulsion system developed in the current XPM program, and will be used largely to demonstrate homing and jet-vane control during boost.

Aerodynamics

During the period covered by this report, an active program of research planning was undertaken by the Bureau of Ordnance Committee on Aeroballistics (BOCA), composed of representatives of BUMBLEBEE, METEOR, NOL, NOTS (Inyokern) and NPG (Dahlgren); positive steps were taken to integrate BUMBLEBEE aerodynamics research with that of the other BuOrd agencies. Panels were formed by BOCA to organize joint programs of research in the following fields: Wing-Body and Wing-Body-Tail Interaction, Diffuser Research, Reynolds Number Effects, Boundary Layer Research, Heat Transfer Research, Dynamic Stability, Hypersonics, Base Pressure Research, and Aeroelasticity.

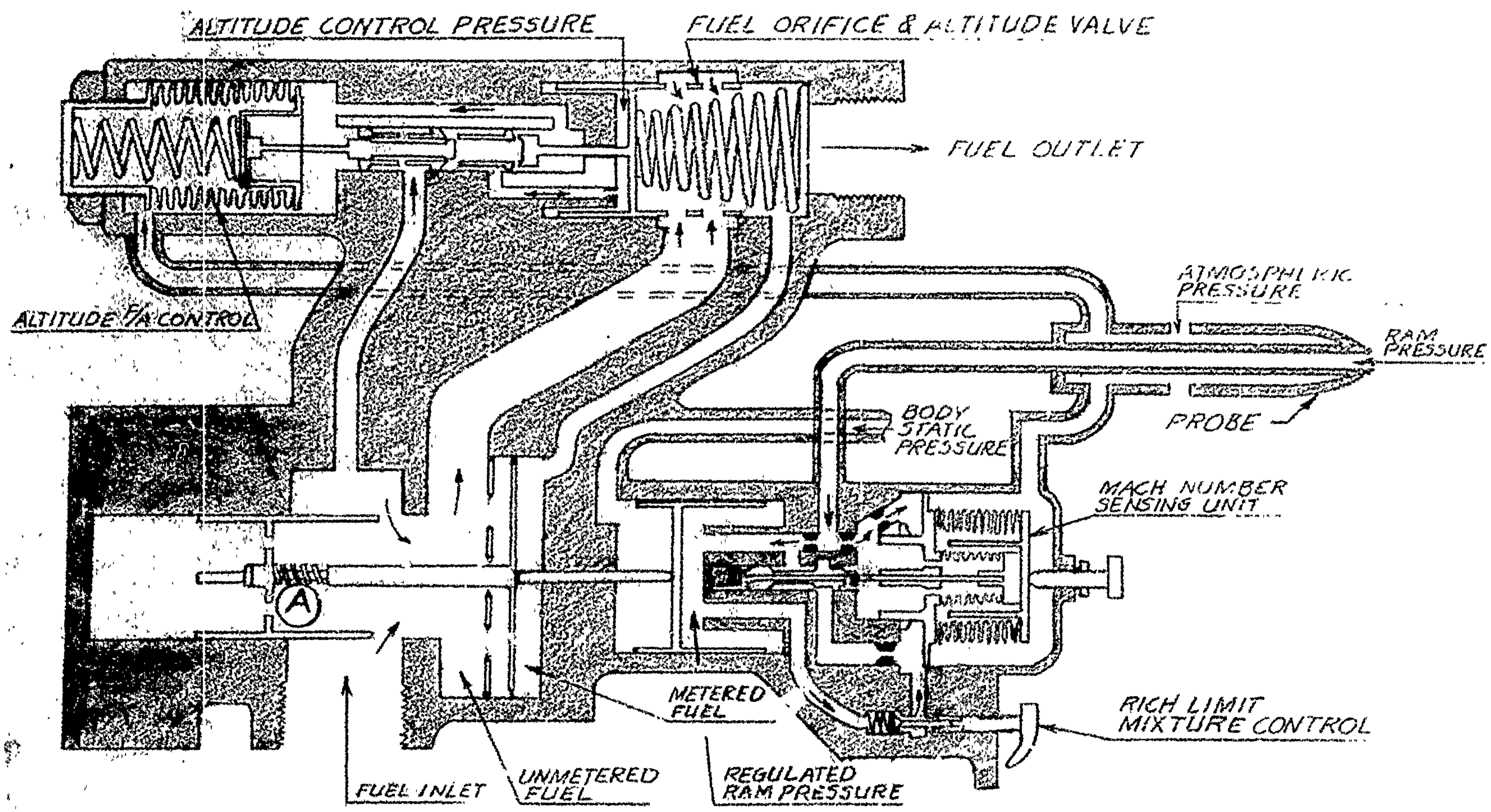
The Terrier has been selected by this committee as the standard missile for prediction and experimental determination of Reynolds number effects. Tests of a Terrier model will be conducted in the Naval Ordnance Laboratory wind tunnel and pressurized firing range at various Reynolds numbers. Similar tests will be run at the Massachusetts Institute of Technology tunnel with Reynolds numbers comparable to those at OAL for comparing results obtained from different tunnels.

Further progress has been made in developing simple wing-body interaction theory suitable for engineering predictions; satisfactory agreement between measured and predicted lift forces has been obtained for rectangular wings on bodies, at Mach numbers of 1.5 and 2.0.

Additional calculations of lift and drag have been made for finite wings and bodies, to assist with the preliminary design of long-range missiles.

Turbulent boundary layer characteristics in the Mach number range from 1.5 to 2.2 have been determined experimentally from pitot pressure surveys along a flat plate; a semi-empirical relation has been derived to permit extrapolation to Reynolds numbers higher than the maximum OAL test Reynolds number of 19×10^6.[11]

[11] See BUMBLEBEE Report No. 117, pages 13-14 (January 1950 Survey).



FUEL METER

Fig. 7 BENDIX FUEL METER. The possibility of flight failure because of transient fuel flow interruptions (caused by a chattering of the flow control poppet valve in the fuel meter under conditions of abnormally high fuel pressures at the meter inlet) has been eliminated by preventing significant compression of the spring which positions the poppet valve on its shaft (A in the diagram). This is done by a sleeve slipped over the spring allowing no more than 0.002 inch of play.

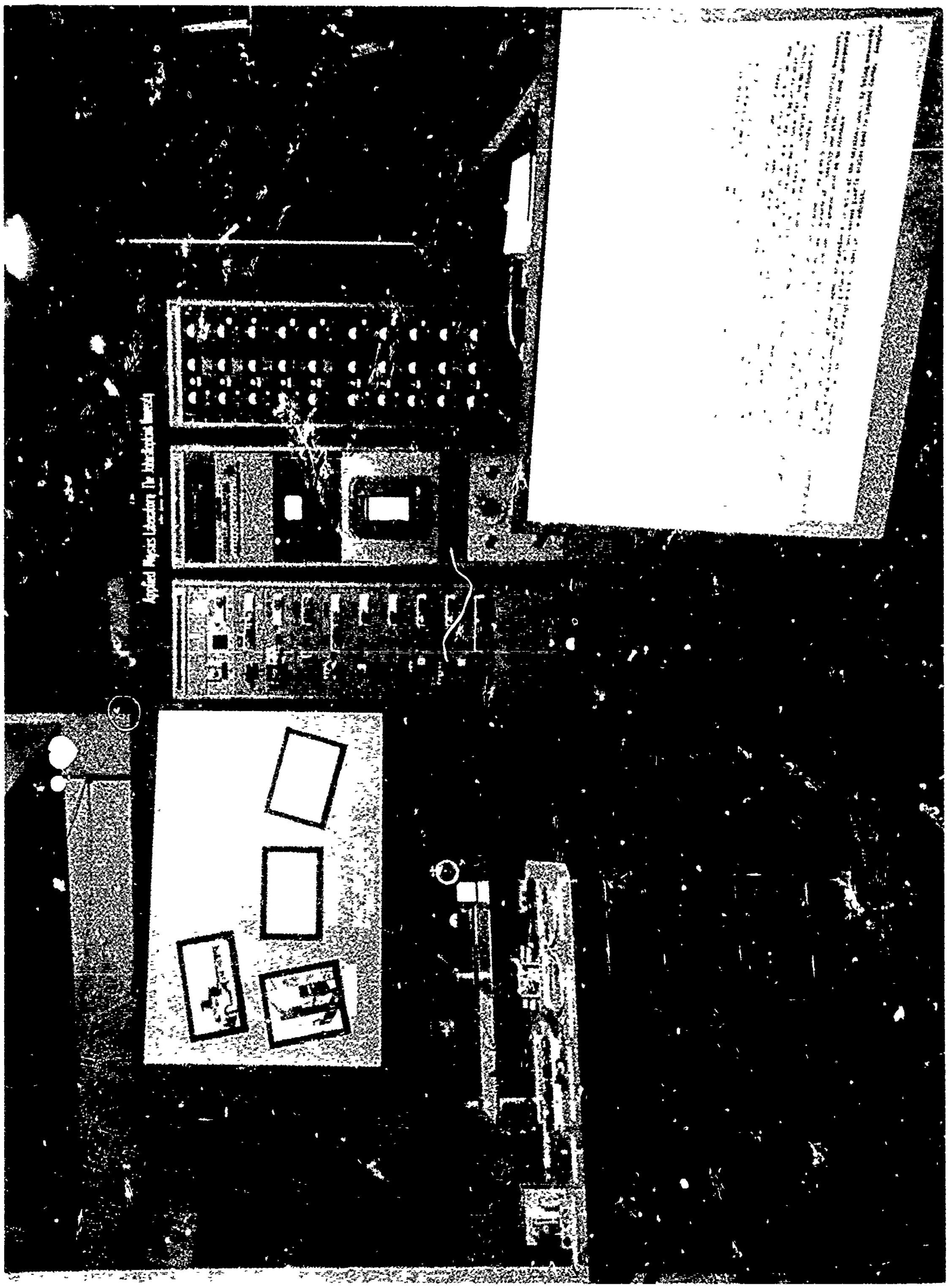


Fig. 8 TELEMETERING DISPLAY. This demonstration unit for the 10-band audio system was first shown at the annual national exhibition of the Instrument Society of America in St. Louis. It aroused considerable comment and, together with the presentation at the National Telemetering Forum and sessions on the classified details of the 10-band system, helped to influence the Research and Development Board Working Group in its decision to expand the system.

