# 1969





# TECHNICAL FACILITIES and CAPABILITIES



## U.S. ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA

*Published by*

RESEARCH AND ENGINEERING DIRECTORATE
U. S. ARMY MISSILE COMMAND
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# U. S. ARMY MISSILE COMMAND

## REDSTONE ARSENAL, ALABAMA

This brochure is being distributed to colleges and universities to acquaint and interest their students, at all academic levels, with the wide variety of professional and technical skills that are essential to accomplish the complex mission of the Army Missile Command, located at Redstone Arsenal, near Huntsville, Alabama.

The Missile Command provides challenging work assignments, extensive career development activities, and good promotional opportunities for its large force of engineers, scientists, and technicians. To keep abreast of technical and scientific advancements, such personnel are encouraged to participate, at Government expense, in the Command's Graduate Study Program, conducted in cooperation with the University of Alabama in Huntsville. Advanced degrees are offered under the program in physics, mathematics, engineering mechanics, and electrical, aerospace, mechanical, and industrial engineering. Opportunities are available also for personnel to take advanced short- and long-term residence training and educational courses in colleges, universities, and service schools throughout the United States. Research and Study Fellowships are offered by the Secretary of the Army. These fellowships provide up to twelve months of full-time study or research at an institution of higher learning in this country or abroad. Undergraduate courses are available for cross-discipline and refresher training.

This brochure will be of interest also to students in college cooperative education programs. The Missile Command's Cooperative Education Program offers periods of industrial training and experience alternated with academic study while students are obtaining a degree in the fields of engineering, science, accounting, business administration, education, journalism, library science, statistics, and others.

JOIN US FOR A CHALLENGING ASSIGNMENT!

## *RESEARCH AND DEVELOPMENT FACILITIES*

The Army Missile Command is responsible for research, development, procurement, and maintenance of the Army's rockets and missiles at the commodity management level. Project management functions are also carried out at the Command headquarters, to permit complete integration of all elements from the earliest development stages. New concepts are investigated and new techniques developed to assure that all components of missile and rocket systems represent the current state-of-the-art, and that the systems are technically and tactically satisfactory for use by our field forces.

Described in this brochure are the major technical resources – the laboratories operated or managed by the Command's Research and Engineering Directorate, which comprise some of the finest laboratory facilities in the world. These laboratories are equipped and staffed to study problems of propulsion, aerodynamics, guidance, structures, and electronics; pilot line facilities are used to research and develop solid propellants; completely instrumented flight and static test ranges are available for obtaining ballistic data; comprehensive environmental test facilities simulate the effects of worldwide environment on missile and rocket systems.

The many supporting elements available on the Arsenal are equally well equipped and staffed, and greatly enhance the capabilities of the laboratories. A description of the research library, operated jointly with the NASA Marshall Space Flight Center, is included. In addition, there are complete photographic and recording studios, and centralized computer and calibration facilities. The Computation Center maintains a full range of commercial and scientific (digital, analog, and hybrid) computer equipment, which is constantly updated or replaced with more refined models or techniques as they become available. All problems – specific or general, experimental or theoretical – can be analyzed; complete systems can be simulated, and new programs, or new or novel mathematical techniques, are developed as required. The Army Metrology and Calibration Center is the calibration authority for the U. S. Army worldwide, and is prepared to provide calibration services in nearly every measurable quantity, with certification accuracies ranging from just under those of the National Bureau of Standards to tolerances associated with portable, rugged field equipment.

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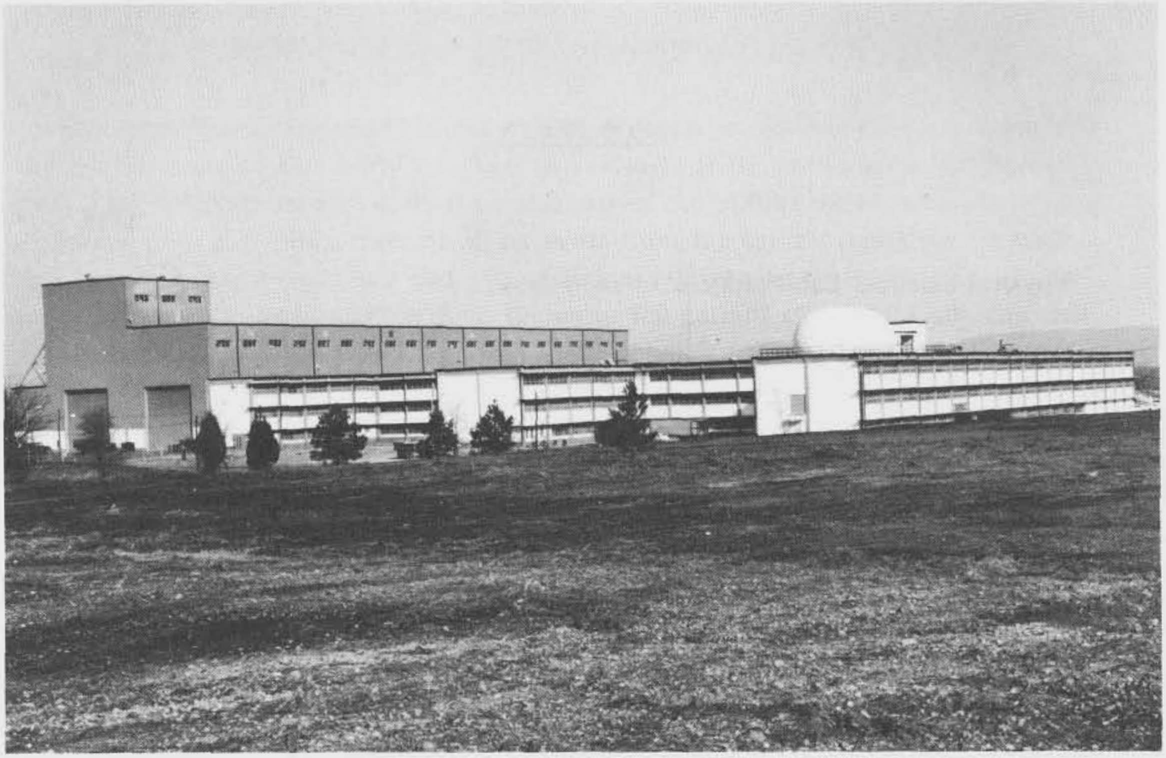


**FRANCIS J. McMORROW LABORATORIES**

This building contains five of the laboratories of the Missile Command's Research and Engineering Directorate: the Army Inertial Guidance and Control, the Advanced Systems, the Advanced Sensors, the Ground Support Equipment, and the Structures and Mechanics Laboratories. It has 286,000 square feet of space, and with its equipment is valued at $17 million. Included is a 50,000-square-foot Crane Bay, serviced by five 20-ton cranes – four with a 50-foot hook height and one with an 80-foot hook height. The facility is the only one of its kind in the U. S. Army, and is designed to provide laboratory equipment and facilities for the development of missile and rocket components.

# PHYSICAL SCIENCES LABORATORY

The Physical Sciences Laboratory does basic and supporting research in the physical, chemical, and engineering sciences. If offers advisory and consulting services in these areas for all interested technical groups: It evaluates and coordinates basic research proposals for the Army Research Office, Durham. In addition to an extensive in-house research program, the laboratory supervises special research projects conducted under contract by other government agencies, industry, and educational institutions. Research is accomplished through the combined efforts of the laboratory's nine branches:

Aeromechanics

Plasma Physics

Solid State Physics

Radiation Physics

Optical Spectroscopy

Aerophysics

Solid Mechanics

Applied Physics

Technical Support.

## AEROMECHANICS BRANCH

*Capabilities:*

The Aeromechanics Branch is concerned with the science of the equilibrium and motion of compressible and noncompressible fluids, including hot shocked reacting and radiating flows. The underlying physics of fluids is considered where the flow regimes are of sufficient velocities (e.g., $M \approx b$) to change the characteristics of the flow to those of a more complex nature and make the classical approach inapplicable. The stability of open and closed loop control systems is investigated, with emphasis on fast systems which require exhaustion of available nonlinear methods, in particular "on-off" servo analysis, and finally synthesis.

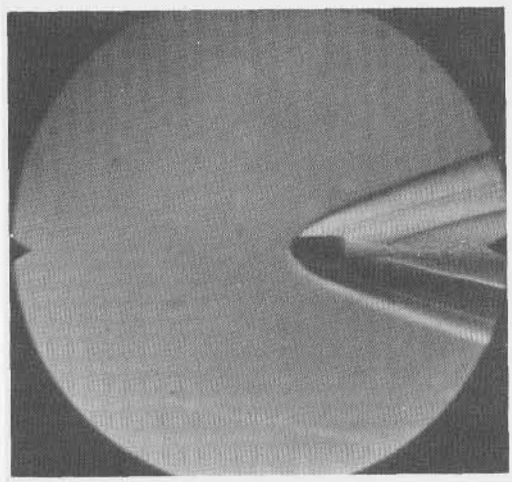
The branch plans, conducts, evaluates, and appraises research programs in the mechanics, control dynamics, and physics of hypervelocity free flight missiles. This includes internal programs and those conducted by other government agencies, industry, and educational institutions. Proposals are evaluated, contract requirements are defined, and technical supervision is exercised during the entire life of the contract.

Technical support is provided to the various missile system project offices, and liaison between the laboratory and these offices, required in the area of mechanics, dynamics, and physics of high speed flow; macroscopic and microscopic interactions between the vehicle, the vehicle's environment, and sensing devices. Research is conducted in these areas using in-house facilities. Of particular interest are the dynamic response characteristics of bodies of different configurations, flow field characteristics, wake properties, and other physical properties.

*Facilities:*

The Hypervelocity Aeroballistics Range consists of a two-stage light gas gun (helium), with 0.6-inch and 1.25-inch interchangeable launch tube. The general view on opposite page shows the gun, gun support, simulation chamber, and instrumentation.

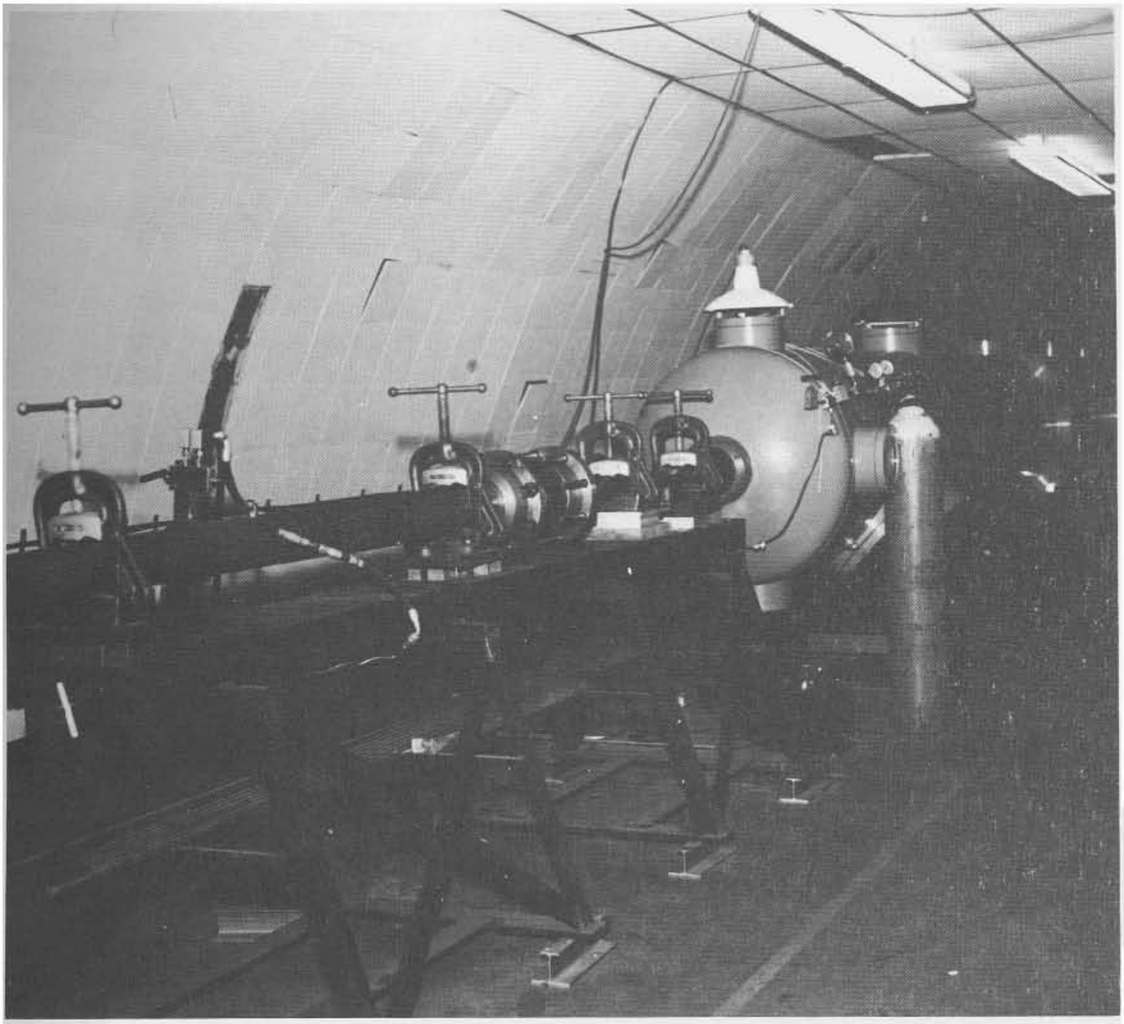
Available on the range are three velocity measuring stations, a radiation measuring station, several flow field visualization stations, and an impact measurement station. The flight chamber can pressure-simulate altitudes from sea level to about 400,000 feet. The current testing capabilities are tabulated below.



