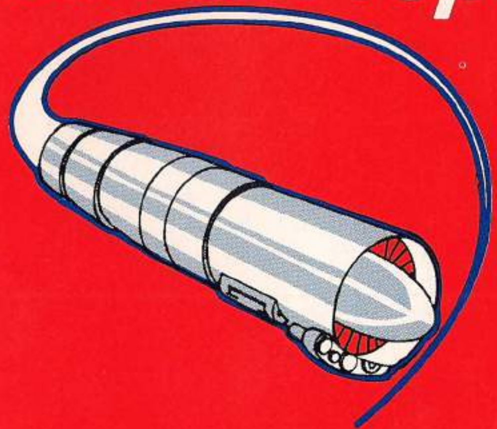
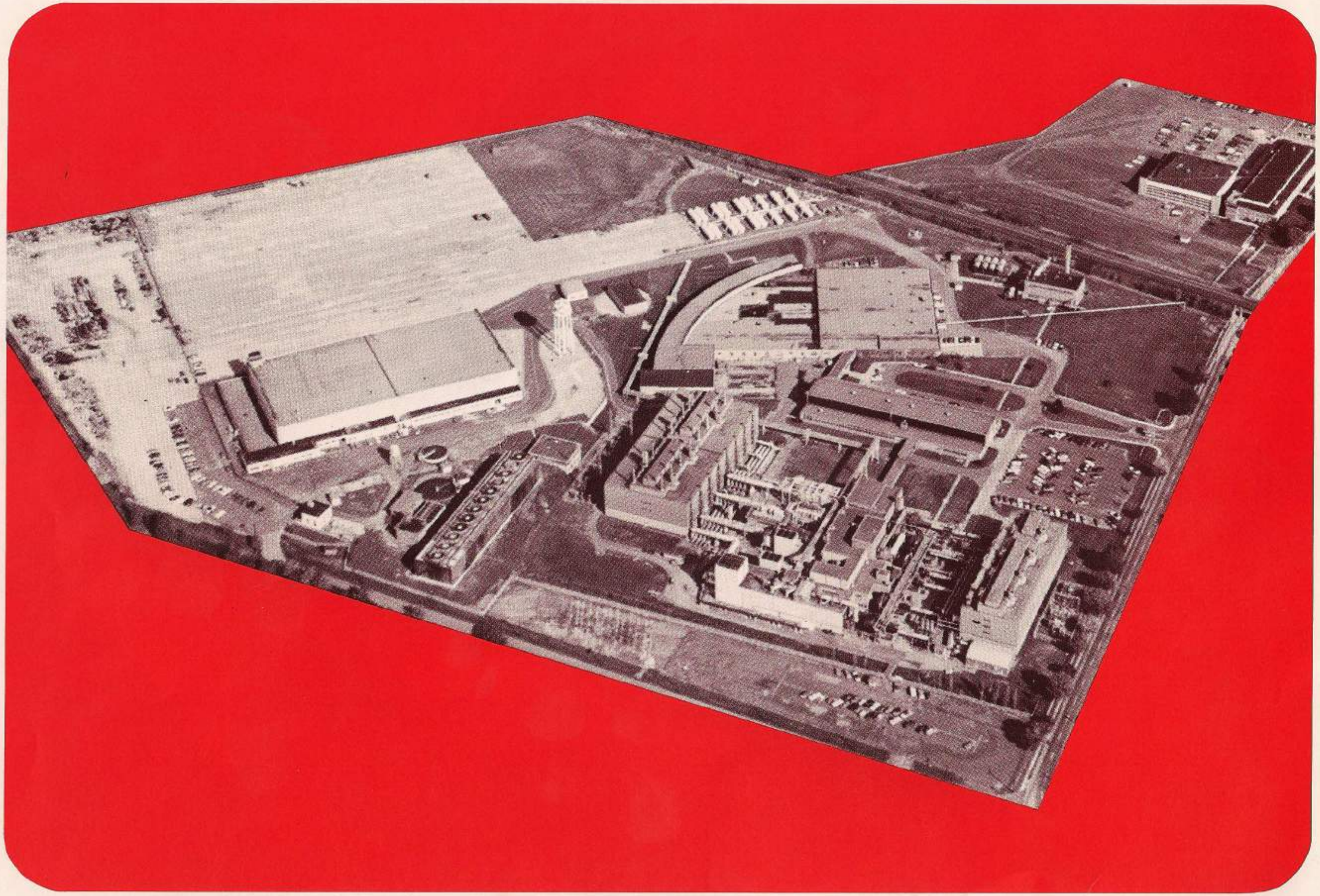
Naval Air Propulsion Test Center

TRENTON NEW JERSEY





Foreword

IN today's world of intercontinental ballistic missiles, satellites, and space flight, the manned aircraft is still a vital part of our national security, and will be for many years to come. The availability and performance excellence of our manned Naval aircraft depend upon reliable, high performance propulsion systems. The Naval Air Propulsion Test Center (NAPTC) serves the Navy's requirements for the test and evaluation of aircraft propulsion systems. The key to the successful development of a new engine is testing - laboratory, as well as flight testing, and both in quality and quantity. The more nearly laboratory testing simulates the flight environment, the less the risk and cost of the flight program.

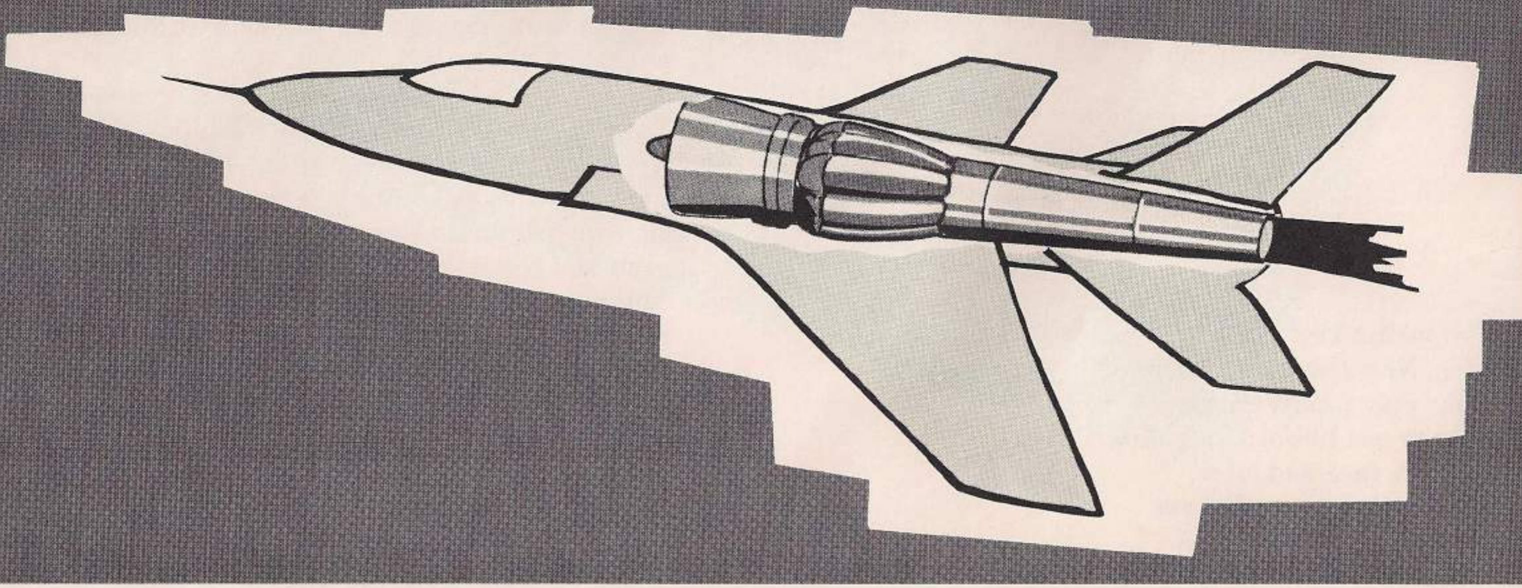
Today's NAPTC facilities have evolved through two world wars and many eras of development. During this time, the constantly changing requirements of the Navy air weapons systems have always been met. The equipment and specialized experience available at this facility continue to assure the dependability and performance excellence of our manned naval aircraft, and are also available in support of other government departments, agencies, and Department of Defense contractors.

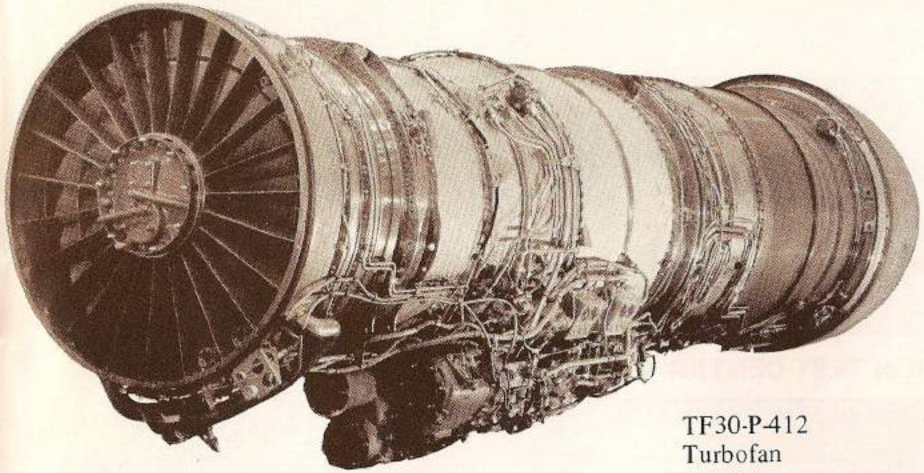
This booklet is a brief description of the facilities and capabilities of the Naval Air Propulsion Test Center and how it contributes to our national security and to the advancement of aircraft propulsion systems.

The Naval Air Propulsion Test Center is located in Trenton, New Jersey on 67 acres of land. NAPTC is the only facility having a range of capability to test turbojet/turbofan, turboprop/turboshaft, fuels and lubes, accessories, piston engines, propellers and helicopter transmissions under sea level, altitude and environmental conditions.

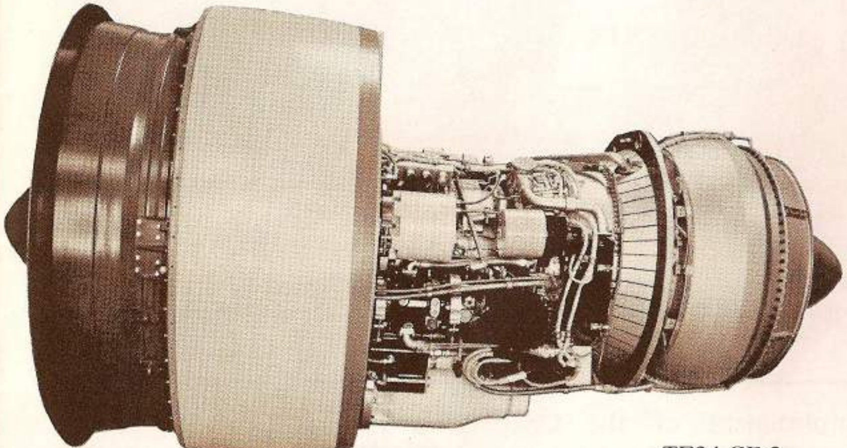
MISSION

TO TEST AND EVALUATE AIRCRAFT PROPULSION SYSTEMS, THEIR COMPONENTS, ACCESSORIES, FUELS AND LUBRICANTS AND TO PERFORM APPLIED RESEARCH AND DEVELOPMENT LEADING TO CORRECTION OF DESIGN DEFICIENCIES AND SERVICE PROBLEMS.