During the last six-month period, considerable aerodynamic information has been received from flight tests of the STV-3 and STV-3A vehicles.[12] (STV-3A has the same aerodynamic configuration as Terrier). These results have been correlated with predictions based on wind tunnel data, theoretical studies, and previous flight data. Drag data are consistent to within 3 per cent in the Mach number range between 1.4 and 1.7. Aerodynamic damping, stiffness (stability) and effectiveness (maneuverability) have been confirmed for only one Mach number (slightly higher than the separation Mach number); estimates agree to within 10 per cent for these parameters.[13]

Considerable effort was devoted to the aerodynamics associated with the failure of LTV-3 Nos. 1 and 2.[14] As noted elsewhere in this report, the causes were isolated and, with the help of wind tunnel measurements, the overall behavior of the vehicles has been accounted for quantitatively.

Although the number of hours for wind tunnel testing at OAL was smaller than during the last period, the total number of runs was larger because of the appreciable increase in efficiency due mainly to an increase in the air-drying equipment and improved instrumentation.

Guidance and Control

Terrier Beam-rider Receivers

Two of the most important problems remaining in the Terrier prototype development relate to the beam-rider receiver and the missile-borne computer. During the research and development stage of guidance, a missile-borne, X-band receiver was developed to derive proper yaw and pitch d-c components. For tactical use, this receiver is deficient in that it can be easily jammed by other friendly radars at X-band frequency since the missile receiver accepts any signal in this band. To make the receiver tactically useful, the system is being redesigned to eliminate effects of friendly interference.

The first step to minimize this jamming problem will be the introduction of a second frequency into the guidance radar beam, differing by a small amount (45 megacycles per second) from the main frequency. An intermediate frequency stage (IF) will be added to the receiver to select signals having this frequency difference. This system is called the ground-based local oscillator heterodyne system and will be incorporated into Terrier missiles of Lots I through III. This complete system has been set up and tested in the laboratory.

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[12] See BUMBLEBEE Reports No. 109, pages 10-11 (August 1949 Survey), No. 112, pages 22-27 (October 1949 Survey) and No. 114, pages 12-15 (December 1949 Survey).

[13] The Aerodynamic Report for Terrier has been completed in accordance with Navy requirements for the complete specifications. This report includes data on maneuverability and performance for typical flight paths in the region in which Terrier is expected to be an effective anti-aircraft weapon. This report, represents a major achievement in that the data are available for the Terrier missile and the report, the first of its kind for a guided missile, can be used as a standard for future reports of this type.

[14] See BUMBLEBEE Report No. 107, pages 4-8 (July 1949 Survey).

The second step will be the coding of the guidance radar pulses. The coding is accomplished by transmitting double (or triple) pulses separated by a fixed time interval. The missile receiver is modified to be sensitive only to pulses with the proper time spacing. A simple selector switch in the missile tunes it to a particular radar on board ship. This modification is planned for incorporation in Lots IV or V of the Terrier production.

The beam-rider receiver for the ultimate Terrier missile is unspecified as yet but it is anticipated that it will be of the true heterodyne type with the local oscillator located on the missile instead of on the guidance radar. This will make Terrier missiles interchangeable with Talos missiles insofar as radar requirements are concerned. This change is being made possible by the development of a ruggedized, X-band, local-oscillator tube for missile application. The 2K25 klystron has been made rugged and temperature insensitive through modifications of its external structure and now seems adequate for missile application.

Terrier Missile Computer[15]

The missile-borne computer, whose function is to transform the beam-rider receiver intelligence signals into control signals, presents the second remaining major Terrier problem. Specifically, the computer must compensate control sensitivity and wing limits for range, altitude, speed, gravity, movement of center of gravity, and beam motion. In this way the accuracy of the missile will be maintained constant through its effective range.

Present effort has been directed to the determination of the control parameters to be used in the tactical computer. To this end, the sensitivity has been adjusted by a timer in the missile in accordance with the predicted missile trajectory. This will be done in most of the Lot 0 flights during the next six months.

The development of a tactical computer, to accomplish this function automatically, is nearing completion. Theoretical studies indicate that such a computer could be designed to function from information obtained from static and dynamic pressure probes on the missile and from a time program. It is anticipated that the design of this computer will be sufficiently tested so that it may be incorporated in Terrier missiles of Lot 4. In connection with this computer development and with the general problem of the accuracy of beam-rider guidance, the APL yaw simulator has beer completely revised to make it sufficiently accurate to predict the miss at the target on these laboratory flights.

Other Developments

Problems associated with gyros, transfer valves, servo amplifiers and valve motors are receiving less attention as Terrier and XPM approach the prototype stage. Two problems pertaining to these components are receiving further attention. Cornell Aeronautical Laboratory is continuing development work on

[15] See BUMBLEBEE Report No. 113, pages 2-3, (November 1949 Survey).

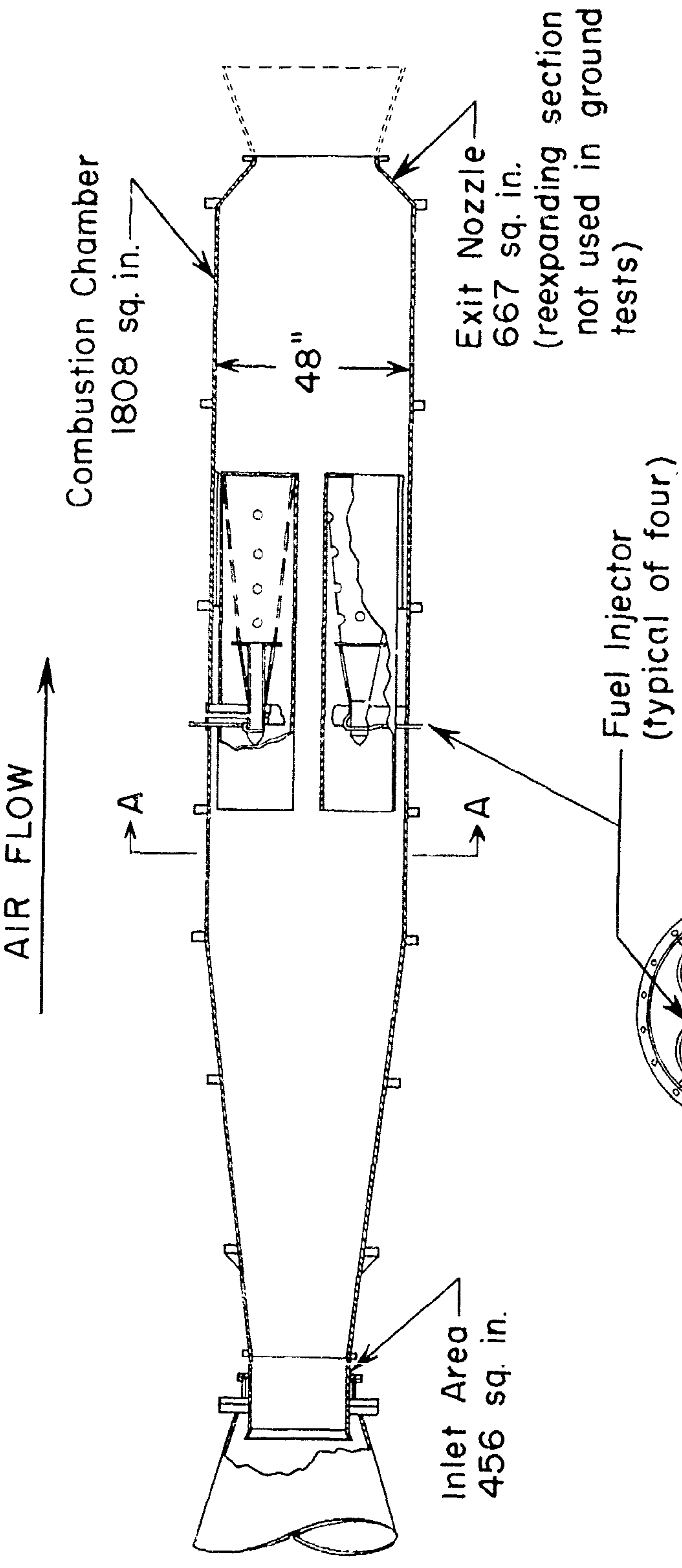

Fig. 9 LONGITUDINAL SECTION VIEW OF 48-INCH RAMJET TESTED AT OAL.

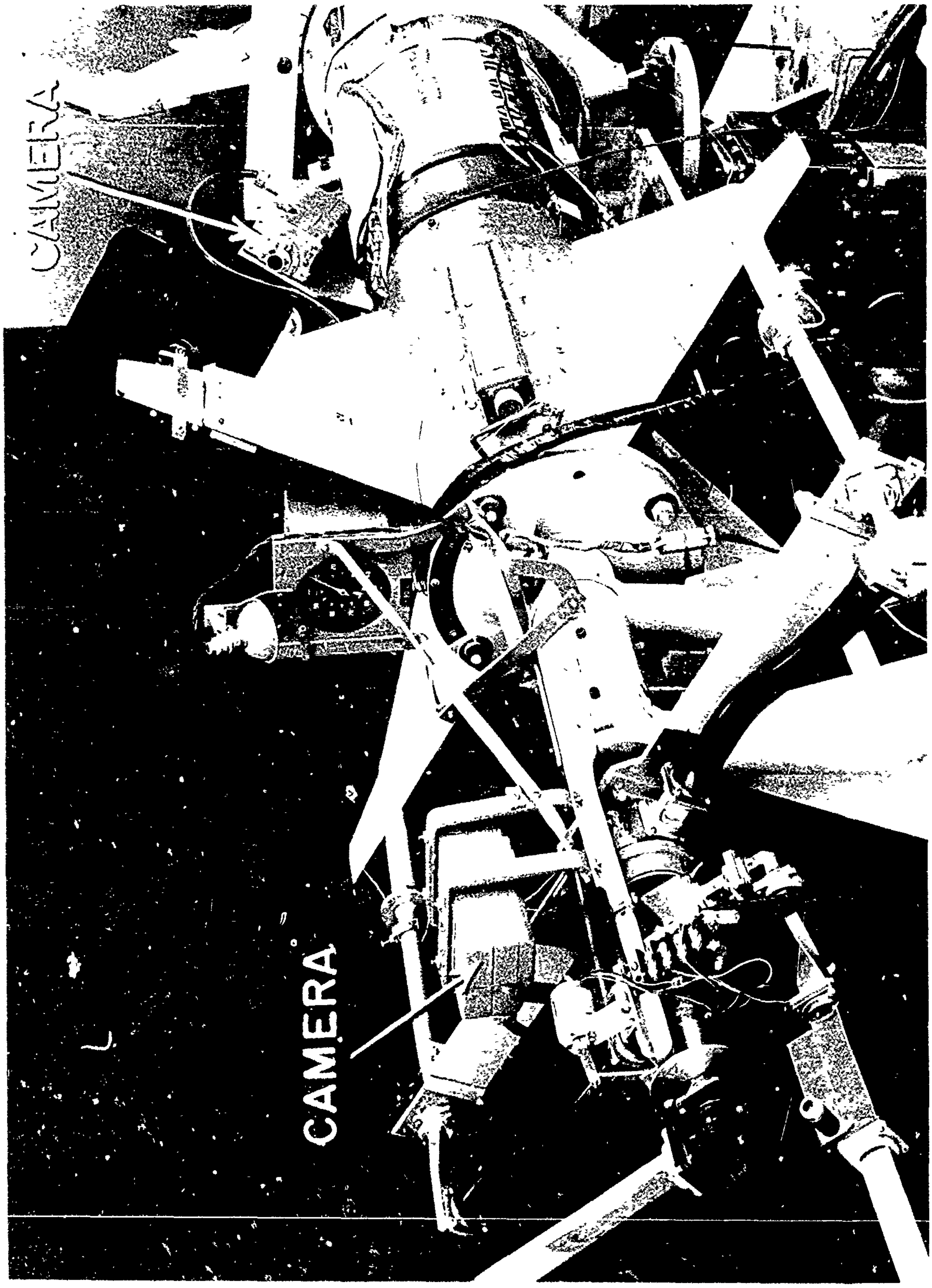

Fig. 10 REAR VIEW OF MISSILE MOUNTED IN ROLL OSCILLATOR SHOWING TWO RECORDING CAMERAS.