Typical Visualization of Flow Field

Compilation of Nominal Experimental Capability

| Launch Tubes $D_b$ (in.) | Type | Trajectory Parameters | | Projectile Parameters | | |
|---|---|---|---|---|---|---|
| | | $P_\infty$ (in. Hg) | $V_\infty$ (fps) | $D_B$ (in.) | $W_P$ (gm) | Type |
| 0.226 | Rifled | $< 10^{-6}$ | $\approx$ 4,500 | 0.226 | 2.6 | Simple shapes, unsaboted |
| 0.588 | Smooth | $< 10^{-6}$ | $\approx$ 21,000 | 0.588 | 2.0 | Simple shapes, unsaboted |
| | | | $\approx$ 18,000 | 0.588 | 3.5 | |
| | | | $\approx$ 13,000 | 0.400 | 8.2 | Compound, saboted |
| 1.250 | Smooth | $< 10^{-6}$ | $\approx$ 12,000 | 1.250 | 8.2 | Simple, unsaboted |
| | | | $\approx$ 7,000 | 1.00 | 10.0 | Complex, saboted |

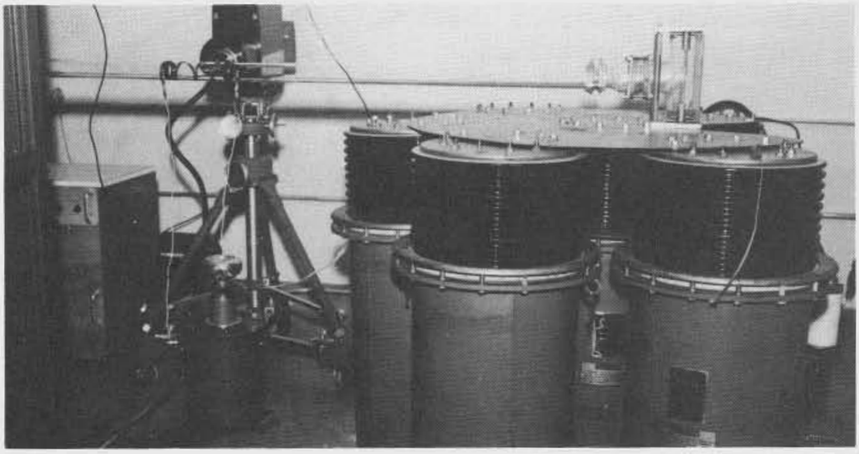


Light Gas Gun and Altitude Simulation Chamber

A Czerny Turner Spectrometer is available with a resolution of 60,000 in the first order with grating blaze of 1.0 micron and a wavelength range of 2500 Å to 20,000 Å with film plate, photomultipliers, and recording equipment.

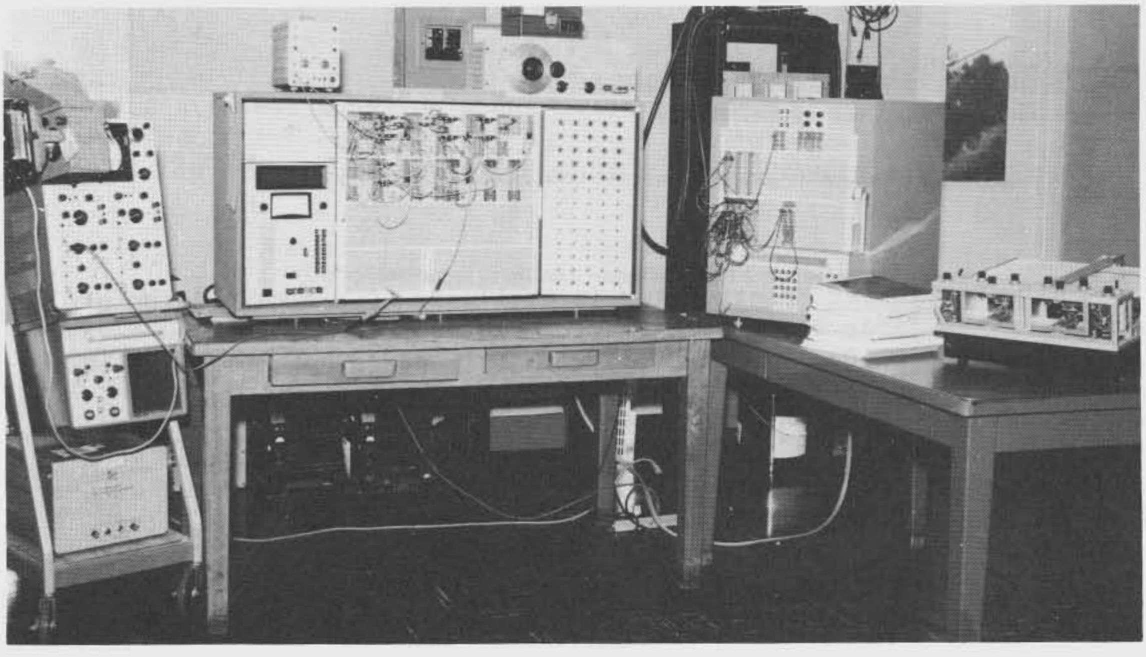
The High Energy Source consists of a 25,000 joule, 100 kV low inductance capacitance bank with time constant of $10^{-5}$ seconds with high voltage switching with a $10^{-8}$ torr vacuum magnetically driven shock tube.

For low intensity high speed radiation events there is a T.R.W. Image Converter Camera with a magnification of 50X and both high speed framing and streak modules. The camera is capable of recording luminous events of less than 1 microsecond duration 50 nanoseconds apart.



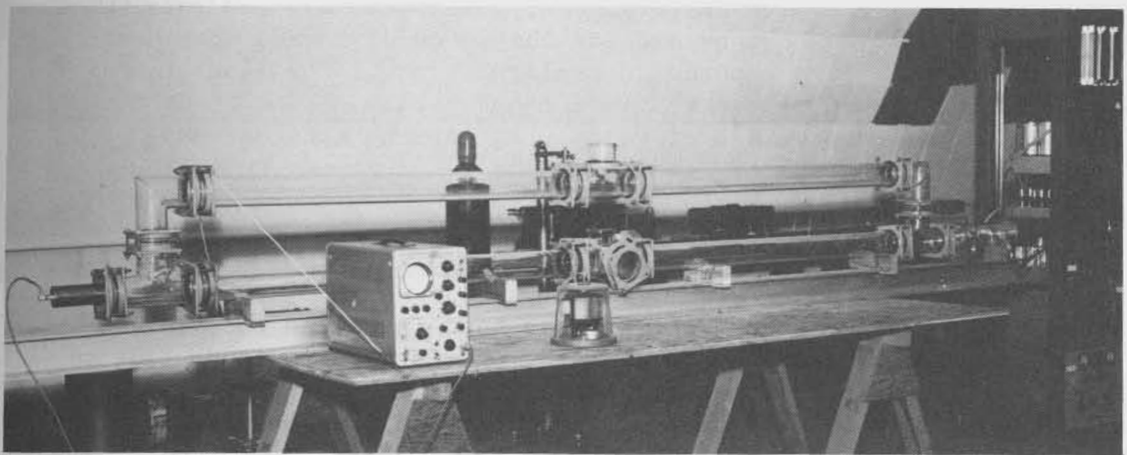
High Energy Source and TRW Image Converter Camera

An Electronics Associates, Inc. Pace 231-R Analog Computer is available for control dynamics simulation studies. Associated equipment includes 75 amplifiers and integrators, a digital voltmeter, 60 potentiometers, three multipliers, six comparators, three function generators, and two patch boards.

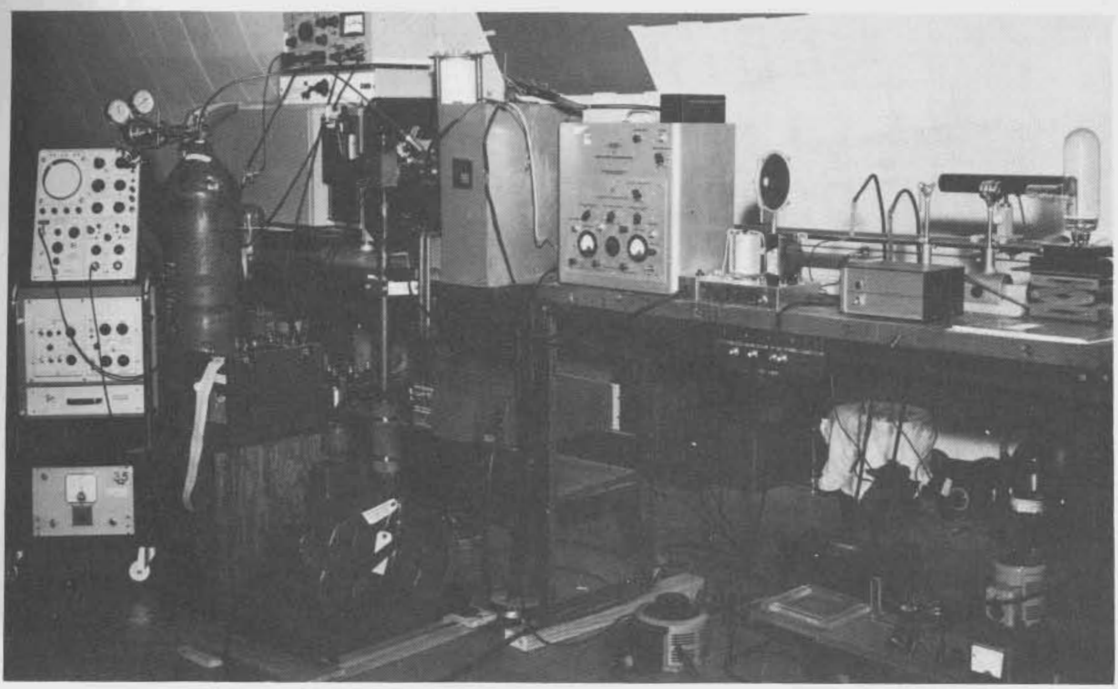


Flight Simulator and Controller

A Neodymium Glass Laser, a 1 megawatt $Nd^{+3}$ Q-switched type, is available for study of laser scattering from contaminated atmospheres under controlled conditions.



Controlled Atmosphere Simulator for Laser Scattering



Neodymium Glass Laser

## PLASMA PHYSICS BRANCH

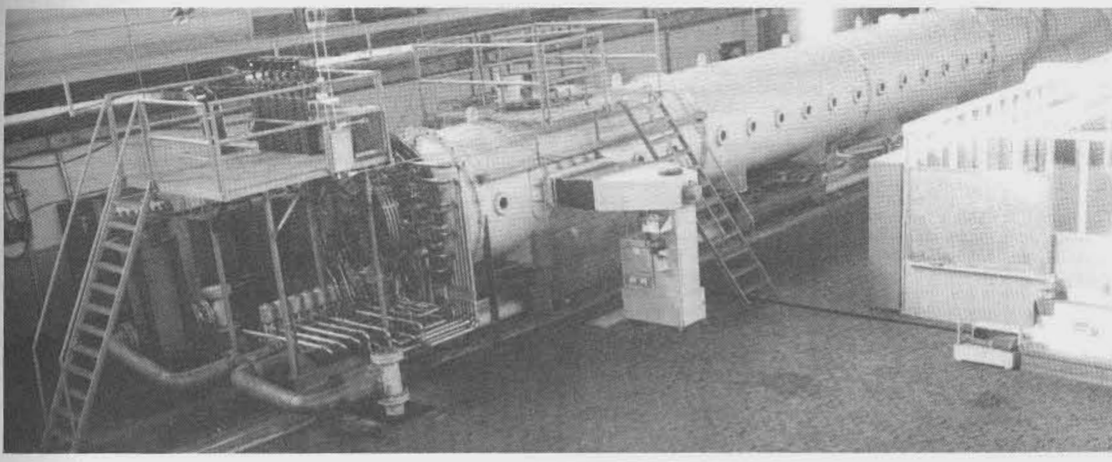
*Capabilities:*

In the Plasma Physics Branch, studies are made of the basic physical phenomena involved in the field of magnetohydrodynamics. Materials can be studied under very high temperatures, pressures, and gas velocities. Spectroscopic analyses can be made of the products formed when heat-resistant materials are exposed to a plasma, and of the gases in the plasma itself. Basic plasma research can be conducted to study the effects on missile materials of reentry at varying altitudes and velocities based on real-time scale. Some aerodynamic properties can also be studied.

*Facilities:*

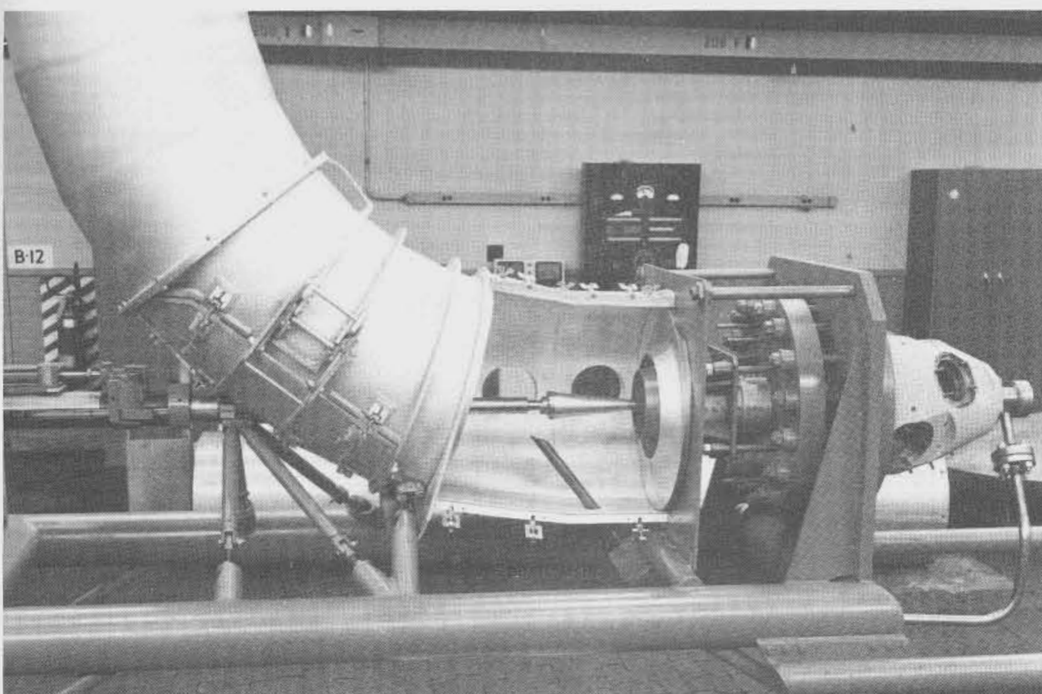
An 8,000-kW Plasma Jet Facility has been installed to simulate certain flight conditions up to Mach 20, and is used to study side-on heating to slender nose cones reentering from 400,000- to 200,000-foot altitudes. It can be used to produce stagnation zone heating over a similar range.