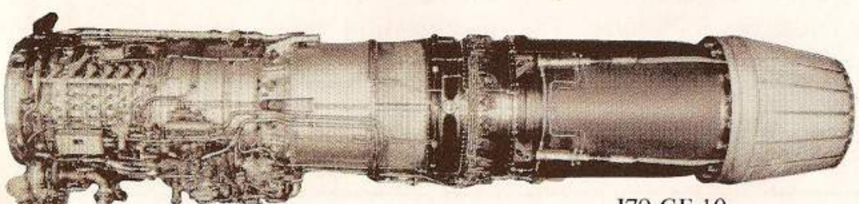




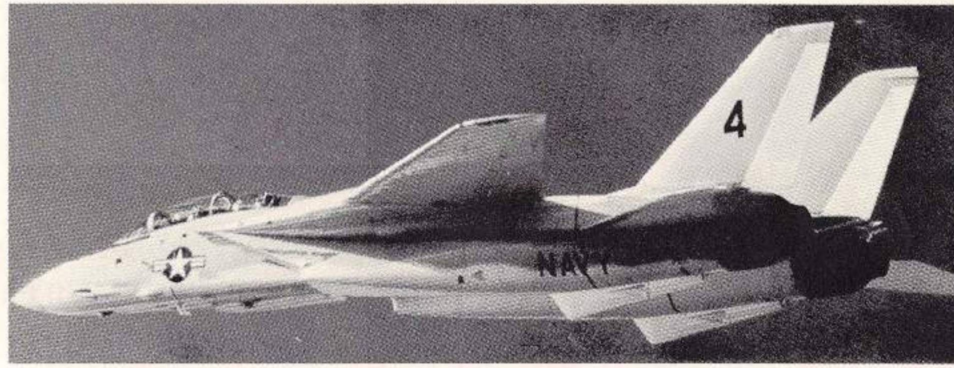
TF30-P-412
Turbofan
Engine



TF34-GE-2
Turbofan
Engine

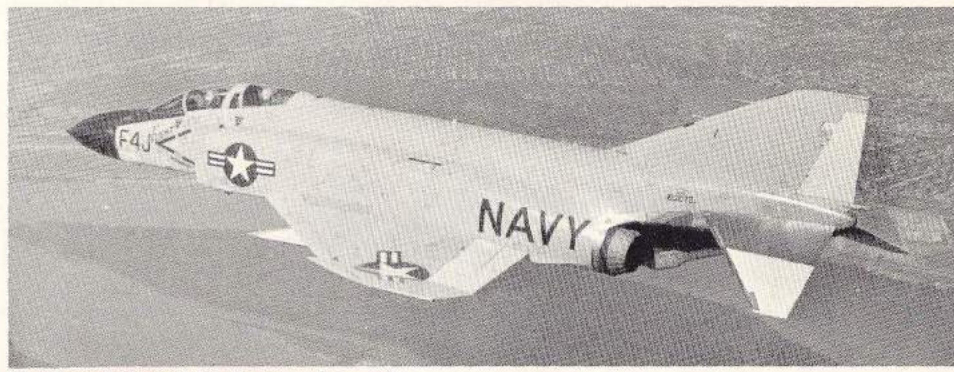


J79-GE-10
Turbojet
Engine



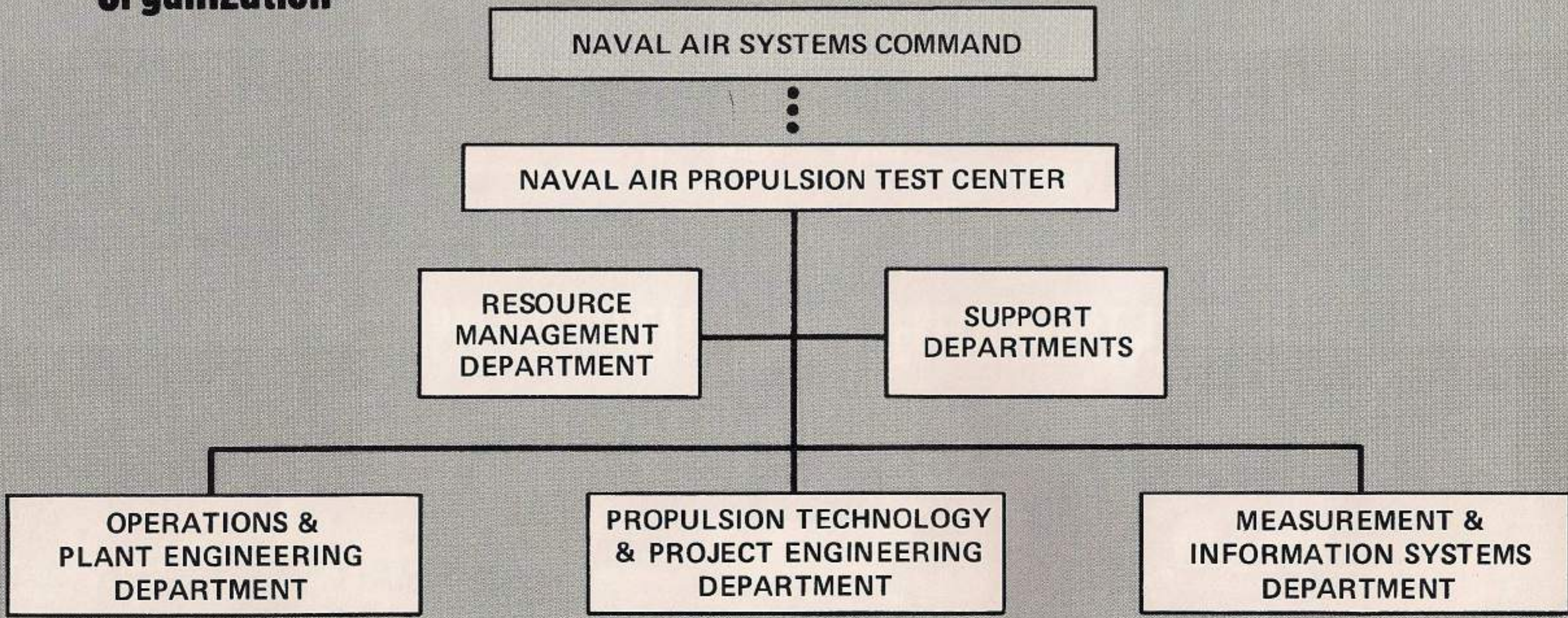
F-14A TOMCAT Fighter Aircraft

S-3A VIKING ASW Aircraft

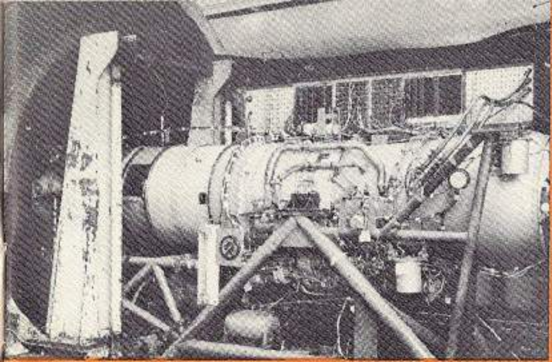
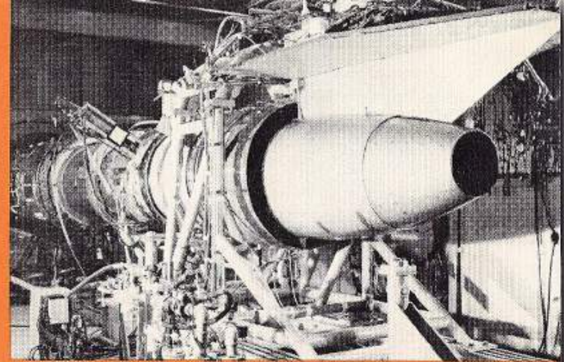


F-4J PHANTOM II Fighter Aircraft

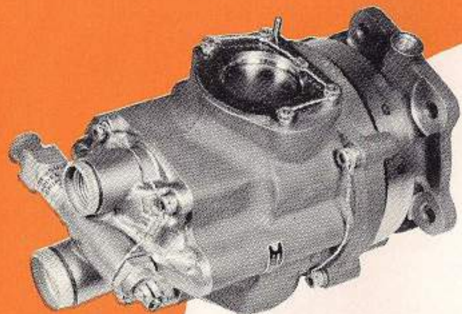
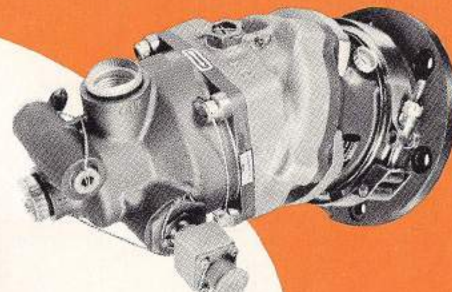
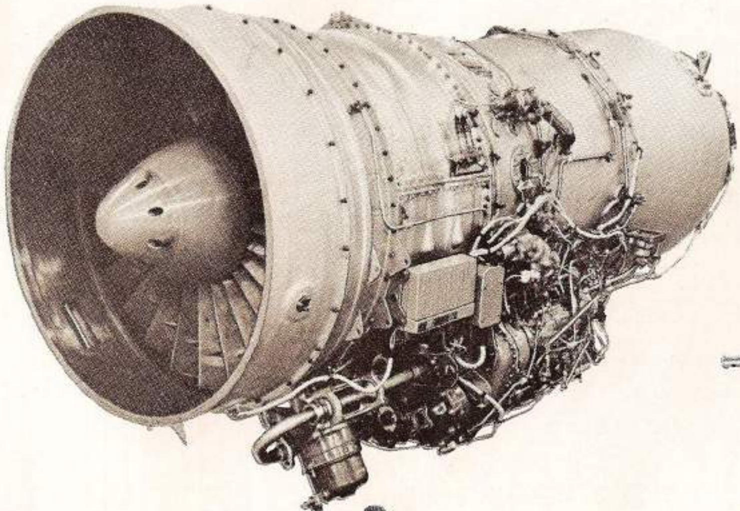
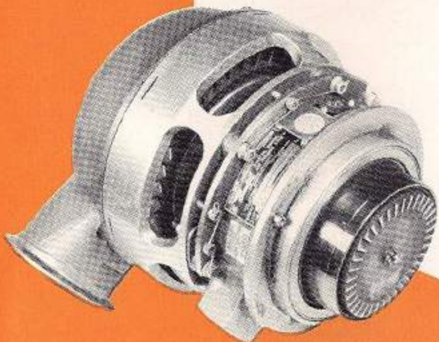
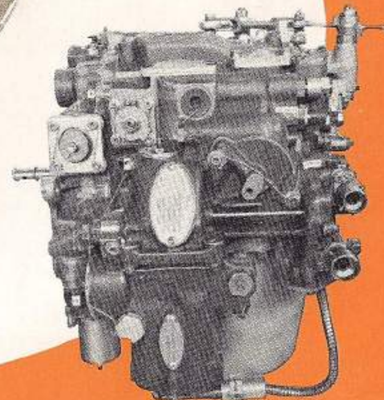
Organization

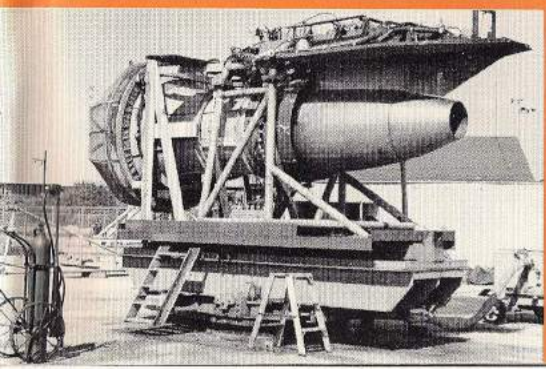
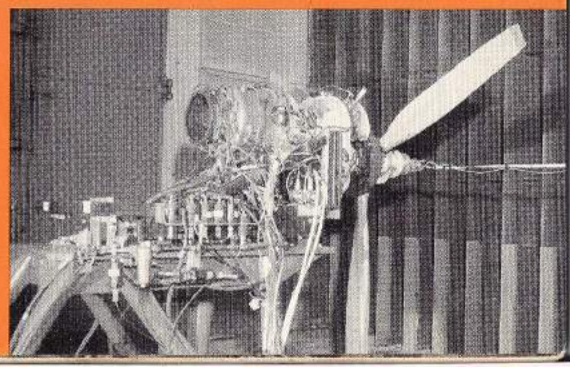


The organization at the Propulsion Test Center utilizes the normal shore station supporting departmental structure, with the addition of three operating departments; Operations and Plant Engineering Department, Measurement and Information Systems Department, and Propulsion Technology and Project Engineering Department. These departments are directly responsible for the accomplishment of the Center's assigned mission. The work force is comprised of 690 civilians and 9 Naval officers; approximately 75% of these people are assigned to the three operating departments while the rest perform supporting functions. The organization includes 180 professional engineers, scientists and mathematicians.

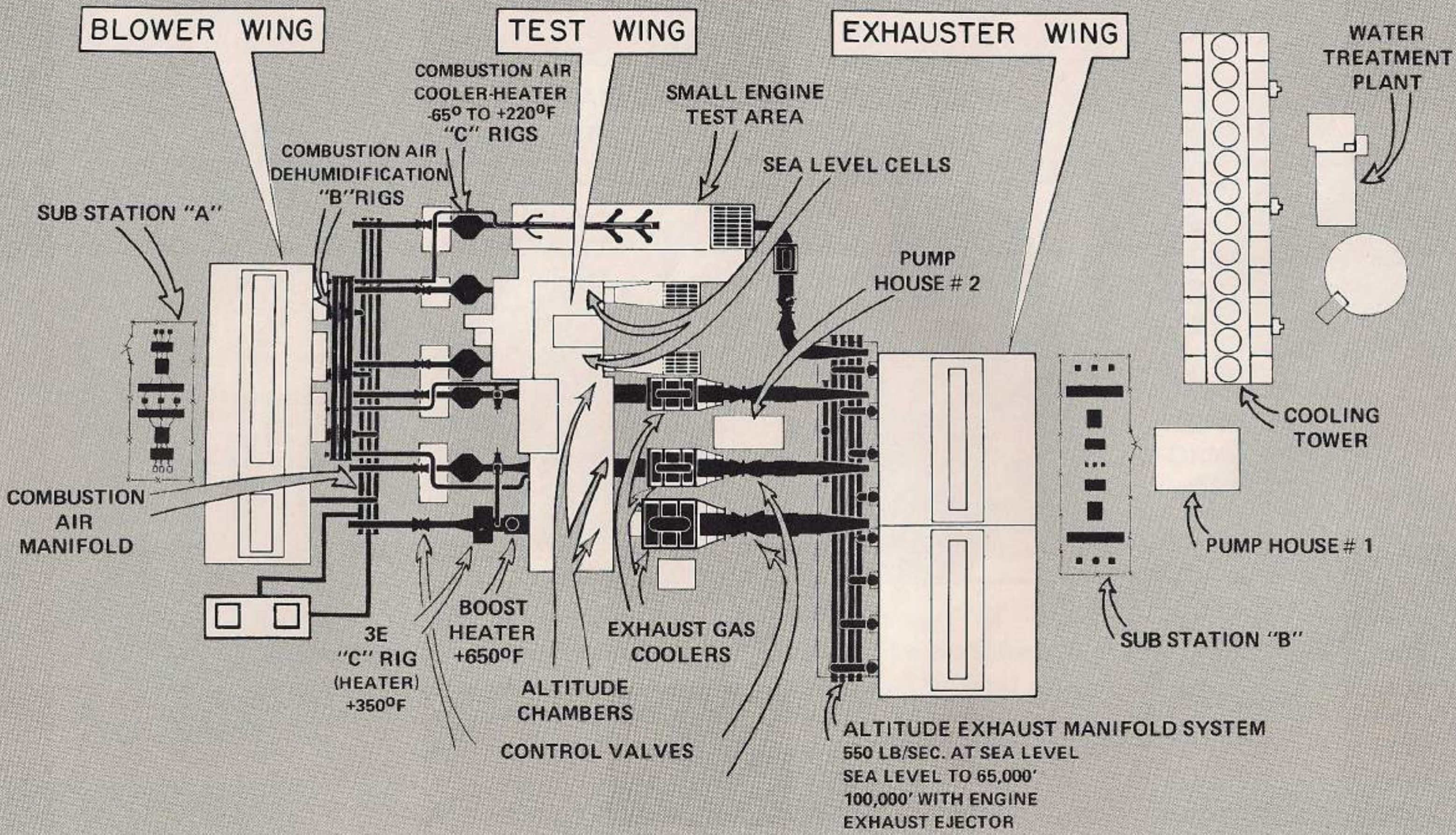



Total Product

Test Facility Schematic



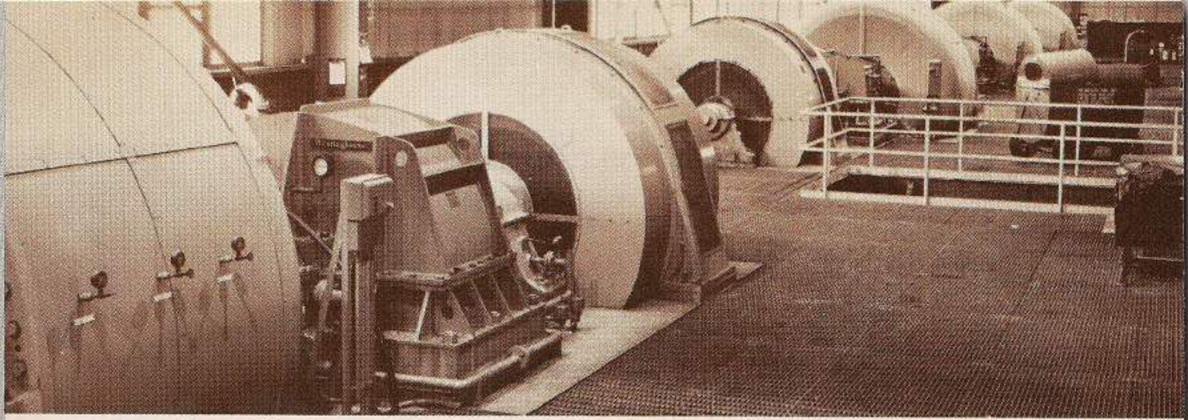
Test Facility

The engine test facility (opposite page) can be divided into three main divisions: the Blower Wing, the Test Wing, and the Exhauster Wing.