The camera for recording roll-wing deflection is on the right; the one for recording roll attitude is on the left. The timer is also photographed. Other cameras not shown record pitch and yaw wing deflections, r-f signal generator program, and metered voltages. Waveguide connections to the missile are also shown transfer valves in an attempt to eliminate the effects of Bernoulli forces and static friction.[16] At the same time, under the BuOrd engineering contract at Convair, new designs of amplifiers, motors, and transfer valves are being considered. The objectives are to obtain (a) a stable d-c control system, and (b) transfer valves which can be manufactured more easily than has been possible in the past.

In connection with the Terrier testing program at NOTS, Inyokern, an M-9 computer has been adapted for converting the guidance radar coordinates into proper control signals for the X-5 launcher. This computer aims the launcher so that the missile will intersect the narrow guidance radar beam at approximately 4500 feet, inserting corrections for wind, parallax, target angular velocity and gravity drop.

An oscillating table has also been designed and constructed for rapid checkout of Terrier missiles.[17] With the unit mounted on this oscillating table, guidance signals can be fed into the missile through the antenna and the over-all response of the control signal can be monitored. This equipment permits rapid and complete assessment of the performance of the system and components with removal of any individual faults.

One important aircraft flight test of the Triton midcourse navigation system, under study at Convair, was made during this period.[18] This round trip flight from Indio, California, to San Antonio, Texas (2490 miles), with accuracies at different points ranging from 2 to 10 miles demonstrated the feasibility of the magnetic system for the guidance of long-range missiles. At the conclusion of the flight, the equipment was dismantled from the aircraft and returned to the laboratory at Convair for further development. Problems still to be solved include the development of a highly-stabilized bucking current, the degaussing of the missile, the miniaturization of the magnetometer and packaging for the particular missile.

More-concentrated attention has been focused on the development of the interferometer homer for the Talos missile. Two units of a homing simulator for similar studies have been designed and are under construction. One each of these units will be installed for guidance studies at APL and at the University of Texas. The XPM has been modified by the addition of a 20-inch length in the forward body to accommodate this homing system; this modified XPM carries the official designation RTV-N-6a4.[19] Flight tests are expected to be made in approximately one year. By far the most emphasis during the period has been on the design and procurement of the homing simulators both at APL and at the University of Texas.[20] Considerable progress has been made in the construction of a breadboard of the actual homing system at APL and on the development of components for the final system. One of the major problems yet to be solved is the development of the range tracking unit which has been added to the system to ease the multiple target resolution problem.

[16]See BUMBLEBEE Report No. 117, pages 19-23 (January 1950 Survey).
[17]See BUMBLEBEE Report No. 114, page 22 (December 1949 Survey).
[18]See BUMBLEBEE Report No. 109, pages 13-14 (August 1949 Survey).
[19]See BUMBLEBEE Report No. 114, pages 1-3 (December 1949 Survey).
[20]See BUMBLEBEE Report No. 98, pages 12-13 (February 1949 Survey).

Launching

The basic objective of the Launching program is to provide reliable and accurate means for shipboard launching of Terrier and Talos missiles to supersonic velocities. The general performance specifications for these missiles require shipboard launching from a trainable "zero-length" service launcher and acceleration to velocities of approximately 2000 ft/sec.

In order to achieve these requirements a research and development program was formulated with the following specific objectives:

1. Design and development of high impulse booster rockets.
2. Design and development of means and equipment for stabilization and control of the launching configuration during the boost phase.
3. Design and development of reliable and accurate means of separation of the booster and missile.
4. Establishment of design criteria for launchers and associated structures to be constructed by the Navy, including criteria for modification of shipboard equipment for protection against blast.

All the principal Section T research and development activities in the field of launching are carried on by associate contractors.

During the past six months, work in launching has been concentrated upon the development of high-impulse boosters and study and development leading to accurate and reliable stabilization and control of missiles during the boost phase. A highlight in the program was the successful launching of LTV-3 No. 3. This missile had the external configuration of XPM and used the new "Mod III" booster, which gives a thrust of 100,000 lbs for 4 seconds.[21]

Research work sponsored during the past few years on high-impulse boosters at the Allegany Ballistics Laboratory gives promise of the availability within the next two years of boosters of Terrier size and larger having over-all specific impulses of 150 or greater. Development of the first of these boosters is now under way.

Studies at Cornell Aeronautical Laboratory, the Curtiss-Wright Corporation and APL have shown the feasibility of shipboard launching of Terrier missiles using jet-vane control for beam riding and stabilization during the boost phase.[22] Development, fabrication and evaluation of the component parts is now in progress and a flight test of a full scale configuration employing these units is scheduled during the next six months.

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[21] See BUMBLEBEE Reports No. 104, page 16 (June 1949 Survey) and No. 111, page 15 (September 1949 Survey).

[22] See BUMBLEBEE Report No. 117, pages 24-27 (January 1950 Survey).

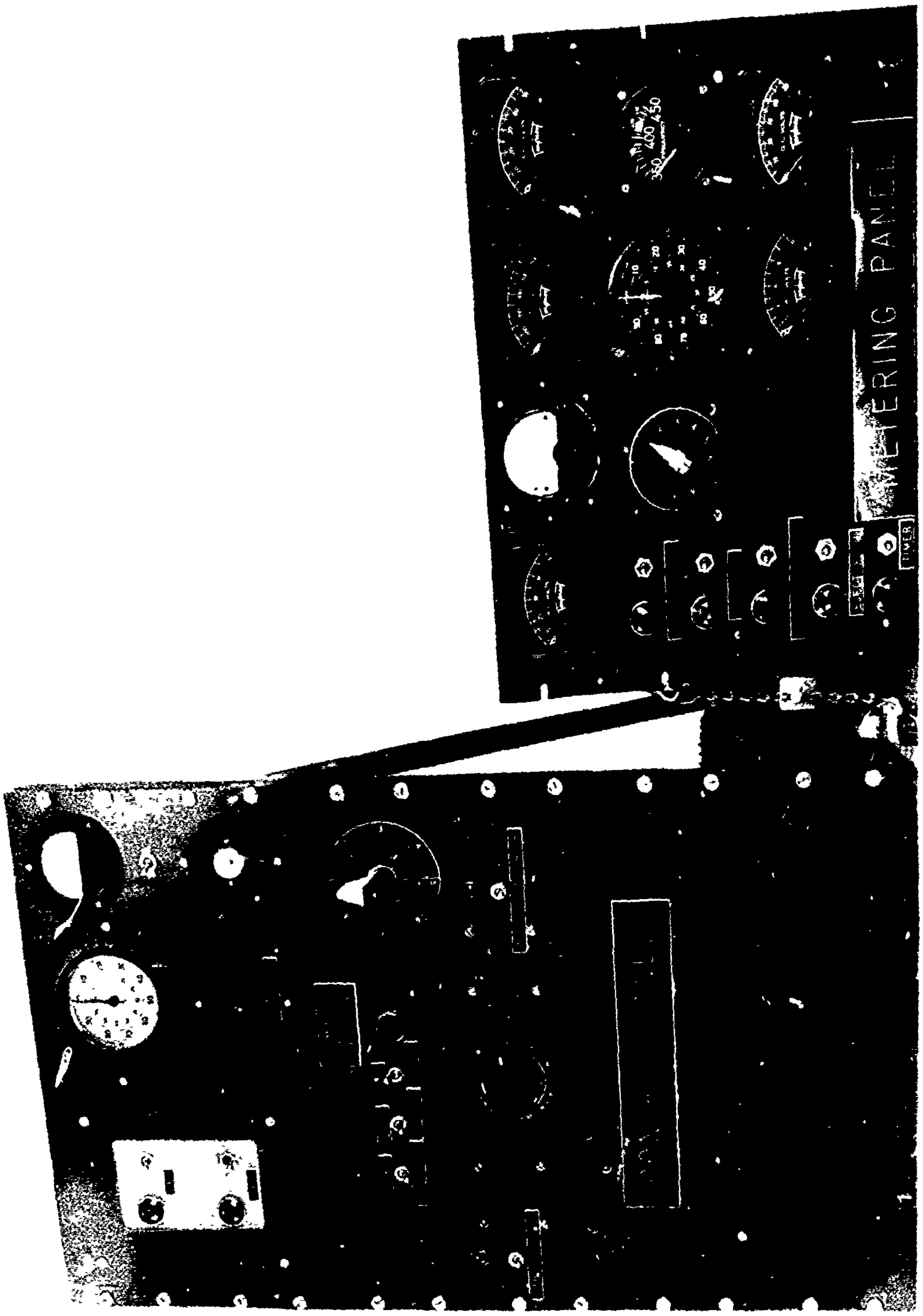

Fig. 11 CONTROL AND METERING PANELS FOR OVER-ALL SYSTEM TEST. The control panel allows remote control of roll oscillator frequency, power circuits, cameras, timers, and lights. It also permits remote switching of various circuits in the missile necessary to carry out the test procedure (such as shorting out derivative circuits, breaking autosyn excitation and so forth). An operator at this panel provides a pre-arranged program of roll oscillation and missile circuit switching