Control Console for 8000-kW Plasma Facility



8000-kW Plasma Facility

A <u>Plasma Driven Shroud Wind Tunnel</u> is under construction which will be used to simulate the boundary layer on high velocity, low altitude missiles.




Shroud

The shroud will be used to measure the performance of various anti-missile missiles as well as high velocity, ground-based research missiles. A test model shape and hypothetical flight pattern have been generated from basic requirements. Neither the model nor the flight pattern are identical to any specific missile or actual flight pattern; however, they are within easy scaling distance for a number of research and weapon missiles and should be of value in predicting boundary layer and surface conditions for these missiles.

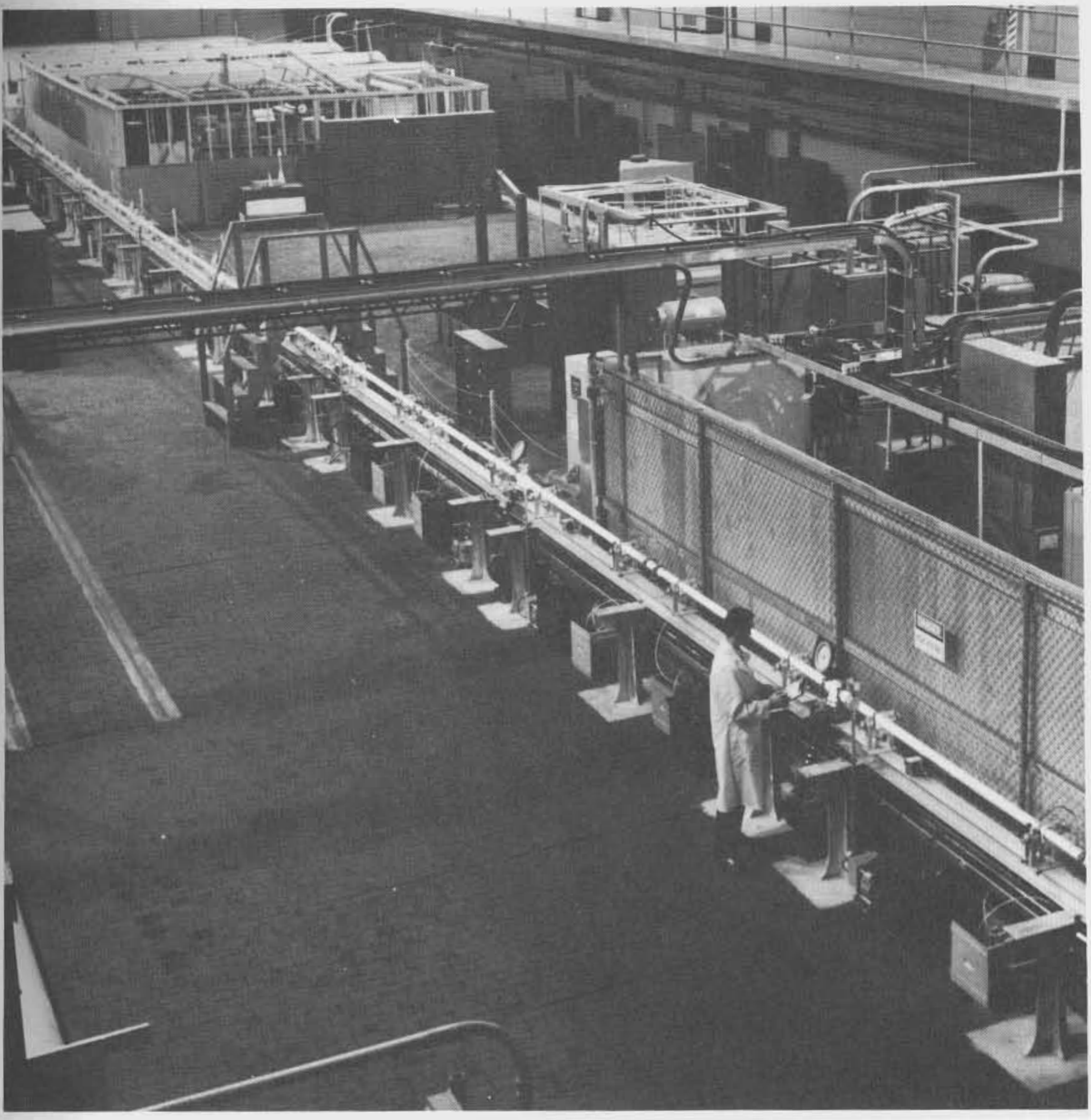
The first test programs will be basically a checkout and performance test of the facility itself. Tabulated below are the expected facility operating conditions for two proposed test regimes. Already on hand is a shroud for the first test simulating layer conditions at Mach 6, 5,000 feet.

Parameters for the Plasma Boundary Layer Simulator

| Test | Simulated Flight | | Plenum Conditions | | Mass Flow Rate of Air (kg/sec) | Enthalpy Flow Rate (Mw/sec) |
|---|---|---|---|---|---|---|
| | Velocity (msec) | Altitude (m) | Pressure (atm) | Temperature ($^oK$) | | |
| First | 2000 | 1538 | 38 | 2280 | 1.1 | 2.79 |
| Max* | 3077 | 7100 | 100 | 3750 | 3.0 | 15.0 |

* Details of this test have not been completed -- data are presented as estimate only.

A 178-foot-long Laser has been built and is being used to study various basic and applied problems in the field of molecular gas lasers. This nitrogen-carbon dioxide-helium laser generates an output power of 2.3 kilowatts at a wavelength of 10.6 microns, with an efficiency ranging between 10 and 14 percent. Scaling laws, various discharge configurations, gas mixtures, optical components, and spectra of the output radiation and discharges are being studied in attempts to determine the optimum operating characteristics and to produce a better understanding of the mechanisms which make these molecular lasers so efficient.



Laser (178-foot)

By proper focusing of the output beam, heating rates on the order of $8 \times 10^8$ Btu/ft$^2$-sec can be obtained. This makes it possible to form very pure crystals of such highly refractory materials as magnesium oxide and alumina. The effects of the laser radiation on undesirable forms of plant life are also being studied in cooperation with the Corps of Engineers.

## SOLID STATE PHYSICS BRANCH

*Capabilities:*

The Solid State Physics Branch conducts fundamental and long range directed research to determine the basic physical properties of solid materials, with emphasis on those atomic, ionic, and electronic properties which pertain to maser and laser processes. Impurities, either induced or natural, are studied to determine their effects on the optical absorption, luminescence, and other physical parameters, and to investigate the transfer of energy between them and the host crystal. Various interaction mechanisms of solids with electromagnetic energy are studied by means of electron paramagnetic resonance, nuclear magnetic resonance, nuclear quadrupole resonance, and ultrasonic absorption.

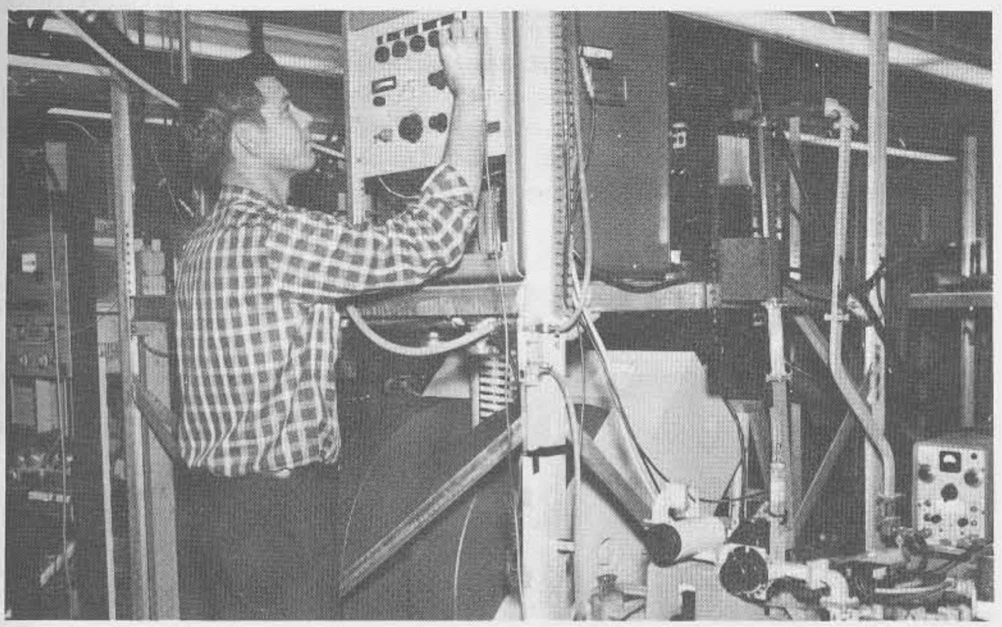
These experiments provide information needed to determine energy eigenstates, as well as transitions between these energy states, and the magnitudes and qualitative behavior of the electron-phonon interaction. The theoretical understanding of these processes is based on the application of modern quantum mechanics to the solid state physics. New theories are evolved and applied to the development of solid state devices for such purposes as light or microwave amplification by stimulated emission of electromagnetic radiation.

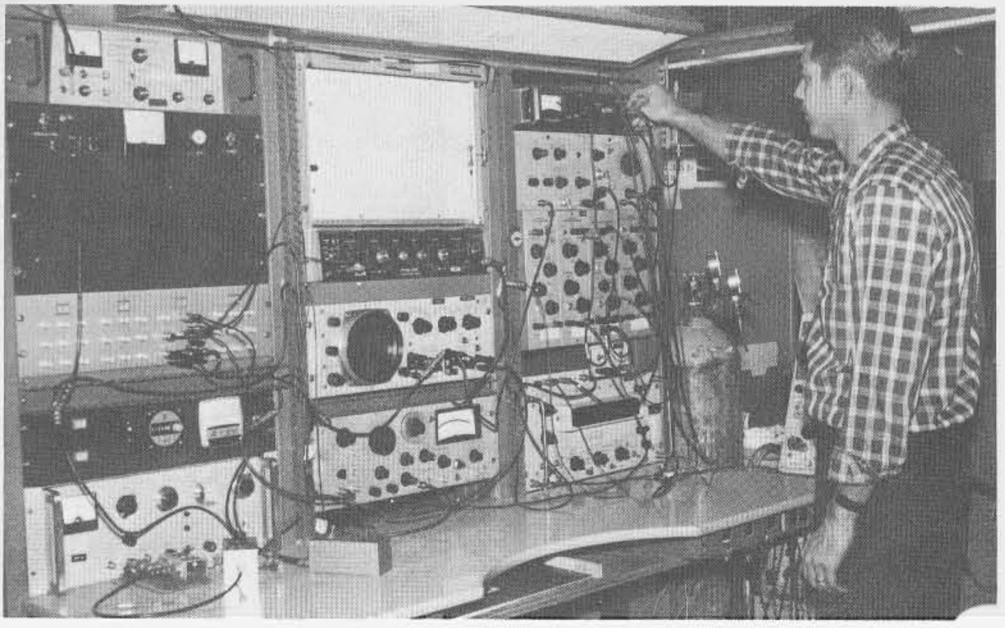
These investigations are carried out by eight research groups specializing in the following areas: (1) electron spin resonance, (2) ultrasonic spin resonance, (3) nuclear magnetic resonance, (4) semiconductor physics, (5) optical spectroscopy of solids, (6) solid state theory, (7) Fermi surface, and (8) crystal physics.

*Facilities:*

### ELECTRON SPIN RESONANCE

The Traveling Wave Tube Electron Paramagnetic Resonance Spectrometer was designed and constructed in this laboratory and can function as either a conventional spectrometer or as a pulse saturation spin relaxation spectrometer. The receiver has a noise figure of 7 dB. The pulse system can measure relaxation times of 0.5 μsec, a factor of 50 improvement on the previous state of the art. The apparatus is located in a 12-inch electromagnet and is equipped to operate at liquid helium temperatures. Nondestructive analysis can be performed on atomic and molecular structures, and studies made of the electronic structure of ions or defects in solids. In the pulsed mode, the TWT spectrometer measures the dynamic interaction between electrons and the crystal lattice in which they are located.

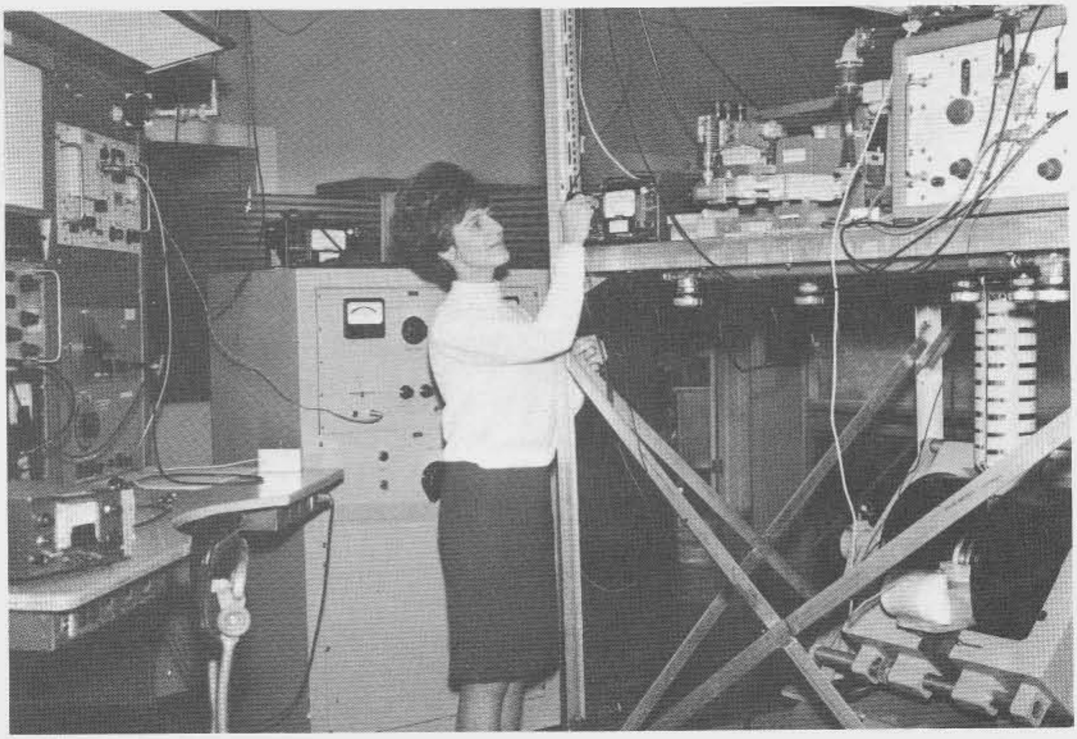




TWT Spectrometer

An X-Band Superheterodyne and Homodyne CW Paramagnetic Resonance Spectrometer have been designed and constructed at a single station so that one can switch back and forth very simply. The homodyne utilizes a backward diode detector which is quite sensitive at low modulation frequencies and relatively high power levels.

