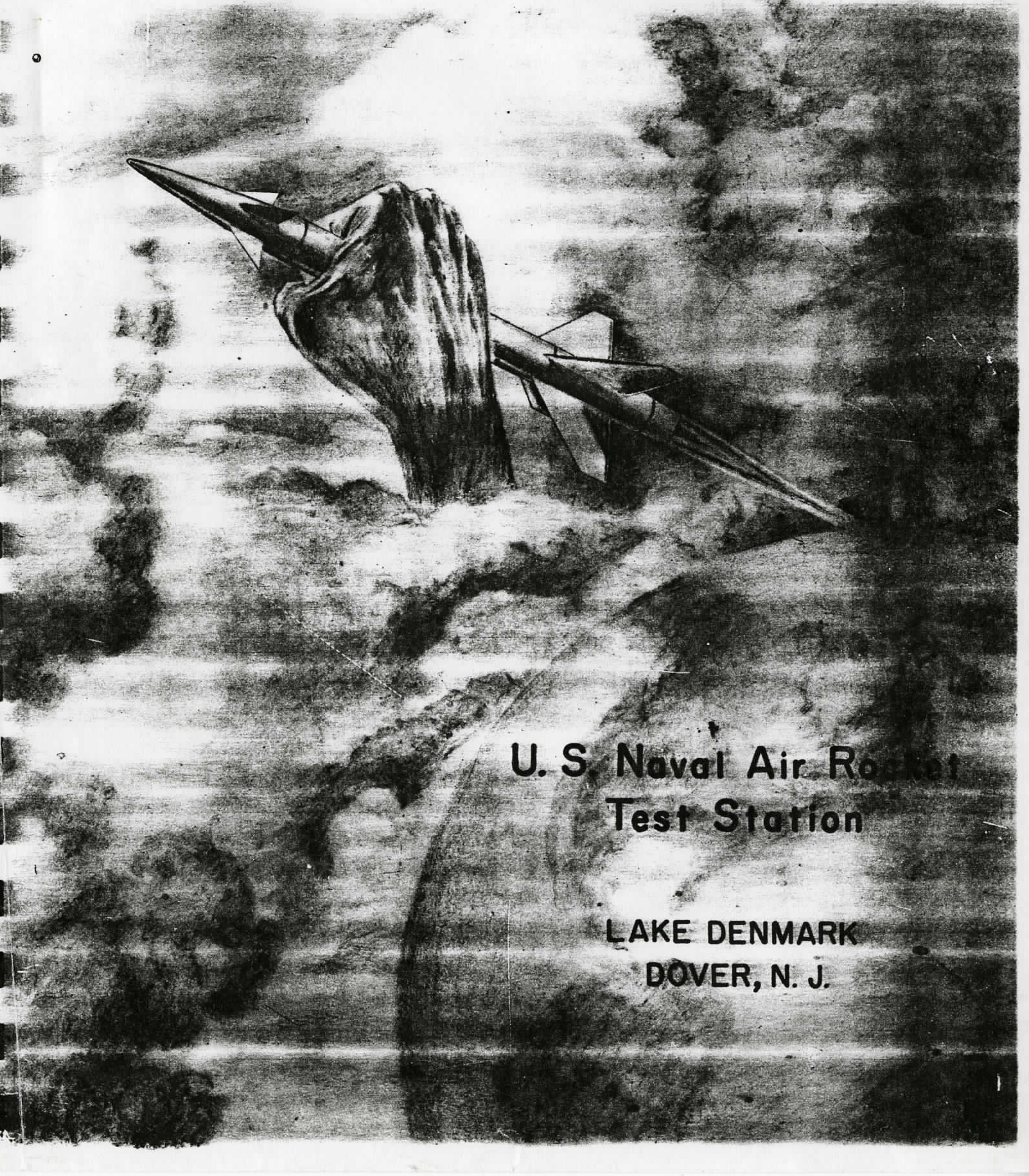
all about NARTS
ENGINEERING FACILITIES



U. S. Naval Air Rocket Test Station

LAKE DENMARK
DOVER, N. J.

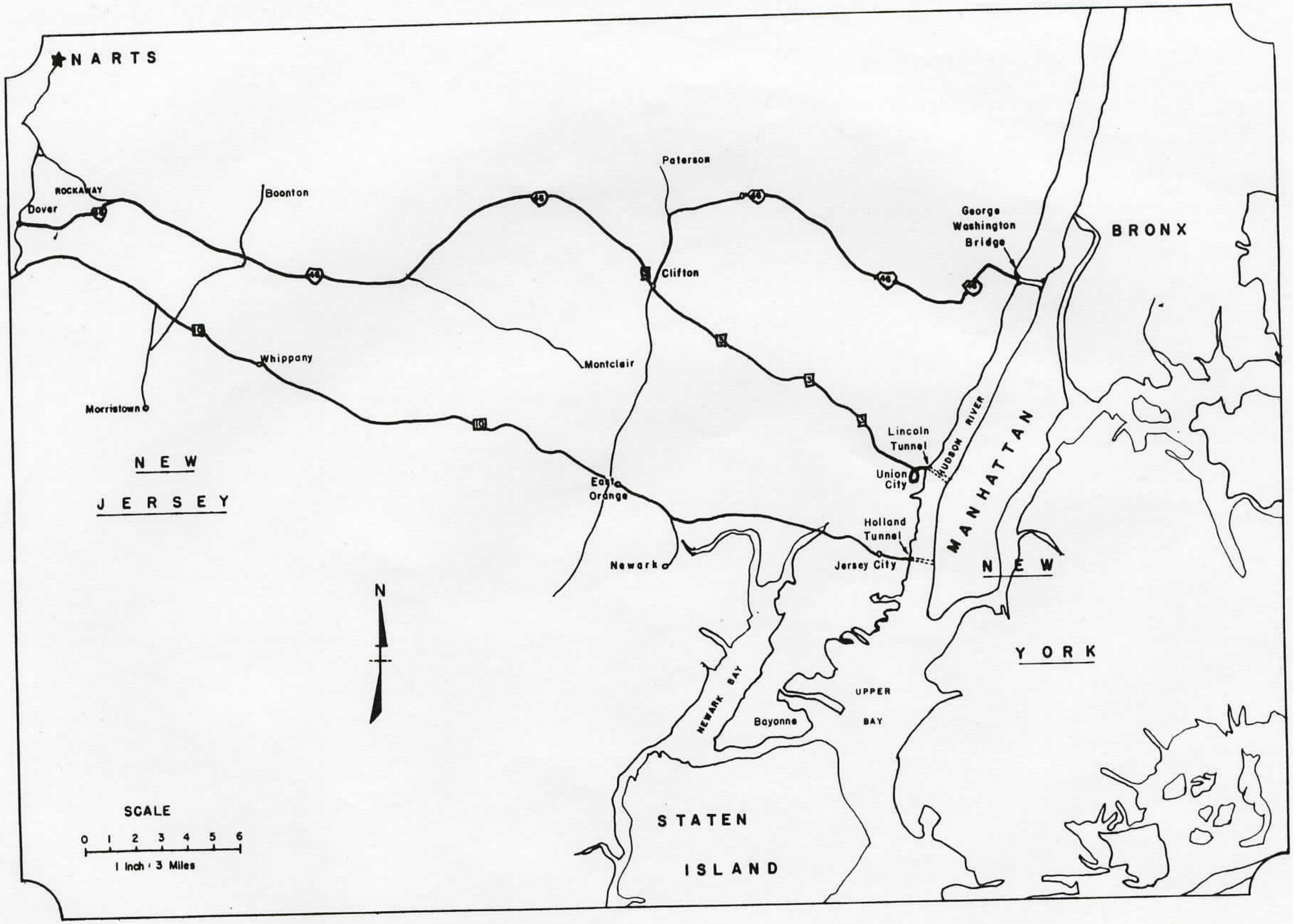
This booklet prepared
and edited by the
Technical Publications
Branch, U. S. NARTS

It is hoped this booklet will help you understand a little better the part the U. S. Naval Air Rocket Test Station (NARTS) plays in the overall rocketry/ missile program of the United States.

NARTS is a field activity of the Bureau of Naval Weapons and while a part of the Third Naval District, the station is under military administration of the Naval Air Research and Development Command, Johnsville, Pa.

As the major Navy static test, research and development activity on the East Coast, NARTS has come to be well known in the rocketry field. Your inquiries are welcomed.

JOHN J. BARANOWSKI
Captain, USN
Commanding Officer



NARTS
ROCKAWAY
Dover
Boonton
Paterson
George Washington Bridge
BRONX
Clifton
Whippany
Montclair
Morristown
Lincoln Tunnel
HUDSON RIVER
MANHATTAN
Union City
NEW JERSEY
East Orange
Holland Tunnel
Newark
Jersey City
NEW YORK
N
NEWARK BAY
UPPER BAY
Bayonne
SCALE
0 1 2 3 4 5 6
1 Inch : 3 Miles
STATEN ISLAND

General view of NARTS. Picatinny Arsenal is in background

HERE WE ARE

INTRODUCTION

The U. S. Naval Air Rocket Test Station (NARTS) at Lake Denmark, near Dover, N. J., is located in an area where munitions and weaponry are no stranger. According to the history books, it all started back around 1750 when a blacksmith by the name of Jacob Ford dammed up Burnt Meadow Brook and began forging iron. During the Revolutionary War, cannon balls rolled out of these same rugged, wooded hills and high-grade iron ore is still being mined in the area, less than 40 miles from Times Square.

The Navy moved into the area in the 1890s and established an ammunition depot at Lake Denmark, next door to Picatinny Arsenal, a major Army ordnance installation. In addition to the Navy and Army, private concerns in the area in the munitions-weaponry field include a Hercules Powder Company plant and Reaction Motors, one of the pioneer firms in the rocketry field.

The Navy Department began deactivating the Lake Denmark ammunition depot after World War II. It was at that time that the Bureau of Aeronautics, foreseeing the need for a rocket engine test center on the East Coast, grasped the opportunity to convert and modify the existing facilities. Thus, the Naval Aeronautical Rocket Laboratory came to be at Lake Denmark. The name was changed to the Naval Air Rocket Test Station in April 1950.

A more advantageous site than Lake Denmark could hardly have been found.

Available for static rocket engine test activities were some 650 acres of hilly timberland in a nearly secluded area. Although far from any extensive habitation (the closest community, Dover, is about five miles to the south), connections with all types of transportation are available. The location affords the advantages of being in the industrial East, so the procurement of personnel and material is not difficult; and because it is close to Washington, liaison with the Bureau of Naval Weapons and other agencies of the Department of Defense is an easy matter.

The ammunition depot had paved roads, railroad track, military housing and scores of warehouses suitable for conversion for use as shops, labs and administration buildings. Here, too, the Navy had already invested in rocket test facilities leased by Reaction Motors. That firm, now a division of the Thiokol Chemical Corporation, still leases extensive facilities.

Since NARTS was established, the range of engineering assignments in the rocketry field has grown considerably and facilities at Lake Denmark have expanded accordingly. The station now takes in some 760 acres and represents a multimillion dollar investment. If future plans work out, facilities and the station's technical staff will be doubled in the next decade.

Work Load . . .

When test activity began at Lake Denmark in 1948, work was devoted mainly to the liquid propellant field. In 1952 solid propellant projects were added to the NARTS workload. The majority of work performed now falls into the following categories:

1. Evaluation of solid and liquid rocket engines under development by commercial and government agencies to ascertain their suitability for production and service use
2. Evaluation of new oxidizers, fuels, monopropellants and construction materials for rocket engine systems
3. Development of methods for analyzing rocket propellants
4. Analysis and evaluation tests of new design concepts
5. Collaboration in preparing military specifications for rocket engines, propellants and associated components and materials of construction
6. Provision of services and facilities for use by contractors
7. Collaboration in writing safety manuals for propellants including their storage and handling and damage control requirements

The three major work categories are identified and explained as follows:

I. Qualification Tests

Qualification tests and related programs include (aside from the actual qualification tests) safety and reliability determinations, evaluation of contractor products, age-test programs, and investigations of performance deficiencies in production items in operational use. Examples of current work are:

1. evaluation of high temperature resisting materials in rocket engine application
2. storage tests of liquid prepackaged thrust units and solid propellant starter cartridges
3. evaluation of electroformed nozzles

Recently completed programs involving qualification were simulated catapulting and arresting landing tests for liquid BULLPUP and SPARROW prepackaged units and qualification tests of the SIDEWINDER powerplant for the Air Force.