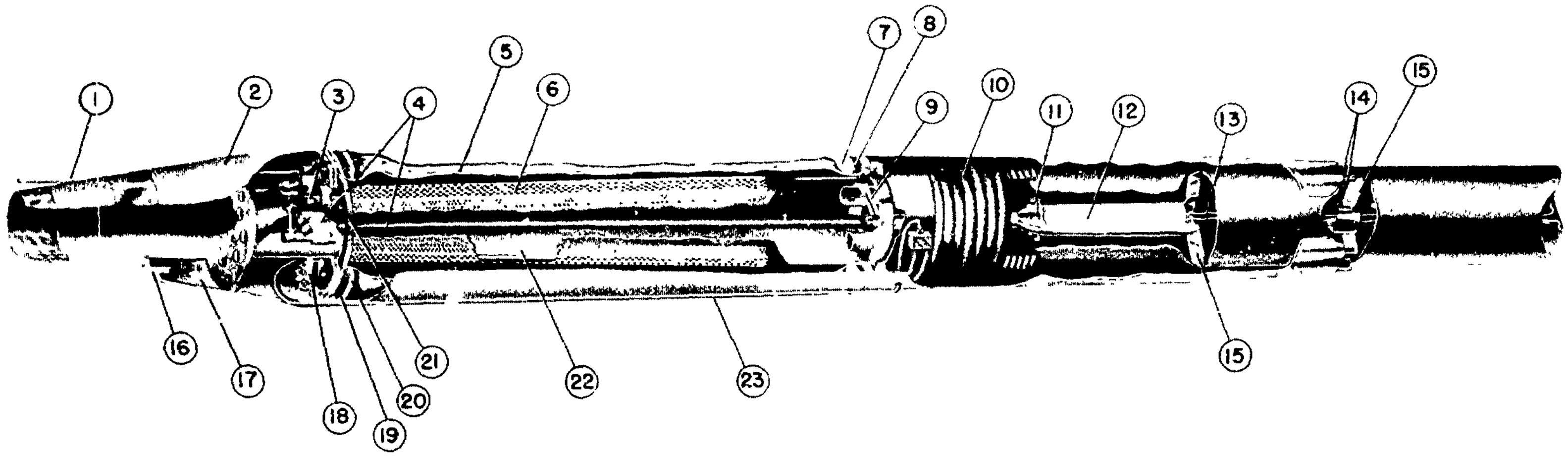

Fig. 12 THE 3F6 COBRA, LATEST MODEL OF THE 6-INCH UNIT USED FOR COMBUSTION RESEARCH, COMBUSTOR DEVELOPMENT AND ALLIED STUDIES.
Numbers refer to parts as follows: 1-Pitot tube (ram pressure), 2-Shroud, 3-Fuel Meter (6H), 4-Fuel feed assembly, 5-Fuel bag, 6-Fuel channels, 7-Rear clamp ring, 8-Gasket, 9-Upstream fuel injector, 10-Nitrogen pressure coils, 11-Downstream fuel injector, 12-Flare, 13-Flare ignition leads, 14-Thrust ring and pins, 15-Flame holders, 16-Static throat pressure tap, 17-Space for telemetering, 18-Nitrogen pressure regulator, 19-Gasket, 20-Clamp ring, 21-Fuel manifold, 22-Diffuser, 23-High pressure nitrogen tube.

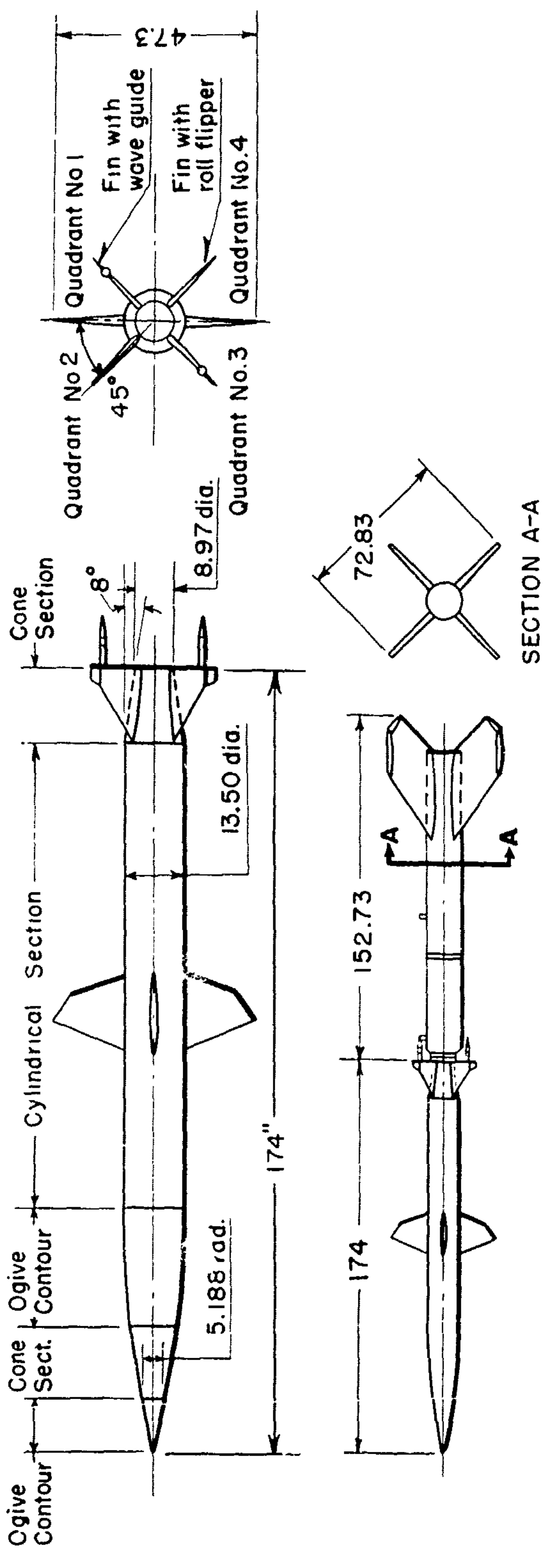

Fig. 13 AERODYNAMIC CONFIGURATION OF TERRIER.

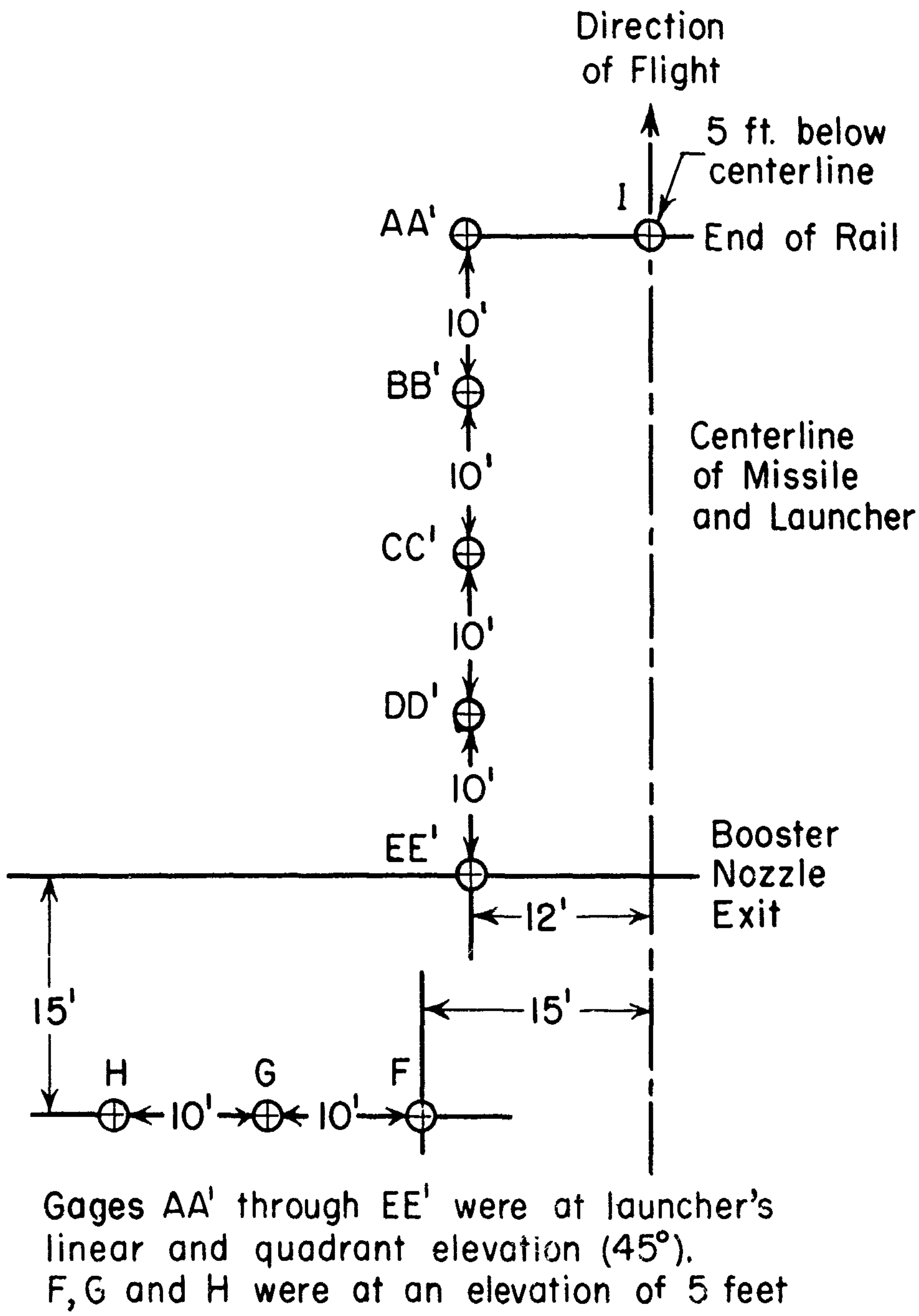

Fig. 14 DIAGRAM OF POSITIONING OF BIKINI BLAST GAUGES ALONG AND TO THE SIDE OF THE VARIABLE ANGLE LAUNCHER AT NOTS, INYOKERN.

The study of blast effects upon equipment and personnel has been accelerated.[23] The literature has been evaluated, some preliminary measurements taken and an extensive program for investigations of this problem has been formulated.

Upon the invitation of the Boeing Aircraft Company (GAPA project) the BUMBLEBEE Launching Panel met in Seattle November 30, 1949. A highlight of the meeting was the inspection of the X-7 Terrier launcher, which is nearing completion at the Puget Sound Navy Yard.