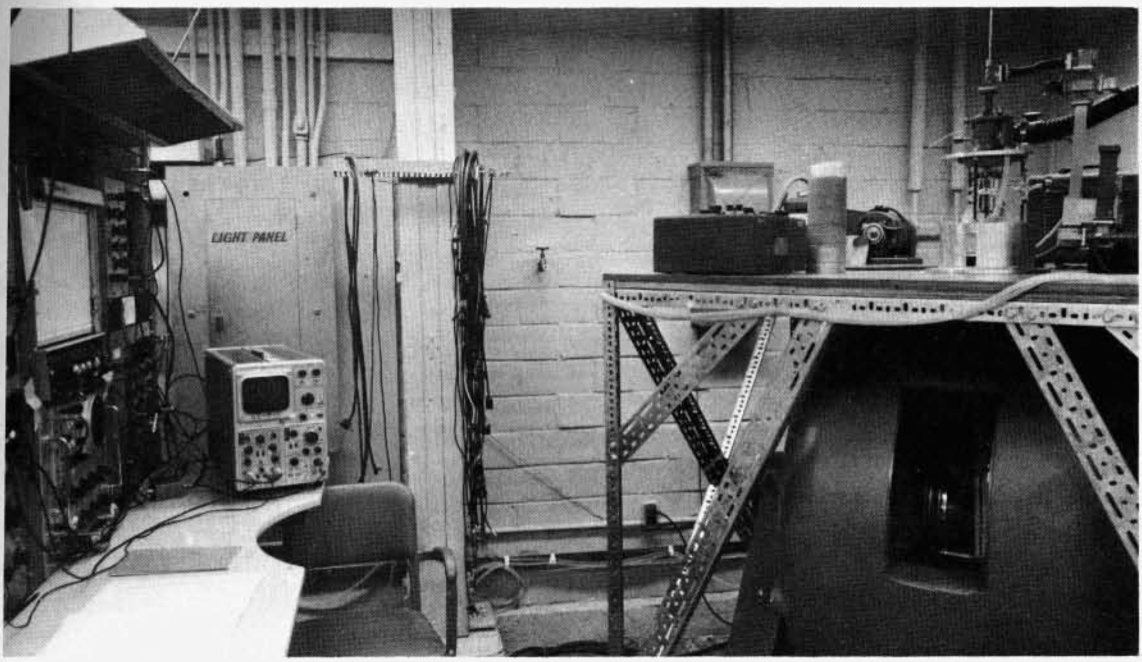
The superheterodyne receiver can be used where low power levels are necessary. This station has access to either a 6-inch variable gap electromagnet for magnetic fields up to 6 kilogauss, or a 12-inch Varian electromagnet for fields up to 12 kG. A 15-inch electromagnet with 24-kG fields is also available when needed. This spectrometer is also used for nondestructive analysis of atomic and molecular structure, as well as ions and defects in crystals.



Homodyne and Superheterodyne Spectrometer (X-Band)

An R-Band (35 GHz) Homodyne CW Paramagnetic Resonance Spectrometer has been constructed in this laboratory, and a supplementary superheterodyne detector is also being built with this spectrometer. The apparatus can be used with the 15-inch electromagnet at fields up to 24 kG, and even more conveniently used with the 12-inch electromagnet; for the latter, special pole faces are on order which should produce fields up to 20 kG. This spectrometer will be a valuable supplement to the X-band spectrometers since it will indicate magnetic field dependence effects.

An X-Band Ultrasonic Paramagnetic Resonance (UPR) Spectrometer has been assembled and is used for taking UPR line shapes in conjunction with a 15-inch Harvey-Wells rotatable electromagnet. Sensitivity of this spectrometer is enhanced by the use of a sampling oscilloscope lock-in amplifier. This UPR spectrometer has been equipped to measure relaxation time by an ultrasonic saturation and monitoring technique. This spectrometer has also been equipped for Ultrasonic Electron Nuclear Double Resonance (or UNDOR) studies. A complete 500-MHz/sec ultrasonic spectrometer is available for testing and checkout purposes.




Ultrasonic Paramagnetic Resonance Spectrometer

A Veeco 401 Automatic Vacuum Evaporator is used for depositing thin metal films for rf shielding of ultrasonic samples, but can also be used for vacuum deposition of ferromagnetic films and piezoelectric films as ultrasonic transducers. It is also available for other types of research work requiring reflecting, absorbing, or conducting coatings. It can be used to prepare specimens and surface replicas, and to enhance surface features by means of shadow-casting. The unit can attain a vacuum of $10^{-6}$ mm Hg, and provides a current for resistance heating from a supply rated at 2 kVA at 115 Vac.

A Varian 4500 EPR Spectrometer is being reconditioned to current Varian specifications by Varian Associates for our use in conjunction with the existing program in the UPR group. Upon acceptance this instrument will be modified to render it a versatile electron nuclear double resonance spectrometer to be used in parallel and in conjunction with the present program.

Other equipment on hand includes the necessary items such as a microscope for preparing acoustic bonds, reentrant microwave cavities, necessary X-band plumbing, and such materials as double-wall dewars and insulated transfer tubes for handling cryogenic liquids. We are now able to obtain CdS transducers for a greater sensivitity in our UPR work.

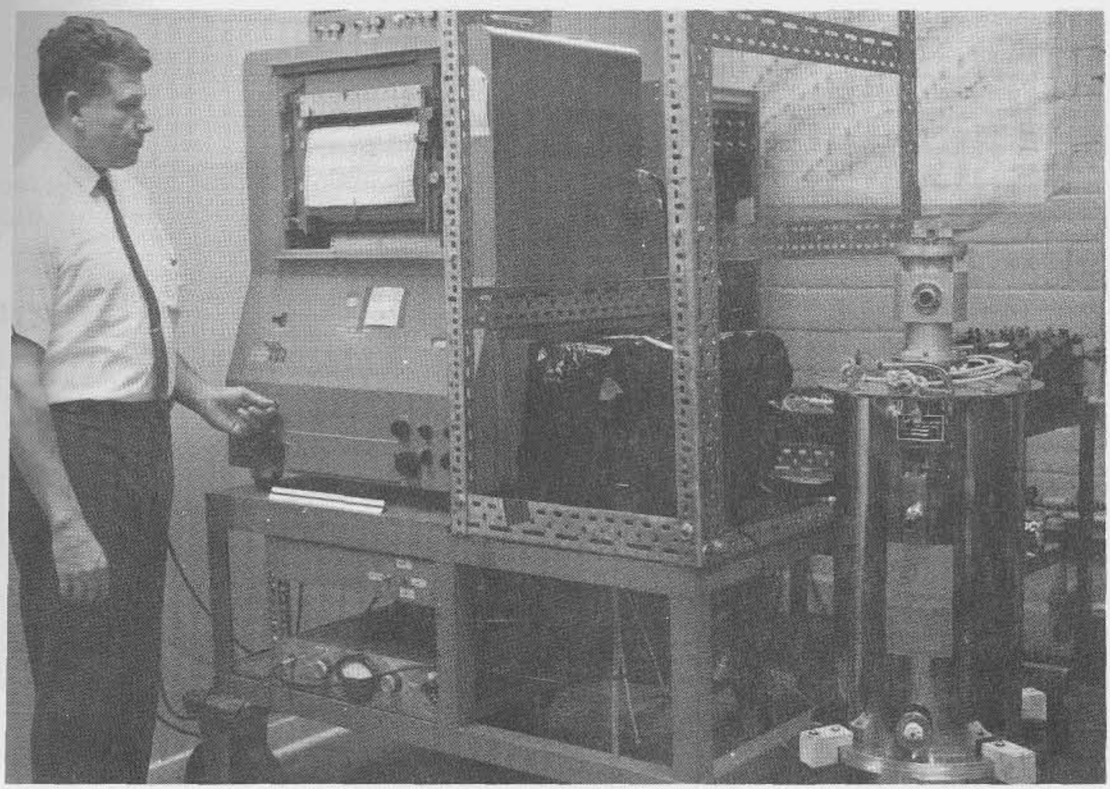
## NUCLEAR MAGNETIC RESONANCE

For the study of both nuclear and electronic ferro- and antiferromagnetic resonances, a set of instruments are available which permit the investigation of most of these resonances by both CW and pulsed techniques. Pulsed oscillators are available from approximately 1 to 1000 MHz, providing pulse power of nominally 0.6 kW at the lower frequencies to 2.5 kW at the center and higher frequencies. The receiver characteristics are primarily determined by a set of wide-band, low-noise preamplifiers which permit rapid recovery after the transmitter burst with small chance of burnout. Wide-band bridges or ferrite circulators are used to connect the transmitter and receiver to the sample cavity or tuned circuit. Because of the large signal-to-noise ratio commonly found for the nuclear resonances in magnetic materials, the CW experiments have been generally performed as either swept-frequency or swept-field experiments, utilizing both first and second harmonic detection but without a tuned sample circuit. Both electromagnets and superconducting magnets have been available for the support of these studies. The pulsed apparatus is equally usable for ultrasonic investigations with the inclusion of proper ultrasonic transducers.

## SEMICONDUCTOR PHYSICS

Spectroscopic investigations of 3-5 semiconducting compound are performed with a Spex 1400 Double Grating Spectrometer having a resolution of 0.1 Å at 650 nm for high resolution luminescence studies; a quarter meter Jarrel Ash and a quarter meter Bausch and Lomb multipurpose monochromator; temperature-tunable GaAs lasers between 840 and 900 nm with a line width of 5 Å and several tenths of a milliwatt output power for absorption studies in GaAs; a Gaertner precision optical bench with accessories and a Varo IR Scope infrared image converter for active area studies in p-n junctions of near infrared semiconductor lasers. Electronic equipment generating current pulses of up to 100 A with less than 150 nanoseconds duration and 120 pps repetition rate has been built in this laboratory and is used in pulsing GaAs laser diodes. Stainless steel dewars with optical windows are available for absorption and luminescence studies at various temperatures. To obtain a high vacuum in the dewars, a vacuum station consisting of a Varian 8$\ell$/sec Vacion pump and an Ultek absorption pump has been assembled.

Optical spectroscopy instrumentation is employed to determine energy levels of defect centers in ionic single crystals. The equipment of primary importance consists of: Cary Model 14-R dual-beam ratio recording spectrophotometer which operates in the UV, visible, and near-IR range; Perkin Elmer Model 112 single-beam IR recording spectrophotometer; Cary White Model 90 IR dual-beam ratio recording spectrophotometer; Cary Model 15 UV-visible dual-beam ratio recording spectrophotometer with an extended ultraviolet spectral range; a Westinghouse 65-kG superconducting magnet for use with the C-W 90 and C-14R in Zeeman-effect studies.



Cary Model 14-R Spectrophotometer

An assorted supply of dewars and vacuum pumps are also on hand for optical measurements at low temperatures. To study symmetry properties of defect centers, uniaxial stress cells operating at cryogenic temperatures have been designed and fabricated in this laboratory. These stress cells are used in piezospectroscopic measurements of no-phonon electronic transitions in defect solids.

## SOLID STATE THEORY

Solid state theoretical calculations employ the computational facilities of the laboratory, such as the free access IBM 1620 computer system. When needed, other computers such as IBM 7094 system are available on a minimal hourly charge basis from the parent organization. A small program library written in Fortran has been compiled for the calculation of various effects on sharp electronic transitions in typical laser materials. A number of desk calculators are available for "order of magnitude" estimates and smaller-scale calculations not requiring computer facilities.

## FERMI SURFACE

Ultrasonic studies of Fermi surfaces and elastic constants in crystals include theoretical investigations of ultrasound absorption in crystalline solids, and from these investigations a determination of the effect of electron scattering by substitutional and interstitial impurities on such properties as the size and shape of the Fermi surface, the elastic constants, and other basic parameters. Experimental studies of the ultrasonic and magnetoacoustic effect in certain metallic and nonmetallic crystals, over a range of temperatures particularly near that of liquid helium, are also planned in order to verify the theoretical predictions and to better understand solids of more complex crystalline structures.