II. Preliminary Investigations

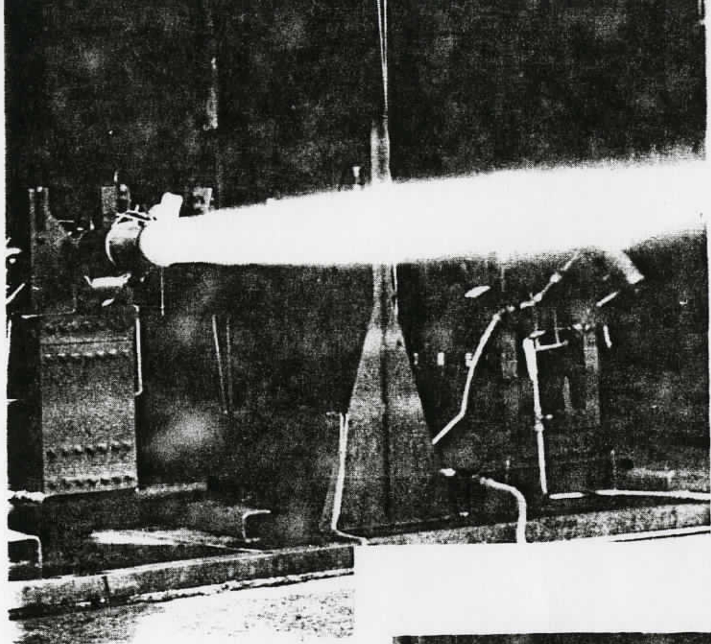
Preliminary investigations of major importance now in progress or planning deal with:

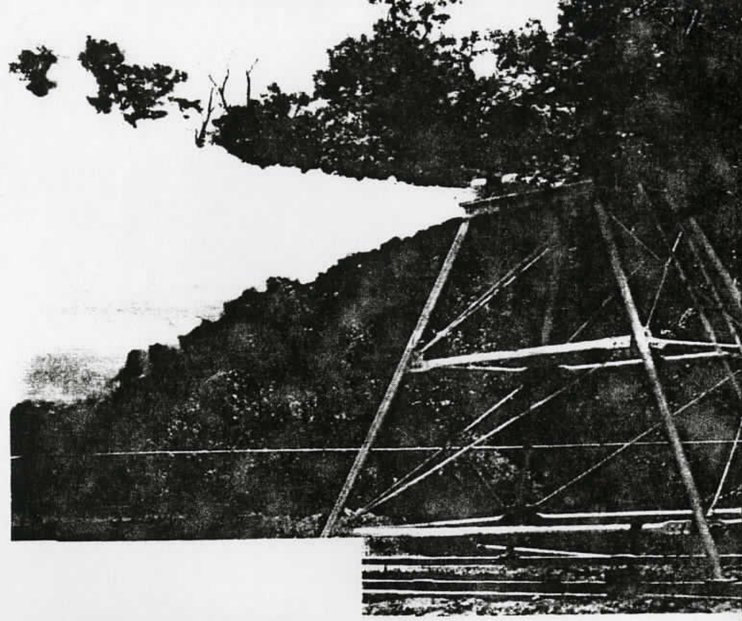
1. damage control of propellant oxidizers
2. combustion instability
3. variable thrust engine for spacecraft application
4. high energy monopropellants
5. mixed oxidizers
6. ultra high-density propellant systems
7. investigation of monopropellants as gas generants

III. Technical Services

Technical services are provided by the Rocket Propulsion Laboratory for BuWeps and other government agencies and private contractors. These services include participation in the DOD standardization program and development of specifications and procedures for mixed amine fuel. Services are currently provided to Standard Oil Company of Indiana and Fulton Irgon Corporation.

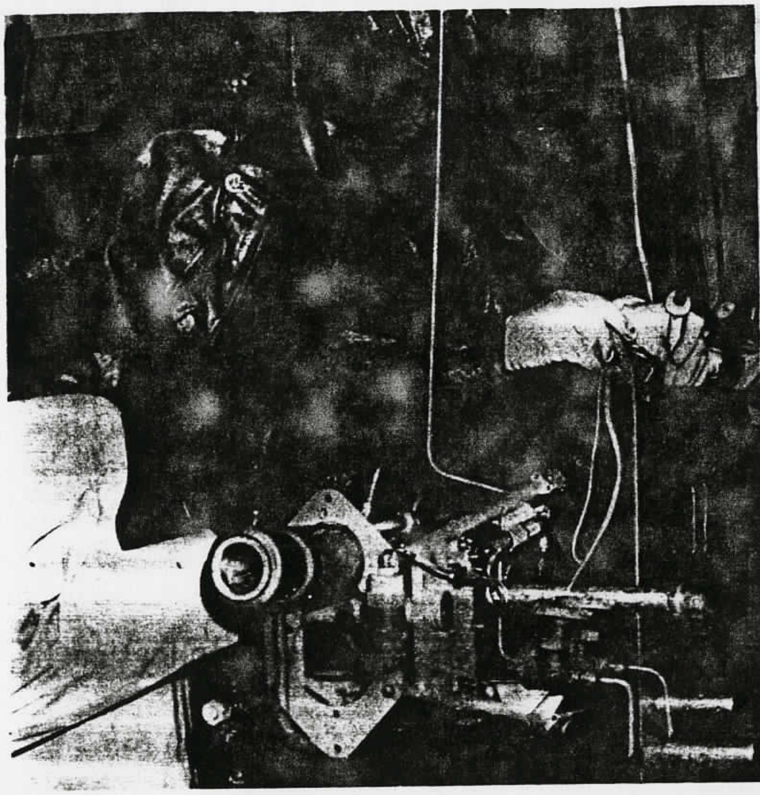
All these functions fit under the broad outline of the NARTS mission as assigned by the Chief of Naval Operations: "to test, evaluate and conduct studies pertaining to rocket engines, their components and propellants."





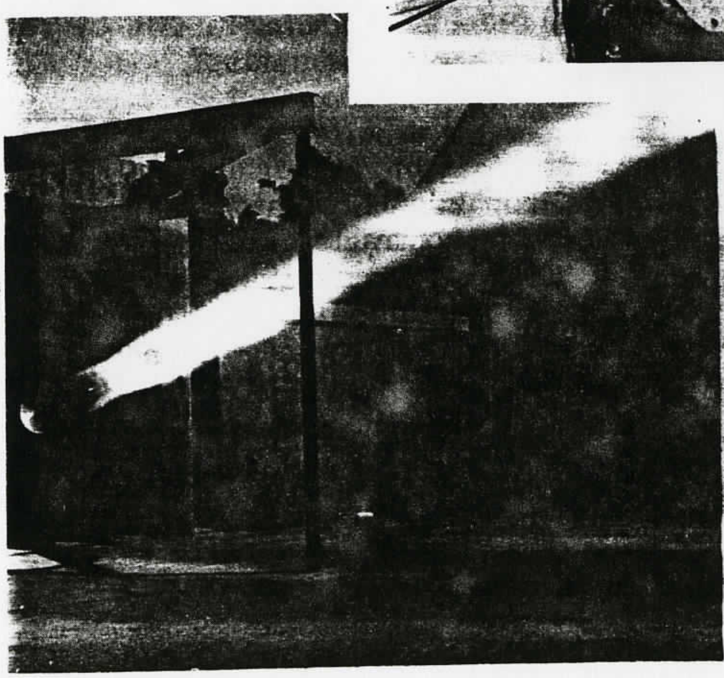
Firing of liquid engine

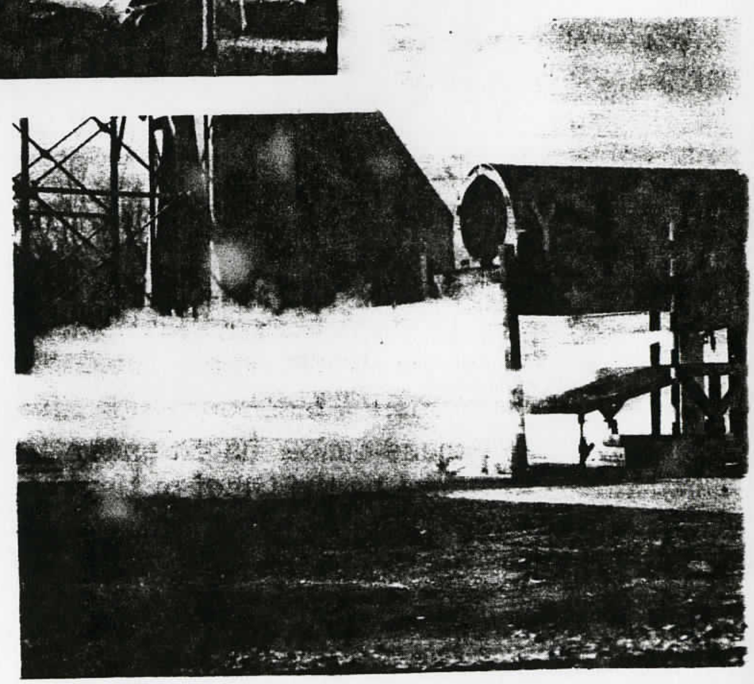
Tower eliminates ground effect



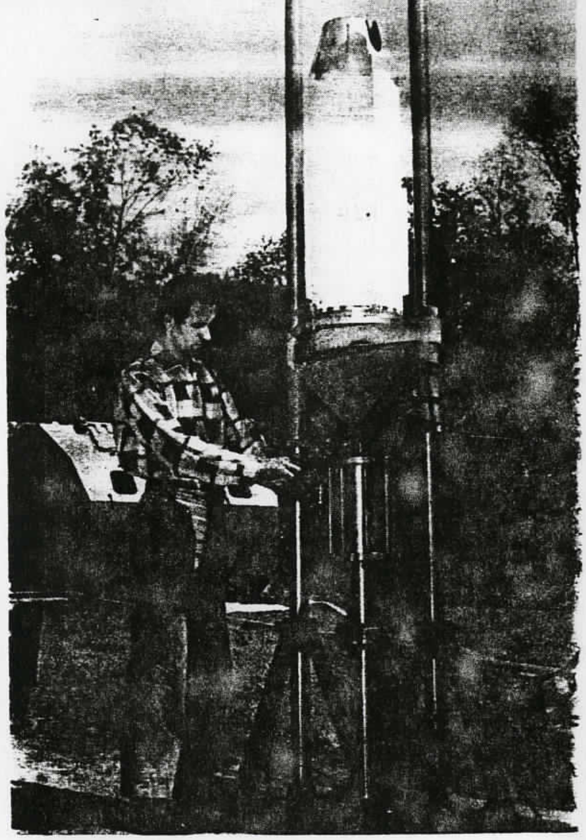
Solid propellant static test

Simulated fuselage test





Preparing for liquid engine firing



Adjusting the controls
of a HYGE shock tester

Accomplishments . . .

The art of liquid propellant rocket engines has been advanced at NARTS through work on variable thrust engines. Other contributions include widely useful studies of missile control through exhaust gas deflection and the measuring of JATO exhaust pressure and temperature. Another accomplishment is the writing and coordination of general specifications for the production of Naval rocket engines (such as the VIKING). In the field of solid propellants, NARTS was one of the first government agencies to complete the qualification testing of a JATO for service use.

NARTS is also known for its research investigations on monopropellants, oxidizers and fuels. The Propellants and Rocket Engine Divisions of the Rocket Propulsion Laboratory work together in these investigations, the first studying the chemical and physical characteristics of the propellant for its possible engine use, and the latter determining the performance of the propellant by static firing tests.

Other notable work includes development of methods of analysis of hydrazine, methyl hydrazine, butyl mercaptan and mixed acids and a widely known method of analysis for white fuming nitric acid. NARTS chemists also have worked out the mechanism of the corrosion of stainless steel by nitric acid. The principle of this advancement is described as "relatively simple" but has proved most important in the transportation and handling of the acid.

Additional NARTS accomplishments include the construction of Mollier charts for the decomposition products of hydrogen peroxide and the combustion products of ammonia and nitric acid and the development of a shorthand method for rocket propellant performance calculation.

U.S. Naval Air Rocket Test Station

COMMANDING OFFICER

CAPT. J.J. Baranowski, USN

EXECUTIVE OFFICER

CDR. W. H. Chester, USN

ROCKET PROPULSION LABORATORY

CDR. D.T. Jensen, USN

DIRECTOR

I. Forsten

TECHNICAL DIRECTOR

Dr. J.D. Clark

HEAD PROPELLANTS DIVISION

F.R. Hickerson

W.F. Lehman

STAFF ASSISTANT

E. A. Jenkins

J.J. Canavan

HEAD ROCKET ENGINE DIVISION

SENIOR PROJECT GROUP

Personnel...