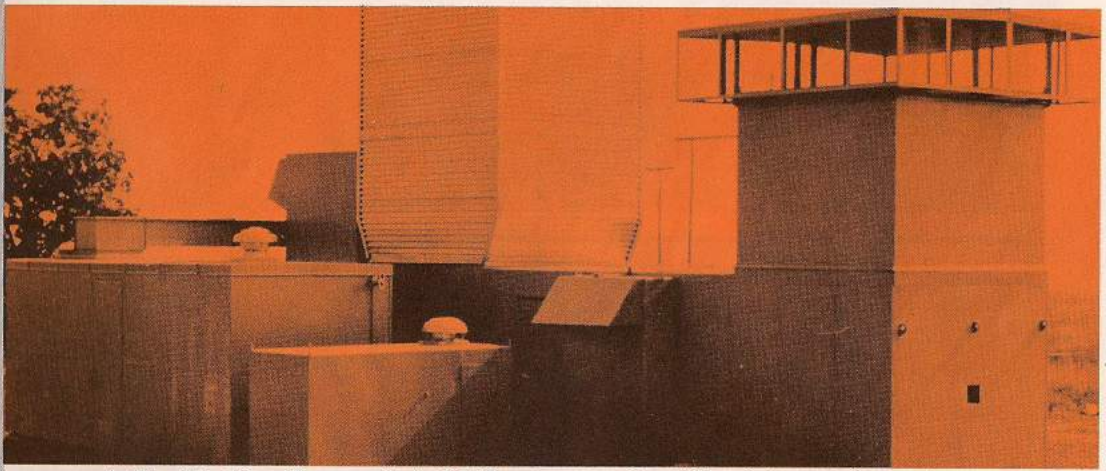
THE BLOWER WING contains centrifugal air compressors and air conditioning systems which provide air to the test engine under the same conditions experienced by an aircraft in flight. Four 6,000 horsepower centrifugal blowers, one turbine powered axial compressor, 5,000 tons of refrigeration, and an oil-fired indirect air heater are utilized to provide air flows up to 710 pounds per second at pressures up to five atmospheres and at air temperatures ranging from -65°F to +650°F. With these inlet conditions to the engine, the Center can simulate flight velocities up to three times the speed of sound.

THE TEST WING contains nine test cells and their associated control rooms. Three of these cells are large altitude chambers, four are small altitude chambers for turboprop/turboshaft/auxiliary power unit testing and two are large sea level test cells.

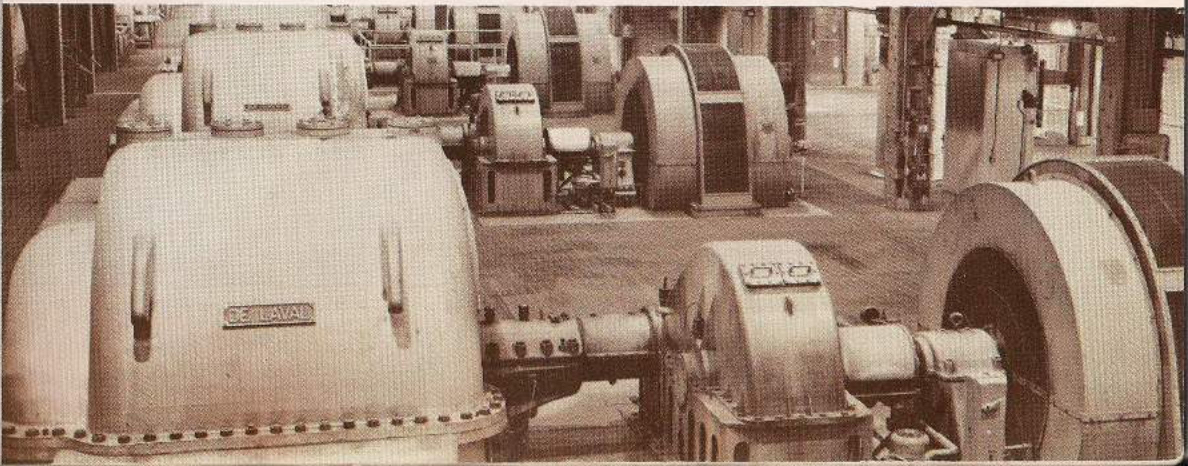
THE EXHAUSTER WING contains the air pumping machinery required to produce low pressure in the altitude test cells. Fourteen of these pumps with a combined power of 56,000 horsepower are utilized in conjunction with Test Chamber exhaust ejectors to simulate altitudes up to 100,000 feet.



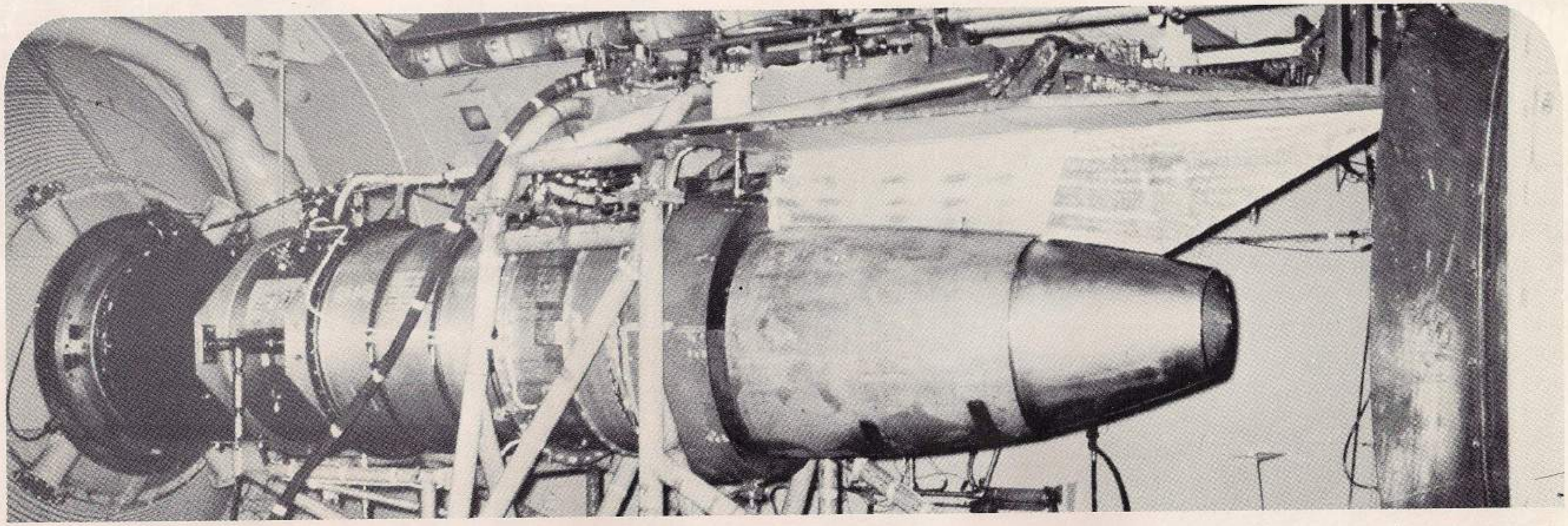
Centrifugal Air Compressors furnish ram air to test chambers.



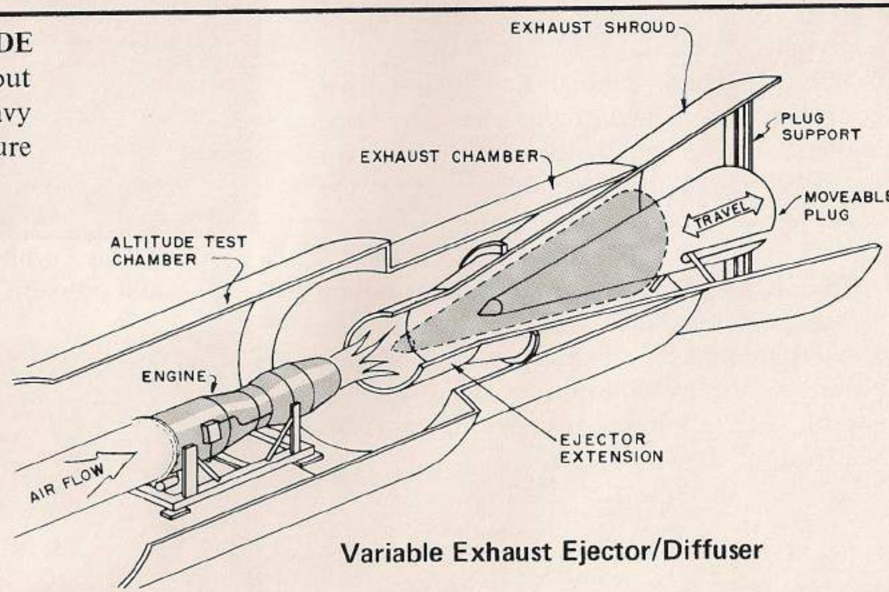
A Gas Turbine Powered Axial Compressor is utilized to supplement and pressure boost the ram air output from the Centrifugal Air Compressors.



Exhausters - Variable Speed Compressors remove exhaust gases and produce low pressure in the altitude test cells.



Test engine installed in the large **3E ALTITUDE CHAMBER.** Performance can be evaluated throughout the entire operating envelope for any existing large Navy turbojet/turbofan engine or those planned for future applications.

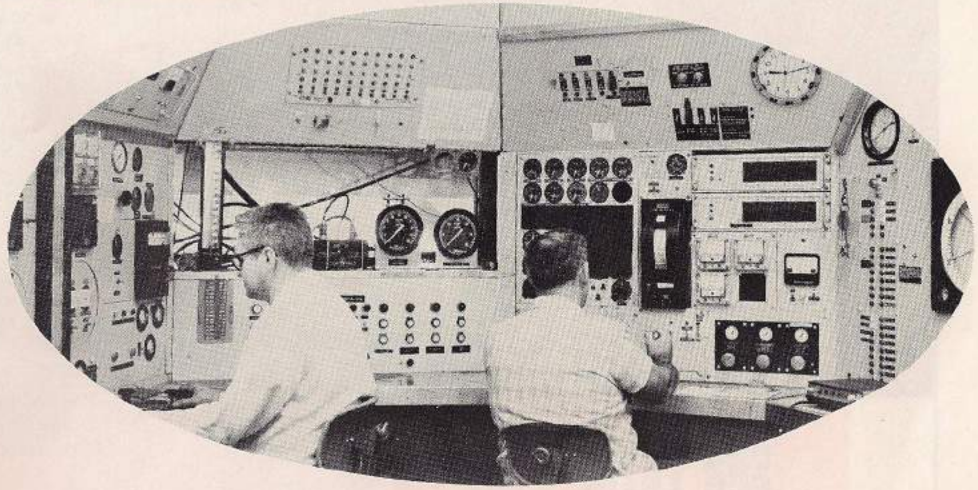


Variable Exhaust Ejector/Diffuser

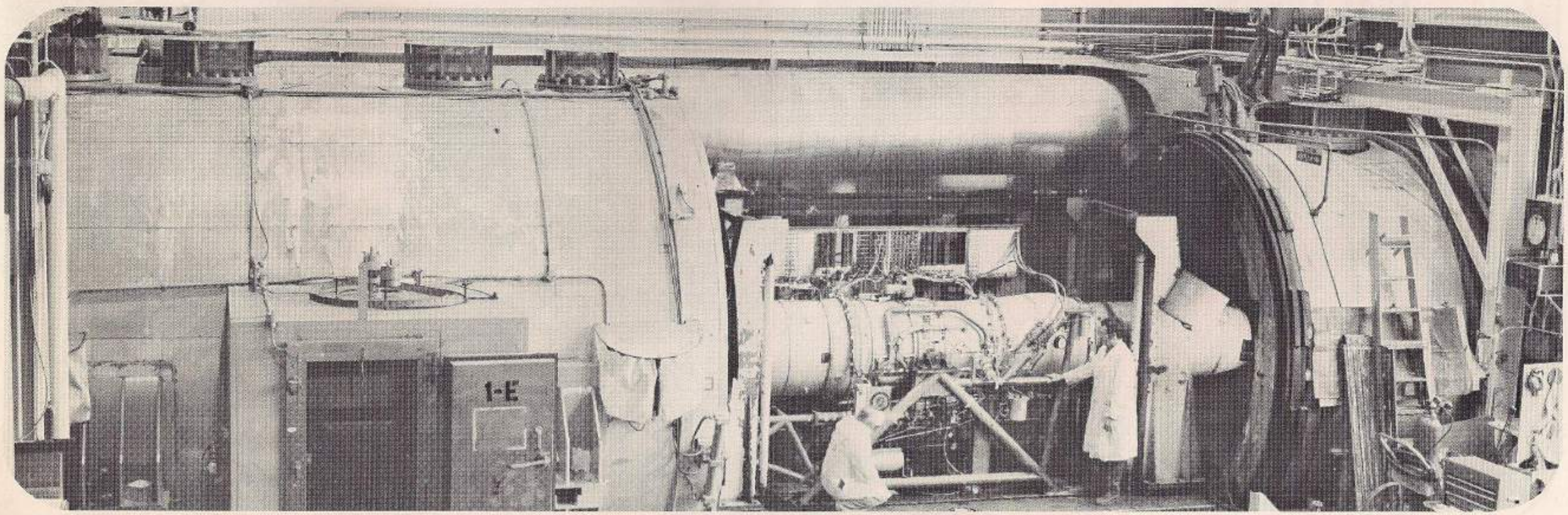
Schematic illustration showing 3E Altitude Chamber variable exhaust ejector/diffuser. Through the use of variable geometry equipment, altitude testing capability is enhanced and performed with greater efficiency and flexibility.

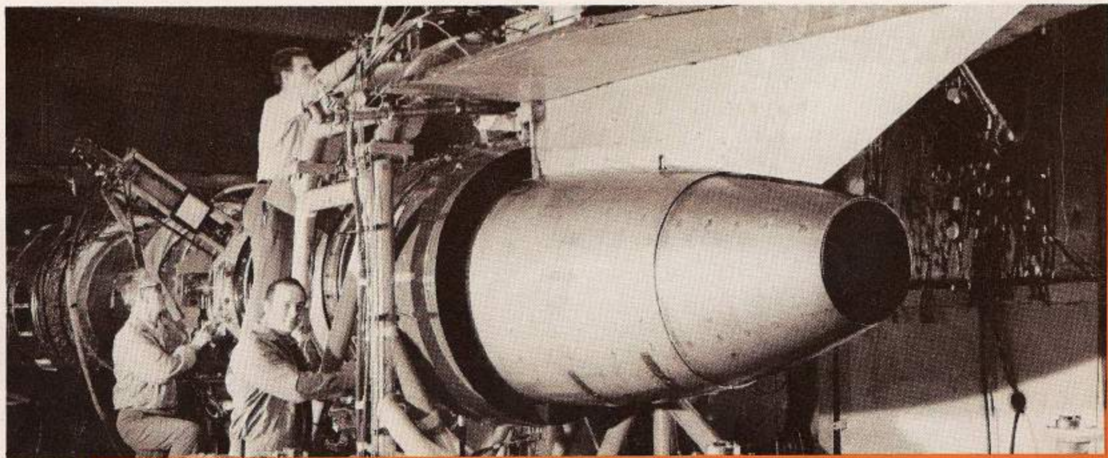
Altitude Chambers

The test cell control rooms contain complete instrumentation to monitor all phases of engine performance.



1E ALTITUDE CHAMBER with Navy Model TF41 engine installed. Engine sea level and altitude performance evaluations, altitude icing, water ingestion, starting, and other miscellaneous tests can be performed in this chamber.