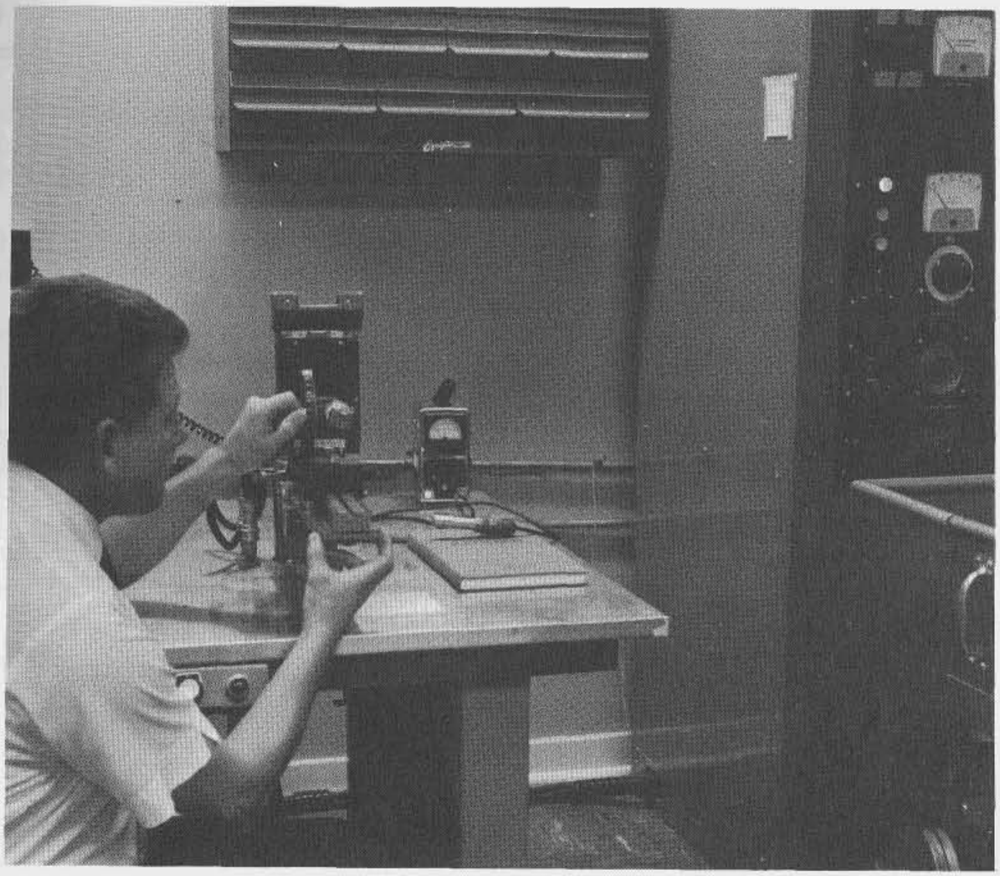
For the experimental phase of the work, the pulsed oscillator and components described below are being acquired:

(1) Oscillator, equivalent to Ahrenberg type PG-650-C; attenuator, 93 ohms, series 187; preamplifier, PA-620-SN273C; wide band amplifier, WA-600-C; auxiliary tuner, TU 626; General Radio type 1211-C oscillator; oscilloscope, equivalent to Hewlett-Packard type 175A with dual trace amplifier.

(2) A rotating magnet and cryostat (double helium dewar) and temperature controller are already on hand. The specimen holder, Bridgman crucible-furnace and electronic instrumentation for crystal growth, and the dry box for handling reactive metallic crystals in inert atmospheres are in the design process and will be built at the laboratory shop.

## CRYSTAL PHYSICS

Crystal physics facilities presently consist of a controlled temperature setup for growing crystals out of liquid phase and several resistance element heated furnaces for crystal annealing, doping, and bleaching experiments. Besides inert gas atmosphere in which heating is done, a quartz-envelope vacuum furnace is available. These facilities are now being expanded to encompass crystal growing out of the melt and various zone-refining processes.



GE XRD-5 X-Ray Diffraction Unit

Also available is a GE XRD-5 x-ray unit with the capability of using polaroid film for quick, accurate alignment of crystalline samples. For the preparation of various sample shapes and surfaces, a thin-wire saw and various polishing tables are housed in the laboratory.

## RADIATION PHYSICS BRANCH

*Capabilities:*

The Radiation Physics Branch pursues basic research in such areas as nuclear cross sections, decay scheme studies, and nuclear reactions. Stable materials such as samarium, neodymium, and cerium are bombarded in the Van de Graaff accelerator to produce radioactive isotopes through neutron reactions. Nuclear cross sections are determined and studies are made of the decay of the nucleus. The particle decay is measured with radiation detection devices, and offers a basis for computing decay rate. Neutron and gamma ray spectroscopy are areas of fundamental interest in this laboratory.

Nuclear reactions such as bombardment of boron 11 and beryllium by deuterons are studied, and the degree of polarization of the emitted neutron beam is determined. Nearly all of the research conducted by this branch is basic in nature, though some applications may be derived for missile warheads that are bombarded by neutrons.

The laboratory also conducts research on the response of scintillation detectors to various nuclear radiations, by bombarding the scintillators with neutrons from the Van de Graaff accelerator and gamma rays from naturally radioactive sources. A cryostat is used to study the variation of the response of scintillators with temperature. Different scintillators can be studied as a function of particle energy. The ability to distinguish neutron from gamma-ray events in mixed fields, using certain scintillators and pulse-shape discrimination, is one objective being actively pursued. Finally, current theories of scintillator response mechanisms are being investigated and used to analyze some of the accumulated data.

A program is under development to perform neutron-gamma ray angular correlation measurements on various nuclear reactions. Beams of deuterons from the Van de Graaff accelerator will be used to produce excited nuclear states by means of (d,n) reactions. The angular correlations between the prompt de-excitation gamma radiations and residual neutrons will be measured using fast coincidence and time-of-flight techniques. These measurements are expected to supplement (d,n) cross section and polarization data, and hence lead to a better understanding of the properties of many excited nuclear states.

*Facilities:*

The primary facility of the branch is an HVEC 2-MV Van de Graaff accelerator which is capable of supplying up to 100 $\mu A$ of monoenergetic protons or deuterons. The accelerator is post-acceleration pulsed, and pulse widths as small as 2.5 nanoseconds have been achieved. A variety of equipment is on hand for data acquisition, much of it in NIM modules for compactness. Triggers, discriminators, gates, fan-outs, and time-to-amplitude converters are available for handling fast signals, and various linear amplifiers, preamplifiers (for both photomultiplier and solid-state detectors), single channel analyzers, linear gates, delays, etc. are on hand for signal processing. A Victoreen 400-channel pulse height analyzer is available, and a 4096-channel analyzer which will have dual-parameter capability will soon be operational.

A Veeco Vacuum Corporation 400 Evapatrol Vacuum Evaporator is capable of producing $10^{-7}$ mm Hg pressure in a bell jar that is 12 inches in diameter by 18 inches high. It is powered by a 2-kVA 5-V secondary winding that produces 400 A. Targets are made with the evaporator and are used for bombardment by beams from the Van de Graaff accelerator.

## OPTICAL SPECTROSCOPY BRANCH

*Capabilities:*

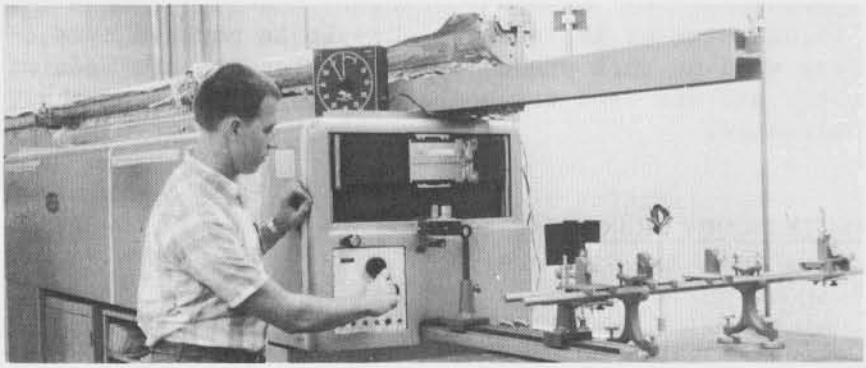
The Optical Spectroscopy Branch conducts research in organic and inorganic chemistry. Basic chemical phenomena are studied, and methods of chemical analysis and separation are developed for identification. Chemical compounds can be studied using infrared, ultraviolet, and spectroscopic methods. A special competence has been developed in the field of molecular structure spectroscopy.

*Facilities:*

A Beckman DK-2A Ratio Recording Spectrophotometer is used for the near-IR, visible, and UV regions of the electromagnetic spectrum -- 4μ to 1750 Å, with nitrogen purging.


Beckman DK-2A UV Spectrophotometer

The laboratory has a 3.4-meter plane grating modified Ebert Spectrograph with foregrating for high resolution molecular structure analysis in the visible and near-UV regions of the spectrum. Various accessories available for use with this instrument include large Hanovia Xe light source, hollow cathodes and hand iron arc standards, flash photolysis unit producing 30,000 joules, rf discharge units, and optical accessories.



Jarrell-Ash 3.4-Meter Ebert Spectrograph

A 21-foot Vacuum Spectrograph with accessories -- 2000 Å to 50 Å, with appropriate light sources and photographic film -- is also available for high resolution studies in the vacuum region.

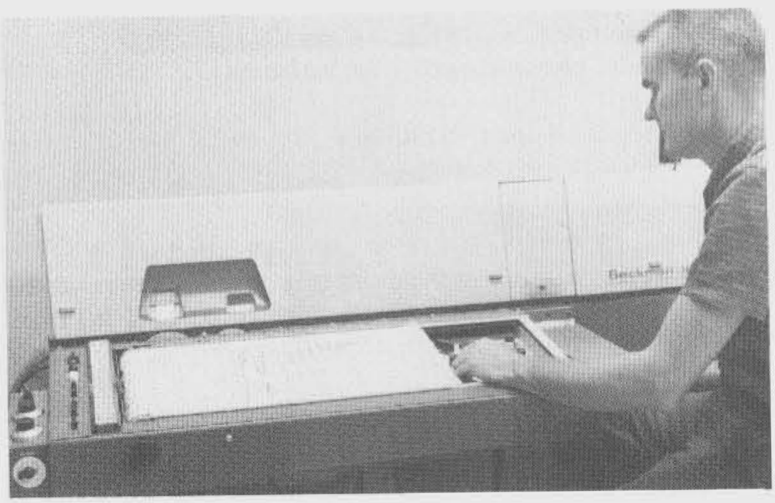

Vacuum Spectrograph

Perkin-Elmer Vapor Fractometer

A Vapor Fractometer and a Megachrom is used to analyze gases for purity. Small, highly pure samples of gas may also be obtained with this instrument, using the appropriate chromatographic columns.

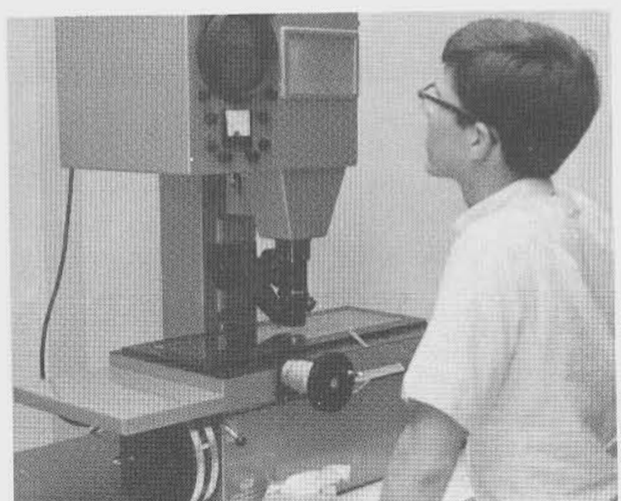
Megachrom

An IR-5 Spectrophotometer is used for routine and exploratory analysis in the rock salt infrared region, and an IR-7 Spectrophotometer with CsI prism-grating interchange for high resolution investigation of molecular structure in the IR region of the spectrum, or 2-50$\mu$. A 10-meter multipath gas cell is available with this instrument for high intensity, low pressure studies.



Beckman
Spectrophotometers
(IR-5 above, IR-7 below)

A <u>Comparator</u>, capable of measuring the "line" spacings of a spectrum on a photographic plate to a 0.0001-mm accuracy, is available for making accurate spectrum analyses.

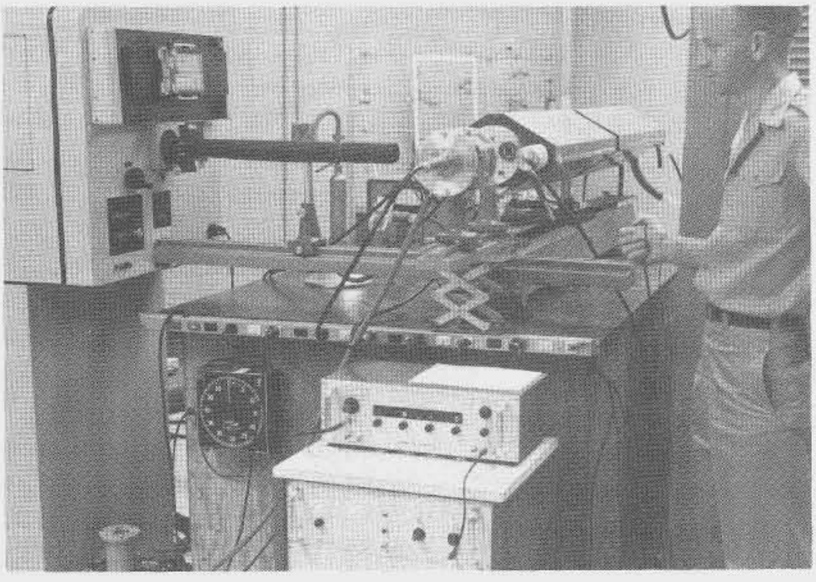


Comparator

Jarrell-Ash Densitometer

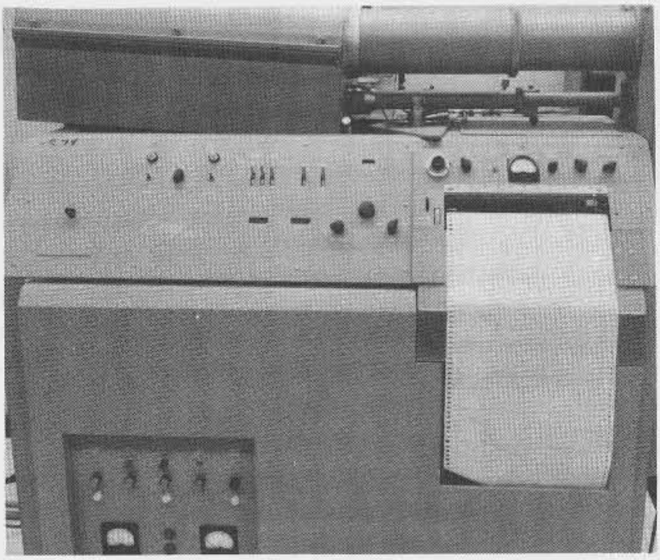
A 12-speed, High Density Microphotometer (Densitometer) compares "line" intensities of various spectra or exposure densities of other photographically recorded data.

The Flash Photolysis Apparatus, used for free radical formation in the gas phase, has an input of 20 kV and 9000 joules.