Propulsion

The most important general development problem of the past six months has arisen from the decision to design the Talos as a missile which meets at once the intermediate range requirements of the Mk 0 model and the longer antiaircraft range requirements of the Mk 1. Development at APL of a stable near-isentropic diffuser (Oswatitsch diffuser with streamlined cowling) makes it possible to meet these requirements with a fixed-geometry missile, that is, without variable intakes and/or exhausts, with quite reasonable demands on the combustor.[24] During the last two months APL, Convair and Esso have cooperated in establishing an inboard profile missile design and a common program for the accomplishment of the burner development. The pilot development at Esso, the mixing studies at APL, and the nozzle design studies at Convair will be combined to establish by March 1, 1950, a full-scale burner for subsequent testing at OAL under both sea level and high altitude conditions.

Instrumentation Techniques.

During the last six months APL and Esso Laboratories have been carrying complementary developments on sampling and analysis techniques for studying,

1. Mixture distributions,
2. Variations in combustion efficiency, and
3. Velocity and airflow.

The apparatus and techniques have already proved to be very valuable tools for the investigation of conditions in the wake of either simplified baffles, pilot flames, or practical burners. Their continued use should increase greatly our understanding of the characteristics of ramjet flames.

The attack on the problem of burning at low pressures in which Esso, Experiment Incorporated, University of Virginia and APL have participated has within the past few months, established with certainty the possibility of burning efficiently down to combustion chamber pressures of one-third of an atmosphere.[25] This should be adequate to meet the requirements of both the Talos and the long-range Triton missiles. Special fuels have been shown to simplify

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[23] See BUMBLEBEE Reports No. 109, pages 15-16 (August 1949 Survey) and No. 114, pages 23-24 (December 1949 Survey).

[24] See BUMBLEBEE Report No. 109 pages 6-7 (August 1949 Survey).

[25] See BUMBLEBEE Reports No. 109, pages 3-6 (August 1949 Survey) and No. 112, pages 13-14 (October 1949 Survey).

the high-altitude problem, but the burner development work at APL and Esso indicates that they are not necessary and that the standard hydrocarbon fuels can be used without serious compromises for low-pressure, high-altitude burning.

Test and performance analyses have been completed for one configuration of a highly efficient power plant for possible use in a long range Triton missiles.[26] This power plant is a combination of four 18-inch burners in parallel designed for a high-thrust, ground-to-air missile. By suitable ducting, the four units were adjusted to burn efficiently a fraction of the total air flow of the 48-inch burner to yield high combustion efficiencies with lean over-all fuel-to-air ratios. The nominal design thrust coefficient of the power plant was selected as 0.18, to be obtained in conjunction with an efficient diffuser. Larger and smaller exit nozzles were provided to cover a range of simulated thrust coefficients from 0.15 to 0.22. Choking burning was obtained with all nozzles except during the leaner burning with the largest. Combustion efficiencies were generally above 80 per cent and peak values above 90 per cent were obtained at an equivalence ratio of 0.20.

Combustion Wall Cooling

The major experimental work on the problem of combustion chamber wall cooling was the engineering development and testing of the louver-type inner-wall liner or shroud, inserted inside the combustion chamber to provide a cool outer wall to meet structural requirements. The units were developed on an 18-inch scale with full-scale engineering and development of a unit for the XPM prototype missile. This unit will not be used in the present XPM because of the excessive percentage of air from the diffuser required for cooling, and because the single-wall construction in use appears adequate for present loading. The study has continued because of its possible application to combustor units that cause higher wall heating, or for missiles that have higher load requirements on the combustion chamber wall. The unit may also have possible application if a "variable leak" type diffuser is used. Recent work on this problem has been concerned with the design of supersonic exit nozzles for ram-jet missiles.

Combustion Research

The research program also has profited through the coordination of the efforts of the various laboratories. University of Wisconsin work[27] on the general theory of flames has progressed rapidly during the last two months, and the checking of its validity will be simplified because of the related but less general work carried on at Princeton University and because of the experimental work on hydrogen-bromine flames at the University of Texas.[28] (The

[26] See BUMBLEBEE Report No. 107, page 2 (July 1949 Survey).

[27] See BUMBLEBEE Report No. 111, pages 20-22 (September 1949 Survey).

[28] See BUMBLEBEE Report No. 113, pages 34-38 (November 1949 Survey).

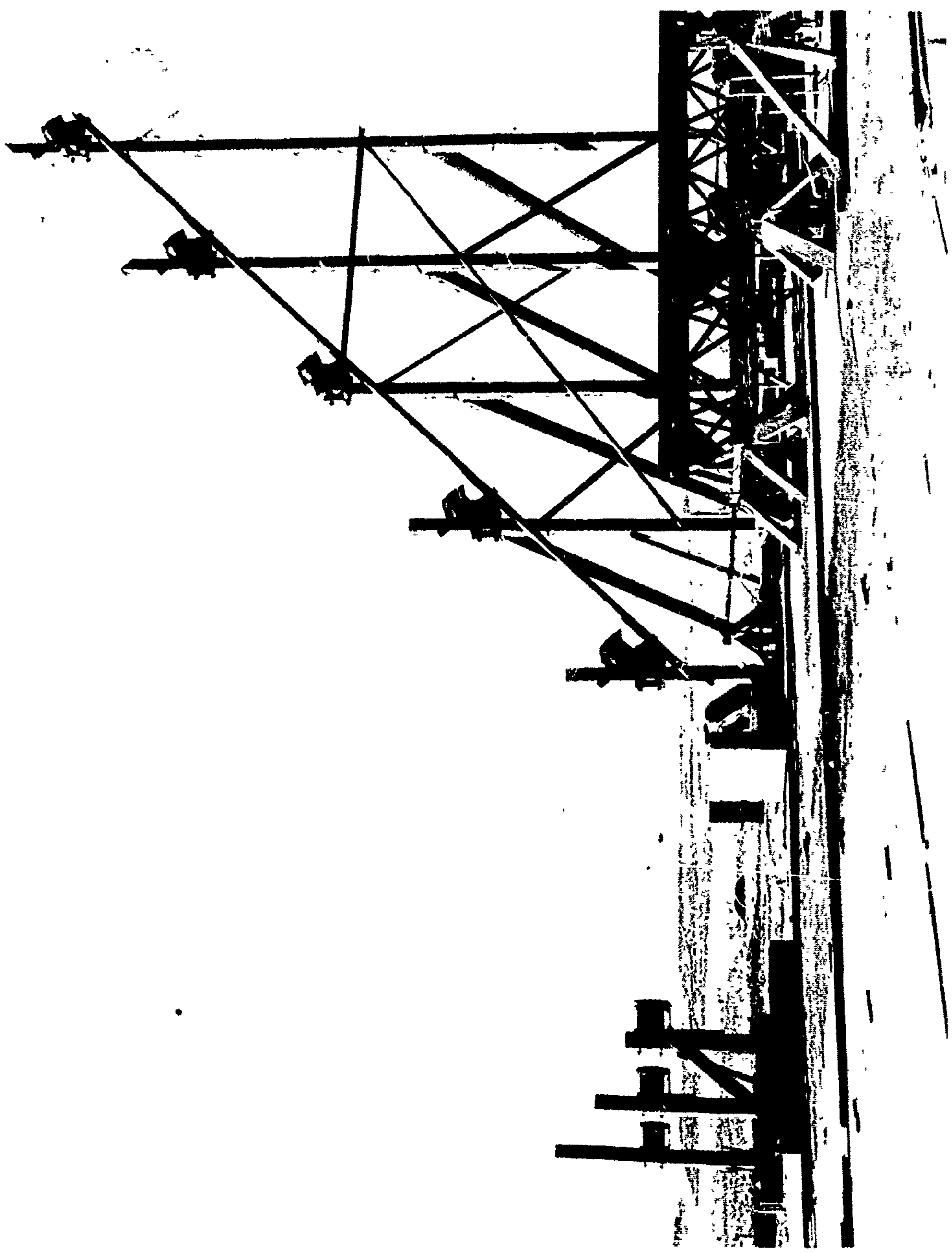

Fig. 15 PHOTOGRAPH OF GAUGE SUPPORT AND MOUNTINGS.

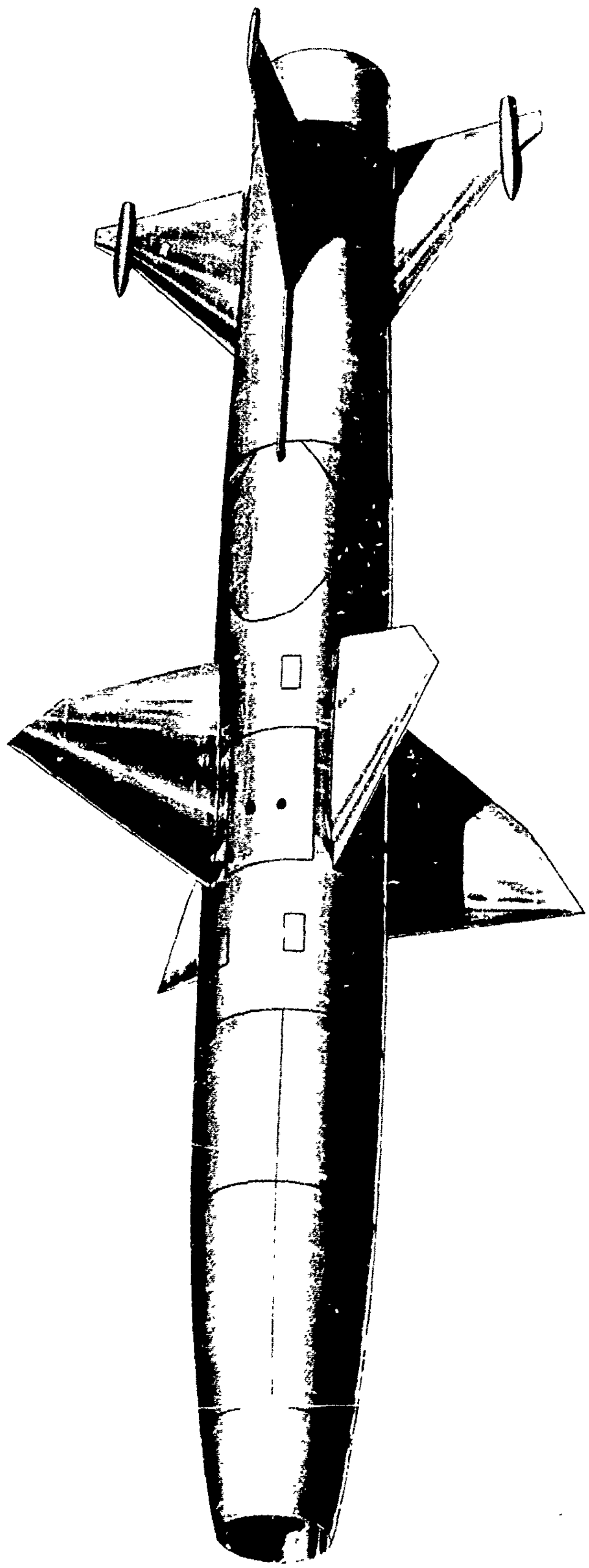

Fig. 16 PRE-TALOS TEST VEHICLE OF TYPE OF XPM-1 AND XPM-2 (RTV-N-6a1a, 1b)

Wisconsin work will be first applied to the hydrogen-bromine case.) The spectral studies of flames at JHU/Baltimore, at Experiment Incorporated, and at APL have given data that call for a radical reconstruction of concepts of equilibrium conditions in the burning zone in the wake of a flame holder. A fundamental study of the initiation and growth of flame pockets has been started at APL and will include the effects of turbulence on their quenching or propagation through a mixture. An early result of this study is a new technique for measuring minimum ignition energies from the size of a gunpowder particle which, when exploded by radiant energy, will just ignite a combustible mixture.

