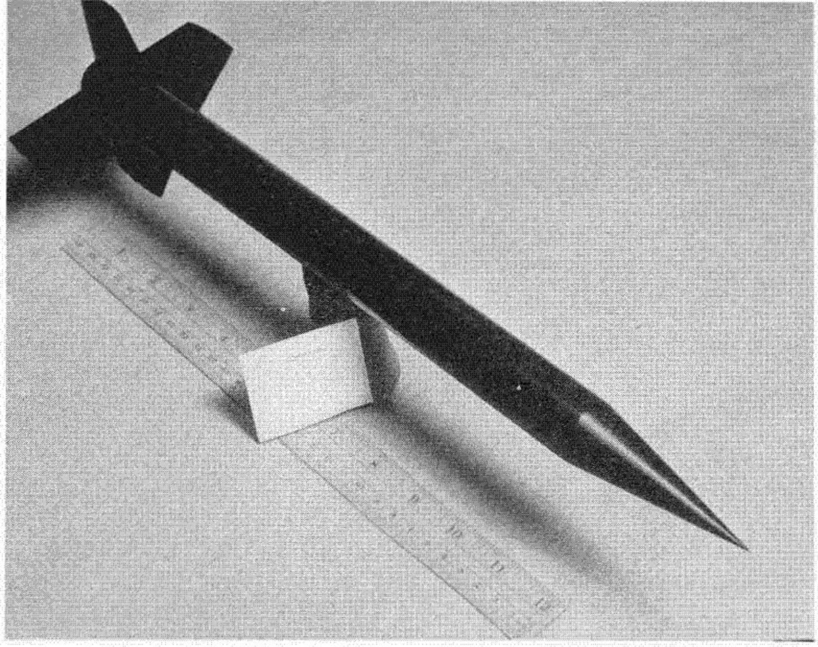


FIG. 9. An early model of the Wac Corporal missile with four fins.

The towing channel built at the Laboratory is open to the weather. Constructed of reinforced concrete, it is 500 feet long, 16 feet deep, and 12 feet wide. Astride the channel rides a towing carriage, the wheels mounted on carefully-leveled steel tracks running the length of the channel. The carriage, driven by an electric motor, can run faster than 40 miles per hour. Originally, it was driven by three liquid-propellant rocket units.

Preparatory to a model test, the carriage is raised on hydraulic jacks. Suspended from the center of the carriage is a strut, adjustable to any length up to 12 feet. A model is attached to the free end of the strut. When the carriage is lowered, the model is submerged ready for testing. Electrical strain-gauges installed within the model connect through the strut with an oscillograph in the carriage. As the carriage tows the model the length of the channel, the strain-gauges measure the hydrodynamic forces acting upon the model, and the forces are recorded by the oscillograph. The quantities to be measured are known technically as lift, drag, and pitching moment.

On one side of the channel, midway between the ends, is an underground observation room with a glass window let into the channel wall. The behavior of flow over the surface of a model is studied visually and recorded by cameras.

RESEARCH ON THE HYDROBOMB

Responsibility for the actual design of different experimental models of the hydrobomb rests with agencies other than the Jet Propulsion Laboratory. The responsibility of the Laboratory in the development of the models is to measure the lift, drag, and pitching moment; in other words, the hydrodynamic forces exerted upon a model in motion. The shape of a model and the size of the control surfaces (fins and rudders) influence not only the behavior of these forces but the extent of cavitation as well.

A special propellant had to be developed for the hydrobomb because its geometry is such that a solid propellant must be made to burn at the rate of one inch per second if the missile is to deliver a 2,200-pound thrust for 30 seconds. The result was GALCIT 65, a modification of GALCIT 61-C, an earlier development of the Laboratory. Work on the new propellant proceeded rapidly after potassium nitrate was introduced in order to slow the burning rate.