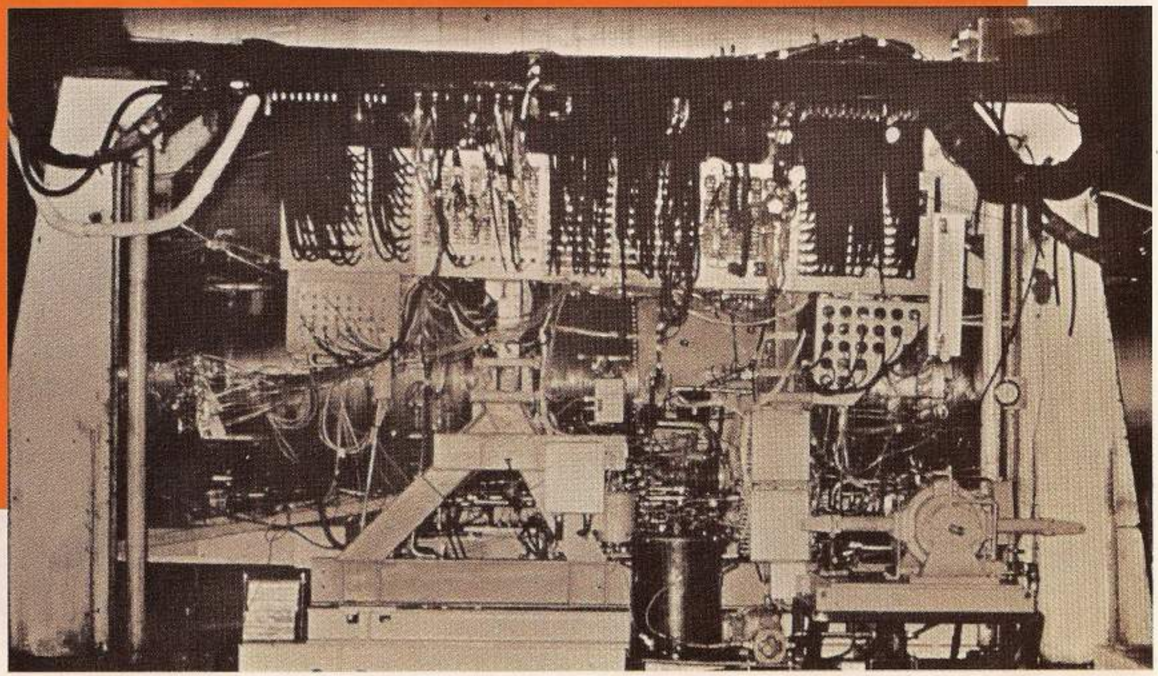


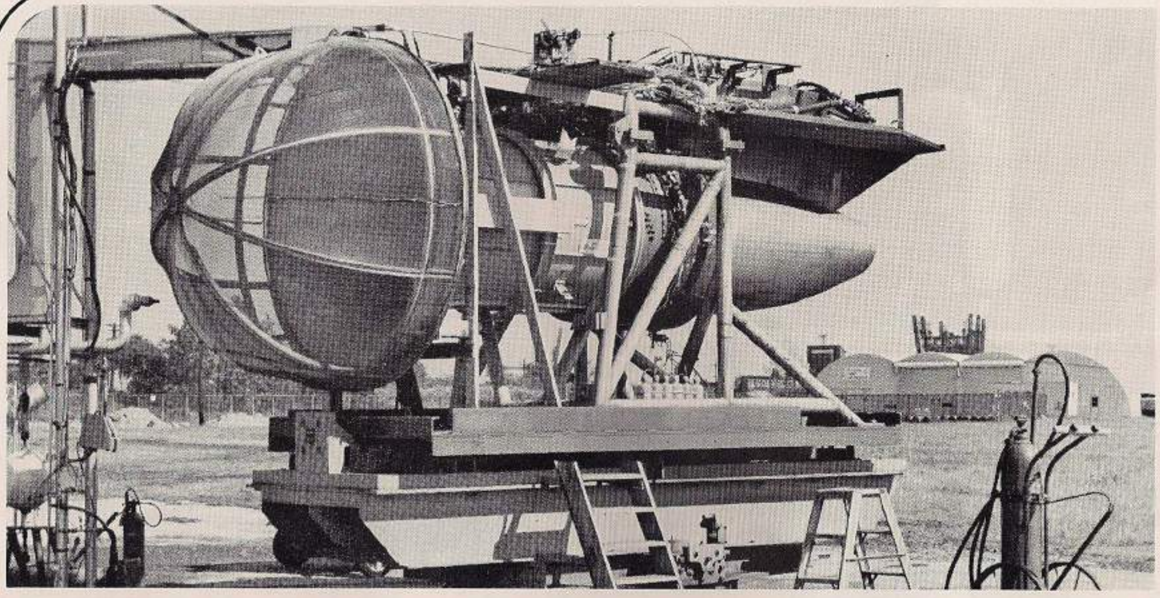


S-3A aircraft, TF34 engine undergoing icing tests in 1W sea level test chamber.

Sea Level Test Facilities

Engine instrumentation is standardized in all test chambers to provide quick disconnect couplings which mate with quick disconnect panels on the engine test stand. This is a unique capability which increases cell utilization by reducing engine installation and removal times.

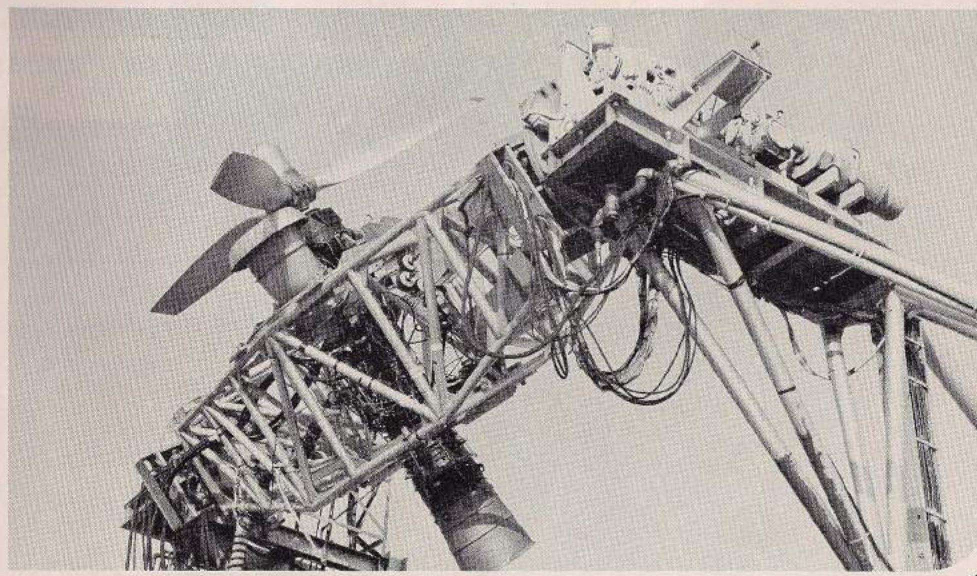




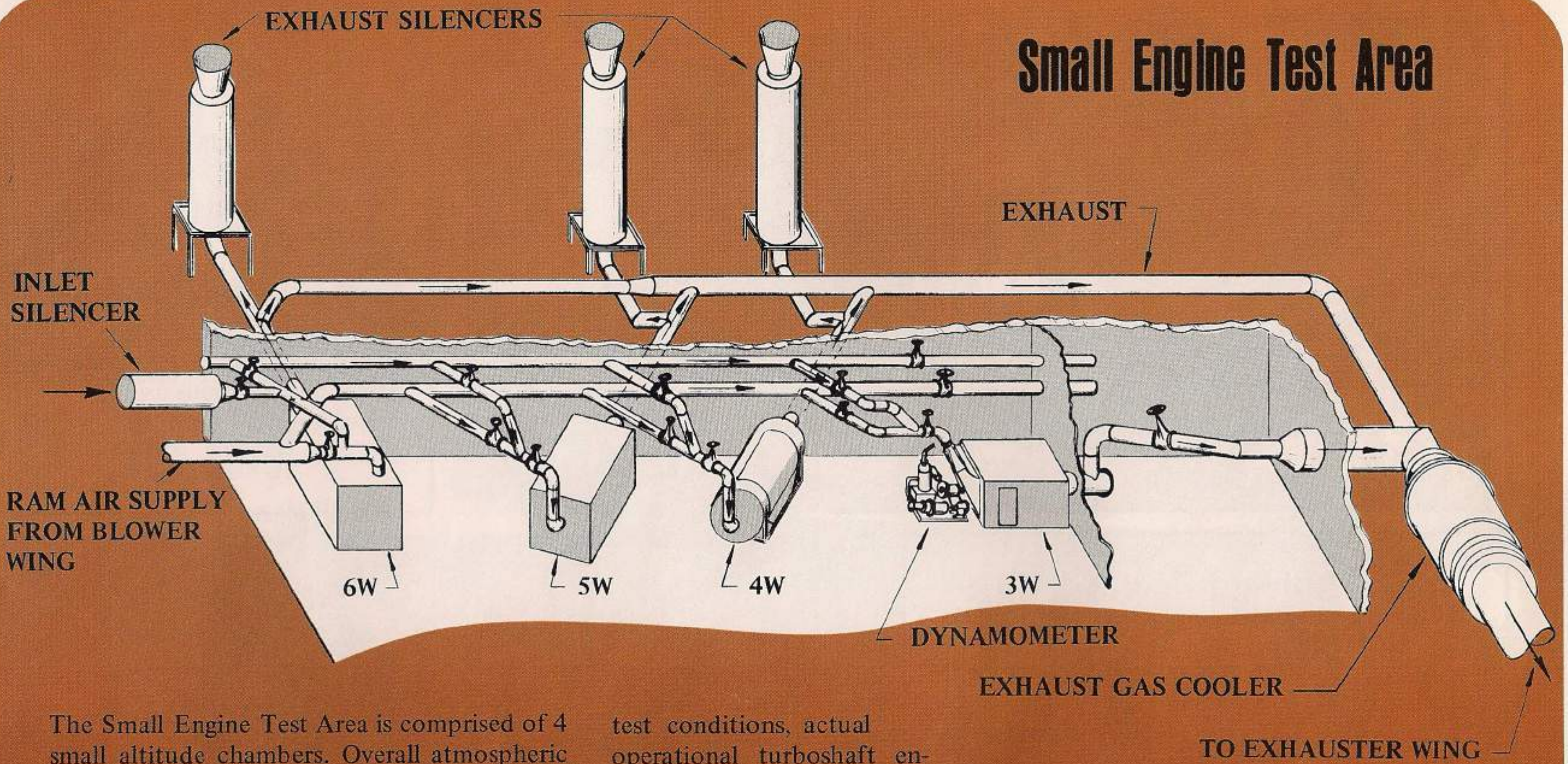
This outside engine test stand is used for turbojet/turbofan engine free air stream performance evaluations; smoke and pollution measurements; sound measurements and noise abatement investigations; infra-red studies and humidity effect investigations using actual aircraft hardware.

Outside Test Facilities

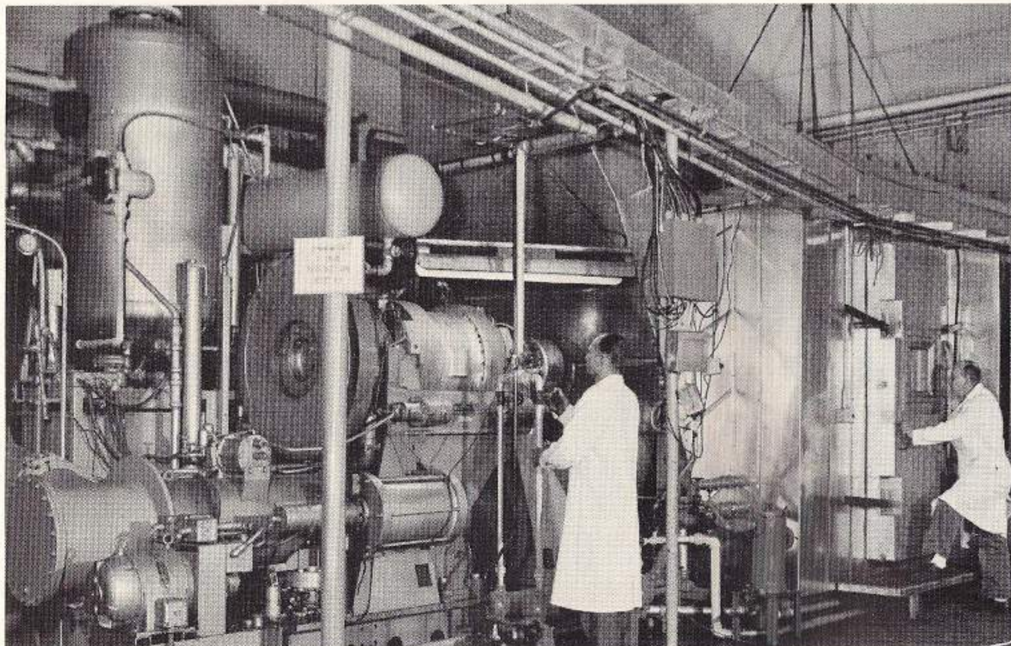
The variable altitude test stand will accommodate engines up to 12,000 horsepower or 50,000 pound thrust and will rotate them from 105 degrees nose up to 45 degrees nose down. The actual hardware has been used to test the T64 engine through its operating attitude design limits. It may be used to test the coming VTOL engines.



Small Engine Test Area



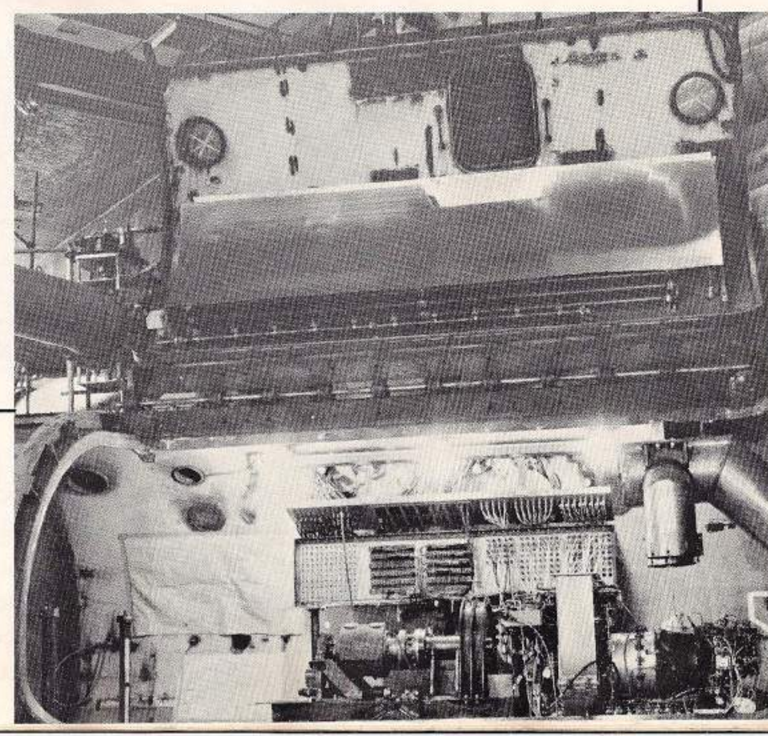
The Small Engine Test Area is comprised of 4 small altitude chambers. Overall atmospheric test capabilities and chamber dimensions are provided on Page 27. Small turbojet/turbofan and turboshaft engines, ground support gas turbine power units and related turbine engine accessories such as turbine engine starters, generators, pumps, etc., can be tested. In addition to simulating atmospheric test conditions, actual operational turboshaft engine loads can be simulated through the use of either a dynamometer or water brake. A unique Center capability is the ability to separately test engine accessories under simulated altitude and atmospheric conditions through the use of an external 300 horsepower drive system.