As a modest-sized installation in this age of giant industrial and government activities, NARTS has a present complement of 280 civilian employees bolstered by a small force of Navy officers and enlisted men. The 70-man technical staff includes engineers, chemists, draftsmen, rocket mechanics and instrumentation specialists and supporting personnel. The roster calls for mechanical, electrical, aeronautical and chemical engineers.

The Commanding Officer at NARTS is Capt. John J. Baranowski, USN. An Annapolis graduate (Class '35), Capt. Baranowski returned to the Naval Academy for post graduate work in aeronautics after winning his wings as a Lighter-Than-Air Pilot in 1941. He now holds a Master's degree in aeronautical engineering as well as a professional engineer's license.

Capt. Baranowski's duties have included gunnery and communications duties aboard the USS SARATOGA and the USS SCHENK; overhaul and Repair Officer at the Naval Air Station, Moffett Field, California; Jet Propulsion Assistant to the Bureau of Aeronautics General Representative on the West Coast; Navy Liaison Officer with the Research and Development Division of the War Department General Staff, and Head of the Fluid Mechanics Branch of the Office of Naval Research; Maintenance Officer of Air Transport Squadron Forty-four and Staff Engineering Officer of Fleet Logistic Air Wing, Atlantic/Continental; Assistant Director of the Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania. Prior to reporting to Lake Denmark, Capt. Baranowski was the Assistant Chief of Staff for Material on the staff of the Commander Fleet Air Western Pacific. Capt. Baranowski assumed command of NARTS on 28 August 1956.

The Executive Officer is Cdr. William H. Chester, USN, who reported to NARTS in November 1958 from the USS KENNETH WHITING (AV-14) which he commanded. He entered the Navy as an Aviation Cadet in November 1939 after graduating from Gettysburg College with a Bachelor's degree in education. He received his wings and commission as an Ensign in August 1940 at Pensacola, Florida. Cdr. Chester's duties have included two years as a primary flight instructor at NAS Jacksonville; transport pilot during the war years in VR-8, VR-2; Commanding Officer VU-3, ATU-10, VP-50, and ATU-700; Assistant Air Operations Officer on CINCPACFLT Staff, and Operations Officer on the staff of Commander Fleet Air Wing Six in Iwakuni, Japan.

The heart of the NARTS organization is the Rocket Propulsion Laboratory. The other departments—Administration, Supply and Fiscal, Public Works, Security, Medical, and Industrial Relations—are primarily in business to serve the needs of the Rocket Propulsion Laboratory. They have, however, collateral functions in maintaining support to contractors to a small degree, and Picatinny housing of military personnel. A small group of Navy personnel also functions in the trainee category.

The Director of the Rocket Propulsion Laboratory (RPL) is Commander Donald T. Jensen, USN. He is an Aeronautical Engineer with a Master's degree from the University of Michigan. The civilian Technical Director of the RPL is Irving Forsten. He holds a Bachelor's degree in Aeronautical Engineering and a Master's degree in Mechanical Engineering from New York University.

Cdr. Jensen came to NARTS in July 1959 from the Office of Naval Research. He entered the Navy as a Naval Aviation Cadet in 1940, won his wings and received his commission as an Ensign at Pensacola in 1941. After two years as a flight instructor there he spent 24 months in Atlantic Fleet squadrons. As a Project Officer at Pt. Mugu after leaving Michigan in 1947, Cdr. Jensen worked on the LARK project, among others. Before moving to ONR he served a tour at the Corpus Christi, Texas, Naval Air Station.

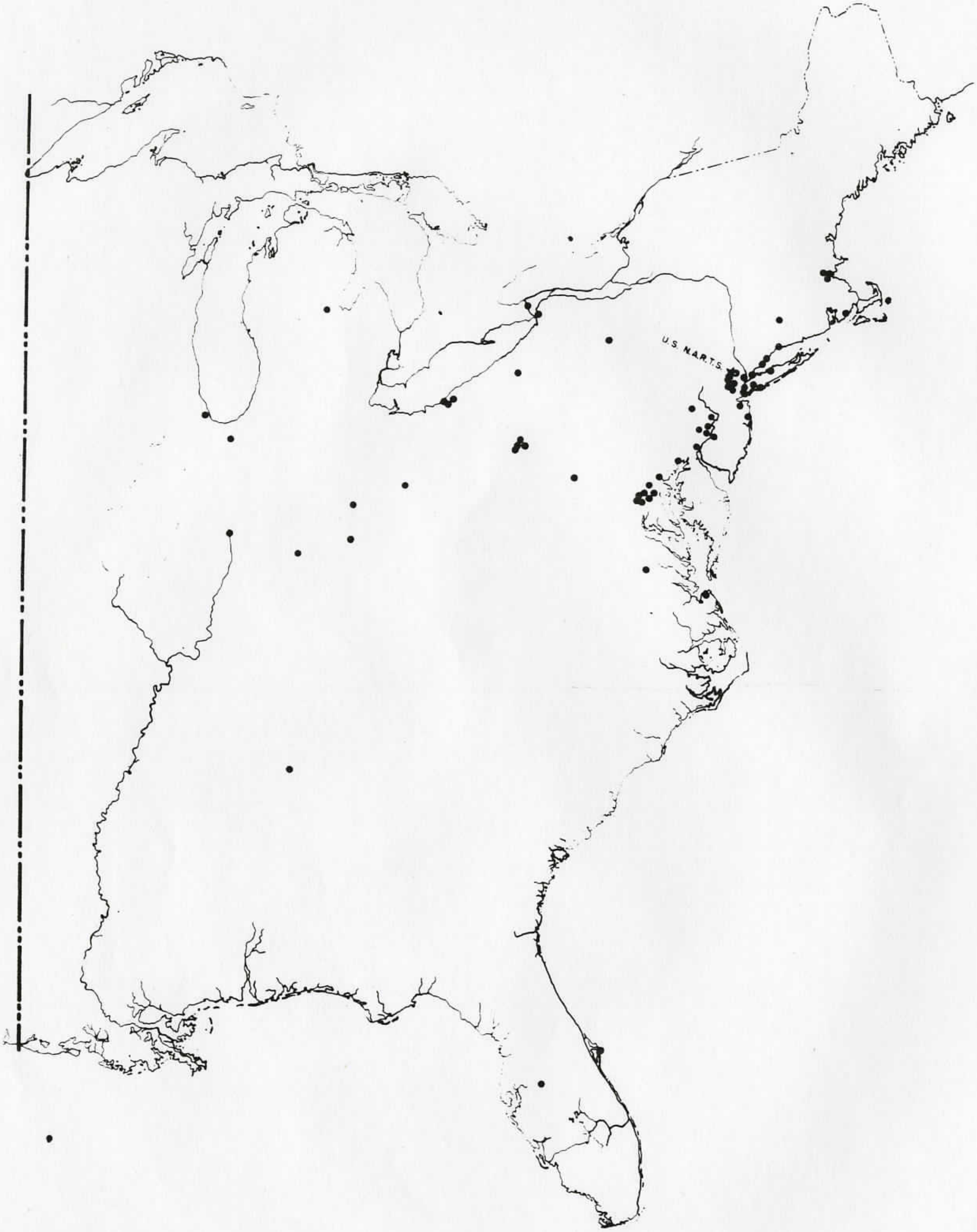
Mr. Forsten came to NARTS in 1950, having worked with the Ranger and Grumman aircraft firms and as a research scientist with the National Advisory Committee of Aeronautics at Langley Field, Virginia. An Associate Fellow of the Institute of Aeronautical Sciences, he holds a professional engineer's license and has served as a member of the faculty of the Mechanical Engineering Department at N. Y. U. Along with other assignments before being promoted to the top civilian post at NARTS, Mr. Forsten was instrumental in developing rocket engines and related hardware used to develop an outstanding new monopropellant and assisted with development of rocket engine specifications now used as a guide by industry and government.

One of NARTS' better known researchers is Dr. John D. Clark. He has served as chief chemist since 1949 and heads the Propellants Division. One of his major achievements is the "invention" of a new family of monopropellants that has been hailed over the past year as a major breakthrough. He also is the designer of a new periodic chart of the elements, the developer of a simplified technique for determining theoretical rocket engine performance and the inventor of a device for use in the field analysis of white fuming nitric acid. A native of Alaska, Dr. Clark attended the University of Alaska, earned his Bachelor's degree at the California Institute of Technology ('30), his Master's at Wisconsin ('32) and his Ph. D. at Stanford ('34).

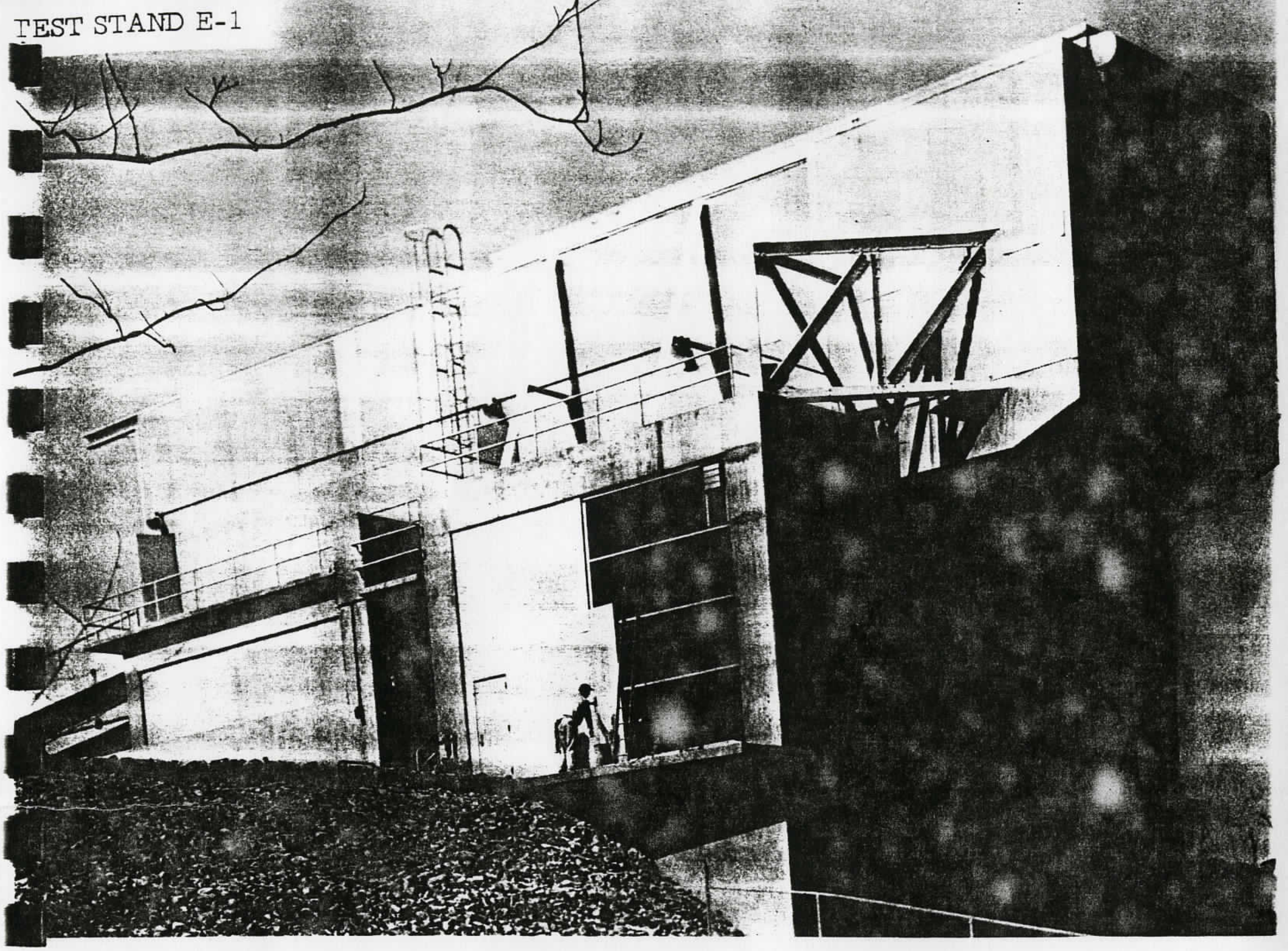
The Head of the Rocket Engine Division, which encompasses the Design, Shops, Test, and Instrumentation Branches, is John J. Canavan. He holds a Chemical Engineering degree from Catholic University in Washington, D. C. He came to NARTS in 1952 from the Naval Engineering Station at Annapolis, Md., where he worked in the Industrial Gas Section. At NARTS he worked his way up the ladder from general engineer to Head of the Facilities and Test Branches and then to his present position.