The new propellant, sealed into rocket motors with the standard liner mentioned in connection with JATO units, was subjected to tests simulating launching from an airplane flying at different velocities up to 400 miles per hour. *(See Fig. 7.)*

A rocket unit launched at high velocity hits the water with such terrific force that it was feared the impact might crack the propellant or liner, or else separate the propellant from the liner, or perhaps separate the liner from the steel walls of the motor. Any one of these mishaps would render undependable the firing of a unit. It was necessary, also, to determine the effect of temperature upon the ability of the propellant and liner to withstand the impact following launching.

The test procedure was to launch a dummy torpedo fitted with a loaded, solid-propellant motor, then later to fire the unit in a test pit where, if it exploded, it would do no harm. Results showed GALCIT 65 capable of withstanding impact resulting from launching velocities up to 385 miles per hour. The launching tests were made at the Torpedo Launching Range developed by the California Institute of Technology for the Navy at Morris Dam, California.

THE ORDCIT PROJECT

The ORDCIT Project was initiated as the result of a memorandum submitted by Dr. von Karman, H. S. Tsien, and F. J. Malina to the Ordnance Department in November, 1943. In January, 1944, Major General G. M. Barnes requested, in a letter addressed to Dr. von Karman, that the Jet Propulsion Laboratory undertake a research and development program on long-range, jet-propelled missiles. The project was the first of its kind in the United States and is based upon a contract between the A.S.F. Ordnance Department and the Laboratory. As a result, the A.A.F. and the Ordnance Department utilize cooperatively the staff and facilities of the Laboratory.

The primary purpose of the contract is to obtain fundamental information to assist the development of long-range, jet-propelled missiles, together with suitable launching equipment.

THE PRIVATE A AND THE PRIVATE F

The first step toward the primary objective—a long-range guided missile propelled by rocket thrust—was the design and fabrication of the Private A. Its purpose was to provide experimental data on the effect of sustained rocket thrust on a missile stabilized by fixed fins, and to provide knowledge on the use of booster rockets for launching missiles.

Approximately 8 feet long, the Private A tapered to a sharp nose designed for supersonic flight, and it was guided at the aft end by four fins, each extending 12 inches from the motor body. Its gross weight was more than 500 pounds, including a pay load of 60 pounds. Driven by a solid-propellant rocket unit, the missile delivered thrust of 1,000 pounds for over 30 seconds.

Firing tests of the Private A were carried out at Leach Spring, Camp Irwin, near Barstow, California, December 1 to December 16, 1944. Twenty-four rounds were fired in all. The average range was approximately 18,000 yards; the maximum, 20,000 yards (11.3 miles). See *frontispiece.*

In the spring following the tests of the Private A, another experimental rocket was ready for testing. It was designed to explore the effect of lifting surfaces upon a guided missile. Called the Private F, it was essentially the same rocket as the Private A; but, instead of four symmetrical guiding fins at the aft end, it had one fin and two horizontal lifting surfaces with a total span of nearly five feet. At the forward end of the missile, to trim it in flight, were two stubby wings, their total span less than three feet.

The firing tests were at the Hueco Range, Fort Bliss, Texas, April 1-13, 1945. The Range was equipped with radar for tracking the flight path of missiles, and with cameras for recording initial trajectories. Though the tests provided valuable data of a highly-technical nature, they demonstrated that a missile with lifting surfaces requires flight control equipment for regular flight.

THE WAC CORPORAL

By far the most spectacular missile the Laboratory has developed is a rocket with the code name Wac Corporal. It was tested during the autumn of 1945. Some information about the missile was released in March, 1946. Now that the ORDCIT contract has been reclassified, the Army Ordnance Department is at liberty to release more about the story of the Wac Corporal from its inception to the flight test already reported.

In December, 1944, the Ordnance Department requested the ORDCIT Project to investigate the feasibility of a high-altitude rocket to carry twenty-five pounds of meteorological equipment to an altitude of at least 100,000 feet, or almost nineteen miles, in accordance with a requirement of the Signal Corps.

The investigation evaluated alternatives for meeting certain of the requirements. It was decided, for example, to initiate flight with a booster, and to use a launching tower for guidance of the missile until it achieved a velocity safe for holding vertical flight. The alternative would have required equipment even more complicated than a launcher and booster to control the flight of the missile on its upward course.