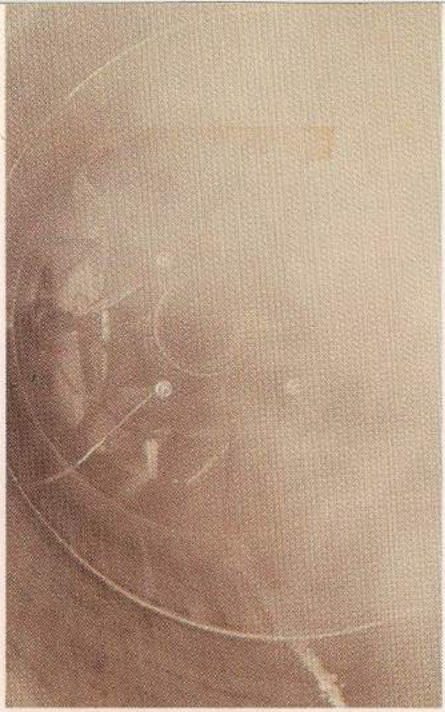


SMALL ENGINE ALTITUDE TEST CHAMBERS

Since the Center also works with shaft power engines as well as jet engines, power absorbing devices such as dynamometers, water brakes, and propellers are required.

Here is a view of a 6,000 horsepower capacity dynamometer in the 3W altitude test chamber (above) and a typical water brake installation in the 4W altitude test chamber.





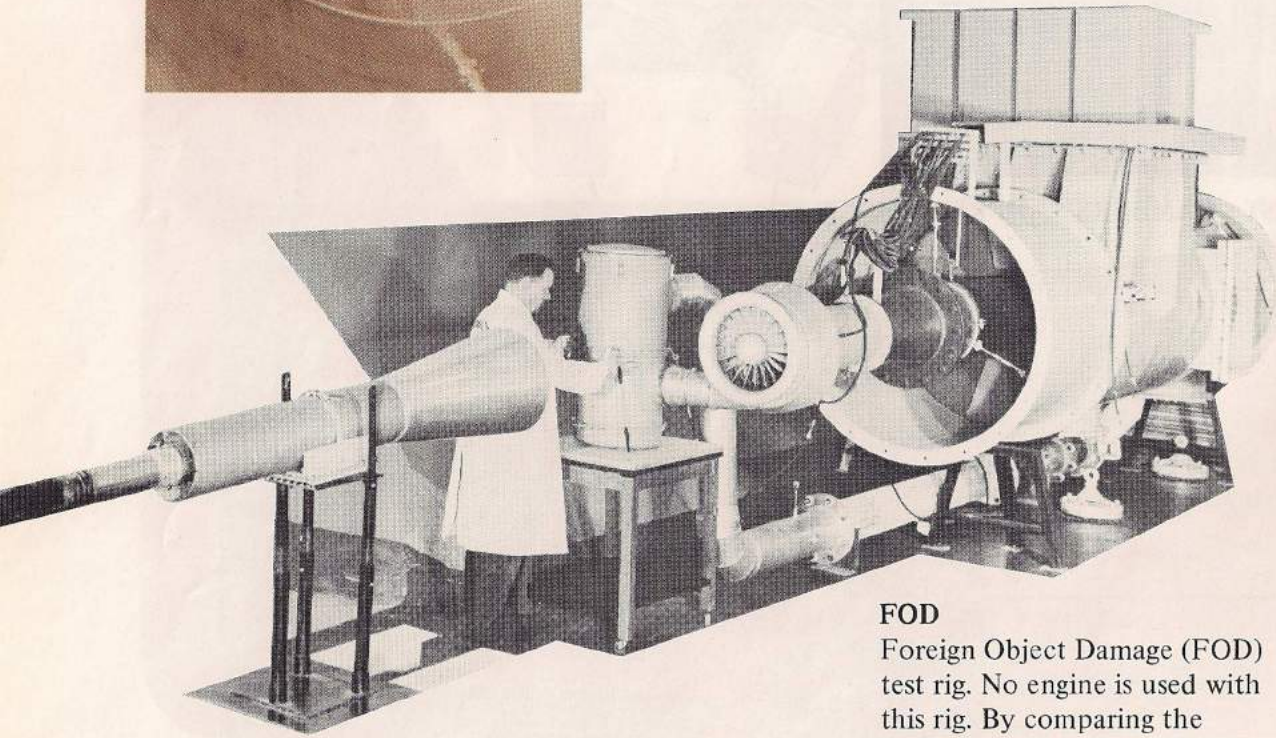
CORROSION

The Salt Corrosion Test Facility permits testing of turbojet and turboshaft aircraft engines under a laboratory-controlled corrosive salt air environment. Salt concentration and humidity levels can be varied to produce desired results. Engines can be operated dynamically or statically "soaked" to reproduce service-type conditions. Water brakes are used as load absorption devices. J79 and T58 Navy engines have been tested with good correlation to fleet service experience.

Environmental Testing

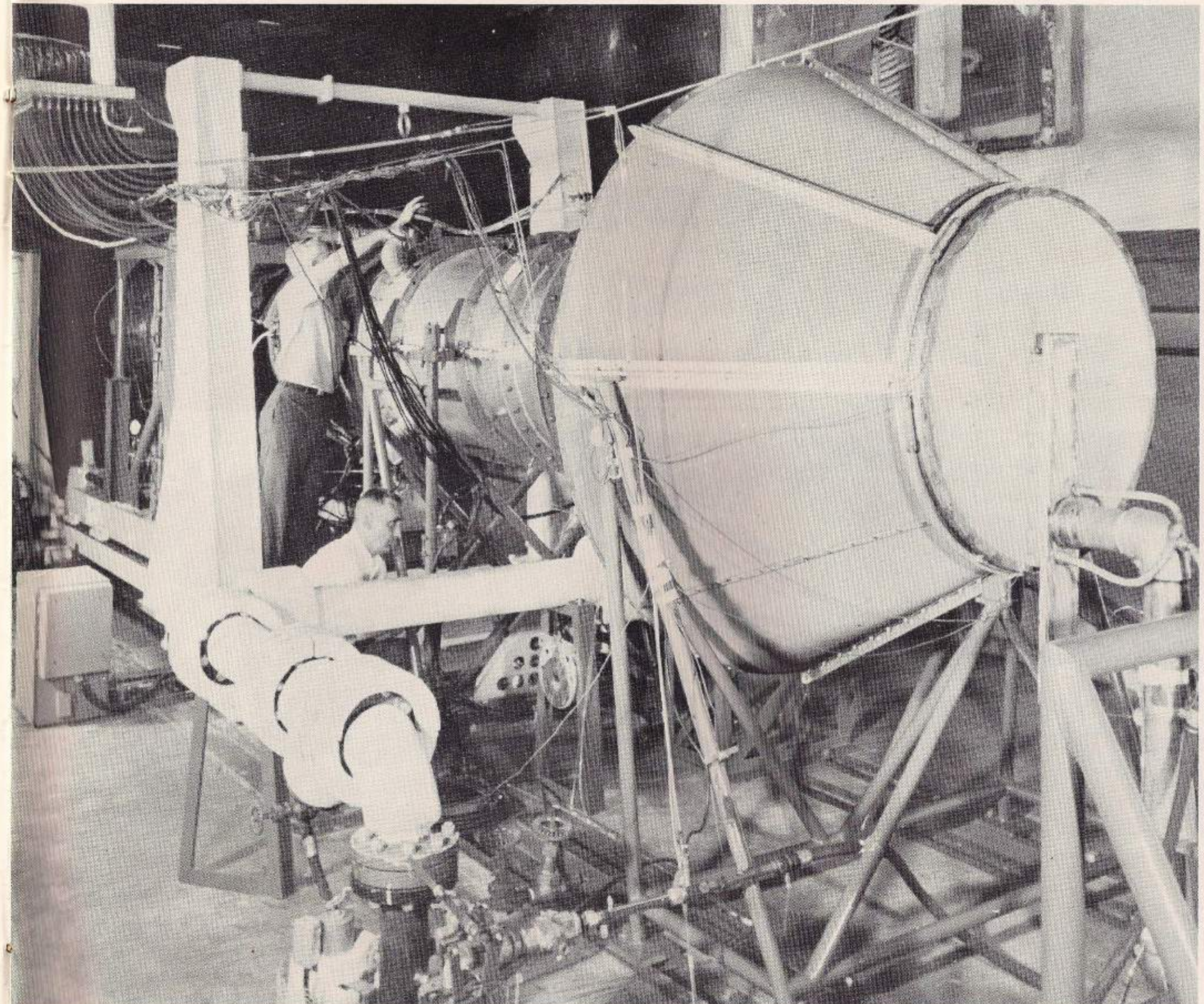
ICING

Shown here is ice accumulation on a turbofan engine inlet during icing tests. The Center can accurately simulate atmospheric icing conditions encountered in flight and evaluate anti-icing characteristics of turbojet/turbofan and turboshaft engines.



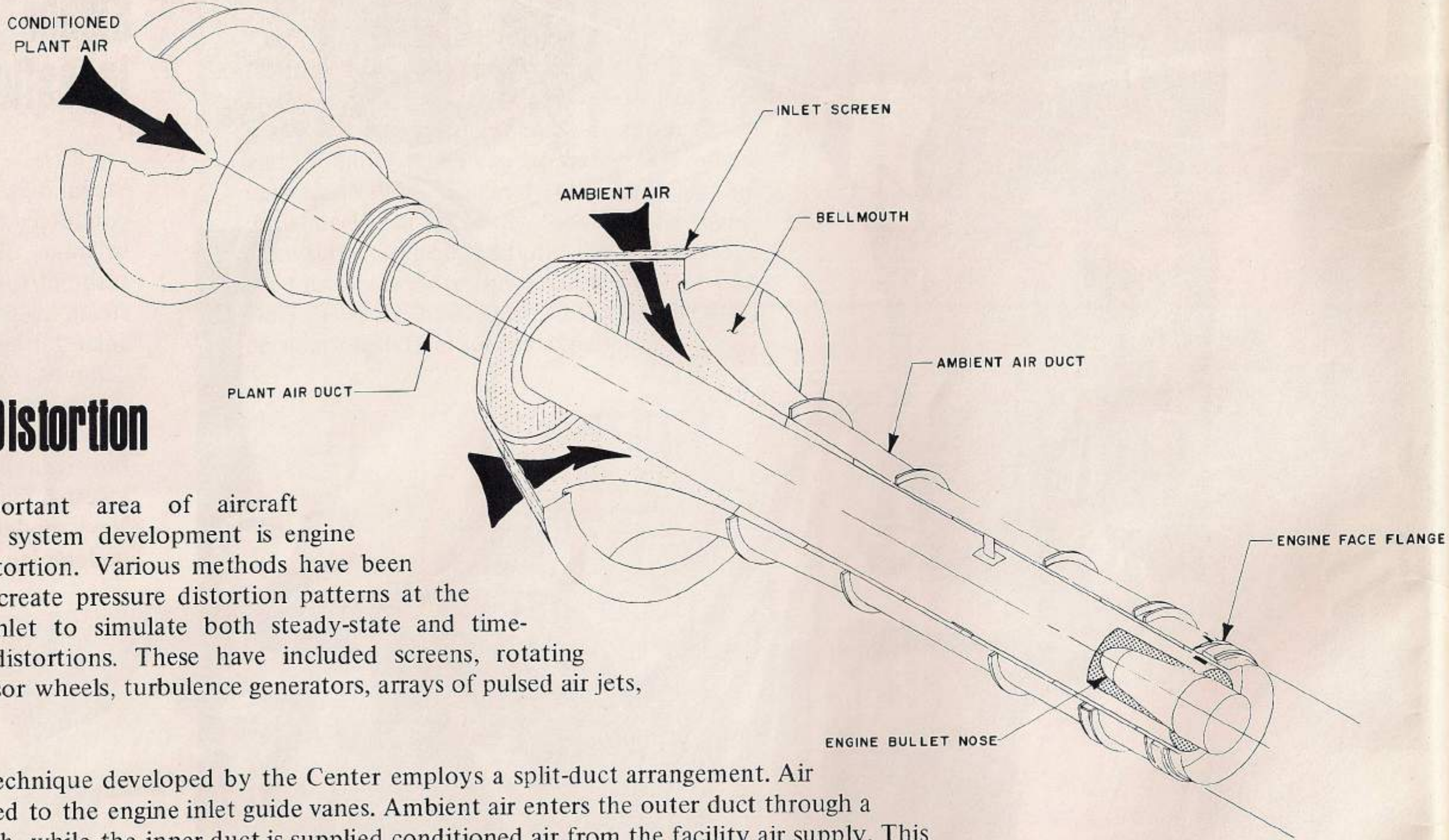
FOD

Foreign Object Damage (FOD) test rig. No engine is used with this rig. By comparing the foreign object input and output of the separator, the separator effectiveness can be determined.



Steam Ingestion

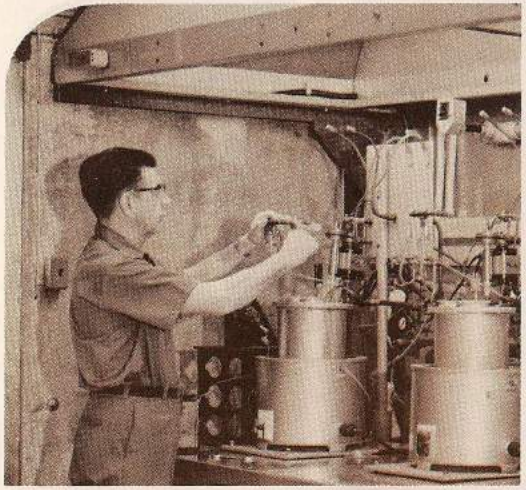
Steam ingestion tests are conducted to determine the tolerance of this turbojet/turbofan engine to steam ingested into the engine inlet during a shipboard catapult launch. If engine compressor stall occurs, various methods of increasing the engine's tolerance are investigated. Shown here is a Navy model TF30 engine undergoing tests.