Heading up the NARTS Project group are a trio of Senior Project Engineers. William F. Lehman, a specialist in qualification test and evaluation programs, also serves as Staff Assistant to the Technical Director. Frederick R. Hickerson, an authority on advanced liquid rocket engine concepts, is credited with the invention of a unique variable thrust engine. Rounding out this experienced and highly diversified group is Edward A. Jenkins. His specialty is electronics and he serves as technical consultant to the Rocket Engine Division in addition to his project assignments.

Mr. Lehman is a graduate electrical engineer (Rensselaer Polytechnic Institute) who also holds a professional license. After doing graduate work at Stevens Institute of Technology he continued on there as a research engineer in hydrodynamics. Mr. Hickerson holds a mechanical engineer's degree from Clemson and his experience includes design and development work for Reaction Motors and Picatinny Arsenal. Mr. Jenkins attended Swarthmore College, earned his electrical engineer's degree at the University of Virginia and also did advanced work at Stevens Institute. He was a project engineer for Westinghouse before coming to NARTS.



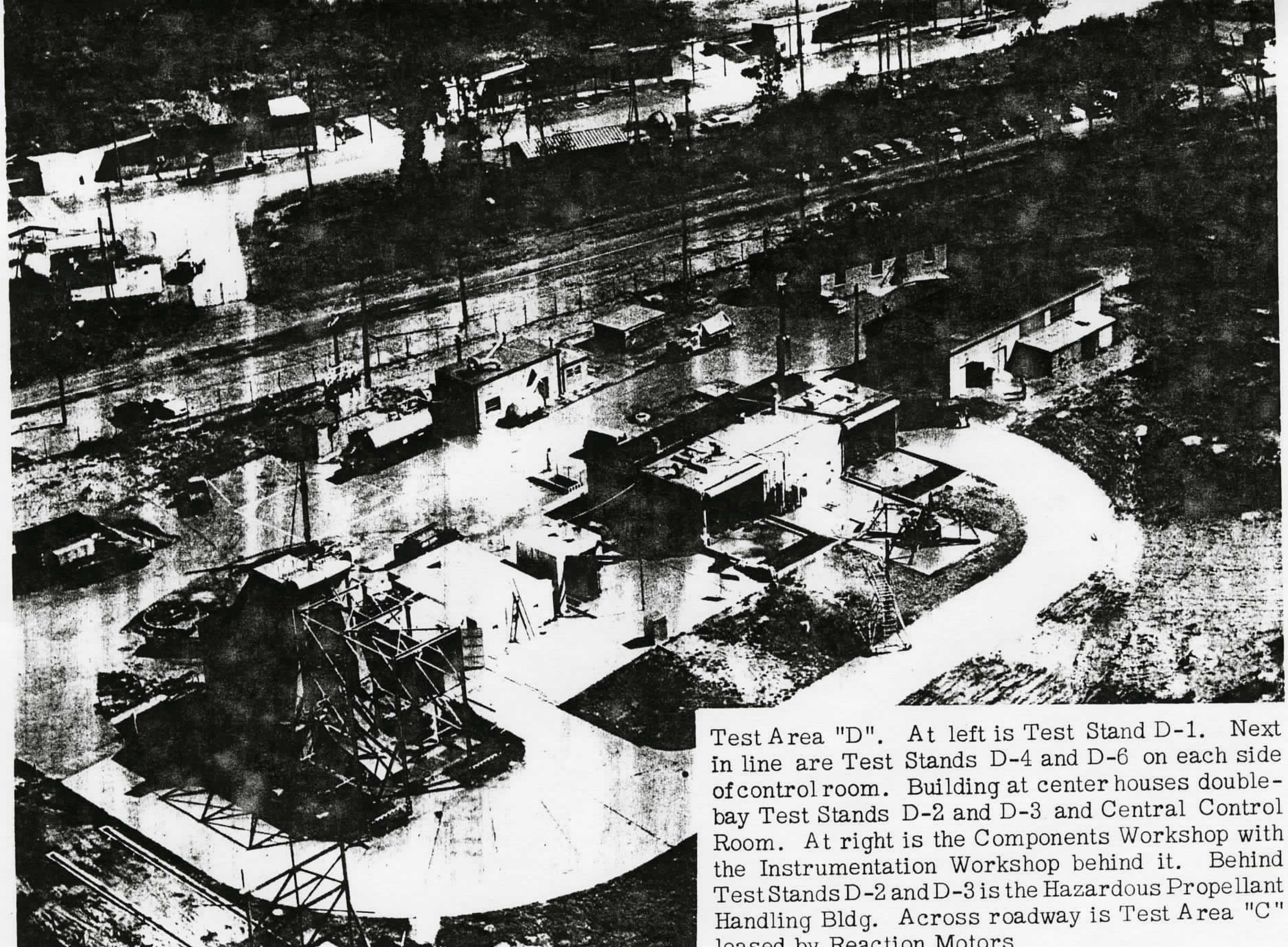
NARTS is within easy reach of hundreds of government agencies and private contractors in the East. Indicated on the map is the geographical spread of a few of the activities associated with NARTS over the past decade



FACILITIES

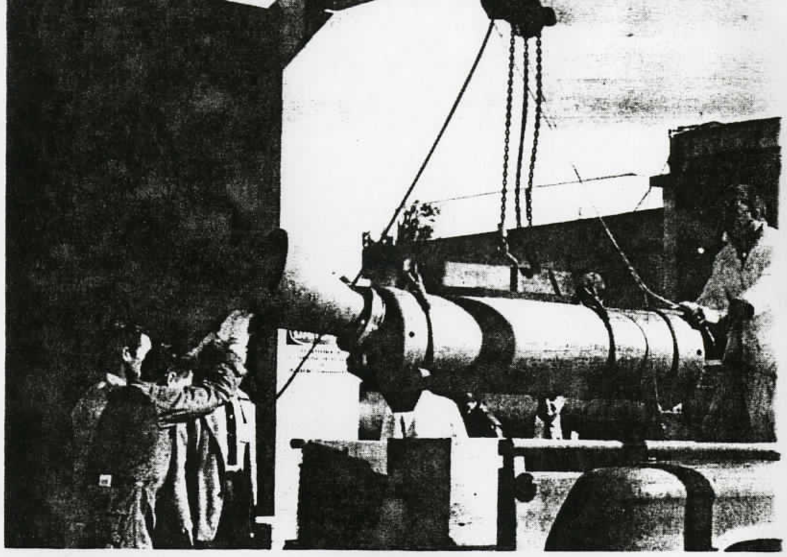
What We Have to Work With

NARTS facilities have come a long way from a beginning when a single, small liquid propellant test stand was about all that was available. Facilities are now well established over a wide area in many buildings, firing bays and other structures. Liquid and solid rocket engines ranging in size up to 350,000-lb-thrust now can be tested. These test facilities are generally grouped into six test areas, two utilized especially for NARTS projects with the others leased to Reaction Motors. The Propellants Division is equipped for both chemical and physical testing of liquid and solid propellants while other major facilities include environmental conditioning and test laboratories, hazardous and gunfire test sites, extensive propellant handling and storage facilities, an experimental machine shop and many other specialized services.



Test Area "D". At left is Test Stand D-1. Next in line are Test Stands D-4 and D-6 on each side of control room. Building at center houses double-bay Test Stands D-2 and D-3 and Central Control Room. At right is the Components Workshop with the Instrumentation Workshop behind it. Behind Test Stands D-2 and D-3 is the Hazardous Propellant Handling Bldg. Across roadway is Test Area "C" leased by Reaction Motors

Unloading a REGULUS I
Booster at the firing bay



TEST AREA "D"

This is the grouping of a variety of facilities where the major portion of the NARTS project tests are conducted. Included are four buildings that accommodate six liquid and solid propellant test stands, a large stand designed primarily for testing liquid propellant booster rocket engines up to 100,000-lb-thrust, components and instrument workshops, on-the-site temperature conditioning equipment and a JATO flame temperature and blast pressure measuring facility. Other specialized equipment includes a special hazardous propellant handling building, a portable shock tester and centrifuge equipment.

TEST STAND D-1

This is a reinforced concrete structure equipped for testing liquid booster rockets having their own tankage or high-thrust solid propellant rockets. Thrust rating is 100,000 lb with firing from horizontal to vertical attitudes for durations up to five seconds without cooling of the flame deflector plate. Maximum size of rockets that can be accommodated is 20 ft in length by 30 in. in diameter. Viewing is indirect by remote control, closed-circuit television. A gantry crane with a 5-ton hoist is used to install and remove rocket motors used for prepackaged tests.

TEST STANDS D-2 AND D-3

These dual-mount test bays are housed in the same building, constructed of reinforced concrete and designed primarily for testing liquid propellant rocket engines up to 10,000-lb-thrust. Each is equipped for testing two separate rocket engine systems. Firings are normally horizontal. Flexure plate parallelogram or bell crank mounts, with the force reacted by a load cell, are attached to steel rails set in the concrete floor. Directly behind the firing mounts are propellant tank rooms separated by steel bulkheads. All tanks are fabricated of Type 347 stainless steel and are rated at 1200 psig working pressure. Tank capacities range from 25 to 550 gallons and are capable of being moved between bays to meet specific firing requirements. Pressurization of the tanks is by nitrogen. Test viewing is indirect by closed-circuit TV and test stand control is from the central control room between the two bays.

CENTRAL CONTROL ROOM

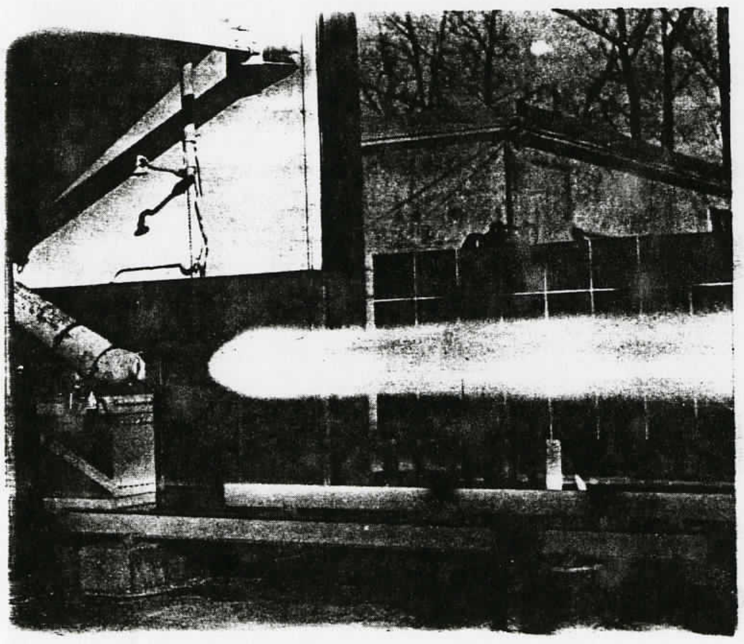
The central control room located between D-2 and D-3 (same building) includes two consoles providing control facilities for the two firing bays. As each cell contains two stands, the control consoles are fitted with selector switches to transfer from one stand to the other. Tank and control pressure display are provided by Bourdon tube gages. In addition, engine firing data presented to the operator include flow, chamber pressure, etc., by electrical meters receiving information from retransmitting slide wire potentiometers mounted on the strip-chart recorders.

Recording facilities are generally standard. Strip-chart recorders and recording oscillographs are used for the major part of data recording. In addition, a 7-channel tape recorder is used for collecting high frequency data. Two transducer systems are used for measuring thrust and pressure. One is a variable reluctance system and the other a DC strain gage system. Normal termination facilities are provided for both. Temperature measurements are made by thermocouples with standard reference units provided for both test cells. Flow measurements are made by turbine-type flowmeter. Flowmeter output is integrated with NARTS-built integrators.

Two special analog computers have been built by NARTS instrumentation specialists. One computes characteristic exhaust velocity or specific impulse and oxidizer-to-fuel flow rate continuously during testing. The second computes heat transfer during testing from any pair of thermocouple measurements.