Two types of air-fuel meters for measurement of fuel flow or fuel-to-air ratio in the burner laboratory have been designed and tested. One operates on the change in the thermal conductivity, measured by a Wheatstone bridge circuit, as a function of gas composition.[29] The other, constructed by the New Mexico College of Agriculture and Mechanic Arts, operates on the principle of change in the electric potential induced in a conducting fluid moving through a magnetic field.[30] These flow meters have been tested and are being used to study such variables as oscillations in the fuel flow which result from pressure oscillations in the burner, and the homogeneity of combustion in 2-inch and 6-inch ramjet burners.

A report was issued on a new method of varying thrusts in ramjets by the introduction of a variable leak in the diffuser. This work shows promise of success and models are being contemplated to test this method of varying thrust.

Due to the importance of vibration on the structural strength of a missile, a study of pressure fluctuations has been made.[31] Data on pressure fluctuations have been obtained in connection with other test programs. A review of these data was made with the object of finding a correlation between fluctuations and geometry. The oscillations are predominantly organ pipe tones whose frequencies are determined by the dimensions of the burner and the air stream conditions, which, in turn, functions of the fuel injector flame-holder system.

Telemetering[32]

A simple 3-band telemetering package, designated "Telepac", has been designed for evaluation and proof test in Terrier missiles. The system was designed for components of the standardized 10-band and 6-band system presently in use in the BUMBLEBEE program. The system retains flexibility in that it transmits one piece of information continuously and has two other channels which can sample a number of measurements as desired. A breadboard model has been supplied to Convair where the units will be procured and assembled in Terrier

[29]See BUMBLEBEE Report No. 112, pages 14-17 (October 1949 Survey).

[30]See BUMBLEBEE Report No. 109, pages 8-9 (August 1949 Survey).

[31]See BUMBLEBEE Report No. 114, pages 7-10 (December 1949 Survey).

[32]For summary of Telemetering performance during this period see BUMBLEBEE Report No. 117, pages 28-29 (January 1950 Survey).

missiles. A simplified telemetering ground station to receive the Telepac has been designed and one system is under construction at APL for the Marine Corps Guided Missile Battalion.

The 10-band FM/FM basic telemetering system for XPM and Talos missiles has been breadboarded and tested in the laboratory.[33] The system principles have been established. With the completion of this rather elaborate data measurement system there is now available in the BUMBLEBEE program telemetering systems of 10-bands, 6-bands, and 3-bands (Telepac).

Because of the recurrent need for describing the operation of the FM/FM BUMBLEBEE telemetering system to a large number of persons, an operating exhibit was constructed to display the functions of the system. This demonstration piece of equipment has been assembled in such a way that the operation and sensitivity of the various end instruments and the radio link are clearly demonstrated.

XPM No. 2, flight tested at the end of June 1949, was instrumented with four 10-band systems arranged to telemeter 45 separate pieces of information. All gave complete data throughout flight, except for the hydraulic pressure channel which failed before firing and was not repaired. Of a total of 99 channels of information telemetered on all flight tests during the six-month period, 72 per cent gave complete information throughout the entire flight and an additional 22 per cent gave information during portions of the flight.

Warheads

Relative merits of (a) small-fragment, high-velocity, (b) large-fragment (rods), low-velocity, and (c) and pure blast-type warheads are still under study.[34] Data on the blast and rod warheads are still insufficient to provide an accurate forecase of absolute effectiveness or a common basis for comparison with existing small-fragment data. Preliminary data and estimates encourage the belief that highly significant improvements are potentially possible with these radically different warhead techniques.

The technique of distributing large numbers of small and fairly high-velocity fragments in an annular conical beam is the accepted design for the Terrier warhead. The results obtained by the New Mexico School of Mines with warheads which detonate to produce 3/8-inch rods a foot or more in length, at velocities under 2000 feet per second, furnish convincing evidence that aircraft structures can be seriously damaged by fragments of this character. Because of these data and the requirement for a periphery type warhead dictated by the air channel of the ramjet, this rod type of warhead has been tentatively specified for Talos. Its design permits an easy change to the blast type if guidance accuracy should justify it.

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[33] See BUMBLEBEE Report No. 112, pages 30-31 (October 1949 Survey).

[34] See BUMBLEBEE Reports No. 113, pages 27-30 (November 1949 Survey) and No. 114, pages 29-31 (December 1949 Survey).

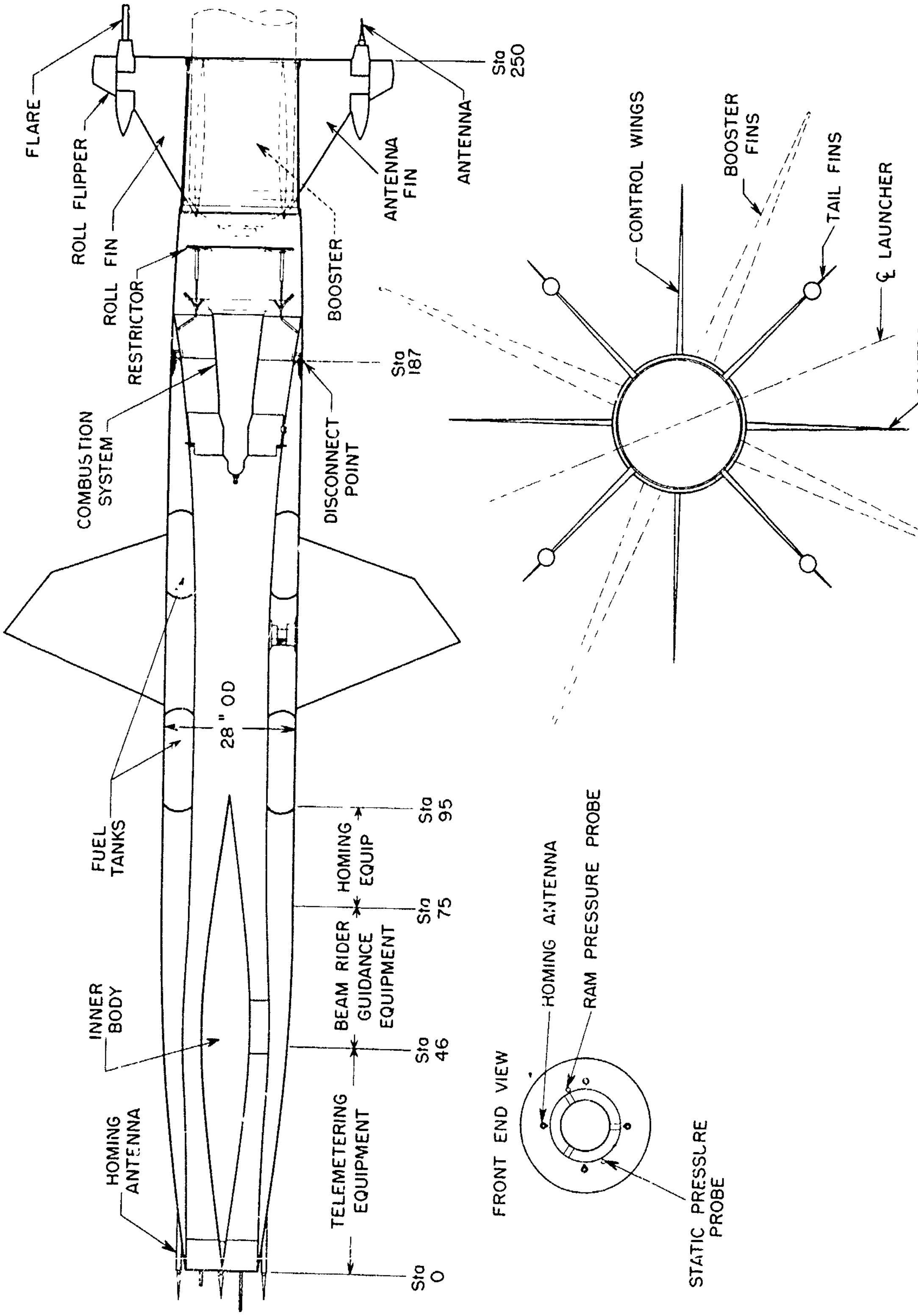

Fig. 17 LONGITUDINAL SECTION OF RTV-N-6a4. This pre-Talos demonstration prototype is an **XPM** modified to permit installation and test of homing equipment.

FUNDAMENTAL RESEARCH

In addition to the research and de elopment work associated with the BUMBLEBEE program, some effort is also being devoted to fundamental research. The university associate contractors in Section T carrying out basic research include The Johns Hopkins University (Baltimore), University of Michigan, University of Texas, University of Virginia and the Applied Physics Laboratory, The Johns Hopkins University.

Research Activities at Associate Contractor Laboratories

Work at The Johns Hopkins University, Baltimore, on the determination of $\frac{h}{e}$ by measurement of the high-frequency limit and continuous x-ray spectrum has been completed. Work has also been finished on the measurement, by means of a double crystal spectrometer, of the $K\alpha_1$ lines of silver, rhodium, molybdenum, copper, iron and chromium. The construction of the synchrotron was substantially completed at the University of Michigan and effort has been directed toward obtaining a beam of high energy electrons from the instrument. Fundamental research at the University of Texas including electronic and sound control studies and investigations in physical and organic chemistry has been steadily going forward.[35] Several important contributions to instrumentation have been made at the University of Virginia; these include a magnetic suspension which can be used as a micro balance sensitive to a change in weight of 10^{-10} grams, a new type of equilibrium centrifuge which increases by a factor of 10 the precision of molecular weight determinations of macro molecules, and a 4-Mev cavity which should give large electron pulses for electron acceleration experiments.