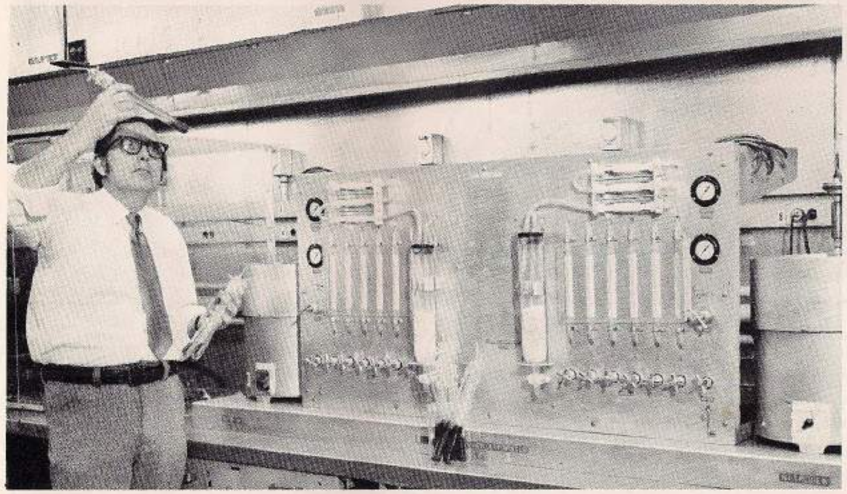
Inlet Distortion

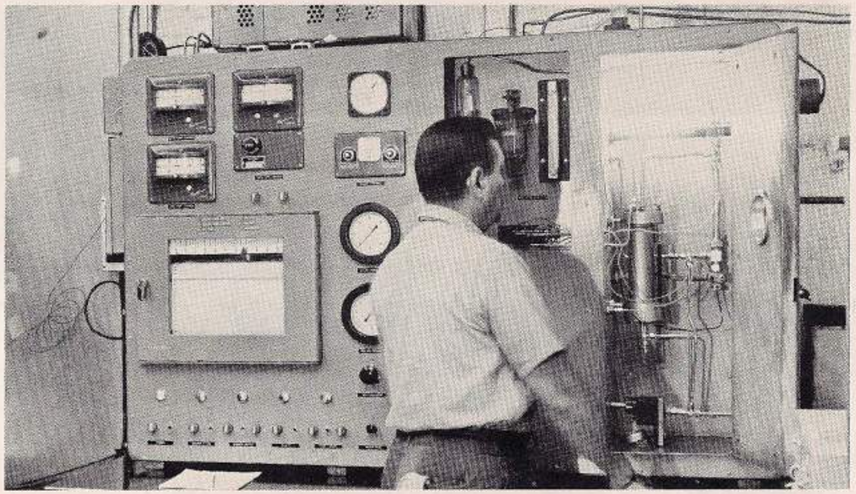
An important area of aircraft weapons system development is engine inlet distortion. Various methods have been used to create pressure distortion patterns at the engine inlet to simulate both steady-state and time-variant distortions. These have included screens, rotating compressor wheels, turbulence generators, arrays of pulsed air jets, etc.

A new technique developed by the Center employs a split-duct arrangement. Air is supplied to the engine inlet guide vanes. Ambient air enters the outer duct through a bellmouth, while the inner duct is supplied conditioned air from the facility air supply. This method allows the pressure in the inner duct to be raised or lowered above the cell ambient pressure to present a controllable, rectangular, steady-state pressure distortion pattern at the engine compressor face. The pressure is adjusted in increments until the verge of engine stall is reached. The method, therefore, does not rely on pressure drop by placing restrictions in the duct. It is also effective in producing steady-state distortion patterns with minimal turbulence. Both circumferential and radial distortion patterns can be produced with this installation.



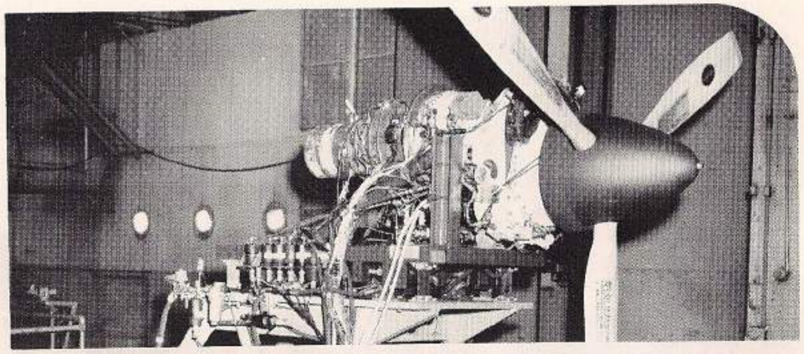
Lubes & Power Drive Systems

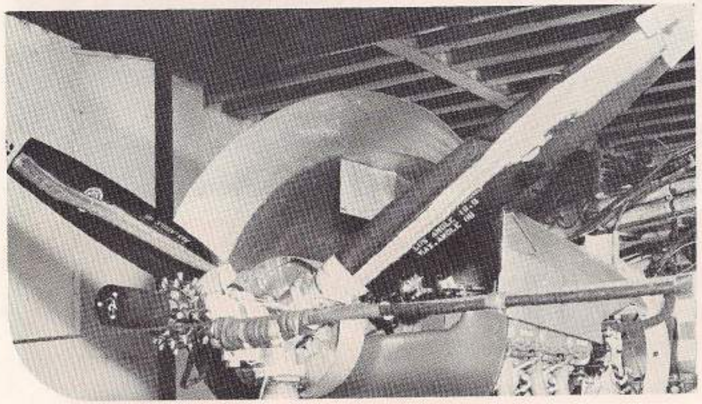




The Center conducts RDT&E programs on aeronautical lubricating oils and gearbox and helicopter transmission hardware, such as bearings, gears and seals. In addition the Center develops specifications for NAVAIR-SYSCOM; performs state-of-the-art reviews, resolves service problems and provides technical assistance to NAVAIRSYSCOM on programs concerning aeronautical lubricating oils.

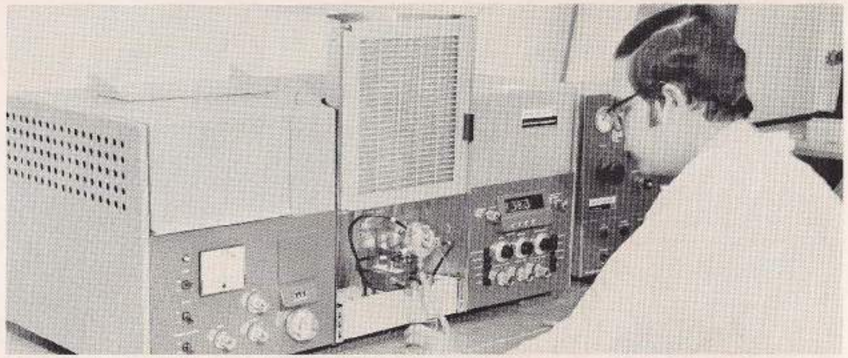
Propellers



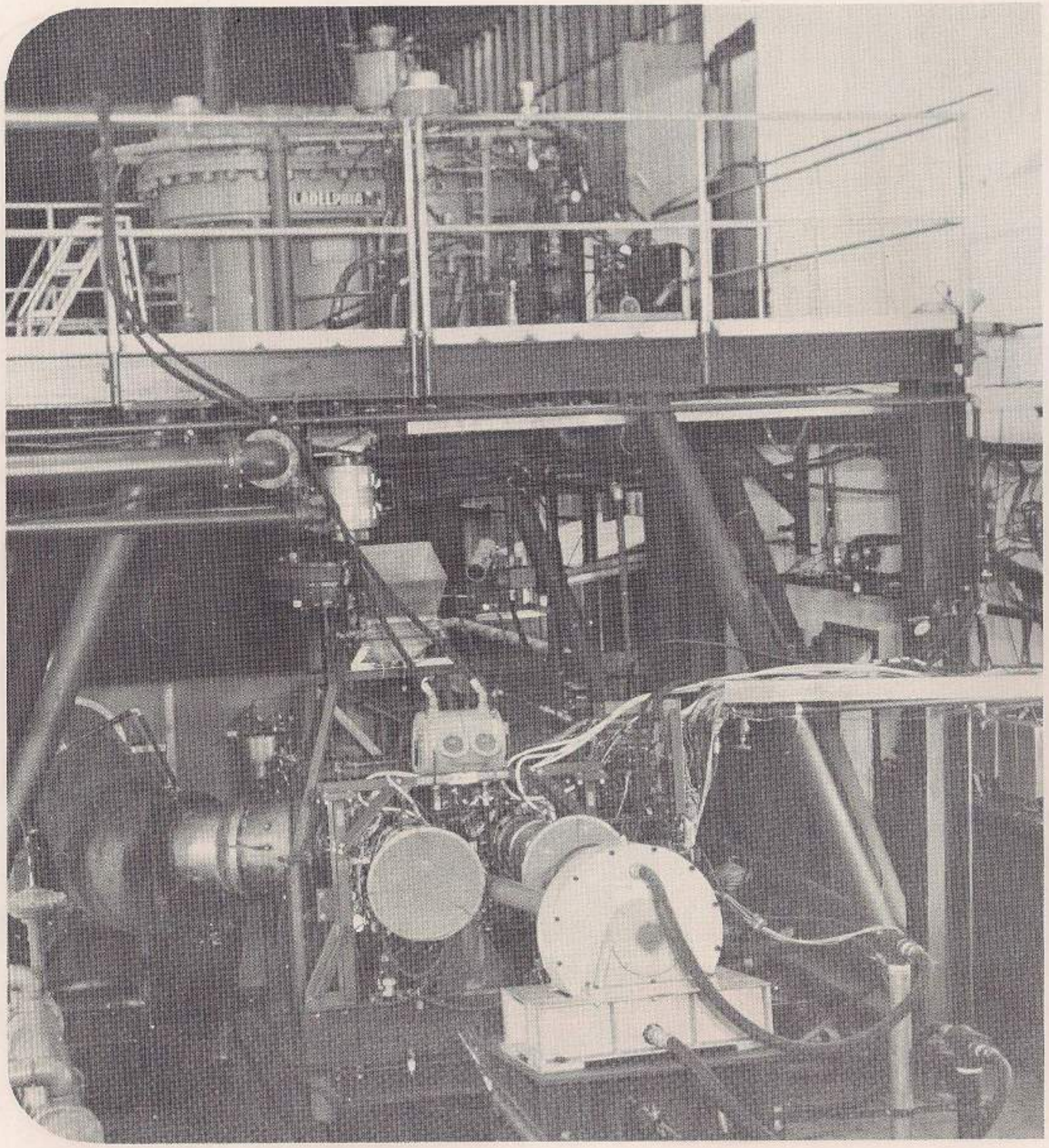


The Center is responsible to NAVAIRSYS-COM for the management of all propeller programs. Management includes product support, component improvement, service problem resolution, design, coordination with Army and Air Force, and administration of overhaul, rework and inspection processes.

Fuels



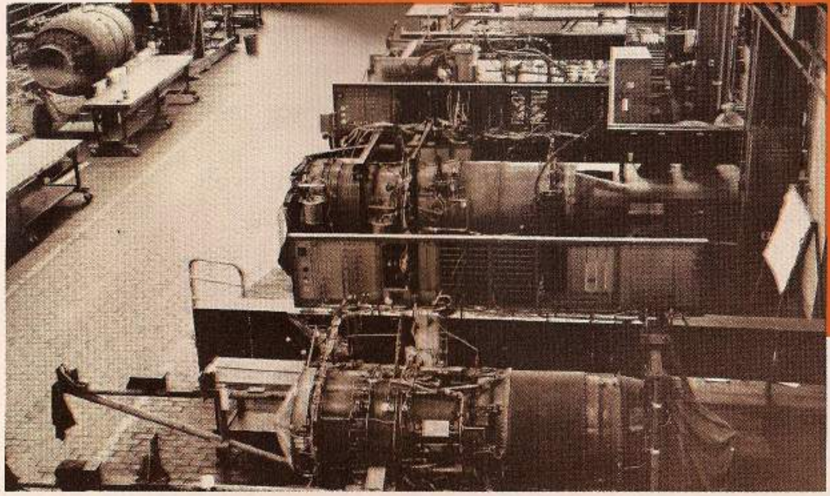
The Center conducts RDT&E programs covering fuels, ground fuel system cleanliness, fuel flammability hazards, pollution, and gas turbine engine combustion systems. Additional Center responsibilities are to develop specifications for NAVAIRSYSCOM; perform state-of-the-art reviews; resolve service problems and provide technical assistance to NAVAIRSYSCOM.



Transmission Test Facility

This facility is designed so that a helicopter main transmission and associated engines can be placed under the large step-up gear box. The 8000-horsepower capability of the gear box enables the power system of current U.S. helicopters to be tested over all power ranges. Component efficiencies, vibrations and other transient data can be recorded. Future helicopter transmissions/power train systems will be qualified in this facility.

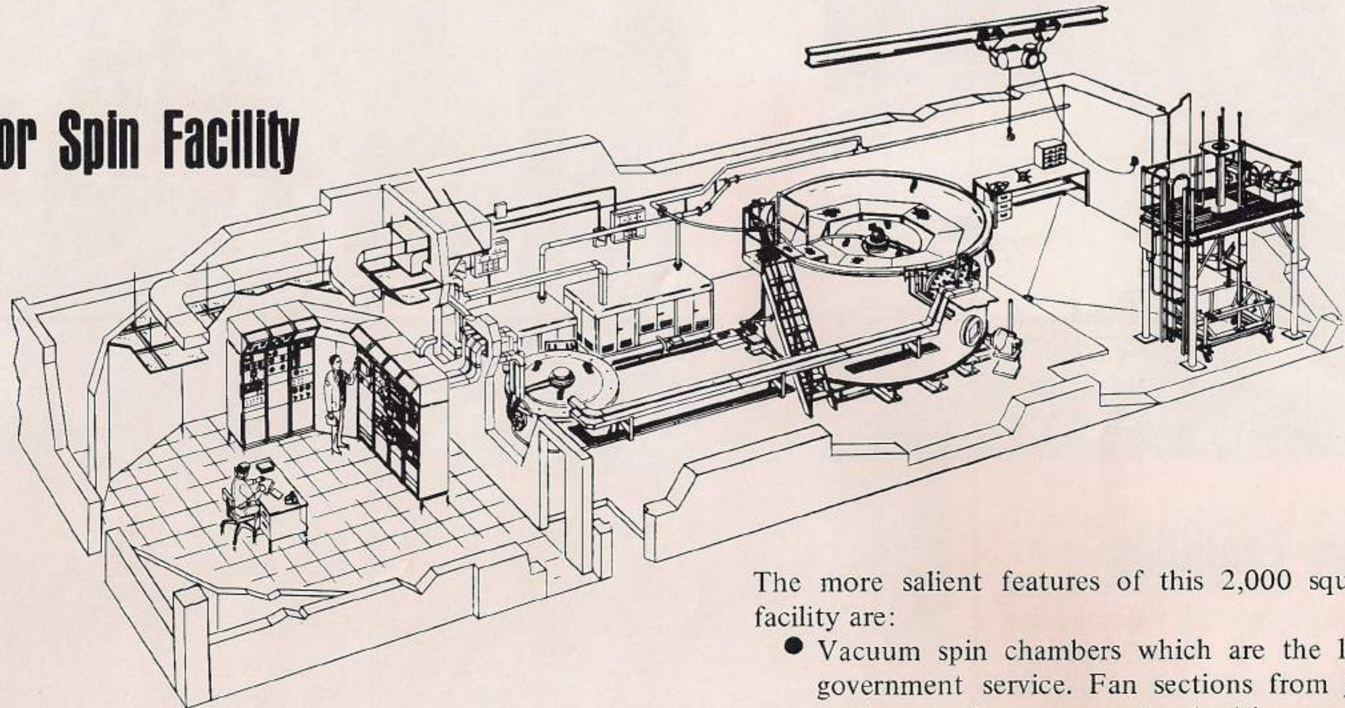
Shop Facilities



The main shop provides facilities for teardown, inspection, assembly and instrumentation of test engines, and houses a complete machine shop facility. Engine modification, repair and fabrication of special instruments and fixtures are also done in this building. Rooms are provided for inspection and cleaning of parts, engine cleaning, grinding, and parts storage.