TEST STAND D-6

This is a reinforced concrete structure for testing solid propellant motors and JATOs up to a thrust capacity of 40,000 pounds. Firings are made horizontally, or at small angles from the horizontal through the use of special mounts. JATOs are mounted in a roller frame bolted to rails embedded in the floor. The thrust of the rocket is reacted through a load cell by a massive concrete block which is anchored to the floor of the stand. Viewing is indirect by closed-circuit TV. Firings are made from a separate control room. Strain gage pressure and thrust pickups are used. Recording is by an Alinco four-channel strain gage amplifier



A JATO during a static firing test

Final countdown in the control room

feeding a recording oscillograph. Transducers in the cell feed two high-speed potentiometer chart recorders. A deadweight tester and a Heise gage hydraulic system are used for calibration of the pressure cells, and a Morehouse ring for thrust calibration.

TEST STAND D-4

Test Stand D-4 is a recently modified facility for testing liquid and solid propellant engines up to 30,000-lb-thrust. Equipment for handling solid propellant motors is the same as that for Test Stand D-6 while facilities for testing liquid engines are the same as that for Test Stands D-2 and D-3. Firing for both D-4 and D-6 is from a separate control room located between the stands. The instrumentation is the same as that used in the Central Control Room. Tankage for D-4 is rated at 2000 psig.

COMPONENTS WORKSHOP (D-5)

This facility is divided into hazardous and nonhazardous areas. The nonhazardous area, about 28 x 44 ft, is used for cold tests of rocket engine components. It contains a flow test system which delivers water at pressures up to 1200 psi and flow rates up to 500 gpm. The hazardous tests are conducted in a concrete-walled room 12 x 27 feet. Tests can be made of high-pressure inert gas equipment, ignition delay, and gas generator performance. Operations are controlled remotely from outside the room in an instrument and control bay which serves the entire building.

Installed in a room outside the nonhazardous area is a small altitude chamber. It is equipped to make ignition-proof tests of electrical components. It is rated to 100,000 ft altitude.

Instrumentation in the components laboratory is semi-portable. Six high-speed potentiometer chart recorders are generally installed. Oscillographs and other recorders are installed as required.

INSTRUMENTATION WORKSHOP

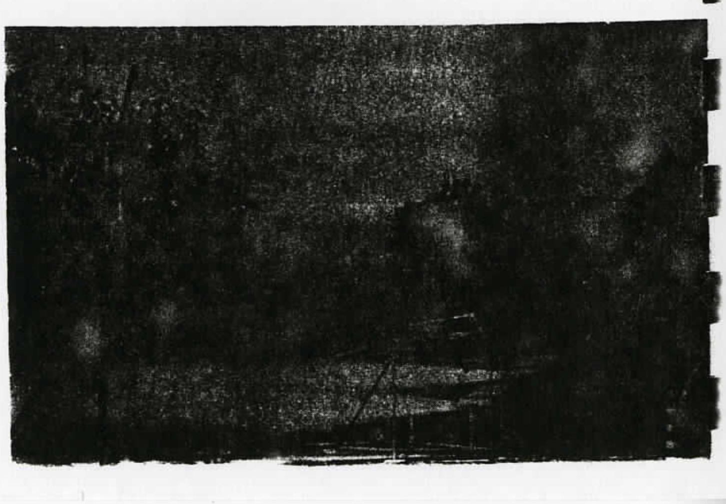
This building, constructed of concrete block, contains an electronic workshop, storage room, instrument calibration room and office space. The workshop area contains electronic workbenches where instrumentation used in static firing can be repaired and overhauled. Fabrication of instruments (computers, etc.) designed by the Instrumentation Branch also is done in the workshop. All instruments and recorders used in conjunction with test firings conducted in Test Area "D" are stored in this building along with spare parts, etc.

TEMPERATURE CONDITIONING PAD

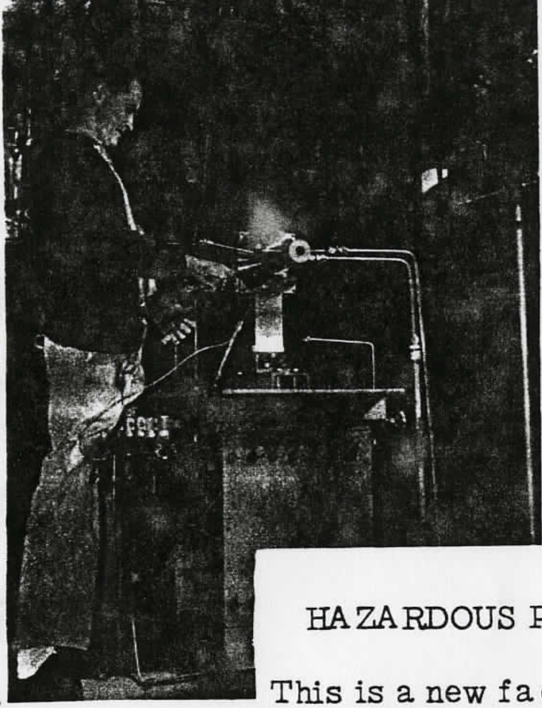
On-the-site temperature conditioning equipment in Test Area "D" is sheltered on a concrete pad. Included are a hot box, a cold box and an ambient box. The cold box is an Airco mechanically-refrigerated unit, 3 x 4 x 10 ft ranging to -90°F. The capacity of both the ambient and hot boxes is 27 cubic feet. The ambient box is mechanically-refrigerated with electrical strip heaters for buffer control. The hot box, with a range of +170°F, is controlled by electrical strip heaters. While generally intended for short-term storage before firing of JATO units, igniters, starter cartridges, etc., the equipment can be used for continuous service if necessary.

JATO EXHAUST TEMPERATURE AND BLAST PRESSURE FACILITY

Equipment used in this type testing includes a 13-ft high tower and a movable frame mounted on tracks. Instrumentation provides for the simultaneous firing of multiple JATO configurations and the measuring of exhaust flame temperatures and blast pressures. The frame for mounting thermocouples and microphones for sound measurements can be moved up to 60 ft from the JATO nozzles.



Multiple JATO firing utilizing exhaust temperature and blast pressure facility



Getting ready for a liquid rocket engine firing

HAZARDOUS PROPELLANT HANDLING BUILDING

This is a new facility, constructed of concrete, 40 x 16 ft, with two 11 x 12 ft propellant storage bunkers attached. The work area is equipped with an exhaust system, a deluge system, and a drainage system connected to a neutralization pit. The facility is adequately fitted to handle any hazardous propellant in making flow calibrations, pickling equipment for use with these propellants and making small-scale hazardous blending tests.

CENTRIFUGE

This equipment is capable of rotating a 200-lb weight at a speed of 100 rpm at a radius of six feet. A special slip-ring assembly permits the firing of up to a 50-lb-thrust unit while rotating. A second centrifuge is described in the section on Environmental Test Building.

SHOCK TESTER

A portable Consolidated Electrodynamics Corporation 3-in. HYGE shock tester is described under the section on Test Area "G".

MISCELLANEOUS FACILITIES

Among other facilities in Test Area "D" is a utility room, allowing on-the-spot assembly and minor repair of rocket engines and components. In the room are a small lathe, drill press, grinders, arc and gas welders, mechanical hack saw, tube bender and tube flaring machines. There are also a darkroom, stockroom, storeroom, offices and lavatory.

Propellants generally brought in by drums are stored in either fuel or oxidizer bunkers located in the area. Propellants brought in larger vehicles, such as tank trucks, also can be handled. Tanks are pressurized by nitrogen, stored in a high-pressure cascade and piped throughout Test Area "D". Nitrogen supply is normally maintained near the maximum level of 2200 psi.

TEST AREA "E"

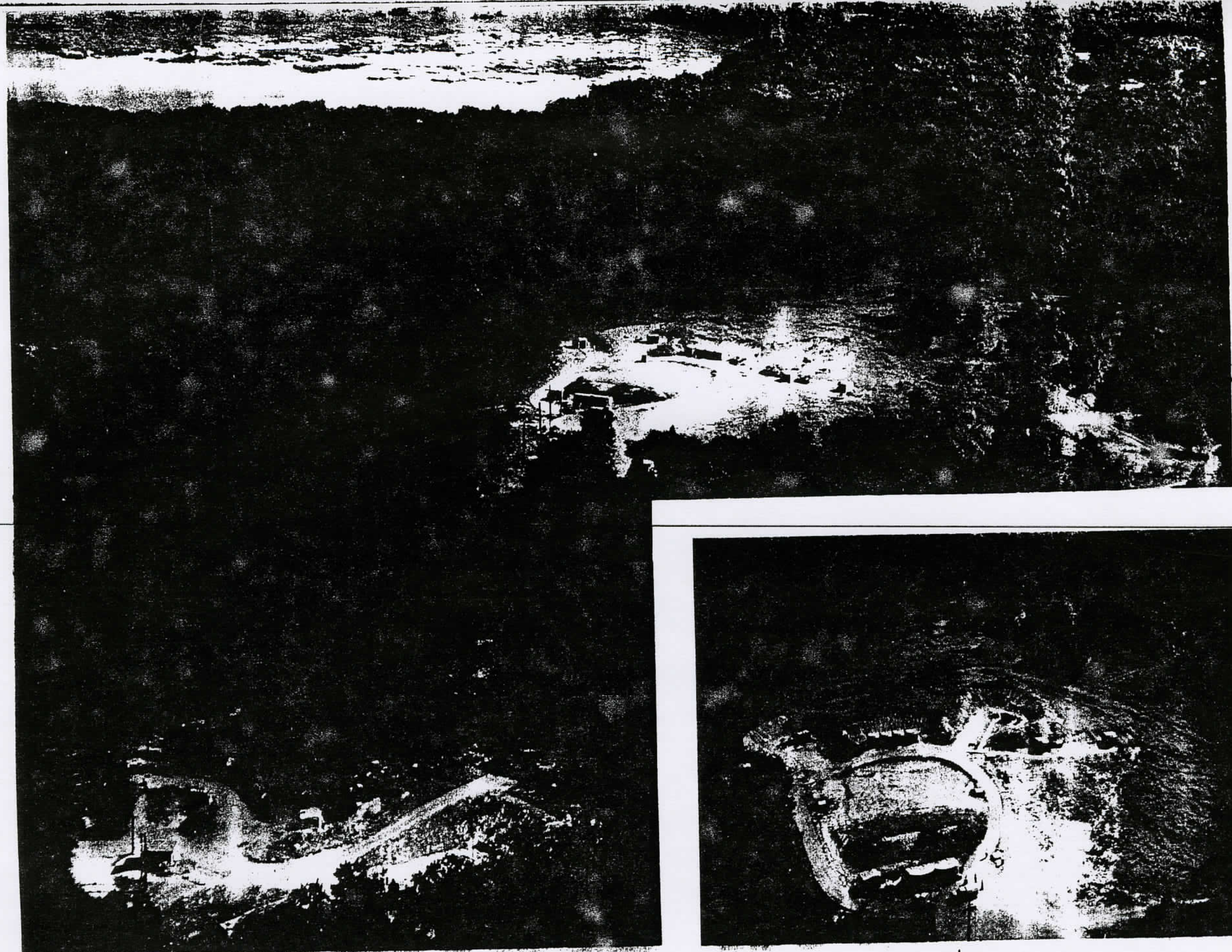
Test Stand E-1 is often considered "elite" among many unique facilities at NARTS. Capable of handling liquid propellant rocket engines up to 350,000-lb-thrust, this huge concrete and steel structure dominates the Lake Denmark test site. One of the largest static test stands on the East Coast when first put into operation, Test Stand E-1 has been utilized for testing the X-15 power plant under a use-agreement contract with Reaction Motors.

Static firings can be made at any attitude on Test Stand E-1 with the test engine "tied" to a mount fastened to trunnions 15 ft apart and located on a cantilevered balcony 60 ft above grade. The engine mount is basically a hollow beam of rectangular cross-section bridging the space between the trunnions. A sliding roof permits vertical erection of missiles up to 90 ft in length.

Two sets of double doors (like a bomb bay) are affixed in the operating floor under the mount. Located under the floor are separate tank rooms for fuel and oxidizer and separate cascade rooms for individual pressurizing of propellants. The liquid oxygen tank capacity is 2500 gal and is rated at 50 psi while the working pressure of the 3000 gal ammonia tank is 225 psi. Also located in the propellant tank room is a 2400 gal water tank, rated at 1500 psi, which is used to cool the engine jacket. Propellants are pressurized by gas stored at 2000-2200 psi. Nitrogen gas is used for pressurizing fuel and cooling water and gaseous oxygen is used for pressurizing the liquid oxygen.