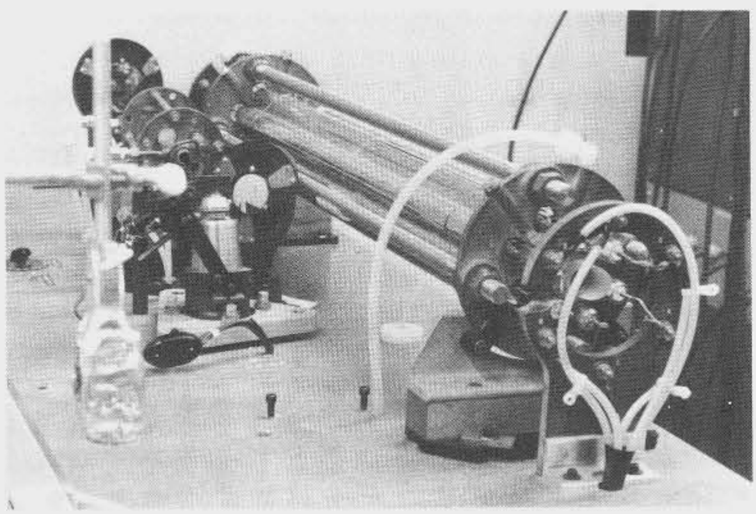


Flash Photolysis Apparatus

Other items include a Raman Spectrophotometer with gas, solid, and liquid sample capabilities, and a Q-Switched $Nd^{+3}$ Doped Laser with 1-GW power output.



Raman Spectrophotometer



Q-Switched Laser

The normal chemical laboratory small equipments -- PM meters, titrators, Kjeldahl apparatus, analytical balances, DK spectrophotometer, constant temperature baths, Parr bombs, vacuum ovens, pumps and gages, electronic test equipment, electroplating equipment, heating mantles and tapes, dark room and accessory equipment, etc. -- are on hand for normal chemical studies.

## AEROPHYSICS BRANCH

The Aerophysics Branch conducts research in atmospheric physics, embracing such objects as analysis and representation of atmospheric parameters, aerodynamics, thermodynamics, and turbulence. Physical and mathematical methods are developed which yield a quantitative treatment of the specific reactions of atmospheric parameters on the missile shell, its components, the trajectory, and the environmental conditions of the missile. The research involves analysis and physical interpretation of meteorological data obtained from high altitudes and pertaining to air density, temperature, wind dynamics, atmospheric composition, and radiative energy transfer processes. Specific topics investigated by analytical representation for consideration in design criteria include the density profile, wind profile, wind shear distribution, turbulent fluctuations, visibility, optical properties, and hydrodynamic impact.

Research in atmospheric density includes the areas of adequate representation, division into atmospheric layers and zones, and general frequency analysis of density profiles and temporal and spatial changes of the three-dimensional atmospheric density field. In hydrometeoric impact research, methods are developed to relate cloud cover and relative humidity to permit analysis of frequency occurrence of hydrometeoric particles from tactical areas where direct measurements and statistics are not available. In addition, visibility and cloud cover data from various sources are evaluated for special project application. Wind structure analyses are aimed at developing techniques for wind profile representation and a set of characteristic wind profiles with probability reference. Methods for proper consideration of shear values for small shear increments have been derived.

## SOLID MECHANICS BRANCH

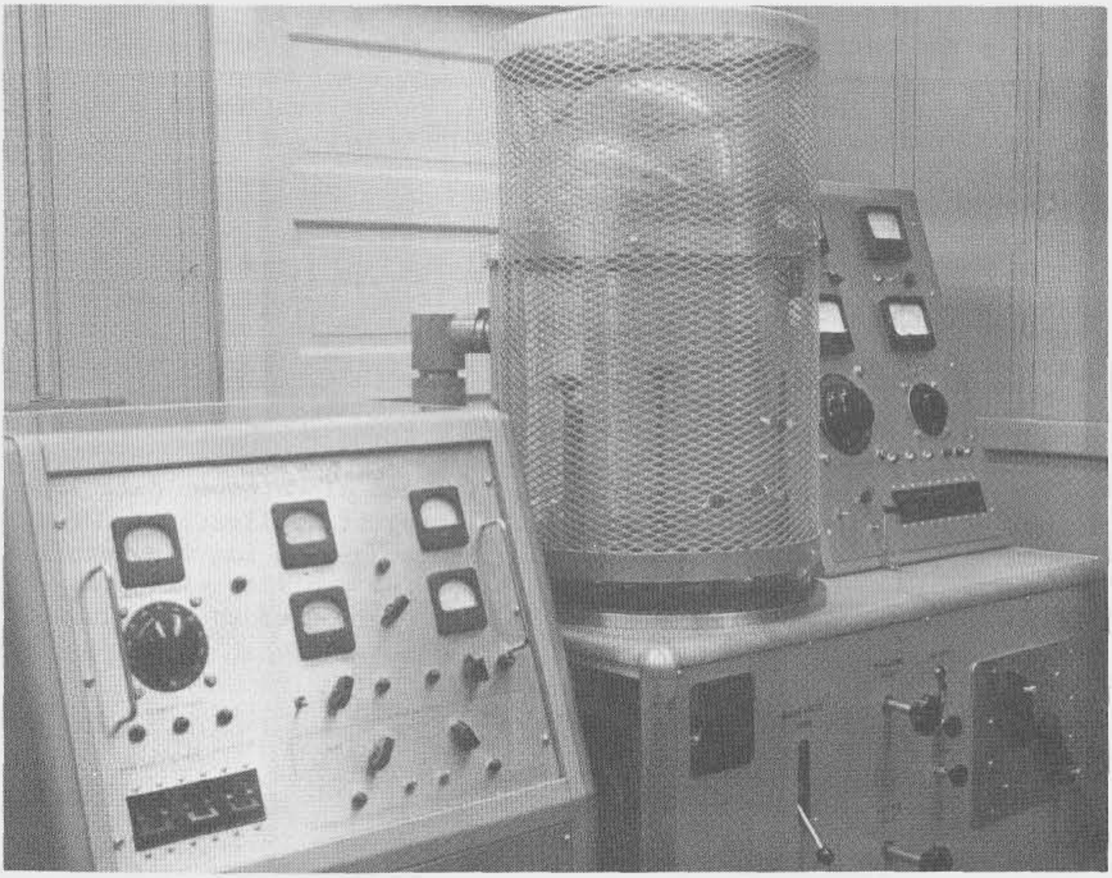
*Capabilities:*

The Solid Mechanics Branch is engaged in applied and basic research in the areas of materials and mechanics of solids. Most of the materials research is directed toward producing new materials for propulsion items or other missile components which must withstand severe thermal environments. High temperature materials receiving attention include ceramics, composites, and refractory metals. Solid and fibrous materials are produced using new processing methods, and their mechanical properties, oxidation resistance, and other characteristics are then examined by various laboratory techniques.

The mechanics studies are devoted both to establishing theoretical failure criteria and to predicting the serviceability of missile structural materials under realistic mechanical and thermal environments. Unique testing methods are used to determine the multiaxial stress-strain properties of both metallic and ceramic materials under elevated temperatures.

*Facilities:*

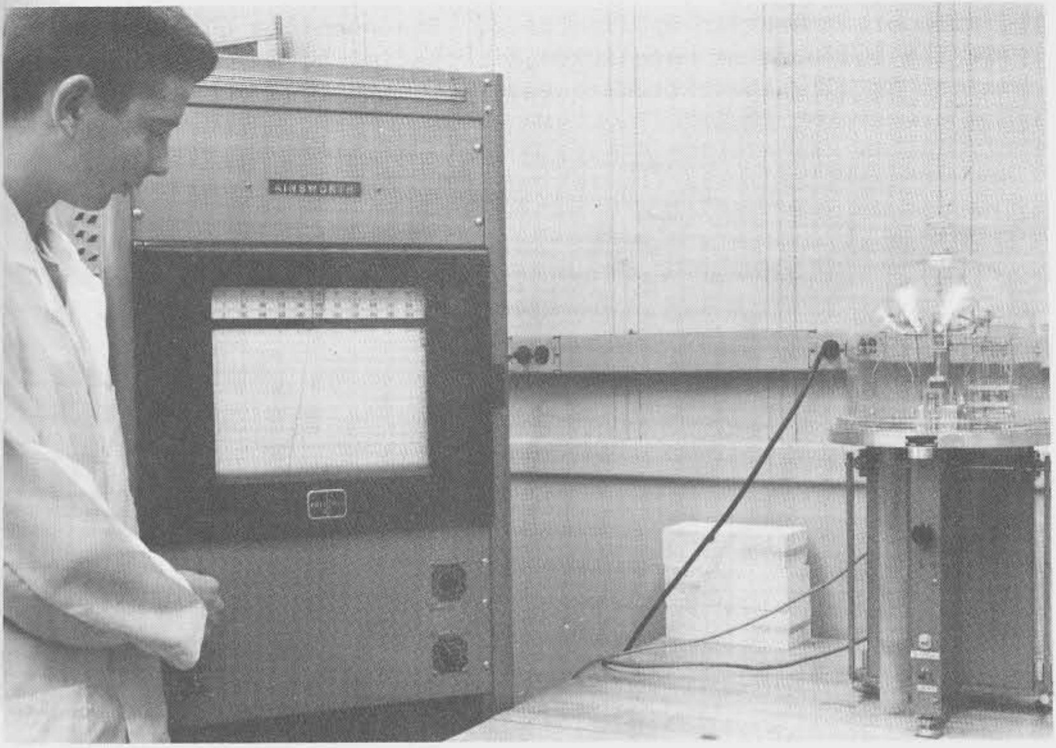
Denton Model DV503FP Vacuum Evaporator and Denton DEG 801 Electron Gun systems are capable of vaporizing all known refractory materials, and are also used to synthesize new refractory compounds.



Electron Beam Evaporation System

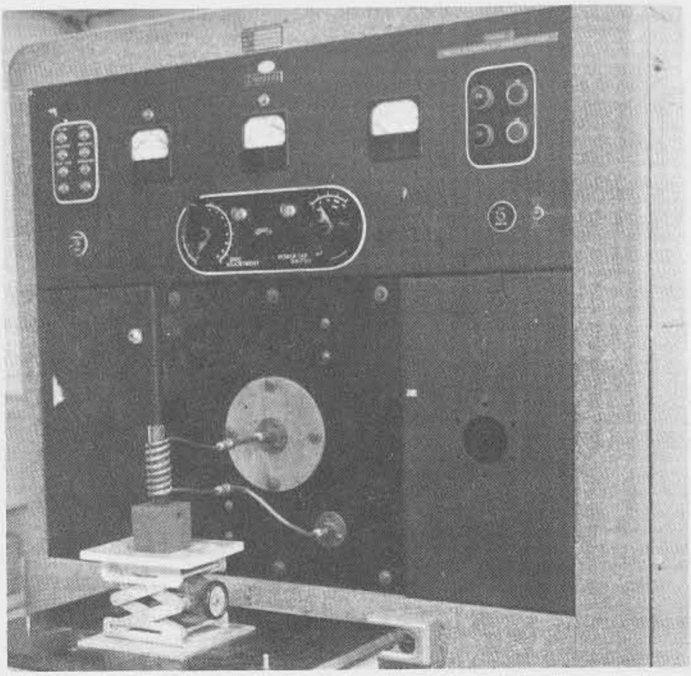
An Ainsworth Type RV Automatic Recording Vacuum Balance is available for studying the change in weight of specimens as they are subjected to changes in atmospheric environment and temperature.

Two Lindberg High-Frequency Induction Heating Units, each with a power rating of 10 kW, are employed for many projects. New materials are synthesized, methods of joining ceramics and metals are developed, and certain thermodynamic properties are evaluated

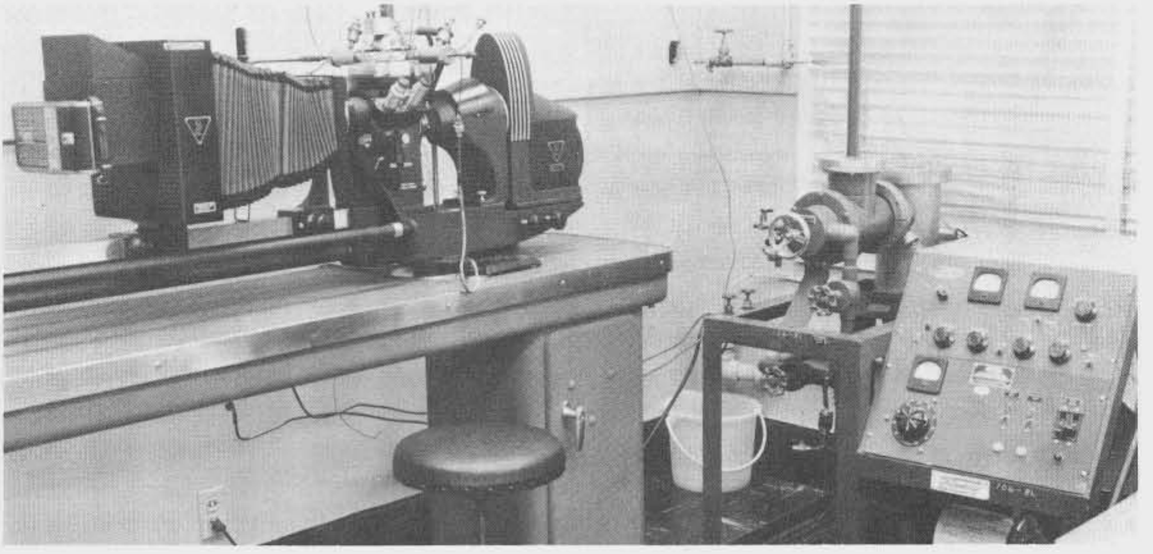



Automatic Recording Balance

Induction Heater

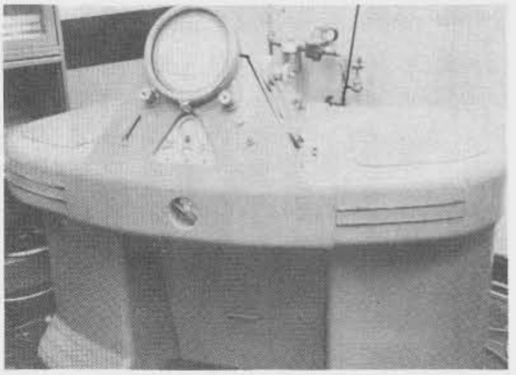


A Metallograph equipped with a vacuum heating stage is used for observing the changes in the microstructures of metals at high temperature, with or without an applied load. Equipment is available to prepare the surfaces of metallographic specimens, using conventional mechanical or ultrasonic techniques.