Research Activities at APL

Aerodynamics

During the last half of 1949, effort in basic aerodynamic research was devoted to the improvement and calibration of the instrumentation as well as the establishment of the characteristics of the newly-completed, 5-inch hypersonic wind tunnel at the Forest Grove Station.[36] The results of this work have been covered in a number of reports and in two papers submitted for publication in a technical journal.

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[35]See BUMBLEBEE Reports No. 104, pages 22-25 (June 1949 Survey) and No. 113, pages 34-38 (November 1949 Survey).

[36]See BUMBLEBEE Reports No. 104, pages 5-7 (June 1949 Survey) and No. 107, pages 8-11 (July 1949 Survey); a detailed description of the equipment is contained in CM-576, "Instrumentation for the Five-Inch Hypersonic Wind Tunnel", by C. T. Holliday, October 1, 1949.

Pressure measurements were made on the four surfaces of an 8-degree, double-wedge airfoil at M = 5. These tests also served to prove-in an M = 5.41 nozzle in the 5-in tunnel and the tunnel instrumentation. This series of tests showed that pressure lags of the order of 0.5 second existed in the pressure recording system. In view of these findings, studies have been carried out on the response time of gauges as a function of their geometry and of the conditions of operation.

The experiments on gauge response have established that the flow through the pressure leads cannot be described accurately by means of existing theories which do not take into account the absolute value of the initial pressure. It has been established, however, that the time lag is directly proportional to the length of the tube over a considerable region. The time lag is also an inverse function of the tube diameter, the pressure increment and of the initial density of the air in the system.

Some preliminary investigations have been carried out on the possibility of producing air streams at M = 10, using a nozzle and test section of extremely simple geometry connected to existing storage pressure and vacuum tank units. The results to date are not conclusive, but indicate that such stream velocities are attainable and may be utilized to obtain useful information in this mach number range.

Upper-Air Exploration

As part of the program of obtaining a comprehensive knowledge of the intensity and composition of cosmic radiation above the appreciable atmosphere and over a wide range of geomagnetic latitudes, efforts of the High-Altitude Group during last half months of 1949 were devoted largely to the planning and instrumentation of Aerobee rockets for shipboard launching.

Two Aerobees were successfully launched from the U.S.S. Norton Sound during March 1949.[37] Two more Aerobee rockets will be fired from the Norton Sound during the month of January 1950, the first in the region of the Gulf of Alaska and the second off the coast of Washington.[38] This operation is intended to investigate further the total intensity and angular distribution of charged particles in the radiation above the atmosphere, the sign of the charge (positive or negative), distribution of the magnitude of the charge (one, two, three, and so forth unit charges) and the energy spectrum. An additional experiment relates to the burst producing properties of the radiation.

Recently completed analysis of the data on the charge of the primary cosmic radiation have established that all of the primary radiation carries a unit charge. This result provides direct experimental support for the conclusion reached from less direct evidence that the primary radiation is probably protons.

[37] See BUMBLEBEE Reports No. 99, pages 17-18 (March 1949 Survey) and No. 101, pages 23-26 (April 1949 Survey).

[38] See BUMBLEBEE Report No. 117, pages 30-33 (January 1950 Survey).

On November 18, 1949, at the invitation of the Signal Corps, APL conducted a cosmic ray experiment in a V-2 rocket. The objective of this experiment was to supplement and confirm data already obtained in a previous V-2 on the nuclear cross section of the primary radiation in lead. In addition, an excellent reel of 35 mm. movie film of the Earth was obtained from a camera mounted in the rocket.

Combustion

Fundamental research in the field of combustion includes studies of flame spectroscopy, mass spectrometry, chemical kinetics and synthetic fuels.

Studies of the flame spectra of low molecular weight hydrocarbon gases have been continued. All but one of the known band systems (Fox-Herzberg bands) of the C_2 molecule have been observed in hydrocarbon flames. In this region (photographic infra-red) the "atmospheric absorption bands" of 0_2 were also found in emission from unsaturated hydrocarbons. Recent studies at high dispersion on a newly acquired 21-ft grating spectrograph reveals considerable residual structure over that reported for the diatomic species 0_2, C_2, OH, and CH. Studies are being carried out to determine whether this structure comprises new bands or band systems of the above mentioned molecules or if the emitter may be some other molecule or radical.

A method is being developed to investigate the dependence of radiation decay on frequency in the infra-red bands emitted from explosions of mixtures of carbon monoxide and oxygen.

Other Research Activities

The principal effort in other basic research work - microwave spectroscopy, structure of solids at low temperatures, the effect of high pressure in fluids - has been devoted to development and construction of instrumentation. Work on the characteristics of materials under stress has been chiefly concerned with crystal structure.

BUMBLEBEE REPORTS AND MEMORANDA
(July 1 through December 31, 1949)

Reports in BUMBLEBEE Series

No.			
105	Acoustical Redesign of The Forest Grove Burner Laboratory (Unclassified)	APL	November
106	Experimental Determination of Base Pressures at Supersonic Velocities (Unclassified)	APL	November
107	Survey of BUMBLEBEE Activities (Confidential)	APL	July
108	An Analytical Approach to Ramjet Design Optimization (Unclassified)	APL	December
109	Survey of BUMBLEBEE Activities (Confidential)	APL	August
110	Semiannual Report of BUMBLEBEE Project, July-December 1948 (Secret)	APL	December
111	Survey of BUMBLEBEE Activities (Confidential)	APL	September
112	Survey of BUMBLEBEE Activities (Confidential)	APL	October
113	Survey of BUMBLEBEE Activities (Confidential)	APL	November
114	Survey of BUMBLEBEE Activities (Confidential)	APL	December
115	Semiannual Report of BUMBLEBEE Project, January-June 1949	APL	December
116	Index to BUMBLEBEE Reports Issued during the Five-Year Period 1945 to 1949	APL	December

CM and TG Memoranda

Aerodynamics

CM 562	Comparison of Theoretical and Experimental Results for the Turbulent Boundary Layer in Supersonic Flow Along a Flat Plate (Unclassified)	Cornell Aero. Laboratory, Inc.	September
CM 568	The Supersonic Calibration of Two Pitot-Static-Yaw Tubes for Free-Flight (Restricted)	APL	August
CM 569	Turbulent Boundary Layer Characteristics at Supersonic Speeds - Theory and Experiment (Unclassified)	Defense Research Lab., U. of Texas	November

CM 573	Simple Hot-Wire Anemometer (Unclassified)	The Johns Hopkins Univ., Baltimore	September
CM 575	An Investigation of the Exact Solutions of the Linearized Equations for the Flow Past Conical Bodies: III. Supersonic Flow Past an Elliptic Cone at an Angle of Attack (Unclassified)	Engineering Research Institute, Univ. of Michigan	September
CM 576	Instrumentation for the Five-Inch Hypersonic Wind Tunnel at Forest Grove Station (Unclassified)	APL	October
CM 579	Transport Phenomena in Very Dilute Gases (Unclassified)	Engineering Research Institute, Univ. of Michigan	November
CM 580	Aero-Elastic Stability of Supersonic Wings: Report No. 4: Some Exact Solutions Based on Plate Theory	Cornell Aero. Laboratory, Inc.	November
CM 581	Calculation of Aerodynamic Coefficients for JHU Series 27 and 28 Wings (Unclassified)	North American Aviation, Inc.	November
TG 14-6	BUMBLEBEE Aerodynamics Panel Minutes Held March 23, 24, 25, 1949 (Confidential)	APL	July
TG 14-7	BUMBLEBEE Aerodynamics Panel Minutes Held July 14, 15, 1949 (Confidential)	APL	September

Guidance

CM 561	Accelerations on Line of Sight Paths (Confidential)	APL	July
TG 9-12	BUMBLEBEE Guidance Panel Minutes Held May 19, 1949 (Confidential)	APL	August
TG 9-13	BUMBLEBEE Guidance Panel Minutes Held May 20, 1949 (Confidential)	APL	December
TG 55	Test and Performance Specifications for Guidance Components and Control Systems Used in BUMBLEBEE Test Vehicles (Confidential)	APL	July

Launching

CM 537A	Additions and Corrections to LTV-N-4b2 (VTV-2) Design, Development and Flight Test (CAL/CM-537) (Confidential)	Cornell Aero. Laboratory, Inc.	October
CM 577	Dynamic Analysis of a Rocket Motor (Restricted)	The M. W. Kellogg Company	October
TG 4-13	BUMBLEBEE Launching Panel Minutes Held July 7, 8, 1949 (Confidential)	APL	September
TG 4-13a	BUMBLEBEE Launching Panel Minutes Held July 7, 8, 1949 (Secret)	APL	September

Propulsion

CM 533	Burning Velocities in Hydrogen-Bromine Flames, II: Effect of Various Diluents and Atmosphere (Unclassified)	Defense Research Lab., U. of Texas	August
CM 534	Burning Velocities in Hydrogen-Bromine Flames, III: With Hydrogen Bromide as Diluent (Unclassified)	Defense Research Lab., U. of Texas	August
CM 535	Variational Methods in the Theory of Gas Flow Through Nozzles (Unclassified)	APL	August
CM 552	Measurement and Correlation of Burning Velocities of Propane-Air Flames (Unclassified)	University of Wisconsin	July
CM 549	Interferometric Measurement of Flame Temperatures (Unclassified)	University of Wisconsin	July
CM 550	Heat Transferred by Flame to Sintered Metal Flame Holder (Unclassified	University of Wisconsin	July
CM 553	The Effect of Sound on the Normal Velocity and Stability Limits of Laminar Propane-Air Flames (Unclassified)	University of Wisconsin	July
CM 563	A Physical Chemical Approach to Reaction Kinetics (Unclassified)	University of Wisconsin	September
CM 578	An Electromagnetic Flowmeter for Hydrocarbon Fluid (Restricted)	New Mexico College of Agri. and Mech. Arts	November
TG 63-5	BUMBLEBEE Propulsion Panel Minutes Held July 28, 29, 1949 (Confidential)	APL	September

Telemetering

CM 340F	Summary Charts of BBT flight Telemetering Records (Confidential)	APL	September
CM 543	Development of Mechanical Devices for Multichannel Sampling and Automatic Calibration in Missile Telemetering (Unclassified)	The Applied Science Corporation of Princeton	August
CM 558	Telemetering Notch Antenna for Aerobee (RTV-N-8a1) (Restricted)	New Mexico College of Agri. and Mech. Arts	October
TG 82	Minutes of Ninth National Telemetering Forum Held at St. Louis, Missouri (Confidential)	APL	November
TG 57	Seventh National Telemetering Forum (Confidential)	APL	August

Warheads

TG 81	The Survival Probability of a Multiple Component Airplane (Confidential)	APL	November