The control room for Test Stand E-1 is located below grade in a concrete building 250 ft away. Instrumentation provides measurement of all the usual rocket engine parameters—pressure, force, flow rate and temperature. The total number of installed recording channels includes 35 potentiometer recorders, eight direct writing Sanborn recorders, and a 2-channel cathode-ray oscilloscope. Terminations are also installed in the recording racks for two 18-channel magnetic oscillographic recorders. Thus there are 79 allocated recording channels with 17 spare channels available.

NARTS engineers not only fathered the original plan for the E-1 facility but also shepherded the design through layout, drew up the preliminary specifications and maintained active liaison during the final architectural detailing and construction. The project is rightly considered one of the major accomplishments of the NARTS engineering staff.



Test Area "G" showing upper end of Lake Denmark.
in background

Insert is closer view of G-2 pads and control
bunkers

ENVIRONMENTAL TEST BLDG.

The Environmental Test Building is another "unique" NARTS feature. The building is equipped to handle units in propulsive state such as solid propellant boosters and sustainers, prepackaged liquid rocket engines and gas generators. The majority of the 5,000 sq ft of floor space is divided into four bays with the hazardous and nonhazardous areas separated. Temperature conditioning equipment installed in three of the four bays includes four walk-in boxes, two hot and two cold, each 4 x 6 x 10 feet. The hot boxes can be operated continuously at +180°F and the cold boxes at -90°F. A small capacity box (20 cu ft) is used for conditioning igniters and small components. Also available are several portable servo units to supply hot or cold air to any insulated space at temperatures ranging from -70 to +220°F. Environmental equipment also includes a 160 cu ft combination humidity, rain and salt-spray cabinet.

The extensive vibration equipment in this building can be used for vibratting rocket engines and components under various temperature conditions. Vibrators are placed outside the boxes and linked to items under test within by force-bars running through ports. The vibrators include four exciters ranging in size from a 50-lb-force, 2000 cps machine; to a 3500-lb-force, 500 cps machine. Each vibrator has its own power supply and control console. All the vibrators are mobile and the test bays are provided with electrical panels to permit operation in any location. Also available is a mechanical shaker with 100-lb table capacity of 10 g's and a frequency range of 10-to-60 cps.

Other equipment installed in Building No. 99 is a Schaevitz Company centrifuge capable of rotating 100 lb and attaining 25 g's at 150 rpm at a radius of three feet. The dimensions are 9 ft diameter x 5.8 ft high and the maximum volume is 18 cubic inches. A specially-designed slip-ring assembly provides 30 rotating, low-noise electrical connections for collecting data while the machine is in operation. Outside the building is a 10-ft drop-test frame actuated by solenoid bomb release from the control room.

Detailed listing of the Building No. 99 equipment follows:

Tenney Engineering Company cold boxes (2)
Internal dimensions: 4 x 6 x 10 ft
Range: Ambient to -90°F, controllable to ±2°F

Tenney Engineering Company hot boxes (2)
Internal dimensions: 4 x 6 x 10 ft
Range: Ambient to +200°F, controllable to ±2°F

American Instrument Company cold box
Internal dimensions: 2 x 2 x 5 ft
Range: Ambient to -65°F, controllable to ±2°F

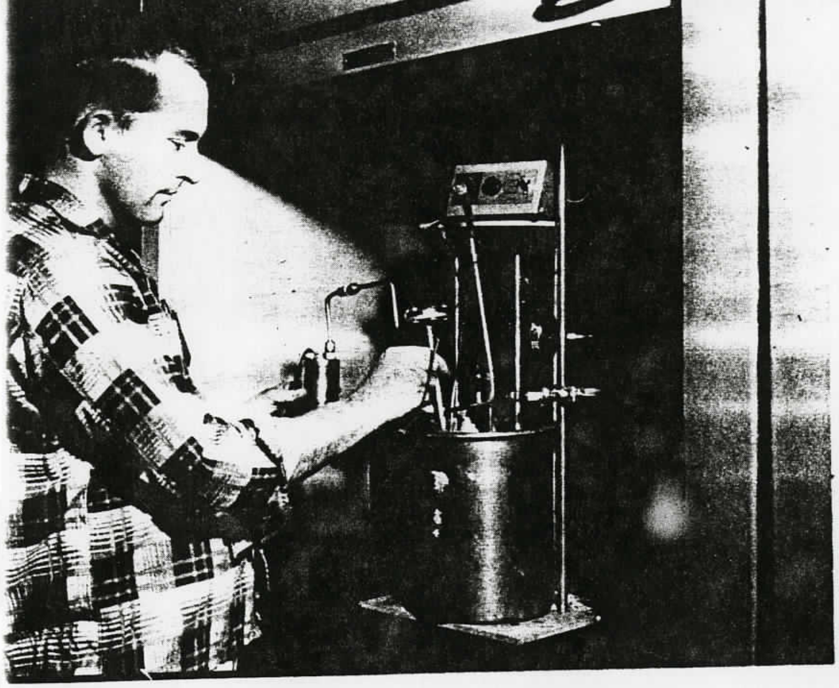
Hot box (NARTS manufacture)
Internal dimensions: 2 x 2 x 3 ft
Range: Ambient to +200°F, controllable to ±2°F

Rain, humidity and salt-spray box (NARTS manufacture)
Internal dimensions: 4 x 4 x 10 ft
Rainfall: 4 in./hr ± 1 in.
Humidity: Up to 100%; temperature +170°F
Salt-spray: 3 ml/hr/80 sq cm

All-American Tool Company vibration fatigue testing machine
Table load capacity: 100 lb (at 10 g)
Total displacement: 0 to 0.125 in. (adjustable)
Frequency: 10 to 60 cps (adjustable)

MB Manufacturing Company electromagnetic vibration exciters (4)
One Model C-11: Force output, 50 lb; frequency range, 0 to 2000 cps
Two Model C-5: Force output, 750 lb; frequency range, 0 to 500 cps
One Model C-25: Force output, 3500 lb; frequency range, 0 to 500 cps

Shaevitz Company Centrifuge
Dimensions: 9 ft dia. x 5 ft 8 in. height
Nominal rpm: 0 to 150
Acceleration: 25 g's
Max. test sample: 100 lb
Max. test sample volume: 18 cu in.



Performing a thermal stability test

PROPELLANTS DIVISION

The Propellants Division is housed in two laboratories divided as follows: one for synthesizing propellants and determining their physical properties, the other for developing analytical procedures for propellants and evaluating their performance and applications. Major work is in these areas:

1. Development of new liquid propellants
2. New propellant research
3. Development of analytical procedures for oxidizers and fuels such as fuming nitric acids, hydrogen peroxide, hydrazines, amines and others
4. Investigations of variation of propellant combination on ignition and performance
5. Preparation of procurement ana operational specifications for propellants

PHYSICAL CHEMISTRY

The physical chemistry laboratory is equipped to determine physical properties and to synthesize propellants. To facilitate operations, the laboratory is divided into two working areas, one for propellants synthesis and the other for physical property determinations.

The propellant synthesis laboratory is equipped with specialized glassware, utilities, and equipment such as vacuum ovens, high-pressure vessels for certain reactions, and melting point apparatus, thus permitting the synthesis and identification of organic and inorganic compounds.

Pilot plant-scale preparations of certain compounds can be readily prepared in a separate building through the utilization of two surplus steam kettles.

The physical chemistry laboratory is equipped to determine heats of combustion, viscosity, density, heats of solution, freezing points, vapor pressures, and thermal stabilities of propellants. Certain specialized equipment such as the Beckman Aquameter, a specially modified Parr adiabatic oxygen bomb calorimeter, Westphal specific gravity balance and freezing point apparatus are used for the various determinations made.

In addition to the areas mentioned, there is a small workshop equipped to handle glass blowing and other small repair work, as well as an outside test pit in which hazardous work can be conducted remotely from inside the main building.

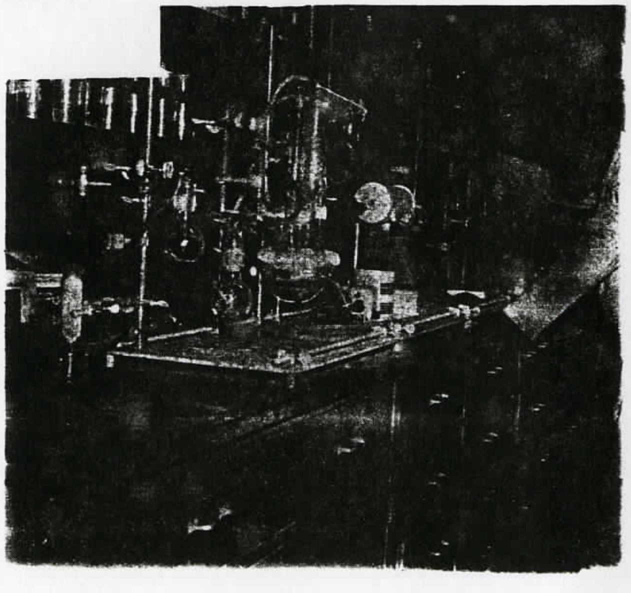
ANALYTICAL CHEMISTRY

Specialized equipment utilized in the Analytical Chemistry Laboratory includes:

- Beckman D. U. Spectrophotometer
- Beckman DK-2 Recording Spectrophotometer
- Todd Spectranal
- Refractometer
- Potentiometer Titrimeters
- Perkin-Elmer Model 21 Infrared Recording Spectrophotometer
- KBR Die Assembly
- Fisher Electrophotometer and Electroanalyzer
- Photovolt Fluorimeter
- Photovolt Colorimeters
- Sargent Model 21 Recording Polaragraph
- Conductivity Bridges
- Gas Analysis Apparatus
- Micro-Analytical Combustion Apparatus
- Photomicrographic Equipment

Other special equipment:

- Impact Tester (JPL Type)
- Burning Rate Bomb (Crawford)
- Card-gap tester
- Adiabetic Compression Tester
- Thermal Stability Tester
- Auto-ignition Temperature Tester



Analytical chemist at work

SHOPS BRANCH

Experimental machine shop facilities at NARTS consist of two buildings with a total floor space of 24,000 sq feet. The buildings are readily accessible by railroad spur, truck and other light and heavy-duty moving and transportation equipment and are located far enough away from the test areas to be free of toxic fumes, test noise and other hazards associated with a rocket facility.

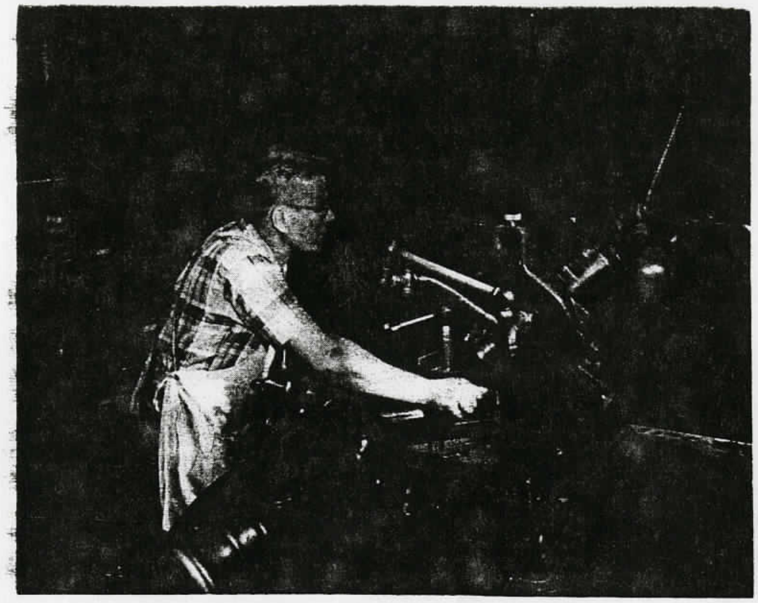
The Shops Branch has facilities for the manufacture and fabrication of various types of specialized test components and assemblies that may be required by an activity involved in research and development assignments. Hundreds of types of equipment and accessories are fabricated for the Rocket Test Division, Engineering Services Division and the Propellants Division such as firing consoles and panels, temperature and pressure sensing devices, cooled and uncooled engines, test mounts, conditioning and vibrating equipment, test chambers, propellant handling test equipment, manufacture and repair of special propellant tanks. Some of the materials employed in this work include aluminum, copper, steel, tool steel, mild and chrome-moly steel, nickel, magnesium and their alloys. Other materials include Teflon, Kel-F, carbon, graphite, rubber, nylon, phenolics and other plastics.