A feature of the experimental program was the fabrication and test of a one-fifth scale model of the Wac Corporal. The purpose of the test was to determine whether three tail fins would suffice instead of the usual four, and whether the missile-booster combination chosen provisionally would perform as anticipated. Tests of the Baby Wac, made at Goldstone Range, California, July 3 to July 5, 1945, confirmed the choice of three fins and the missile-booster combination selected.

Approximate outside dimensions of the Wac Corporal were: length 16 feet from the needle-pointed nose to the tri-finned tail; diameter 12 inches. The gross weight was 665 pounds. Empty, the missile weighed less than 300 pounds. It delivered thrust of 1,500 pounds for 45 seconds.

The source of power was a liquid-propellant rocket motor. The motor was cooled by the flow of fuel within the jacket walls just before it entered the combustion chamber. The Laboratory adapted the motor to utilize nitric acid as an oxidizer; and aniline as a fuel—a spontaneously-combustible propellant combination the Laboratory had begun to develop in 1942, shortly after the test flight of the A-20A.

The pressure required to force the propellants into the combustion chamber was supplied by compressed air instead of nitrogen, conventionally used for the purpose. The substitution was made to simplify operation in the field.

The propulsive system was started by the operation of a device known as an inertia valve, incorporated in the compressed-air circuit. When the booster accelerated the missile out of the launcher, the force of inertia automatically opened the valve, which transmitted air pressure, at one and the same time, to the propellant tanks and to the actuating piston of the main propellant valve.

Fitted into the nose of the Wac Corporal, in addition to meteorological instruments, were parachute and automatic devices for releasing both the entire nose cone and the parachute; an arrangement that recommended itself if the instruments installed were to be recovered intact.

The booster, planned originally to accelerate the missile, proved to be inadequate. Substituted for it was a modification of the Navy rocket known as Tiny Tim. Changes were made in the fins and nose and thrust was increased. Designed to deliver thrust of 30,000 pounds for one second, the rocket was modified to deliver 50,000-pound thrust for little more than half a second.

Calculations indicated, however, that in little more than half a second the booster and missile would rise some 216 feet, a prohibitive height for a launching tower. It was decided, therefore, to retain a tower height of 100 feet, the height agreed upon earlier to meet specifications as planned originally. Design had to allow, then, for part of the boost to take place in free flight, unguided by the launching tower.