An auxiliary shop is located adjacent to the main shop and provides space for storage, an electrical shop, a sheet metal shop, a weld shop and shipping and receiving facilities.

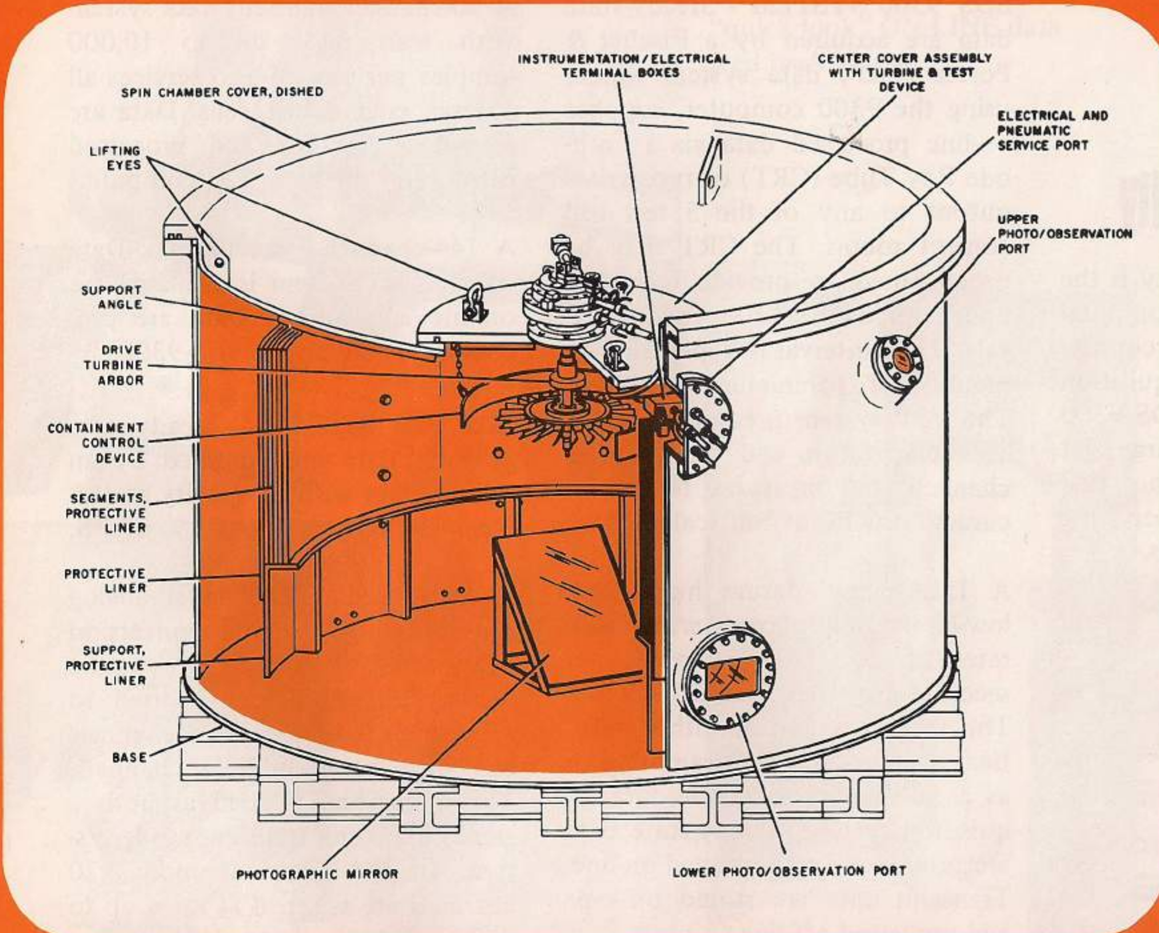
Rotor Spin Facility

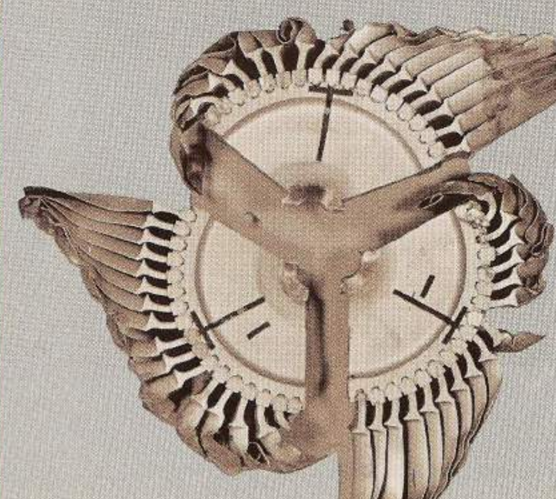


The more salient features of this 2,000 square foot facility are:

- Vacuum spin chambers which are the largest in government service. Fan sections from jumbojet engines can be accommodated with room to spare.
- Air turbine drive systems which can generate rotor speeds up to 150,000 rpm.
- Heating systems capable of producing rotor temperatures in excess of 3,000°F.
- High-speed slip rings that can transfer millivolt signals at 100,000 rpm.
- Temperature measurement systems that incorporate the latest in thermo-optical and infrared detection concepts.
- High-speed photographic systems capable of taking photographs at rates of 35,000 pictures per second.

The rotor spin facility is used to experimentally develop and evaluate the structural and material aspects of gas turbine engine rotor design. Under simulated engine conditions, component tests are conducted to establish the structural integrity and durability of the various rotor designs that are used in Naval aircraft engines.

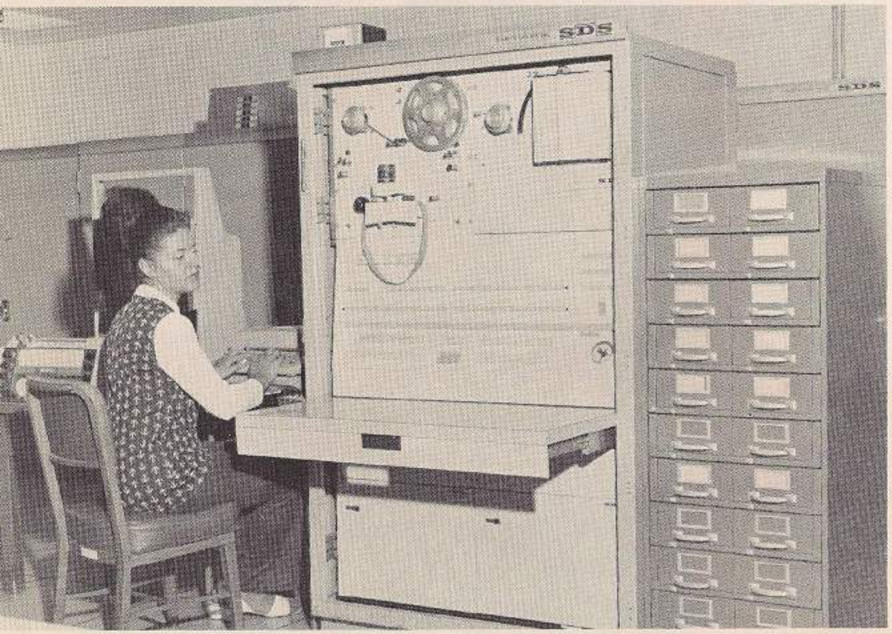




Shown above is the larger of the two spin chambers. Its above ground installation simplifies operation and facilitates easy optical access for high-speed photographs, infrared scanning or holographic processes. The high-speed photographs at the right show rotor burst fragments impacting a containment ring. These photographs, which vividly depict the mechanisms involved in rotor burst containment, were the first of their kind ever produced.

Data Aquisition, Reduction & Computation Facility

The function of this facility is the acquisition, recording and computation of engine test data. It consists of two independent acquisition systems; one, tied to an SDS 9300 computer, servicing 5 large jet engine test cells, and the other, tied to an SDS 910 computer, servicing 4 small shaft engine test cells.



SDS 9300 SYSTEM - Steady-state data are acquired by a Fischer & Porter (F&P) data system which, using the 9300 computer, supplies on-line processed data via a Cathode Ray Tube (CRT) or typewriter output to any of the 5 test cell control rooms. The CRT may be programmed to provide real time update of data at 30-second intervals. Time interval is dependent on number of parameters displayed. The F&P system presently records 150 temperature and 125 pressure channels and measures to an accuracy of 0.1% of full scale (FS).

A 150-channel datum high-speed, low-level multiplexer with scan rates up to 10,000 samples per second also uses the SDS 9300. This system is used for either statistical steady-state data sampling or as a 50-channel transient data acquisition system. Steady-state data are processed and displayed on-line. Transient data are stored on tape and processed off-line.

A 50-channel transient data system with scan rates up to 10,000 samples per second also services all 5 large engine test cells. Data are recorded on tape and processed off-line by an SDS 920 computer.

A 144-channel FM Multiplex Data Acquisition system is available for on-line acquisition. Data are processed off-line on the SDS 9300.

SDS 910 SYSTEM - Steady-state pressure data are acquired by an F&P system with a capacity of 108 channels. Accuracy is 0.1% of FS.

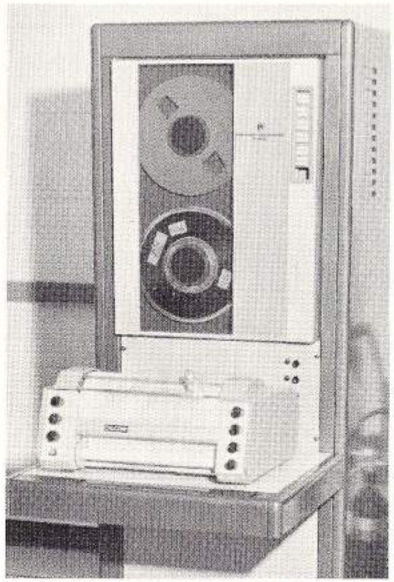
A high-speed, 200-channel analog acquisition and digital conversion subsystem utilizing Microsadic Series 500 equipment is used to acquire 160 temperature channels and 40 low level millivolt channels. This subsystem is used as both a steady-state and transient mode system. In the transient mode, 20 channels are scanned at rates up to 250 samples per channel per second.

The SDS 910 computer processes data on-line from both systems and supplies processed data to each control room via a CRT which has both numerical and graphic capabilities.

CATHODE RAY TUBE
"quick look" ON-LINE data
feed back system.

SDS 9300 Computer High
Speed Printer.

SDS 920 Computer Console &
Central Processing Unit.

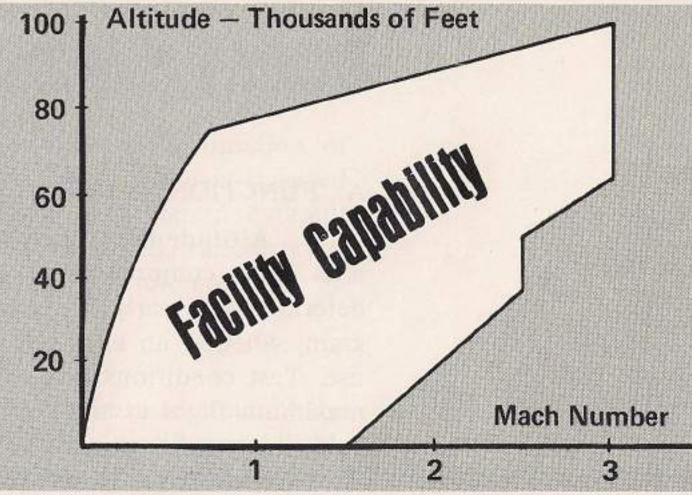


Computer Off Line Digital
Plotting Data System.

Research & Technology

In Research and Technology, the Center actively participates in the formulation and implementation of Research, Exploratory and Advanced Development propulsion programs for the Navy. Historically, aircraft propulsion systems require six to twelve years of development to attain production. NAPTC ensures an orderly **Progression of Technology** which provides the basis for future propulsion systems. Costly duplication of effort is avoided by close coordination between other branches of the Department of Defense and various agencies of the Government. An integrated Navy-U.S. Air Force Advanced Demonstrator Engine is currently planned to undergo tests in 1976. This demonstrator will be the culmination of various Navy/Air Force exploratory and advanced programs.

Facility Capability can provide air to meet requirements for present and future planned Navy Aircraft Engines.



SUMMARY OF TEST CELL CAPABILITIES

CONDITIONS	3E	2E	1E	1W	2W	3W	4W	5W	6W
Nominal Airflow (lb./sec.)	550 (Max.)	350	350	350	350	50	50	50	50
Cold Inlet (^{O}F)	- 65	- 65	- 65	- 65	- 65	- 65	- 65	- 65	- 65
Hot Inlet (^{O}F)	+650	+320	+320	+220	+220	+220	+220	+220	+220
Inlet Pressure Range (in. HgA)	150 to 1.7	84 to 1.7	84 to 1.7	84 to 1.7	84 to 1.7	60 to 1.7	60 to 1.7	60 to 1.7	60 to 1.7
Exhaust Pressure Range (in. HgA)	S.L. to .3	S.L. to .3	S.L. to .3	S.L.	S.L.	S.L. to .8	S.L. to .8	S.L. to .8	S.L. to .8
Test Area Length (ft.)	30	18	18	56	56	15	20	17	17
Width or diameter (ft.)	17	14.5	14.5	23	23	8	10	10	10
Height (ft.)	—	—	—	14	14	8	—	10	10

Summary of Tests

The broad categories of functional and environmental tests conducted consist of specific tests which are as follows:

A. **FUNCTIONAL TESTS**

1. **Altitude Qualification Test** - This test is a very comprehensive test designed to determine, as early as possible in the program, whether an engine is ready for service use. Test conditions range from sea level to maximum flight at the extremes of hot and cold day conditions and for all flight speeds.

2. **Overall Engine Performance** - Determination of engine performance (thrust and fuel consumption) throughout the engine flight envelope. Particular attention is paid to flight conditions where aircraft performance is critical.

3. **Component Evaluation**

(a) *Compressor* - Determination of compressor efficiency, pressure ratio and pumping capacity at various altitudes and flight conditions; and establishment of compressor map and surge requirements.

(b) *Combustor* - Determination of combustion efficiency, pressure drop, blowout limits, and temperature profiles for specified fuels at various flight Mach number - altitude combinations.

(c) *Turbine* - Determination of turbine pressure ratio, adiabatic efficiency and steady-state performance at various altitudes and flight conditions; and establishment of turbine flow characteristics and choking limits.

(d) *Exhaust Nozzle* - Determination of exhaust nozzle pressure loss (hot and cold) and the nozzle gross thrust coefficient. Results are used for in-flight thrust determination for aircraft range studies.

4. **Service Problems** - Investigation of the cause and evaluation of possible fixes to service-incurred problems. Usually involves malfunctioning of major engine components or combinations thereof e.g. - compressor surge, exhaust nozzle problems, slow acceleration, turbine over-temperature, poor ground or windmill starting in an aircraft, inlet distortion, water ingestion, flameout, etc.