The machine tools utilized in experimental work are capable of producing work of extreme accuracy and preciseness. The manufacturing section is divided into several units, each with specific work assigned. These include:

Grinding—Grinding equipment includes surface, cylindrical, tool and cutter and drill grinders, boring machine, filing machine and related accessories.

Milling—Milling machines include plain, universal, vertical and precision, and sensitive milling attachments.

Jig-Bore—This equipment is complete with variable-speed drive and an optical measuring system.



Turning out an experimental chamber

Main Shop Area—More generalized machine shop equipment is located in the Main Shop Area. This includes various size lathes capable of turning up to 45 in. diameter with tracer attachment for contour turning; several standard floor and bench-type drills, radial and sensitive, and precision for small hole drilling; saw equipment includes power pack saws; horizontal cut-off and vertical contour saws; engraving machines; tool crib and general bench and machine tool accessories.

Other facilities:

Heat Treatment—Heat treatment facilities include a small tool room furnace, a large-size furnace, tempering furnaces and quench tanks.

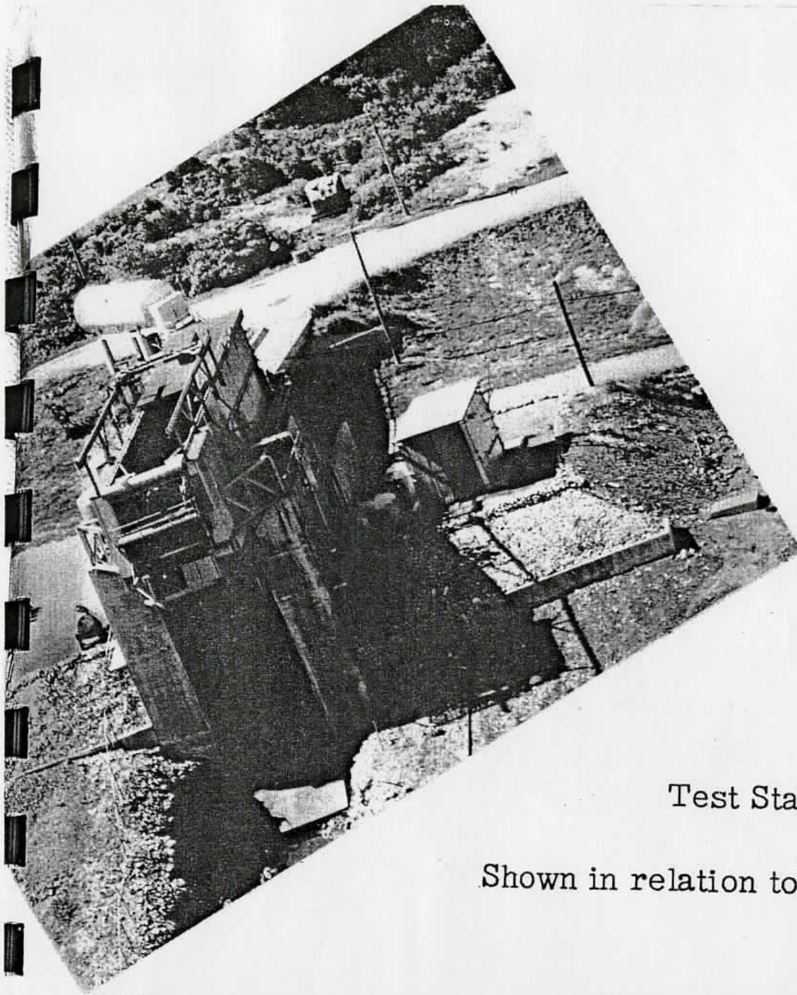
Sand Blasting—Rust and scale-removal and general preparation of metal is handled by the usual sand blasting equipment.

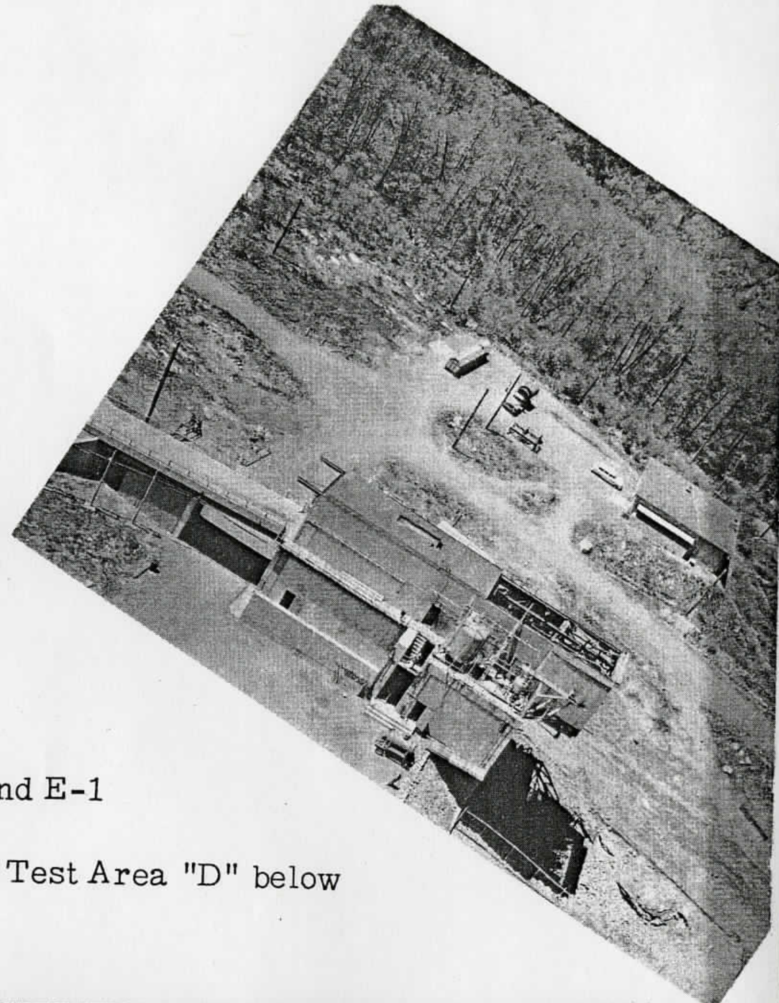
Degreasing—This equipment includes: vapor degreaser for cleaning and removing oil traces before assembly.

Valve Repair—A valve repair area handles any maintenance necessary.

Inspection—Inspection equipment includes a contour projector, precision gage blocks, thread plug and ring gages, indicators and related precision measuring equipment.

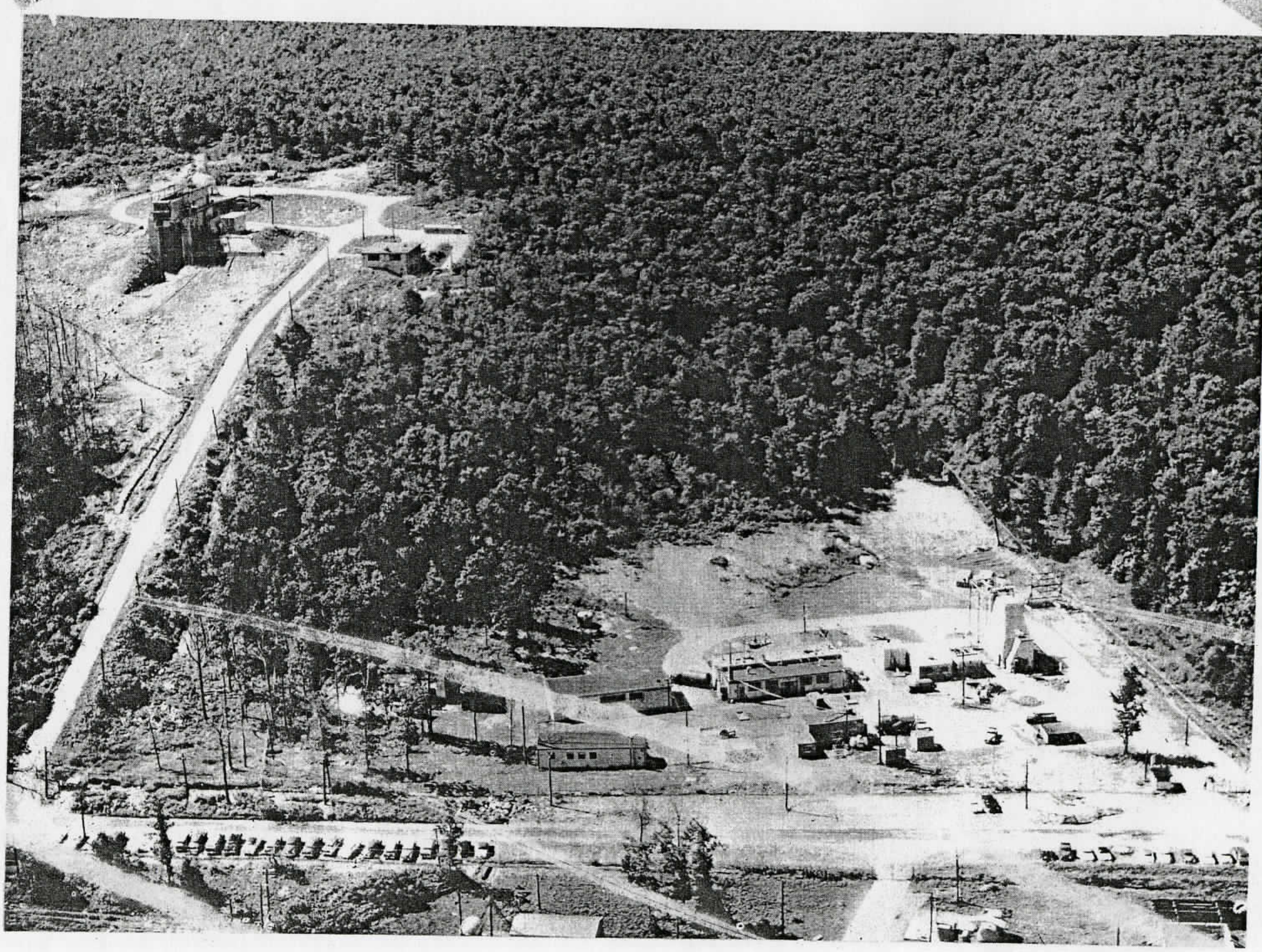
Fabrication Annex—This section is located in a building adjoining the main shop and is primarily utilized for fabricating heavy and large test equipment and associated components. The building houses all welding equipment for both ferrous and non-ferrous metals, specialized welding units and torch cutting equipment. For fabrication of assemblies requiring use of heavy steel plates, equipment is available such as power brake, power rolls, shears, radial drill and related equipment. In addition, sheet metal equipment of lighter gage capacity also is available. Ample space is available for handling large assemblies by using fork trucks and other heavy equipment.





Test Stand E-1

Shown in relation to Test Area "D" below



TEST AREA "G"

This is a newly developed test area equipped with three concrete test pads for performing damage control tests and tests to determine the destructive effect of chemicals used as rocket propellants. These tests involve fire fighting; mixing of oxidizers with fuels; 50 calibre and 20 mm gunfire into containers of oxidizers, fuels and monopropellants; and detonation tests. The largest total weight of oxidizer and propellant used so far in damage control tests is 100 lb with varying proportions of oxidizer and fuel.

Another test pad area is set aside for testing the shock sensitivity of propellants by means of the card-gap test. This area is enclosed by a gun turret to deflect shrapnel from the propellant cup and steel plate used in the test. Located near this pad is a propellant storage and preparation building where test setups can be assembled and propellants stored until needed.

There is a separate control room for each test pad. Each control room is equipped with recording and control instrumentation and photographic coverage is provided. The area is amply supplied with water and electricity.

Also performed in Area "G" are shock tests of prepackaged liquid thrust units loaded with propellants. These shock tests are performed using a mobile Consolidated Electrodynamics Corporation HYGE 3416, 3-in. diameter shock tester. This machine, operated by compressed gas, is capable of imparting an acceleration of 33 g's to a 250-lb weight and 100 g's to smaller specimens. The shock tester also is used in Test Area "D".

Another Area "G" facility is a 10 x 10 x 8 ft simulated missile magazine fabricated of 1/2-in. steel plate. The purpose of this mockup is to determine the pressurization rate and resulting pressure from propellant reactions and to permit investigation of control of the reactions.