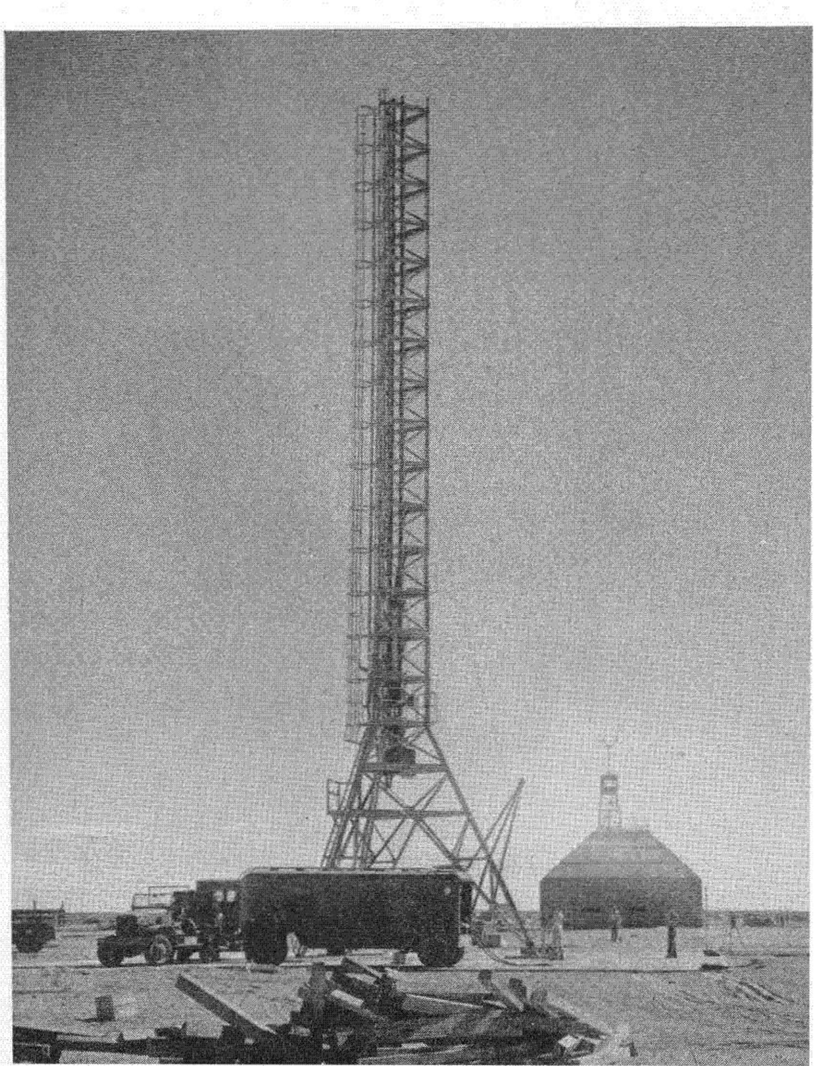
The launcher, fabricated of structural steel, as depicted in *Fig. 10*, was a triangular tower 102 feet high, with three launching rails set 120° apart, providing an effective length slightly more than 80 feet, after allowance for the height of the tower base. Piping was attached to the launcher for servicing the missile with propellants and compressed air. A Field Service Trailer simplified the handling of the propellants.

A bomb-proof control house, erected approximately 500 feet from the launching tower, housed measuring instruments and fire control and communication equipment.

THE TESTS

Firing tests of the Wac Corporal were carried out

FIG. 10. Launcher of the Wac Corporal at the White Sands Proving Ground.



at the White Sands Proving Grounds, Las Cruces, New Mexico, between September 26 and October 25, 1945. Tracked by radar the missile reached, as reported, an altitude of about 43.5 miles in vertical flight. The great increase in altitude over that planned in preliminary estimates was the result primarily of reduction in weight achieved by changes and improvements made as the design matured, and of the added impulse provided by the Tiny Tim rocket adopted as a booster.

The Ordnance Department acted as coordinator for the various organizations involved in the development and firing of the missile. The ORDCIT Project was responsible for the preparation of each round for firing, and for the technical phases of the firing program. The Signal Corps, besides providing weather data, provided the equipment for tracking and for receiving signals from radio sonde sets released from the missile. The Aberdeen Ballistic Research Laboratory installed and operated five special camera units and three radar stations located at strategic points around the launcher.

REMOTE CONTROL AND THE TRANSMISSION OF FLIGHT DATA

As part of the ORDCIT Project, the Laboratory is at work upon a system designed for the remote control of guided missiles; and upon two systems for transmitting to ground stations data from vehicles in flight.

This control system has been designed, not to meet service requirements, but as a means to study control problems. The position of the missile in flight will be plotted by radar, recording the trajectory in both horizontal and vertical planes so that deviations will be apparent. A radio link will be provided for an operator on the ground to signal corrections to the missile, which automatically will apply them. All the control equipment is to be mounted in the nose cone of the missile.

THE GRADUATE COURSE IN JET PROPULSION

At the request of the A.A.F. Materiel Command, three years ago, a course in Jet Propulsion was instituted at the California Institute of Technology by the staffs of the Guggenheim Aeronautical Laboratory and the Jet Propulsion Laboratory. The course has been limited to officers of the Army and Navy assigned for graduate study at the California Institute of Technology. However, provision has recently been made to open the course to a few especially-selected civilian students.

The course covers the basic principles of all known jet-propelled power systems, and the performance of jet-propelled devices. The Laboratory offers the students first-hand experience with working models of various types of power systems.