5. **Inlet Pressure Distortion** - Determination of the tolerance of an engine to inlet pressure distortion caused by the air-frame inlet duct. Simulation of in-flight inlet pressure distribution is required. Past efforts have used screens to simulate "steady-state" pressure distortion. Experience (F-111) has shown that it is necessary to simulate the "dynamic" inlet pressure environment to

determine the engine tolerance to inlet pressure environment. Inlet pressure turbulence generators will be needed for future tests.

B. ENVIRONMENTAL TESTS

1. **High and Low Temperature Qualification Tests** – Determination of engine ground starting and operating characteristics after soaking for prolonged periods at extreme hot and cold temperatures. This test is an acceptance requirement for all new model engines; includes engine start, acceleration to idle - then intermediate.

2. **Water Ingestion** - Determination of the tolerance of an engine to heavy rainfall environment at various altitudes, on flight speeds and power conditions. Effects on power output, general operation and mechanical integrity of the engine are evaluated. Distorted water patterns tested include 50% of water in a segment equivalent to 1/3 of the inlet area.

3. **Anti-Icing** - Determination of the capability of the engine anti-icing system to protect the engine from icing conditions. Performance degradation, ice build-up locations and Foreign Object Damage (FOD) effects are studied during the test.

4. **Missile Exhaust Gas Ingestion (MEGI)** - An evaluation of the tolerance of an engine to ingest the exhaust gases from airborn missiles or other aircraft armament. Test rigs to simulate missile firing were developed by NAPTC.

5. **Steam Ingestion** - Determination of the tolerance of an engine to steam ingested into the inlet during a shipboard catapult launch. If stall is encountered, various ways of increasing the engine's tolerance are investigated.

C. **SPECIALIZED TESTS**

The Center has the expertise to conduct the following specialized tests on a demand basis:

1. **Pollution - Smoke.** Evaluation of Fuel Additives to eliminate gas turbine engine smoke; on line measurements of gas turbine engine exhaust gas emission and evaluation of proposed air pollution standards and legislation.

2. **Infrared** - Measurement of turbojet/turbofan and turboshaft engine infrared signatures can be performed to accurately assess infrared vulnerability. Also various engine exhaust component geometry modifications can be evaluated to determine their effectiveness in reducing infrared emissions.

3. **Foreign Object Ingestion** - Various engine inlet protection devices are tested and evaluated to determine their effectiveness in protecting an engine from ingestion of sand, debris and large foreign objects such as nuts and bolts.

Center Instrumentation Capability

Test instrumentation capability falls into three categories:

1. **General Monitoring Instruments** - These instruments include pressure, temperature, position, frequency, thrust, vibration indicators, etc., and are used primarily to set and/or maintain correct engine operation. Data are recorded manually from these instruments if required. A large variety of types and ranges of indicators and calibration facilities are available.

2. **Steady-State Instrumentation** - For steady-state engine testing, a Fischer & Porter on-line data acquisition system is used. This system has on-line computing capabilities using SDS 9300 and 910 computers in conjunction with remote typewriters and Cathode Ray Tube displays in the test cell control rooms. The major function is that of permanent tape storage of test data with subsequent processing into final printed form.

3. **Transient Instrumentation** - Two types of equipment available for transient data recording are oscillograph and tape systems which are installed as needed for test programs in any cell.

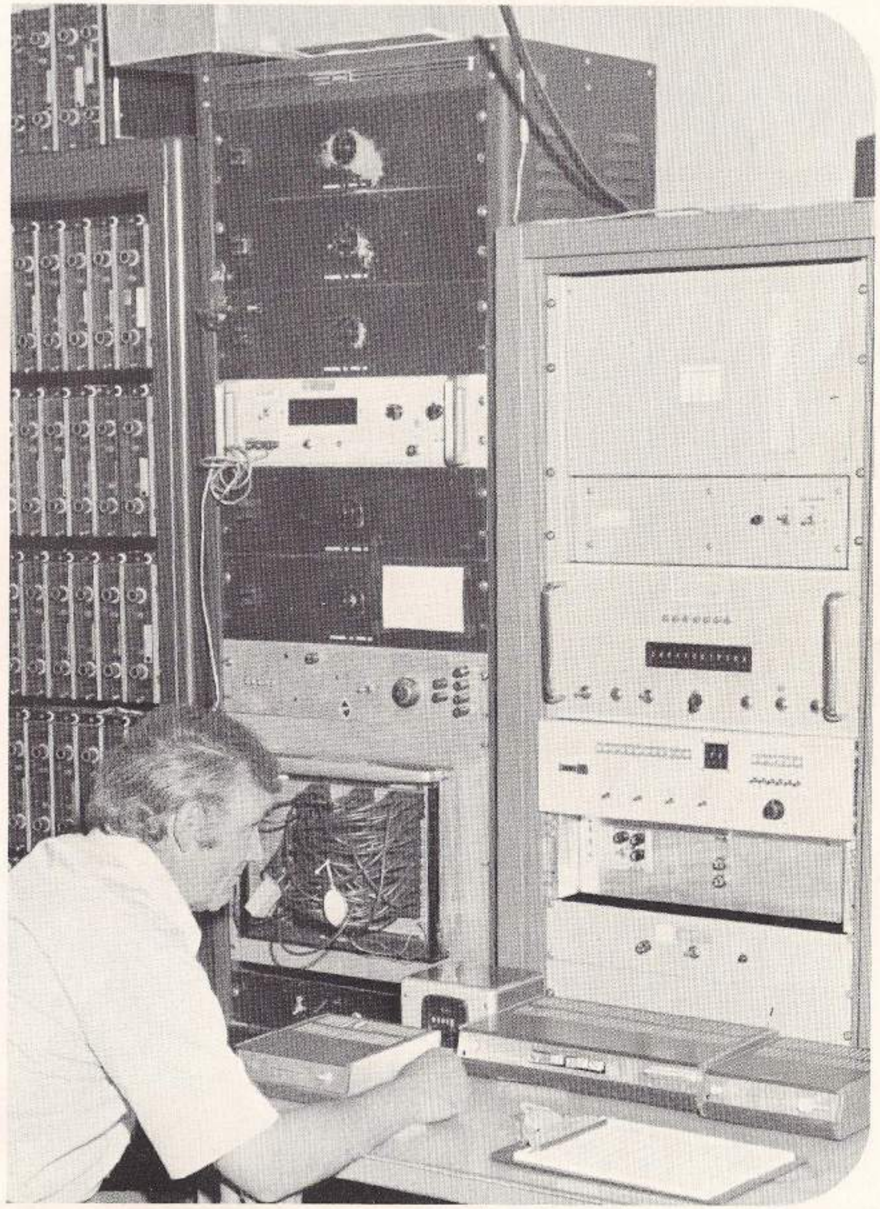
Examples of capabilities and accuracies of instrumentation are as follows:

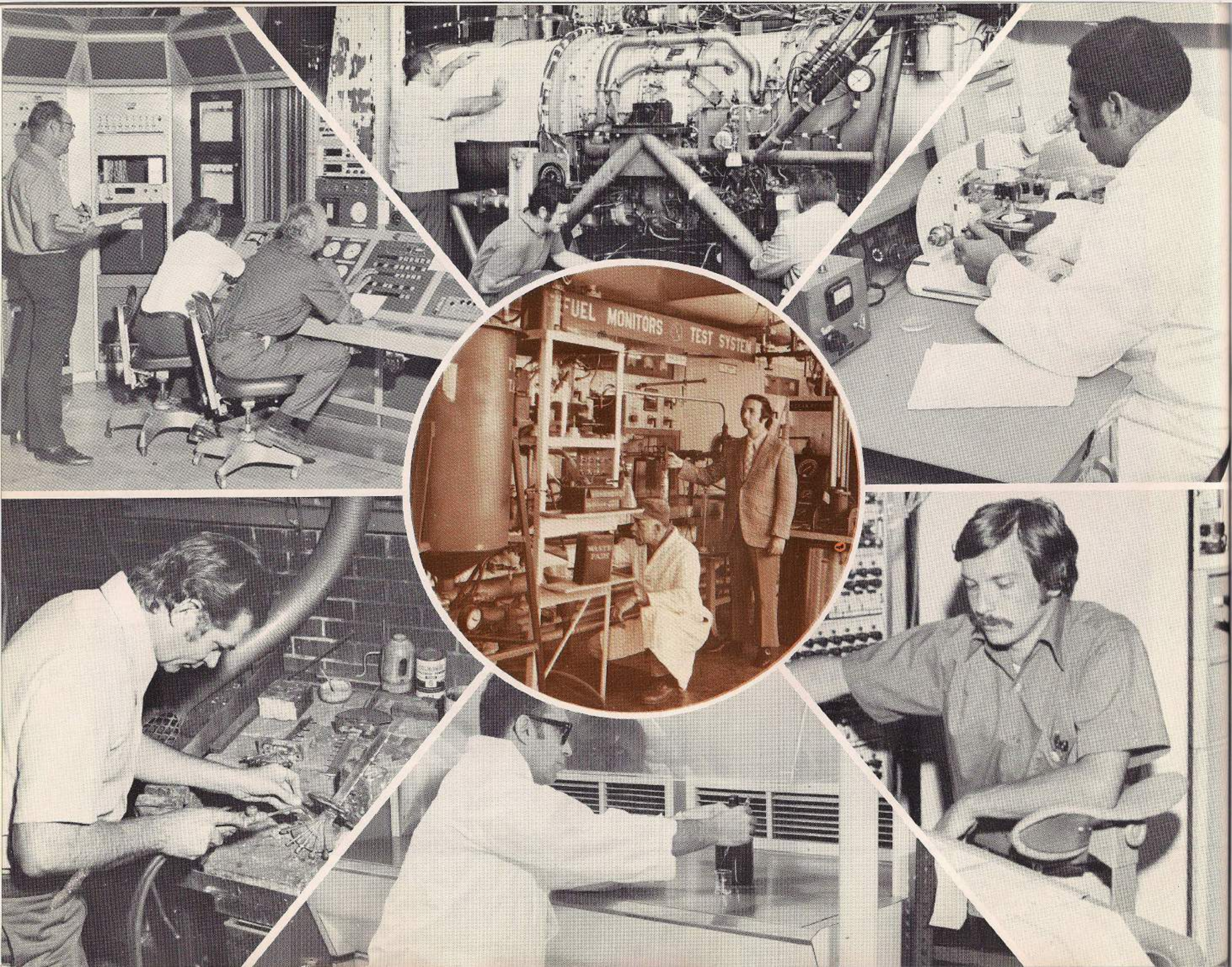
Parameter	*Range*	*Accuracy*
Pressure	1-60 in. HgA	±.08% fs
Pressure	10-300 in. HgA	±.08% fs
Pressure	10-600 in. HgA	±.08% fs
Pressure	0-1200 in. HgA	±.15% fs
Pressure	0-200 in. H_2OD	±.08% fs
Pressure	0-8 in. HgD OR 1-9 in. HgA	±.10% fs
Frequency	0-10 KC	±.004 fs
Millivolts (Thermo-couple or Transducer	-10 to + 50 MV	±.1% or 0.03 MV

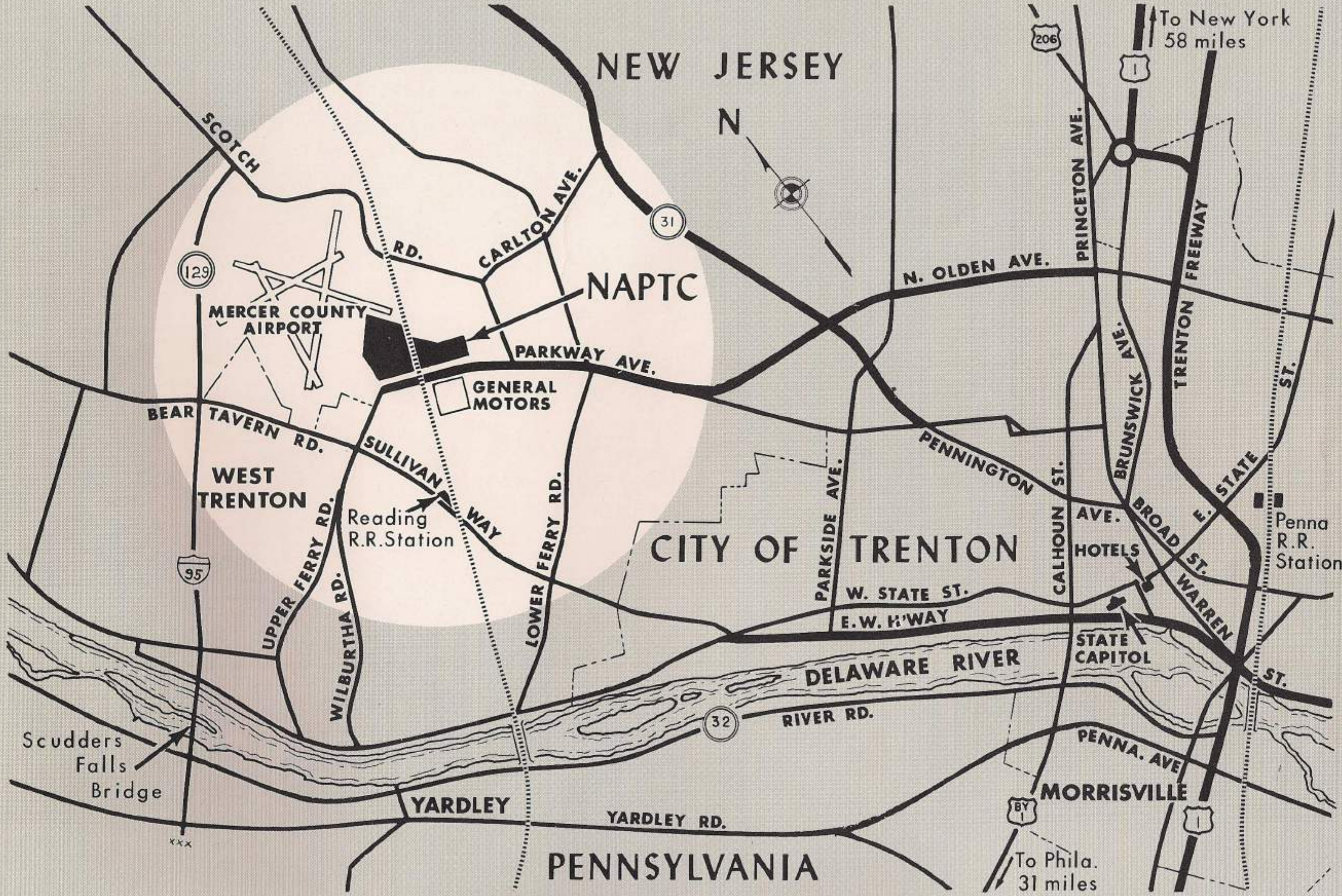
A Calibration Room is staffed to maintain and operate the laboratory primary standards and to calibrate all transfer standards and instrumentation used for data acquisition.

The primary standards are calibrated by the Eastern Standards Laboratory, Washington, D.C. on an automatic periodic recall basis.

In-house transfer standards, instruments and transducers are calibrated at prescribed intervals in accordance with the established standards.




FUEL MONITORS TEST SYSTEM



Naval Air Propulsion Test Center

Vicinity Map

Reviewed and Approved:

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Commanding Officer,
Naval Air Propulsion Test Center