Also available in Test Area "G" is a drop test facility. The equipment is presently set up for drops up to about 20 ft but it can be adjusted to practically any height desired.

ENGINEERING SERVICES

The Engineering Services Division provides a variety of miscellaneous special functions not provided by other units of the Engineering Department.

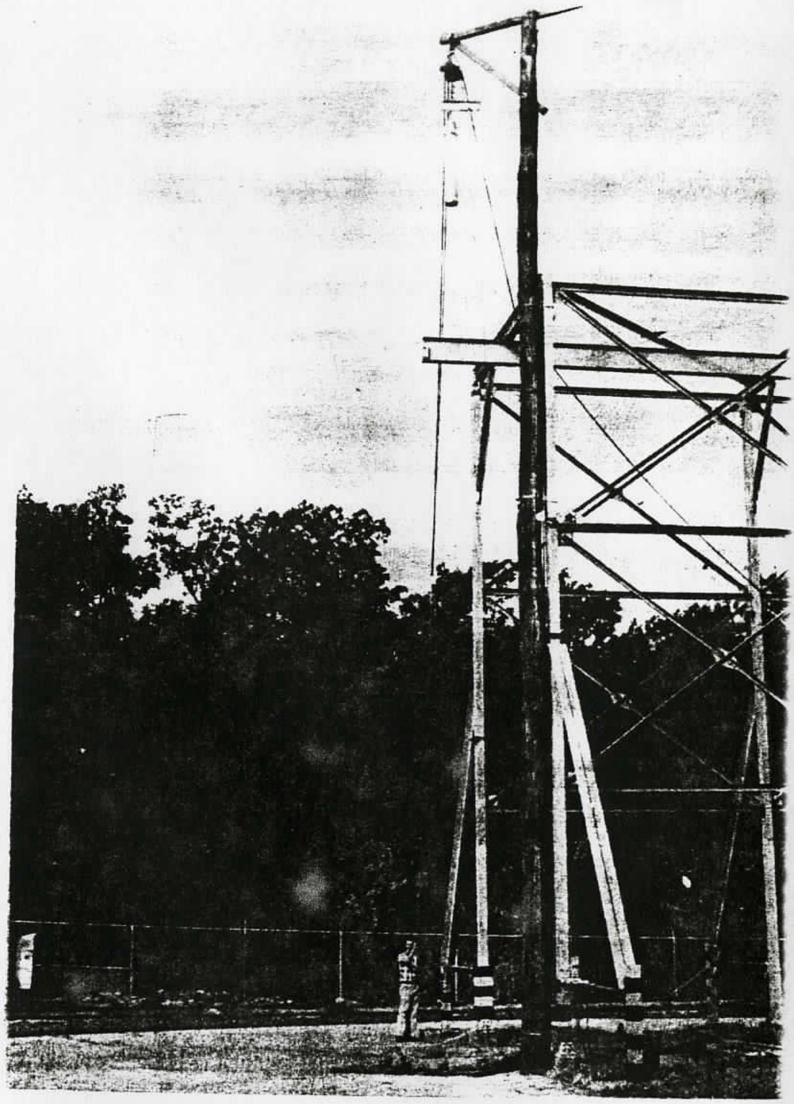
Propellant Handling and Storage—Because of the economics to be derived through volume purchases, propellants used in large quantities, such as liquid nitrogen and ammonia, are procured jointly by Reaction Motors and NARTS. In some cases these propellants are stored and/or handled by Reaction Motors and in some cases by NARTS personnel. This is one of the major functions of the Engineering Services Division.

Liquid Propellants—A wide variety of liquid propellants are used by both Reaction Motors and NARTS. Propellants used in relatively small amounts are generally shipped in drums or cylinders, depending upon their characteristics. On the station proper there are five warehouse-type buildings used for storage of either fuels or oxidizers in drum quantities. There are also two sub-surface magazines, one for storage of fluorine gas and fluorine compounds in cylinders, and the other for nitromethane and propyl nitrate.

Liquid propellants consumed in large amounts cannot be handled economically in drum quantities and are therefore received in containers varying from tank cars to tank trucks in size. Such propellants include liquid oxygen, liquid nitrogen, ammonia, nitric acid and hydrogen peroxide. Liquid oxygen is received either in tank trucks or tank cars. Liquid nitrogen, used for pressurizing propellant tanks, is brought in by tank truck and unloaded into a sphere of 250,000 cubic foot capacity. Adjacent to this sphere is a high-pressure pump which pumps the liquid nitrogen up to 2200 psi, and an electrically-powered heat exchanger which vaporizes the liquid into high-pressure gaseous nitrogen. The gas is then fed to three cascades containing high-pressure bottles manifolded together for nitrogen storage. From these cascades, underground distribution pipes run to all of the test cells where the nitrogen is used. All of the fixed liquid oxygen and liquid nitrogen equipment plus one of the three cascades, is leased from the vendor.

Ammonia is received in tank-car quantities. It is transferred from the tank car to a 1000-gal capacity tank truck and then into a storage tank. From this tank the ammonia is transferred to smaller tank trucks and delivered to test cells.

Unit in place for
40-ft drop test



Nitric acid is brought in on tank cars to a siding on the station. It is transferred from these tank cars to a specially designed acid trailer on loan to Reaction Motors by the Air Force, and is transferred from this trailer to the various test sites requiring nitric acid.

In describing liquid propellant storage and handling, it should be noted that there is an underground tank farm in the "B" test area. This tank farm, intended for fuel storage, contains 11 tanks, nine of which are of 5000-gal capacity and two of which are of 1000-gal capacity. To date, however, use has been made of only one of the 5000-gal tanks for the storage of alcohol.

Solid Propellants and Prepackaged Liquid Thrust Units—There are on the station proper 18 sub-surface magazines approved for storage of high explosives. Most of these magazines are 12 x 18 feet. Fourteen of the magazines are being used for storage of JATOs, prepackaged liquid units, igniters and solid propellant gas generators. The station uses two vehicles for transportation of explosives, one a two-and-one-half-ton closed van, and the other a one-half-ton closed pickup truck. Both vehicles are equipped with the necessary safety devices for explosives' handling.

LEASED FACILITIES

(Presently being utilized by Reaction Motors Division of Thiokol Chemical Corporation)

TEST AREA "A"

Eight test stands constructed of reinforced concrete walls and corrugated metal roofs designed primarily for the purpose of testing liquid propellant rocket engines up to 10,000-lb-thrust turbine pumps, and other rocket motor components. Firings are nominally horizontal with engine attached to reinforced concrete block mount. Behind the firing mounts and separated from the firing bay by concrete walls, are fuel tanks and oxidizer tanks in separate bays. Tank capacity varies from 250 gal up to 3200 gal subject to periodic modifications by the tenant contractor. Firings are viewed directly from control rooms through armored glass windows. Each stand has separate control and instrument rooms designed and wired to accommodate oscillograph, circular chart, and strip-chart recorders for determination of rocket engine performance.

TEST AREA "B"

Two test stands, one a double-bay stand and the other a variable attitude test stand, are designed for testing liquid propellant rocket engines. The double-bay stand is of reinforced concrete construction with one bay set up for model and full-scale liquid propellant catapult testing and the other bay suitable for rocket firings up to 15,000-lb-thrust.

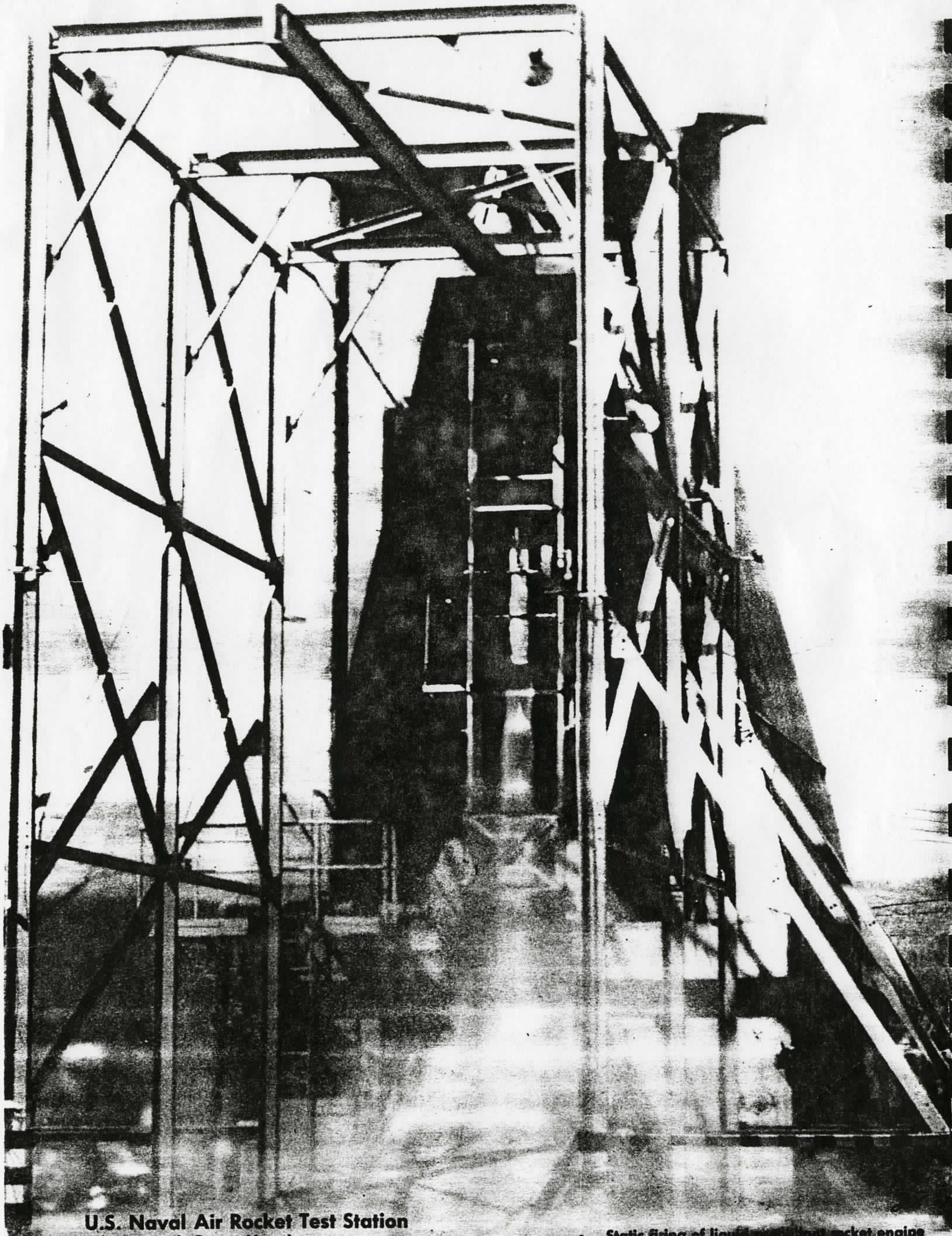
One control room, containing working space and instrumentation, separates the two bays. Propellant tanks are located at the ends of each bay, suitably protected by reinforced concrete walls. The variable attitude test stand is suitable for rocket firings up to 20,000-lb-thrust in any attitude from vertical to horizontal. The stand has a reinforced concrete base containing four tank rooms. Over this is a rotating beam which can be used to test missile power plants or rocket engines in various attitudes. A nearby concrete blockhouse contains instrumentation while the control room is located approximately 200 ft away in a protected dugout.

TEST AREA "C"

This area includes three double-bay concrete stands designed primarily for the purpose of testing liquid propellant rocket engines up to 15,000-lb-thrust. Firings are nominally horizontal with engine attached to reinforced concrete block mount. The cells are constructed in pairs with a control and instrument room between each pair of cells. Fuel and oxidizer tanks are installed at the end of each cell, separated from the firing bays by concrete wall. Tanks of varying sizes are installed periodically to meet the requirements of the test work in progress. Recording instrumentation is also varied as dictated by test requirements.

Ammonia Storage—An ammonia storage facility is installed in Area "C" consisting of a 13,000-gal (66,040 lb) horizontal steel tank housed in a corrugated structure. Working pressure is 220 psi.

Nitrogen Storage—Leased high-pressure gasification equipment supplies nitrogen gas at 2000 psia for pressurization of tanks to all test areas through a network of underground pipes. A cascade made up of 135 eight cubic ft high-pressure gas storage bottles provides gas used in Areas B, C and D.



U.S. Naval Air Rocket Test Station

- **Lake Denmark, Dover, New Jersey**
- **Static firing of liquid propellant rocket engine**