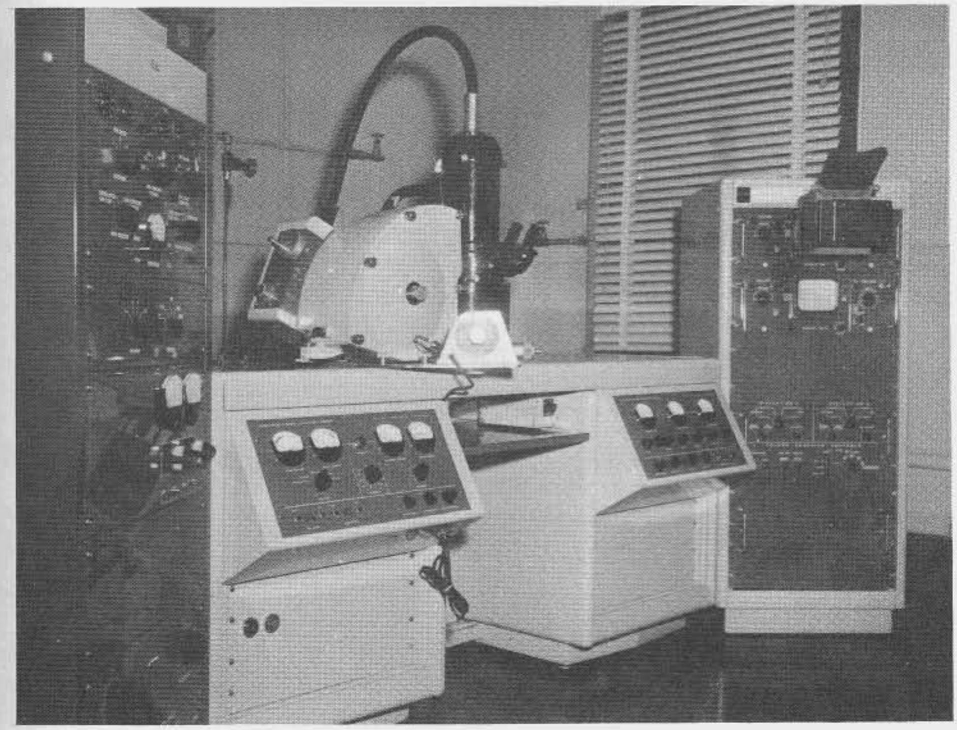
B & L Metallograph with Heating Attachment

A Phillips EM-100 Microscope is available for problems in the fields of chemistry and physics. It is equipped to investigate specimens in various forms including bulk, film, wire, and powder. Photographic recording of surface features and of transmission and reflection diffraction patterns are integral functions of the instrument. The use of accelerating voltages of 40, 60, 80, and 100 kV can give a resolution down to 50 Å and produce continuous variable magnification up to 60,000X with the microscope. The crystalline structure of specimens can be determined by electron diffraction, while surface morphology can be examined by shadowing and replica techniques.



Electron Microscope

A Norelco AMR/3 Electron Probe Microanalyzer is used to characterize material surface deposits, oxidation and corrosion products, inclusions, microsegregation and diffusion, and the chemical decomposition of composite fibers. This instrument uses a focused 1-micron electron beam to excite characteristic x-ray spectra of atom species contained in an approximate 1 cubic micron volume of material. A curved crystal x-ray spectrometer is used to obtain qualitative and quantitative chemical analysis of the small volume for all elements above atomic number 3. Concentrations of elements over a linear path can be investigated by means of either beam scanning or sample movement with a fixed beam. Both absorbed and backscattered electron visual displays may be obtained to investigate chemical variations and surface detail.



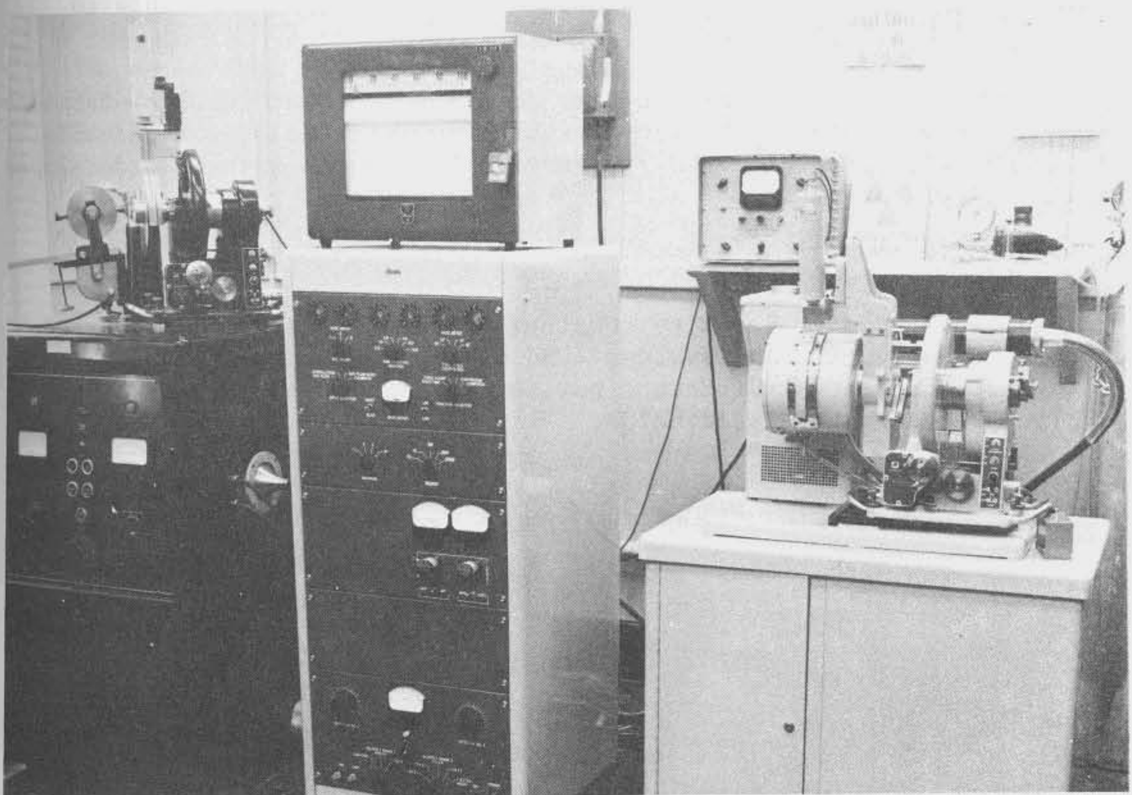
Electron Probe

A Tinius-Olsen Tester, 120,000-pound capacity, is used to actuate apparatus for subjecting nonmetallic tubular specimens to biaxial loading consisting of internal fluid pressure and axial loads. Biaxial properties of both polymeric and ceramic materials are examined. An Instron Tester and other high speed axial loading machines are available for investigating the dynamic properties of materials for fracture times ranging from 1 msec to ½ hour.


Universal Tester

MTS Biaxial Stress Testing Machine

An MTS Division Research Electro-Hydraulic, Program-Controlled, Closed-Loop Testing Machine, capable of applying axial tension and compression loads of 30,000 pounds and providing gas pressures of 20,000 psi is available for applying various combinations of biaxial loading to tubular test specimens by axial loading and internal pressurization. Ancillary apparatus consists of a 30,000-psi gas supply system, a 22.5-kVA transformer and saturable-reactor-control system for resistance heating the test specimen for high temperature tests, and electrooptical and strain-gage strain measurement systems. A 20,000-pound capacity creep testing machine is also available for performing stress-rupture and creep tests on materials.



X-Ray Diffraction and Vacuum Spectrographic Units

Norelco X-Ray Diffraction and X-Ray Vacuum Spectrographic Apparatus, with cameras and accessories, for identification and crystallographic characterization of organic and inorganic crystalline materials, solid state phase transformation studies, nondestructive stress analysis, preferred orientation studies, and both nondestructive qualitative and quantitative chemical analysis.

## APPLIED PHYSICS BRANCH

*Capabilities:*

The Applied Physics Branch develops and adapts lasers and laser devices for application to guided and ballistic missile systems. Very high laser energies and powers are available with time durations which range from nanoseconds to milliseconds. An energy system including chargers, capacitors, pulse forming networks, discharge equipment and associated instrumentation is available.

A laser radiation facility consists of laser sources that operate at 1.06, 0.6943, 10.6, and 0.6324 microns. This equipment is flexible in terms of beam pointing, energy and power densities, wavelength, and pulse length. In the past this facility has been made available to other agencies, subject to Army requirements.

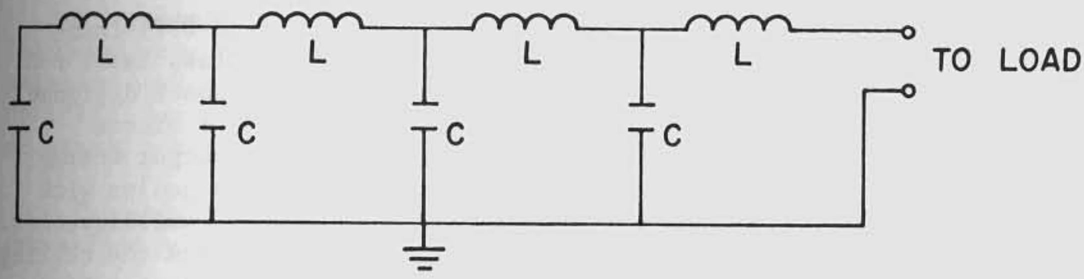
An optical fabrication facility is oriented toward design, fabrication, and maintenance of high-energy as well as small, man-portable laser devices. Several laser fabrication techniques have been developed in this area.

*Facilities:*

The Energy/Power Facility consists of seven power supplies, three capacitive energy storage systems, and other equipment to monitor voltage and current at different points in the system. The seven power supplies used are tabulated below:

| Power Supply | Maximum Voltage | Maximum Current | Manufacturer | Model No. |
|---|---|---|---|---|
| 1 | 25 kV | 200 mA | Kilovolt Corp. | KV25-200 |
| 2 | 25 kV | 200 mA | Kilovolt Corp. | KV25-200 |
| 3 | 10 kV | 500 mA | Kilovolt Corp. | KV10-500 |
| 4 | 10 kV | 500 mA | Kilovolt Corp. | KV10-500 |
| 5 | 10 kV | 200 mA | Built in Laboratory | |
| 6 | 50 kV | 3 mA | Del Electronics | None |
| 7 | 6 kV | 100 mA | Sorenson | 1006-500 |

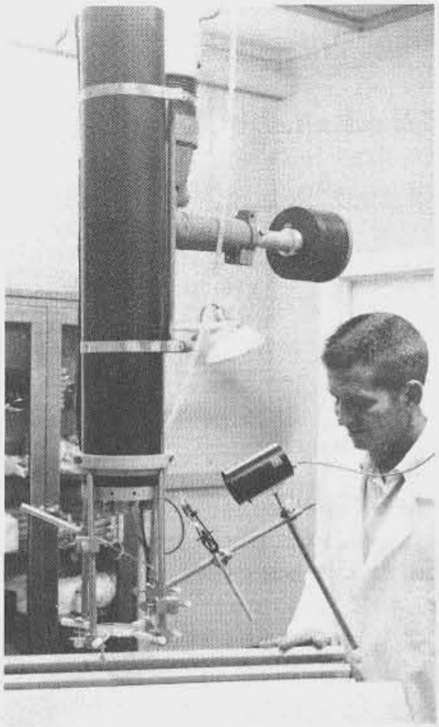
Power supplies 2, 3, and 4 are used to charge the capacitive energy storage systems; power supplies 1, 5, and 7 are used to sustain ionization in the laser flashlamps; and power supply 6 is used to start the ionization of the flashlamps.




Capacitive Energy Storage System

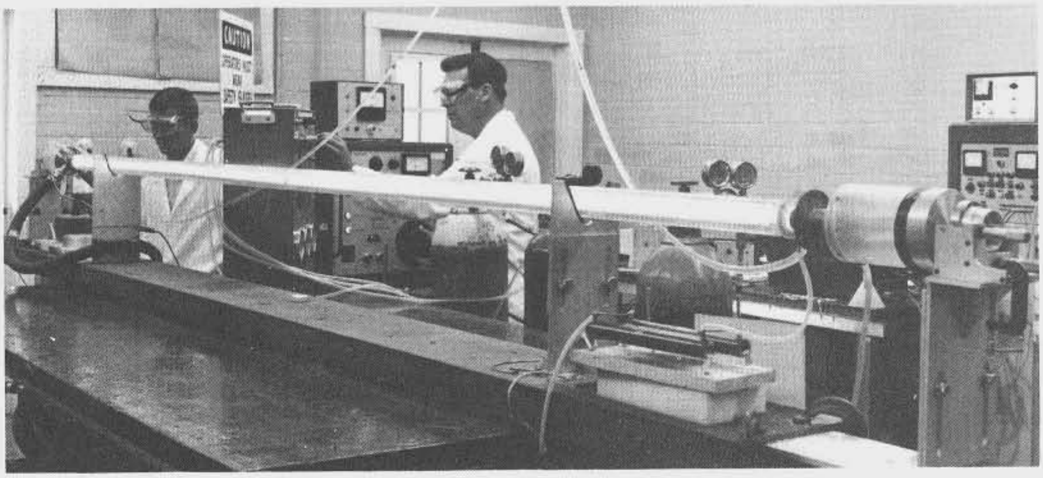
The capacitive energy storage systems used are constructed as delay lines to provide a rectangular-shaped current pulse to the flashlamps. The diagram above shows the construction of the smallest of the three energy storage systems.


Power Supplies



A 36-inch-long and 0.75-inch-diameter $Nd^{+++}$ doped glass laser rod is the heart of an in-house designed and built source of 1.06 micron laser radiation. The output energy is variable from 0-1200 joules with pulse lengths of 2 and 4 milliseconds. The unit is suspended from the ceiling in a telescope mount to give a high degree of versatility pointing the beam. This unit is used primarily for biological impact and other materials interaction studies.