General

TG 80	The Section T Pattern (Unclassified)	APL	December

Publications and Papers Presented at Scientific Meetings

1. Hydrocarbon Flame Spectra
R. C. Herman and G. A. Hornbeck
The Journal of Chemical Physics 17, 1344 (1949)

2. The Rise in Brightness of Infra-red Sensitive Phosphors
R. C. Herman and C. F. Meyer
The Journal of the Optical Society of America 39, 729 (1949)

3. The Deslandres-D'Azambuja Band System of the C_2 Molecule in the Ethylene-Oxygen Flame
G. A. Hornbeck and R. C. Herman
The Journal of Chemical Physics 17, 842 (1949)

4. Spectroscopic Investigation of the Carbon-Monoxide-Oxygen Reaction
G. A. Hornbeck and H. S. Hopfield
The Journal of Chemical Physics 17, 982 (1949)

5. The Zenith Angle Dependence of Flux of the Hard Cosmic-Ray Component up to 36,000 Feet
J. F. Jenkins
The Physical Review 76, 992 (1949)

6. The Kinetics of Heterogeneous Atom and Radical Reactions. II. The Recombination of Hydroxyl Radicals
K. E. Shuler and K. J. Laidler
The Journal of Chemical Physics 17, 1356 (1949)

7. The Specific Ionization of the Cosmic Radiation Above the Atmosphere
S. F. Singer
The Physical Review 76, 701 (1949)

8. Interference Phenomenon in the Schlieren System
E. L. Gayhart and R. Prescott
Journal of the Optical Society, July 1949

9. Bands from Doubly Excited Levels of the Hydrogen Molecule
G. H. Dieke (JHU-Baltimore)
The Physical Review 76, 50

10. Supersonic Guided-Missile Progress. Part I. Background and Problems of Guidance and Control
R. E. Gibson
Aero Digest, July 1949

11. How Readable is Your Technical Report
D. E. Gray
Journal of Chemical Education, July 1949

12. On the Theory of the Radiation Patterns of Electro-Magnetic Horns of Moderate Flare Angles
C. W. Horton (DRL-Texas University)
Proceedings of the IRE, Vol. 37, No. 7, July 1949

13. Supersonic Guided Missile Progress. Part II. Propulsion Systems
R. E. Gibson
Aero Digest, August 1949

14. Comments and Additions to H. V. Craig's Paper on 'Extensors and the Lagrangian Equations of Motion'.
C. W. Horton (DRL-Texas University)
Mathematics Magazine Vol. XXIII, No. 1, September- October 1949

15. The Configuration of the 1,3-Dichloropropenes
L. F. Hatch and R. H. Perry (DRL-Texas University)
Journal of the American Chemical Society, Vol. 71, p. 2577, September 1949

16. The Quenching of Laminary Oxyhydrogen Flames by Solid Surfaces
Raymond Friedman (NRL, U. of Wisconsin)
Presented at Third Symposium on Combustion and Flame and Explosion Phenomena, September 1948

17. Supersonic Guided Missiles
R. E. Gibson
Journal of the American Rocket Society, Vol. 79, September 1949

18. The Kinetics of Membrane Processes. Part I: Mechanism and the Kinetic Laws for Diffusion through Membranes. Part II· Theoretical Pressure Time Relationships for Permeable Membranes. Part III: The Diffusion of Various Non-electrolytes through Collodion Membranes
K. E. Shuler
Journal of Chemical Physics, October 1949

19. Studies on Hydrogen-Bromine Flames
J. A. Lasater, R. C. Anderson and H. R. Garrison
Presented at Third Symposium on Combustion and Flame and Explosion Phenomena
September 1948 (Reprint issued November 1949)

20. Kinetics of Heterogeneous Atoms and Radical Reaction I. The Recombination of Hydrogen Atoms on Surfaces
K. E. Shuler and K. J. Laidler
Journal of Chemical Physics, Vol. 17, No. 12, December 1949

21. Convection Currents in Porous Media, II Observation of Conditions at Onset of Convection
C. W. Horton (DRL, Texas University - with F. T. Rogers, Jr. and H. L. Morrison)
Journal of Applied Physics, Vol. 20, November 1949

22. On the Non-Equilibrium Theory of Absolute Reaction Rates
J. O. Hirschfelder (U. of Wisconsin)
Journal of Chemical Physics, Vol. 17, No. 10, October 1949

23. Burners for Ramjets
James W. Mullen, II (Experiment Inc.)
Industrial and Engineering Chemistry, September, 1949

In addition the following addresses were made by staff members of APL and associate contractor laboratories:

24. Spectroscopic Studies of Flame
G. A. Hornbeck
Physics Section, National Research Council of Canada
Ottawa, Canada

25. Spectroscopic Studies of Flames and Explosions
G. A. Hornbeck
Thermodynamics Colloquium
National Bureau of Standards
Washington, D. C.

26. Transient Gas Temperature Measurements
S. Silverman
Instrumentation Session
Gordon Research Conferences,
New London, New Hampshire

27. Extensive Cosmic Ray Air Showers
S. F. Singer
Colloquium
Naval Research Laboratory
Washington, D. C.

28. Exploration of the Upper Atmosphere by Means of Rockets
J. A. Van Allen
Research-Reserve Unit of the Office of Naval Research
Eastman Kodak Company
Rochester, New York
and
Boston Section, American Institute of Electrical Engineers
Boston, Massachusetts

29. Upper Atmosphere Research
J. A. Van Allen
Technical Reserve Officers
Naval Ordnance Laboratory
Washington, D. C.

30. Elements and Application of Guided Missiles
R. A. Alpher
Naval Reserve Volunteer Ordnance Division W-1,
Washington, D. C.

31. Guided Missiles
R. E. Gibson
Young Men's Business League and Exchange Club, Austin, Texas

32. Propulsion Systems Used in Guided Missiles
R. E. Gibson
American Chemical Society, University of Texas

33. Guided Missiles and Push-Button-Warfare
R. E. Gibson
Naval Reserve Research Unit and Sigma Pi Sigma, Austin, Texas

34. Guided Missiles and Push-Button Warfare
R. E. Gibson
New Mexico College of A. and M. A.

35. Objectives and Progress of BUMBLEBEE Program
R. E. Gibson
Bendix Aviation Corporation, Hollywood, California

36. The BUMBLEBEE Program
R. E. Gibson
Consolidated Vultee Aircraft Corporation, San Diego,
California

37. Power Supplies Used in Missile Telemetering
P. J. Ambrose
National Telemetering Forum, Buffalo, New York

38. Guided Missiles for Air Defense of a Task Force
J. E. Cook
Naval Ordnance Laboratory, White Oak, Maryland

39. Launching and Propulsion
J. F. R. Floyd
Naval Reserve Volunteer Ordnance Division W-1, Washington, D. C.

40. Guidance and Control
J. T. Massey
Naval Reserve Volunteer Ordnance Division W-1, Washington, D. C.

41. Transient Gas Temperature Measurements
S. Silverman
Instrumentation Session of the Gordon Research Conference, New London, N. H.

42. Guided Missiles and their Significance to the Navy
R. E. Gibson
Aviation Unit, Communications Unit and Naval Transportation Service Company, Washington, D. C.

43. The APL/JHU 10-Band FM/PM Telemetering System; The Importance of Vibration Testing of Airborne Telemetering Equipment
W. J. Mayo-Wells
National Telemetering Forum, St. Louis, Missouri

44. Guided Missiles and their Significance to the Navy
R. E. Gibson
Composite Group and Public Relations Unit, Naval Gun Factory, Washington,D. C.

45. An FM/PM Telemetering System
W. J. Mayo-Wells
Instrument Society of America Convention, St. Louis, Missouri

46. Atomic Energy
C. P. Boner (DRL-U. of Texas)
Kiwanis Club of Taylor, Texas

47. Section T Pattern and Developments
H. H. Porter
Yale University, American Society of Electrical Engineers

48. Atomic Energy
C. P. Boner (DRL-U. of Texas)
Volunteer Supply Corps, Unit 8-4, U. S. Naval Reserve, Austin, Texas

49. Rockets and Space Travel
R. E. Gibson
Society of Sigma Xi, JHU, Baltimore

50. The Application of Rockets and Ramjets to Supersonic Flight
J. H. Walker
Washington Unit of the Society of Automotive Engineers

51. Atomic Energy
C. P. Boner (DRL-U. of Texas
Armed Forces Luncheon Group, Austin, Texas

52. An FM/PM Telemetering System for Rockets
W. J. Mayo-Wells
AIEE and Army Reserve Officers Meeting, Washington, D. C.

53. BUMBLEBEE Flight Test Program
A. R. Eaton, Jr.
Volunteer Ordnance Unit at OAL, Daingerfield, Texas

54. Upper Atmosphere Research
J. A. Van Allen
Technical Reserve Officers Group, NOL

55. Exploration of the Upper Atmosphere
J. A. Van Allen
Research-Reserve Unit of the Office of Naval Research at the Eastman Kodak Company, Rochester, N. Y.

56. Rockets and their Implications
R. E. Gibson
PTA Woodland School, Montgomery Hills, Silver Spring, Maryland

57. Telemetering Organization and Relations with User Groups
W. J. Mayo-Wells
National Telemetering Forum, Sandia Corporation, Albuquerque, N. M.

58. Measurable Functions
H. J. Ettlinger, DRL, U. of Texas
University of North Carolina, Mathematics Seminar

59. Ultrasonic Study of Rubber at Low Temperatures
A. W. Nolle (DRL, U. of Texas)
Acoustical Society of America, St. Louis, Missouri

60. Acoustic Design of Studies
C. P. Boner (DRL, U. of Texas)
Austin and San Antonio Chapters of I.R.E., Austin, Texas

61. Compilation of Thermal Properties of Wind-Tunnel and Jet Engine Gases at the National Bureau of Standards
C. N. Warfield
American Society of Mechanical Engineers, New York, N. Y.

62. Complexes of Copper (II) and Amines in Various Solvents
R. C. Anderson (DRL, U. of Texas)
American Chemical Society, Oklahoma City, Oklahoma

63. Relative Reactivities of Cis and Trans Crotyl Cholorides
L. F. Hatch (DRL, U. of Texas)
American Chemical Society, Oklahoma City, Oklahoma

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C. P. Boner (DRL, U. of Texas)
I.R.E. Meeting, Houston, Texas

65. Rockets and Ramjets
R. E. Gibson
American Physical Society, University of Virginia

66. Problems on the Fundamentals of Shock and Vibration Design Criteria for Guided Missiles
C. W. Besserer
Symposium, California Institute of Technology

67. Vibration of Cantilever Plates
Barton, M. V. (DRL, U. of Texas)
Symposium, California Institute of Technology

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