1.06 Micron Pulsed Laser

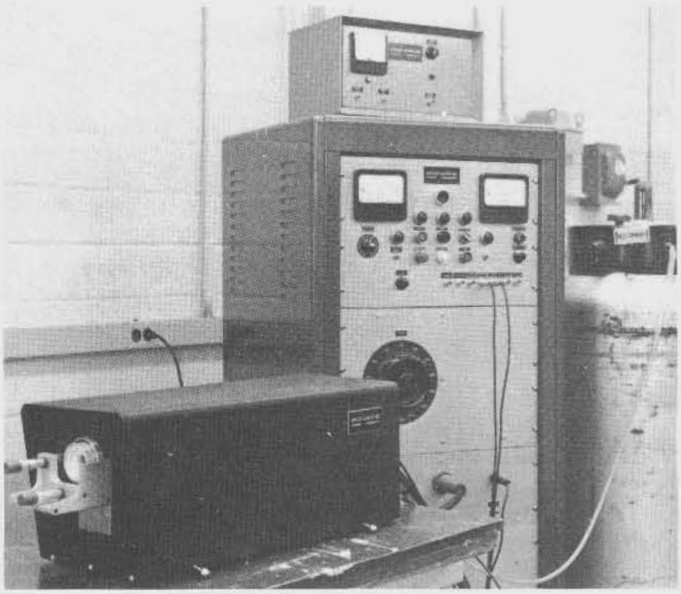


10.6 Micron CW Laser

A Molecular Gas Laser gives a continuous wave output at 10.6 microns. A mixture of nitrogen, helium, and carbon dioxide is used in a continuous flow arrangement. Output powers in excess of 100 watts can be obtained from this unit.

A commercially built Ruby Laser is used both in the long pulse and the Q-switched mode. Utilizing a dual element Q-switch and a rotating prism in conjunction with a passive filter, pulses of 5 joules with a $30 \times 10^{-9}$ second duration are possible. In the long pulse $2 \times 10^{-3}$ sec, an output energy of 100 joules is available.

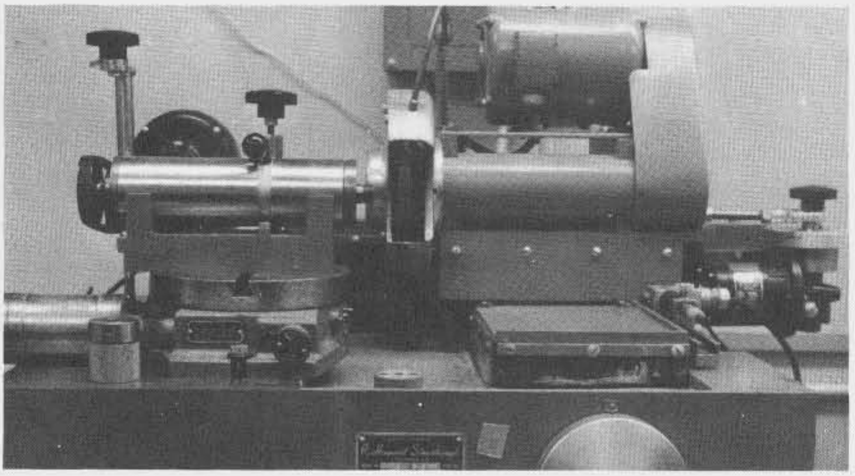
The Strasbaugh Machine is a precision diamond saw with calibrated cross-feed and a hydraulic forward or reverse table feed.



Ruby Laser

Precision Diamond Saw

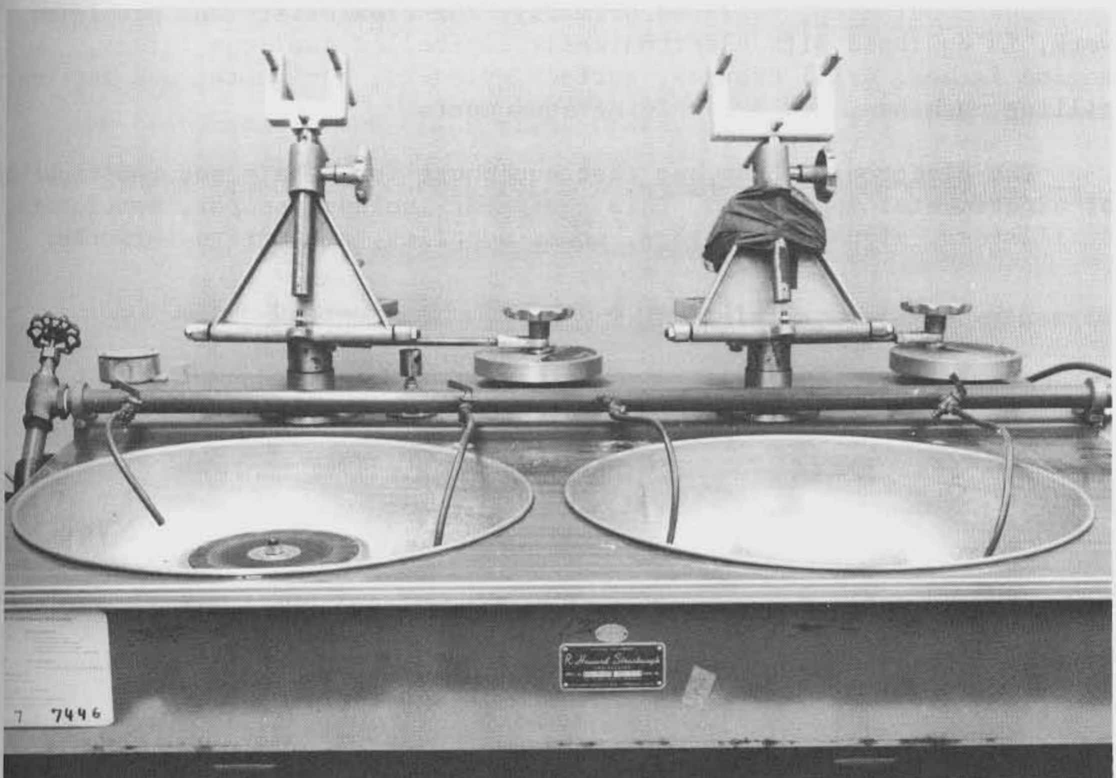
The R. Howard Strasbaugh Centering and Edging Machine will grind bevels on lenses and glass tubing with a diamond grinding wheel. The work spindle has variable speed, with an angle set for varying degrees of bevel. The machine will also center a glass blank on the work spindle for grinding and polishing. The grinding wheel has a variable forward feed for automatic grinding, with automatic preset stop for precise depth of grinding.



Strasbaugh Centering and Edging Machine

Strasbaugh Curve Generator

The R. Howard Strasbaugh Curve Generator is capable of grinding (to a rough finish) flats or lenses of any degree of curvature and diameters up to six inches. It uses diamond impregnated grinding cups of various diameters and the vertical work-spindle rotates either direction at a continuously variable speed. The grinding wheel likewise operates either direction, at speeds up to 1800 rpm and tilt angles variable either side of 0 degree.



Strasbaugh Polishing and Lapping Machine

The R. Howard Strasbaugh Polishing and Lapping Machine, having two spindles with continuously variable speeds, provides a random polishing and lapping motion through an intricate arrangement of preset cams. This machine will handle materials up to 36 inches in diameter.

## TECHNICAL SUPPORT BRANCH

*Capabilities:*

The Technical Support Branch provides advanced engineering design, development, fabrication, and testing of unique tools and electronic equipment. Existing research tools are modified for special applications, increased reliability, and ease of operation. Supplies of electronic components and electronic testing equipment, ordered from manufacturers or fabricated in the shop, are kept available for all of the laboratory.

*Facilities:*

The Model Shop, designed primarily for flexibility and precision work, is equipped with electronically controlled toolroom lathes, engine lathes, drill presses, surface grinders, horizontal and vertical milling machines, and arc welding equipment.

The Electronics Shop has test equipment for repair and modification of experimental apparatus. This equipment includes scopes, modulators, oscillators, signal generators, power supplies, and bridge networks.

# ARMY PROPULSION LABORATORY AND CENTER

The Propulsion Laboratory exercises executive management control and technical direction over supporting and engineering research programs in the field of propulsion, and accomplishes or supervises the design, development, and evaluation of missile propulsion systems and gas-operated auxiliary power systems. Advisory and consulting services in these areas are provided to the Command, contractors, and other interested technical groups.

The organization comprises eight operating branches:

| | |
|---|---|
| Solid Propellant Chemistry | Advanced Propulsion Engineering |
| Measurement | Motor and Power |
| Motor Processing | Propulsion Systems Engineering |
| Propulsion Mechanics | Liquid Propulsion Technology. |

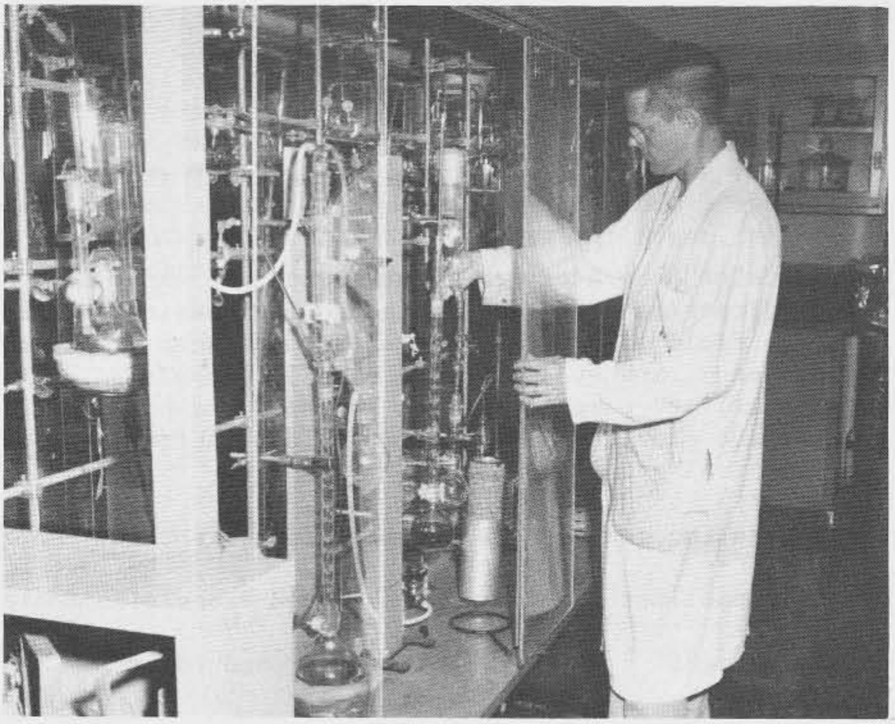
## SOLID PROPELLANT CHEMISTRY BRANCH

*Capabilities:*

The research and development conducted by the Solid Propellant Chemistry Branch is aimed at deriving propellant compositions with improved physical or ballistic properties. The branch is equipped to analyze for practically every element in the periodic table. Improved ingredients for propellants and igniters are developed in-house, and all ingredients, both old and new, are evaluated in terms of functional characteristics in a specific rocket or missile.

A program of polymer synthesis and evaluation specializes in the preparation of polymers specifically for propellant applications; emulsion polymerizations, Zeigler-type catalyst, butyl lithium, lithium dispersions, and other techniques are used. Often special polymerization catalysts are used which can introduce functional groups into the polymer molecule.

The branch prepares contractual requirements and exercises technical supervision over contract performance in the assigned areas.



Polymer Synthesis

*Facilities:*

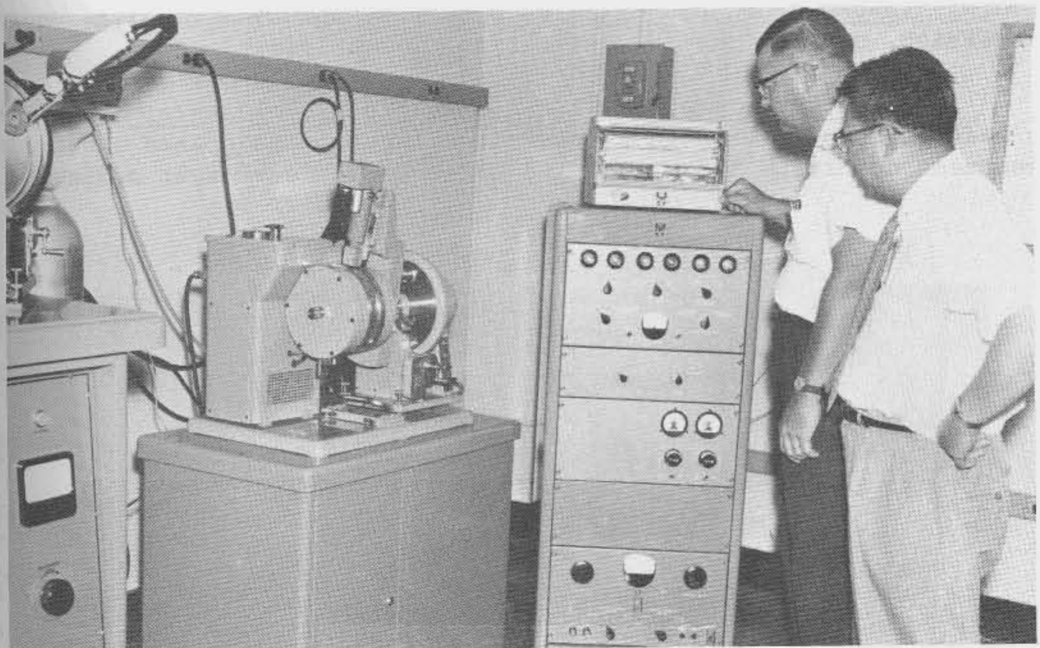
The branch's laboratories contain the finest analytical equipment available for the rapid examination, identification, and analysis of propellant materials. In addition to the standard equipment, the following specialized units are available:

A Philips EM-75B Electron Microscope, for the examination of minute structures, magnifying up to 12,000 diameters.

A Philips X-Ray Diffractometer and Spectrograph for identifying crystalline elements and compounds. The diffractometer consists of a proportional counter readout and multipurpose vacuum x-ray fluorescence spectrometer with the complete crystal accessories and the entire set of x-ray equipment.

A Sargent-Malmstadt Automatic Titrator, Model SE, applicable to all types of titrations which may be classified as potentiometric including acid-base, oxidation-reduction, compleximetric, and precipitation. Complete analysis of a propellant mix can be made in a few minutes.

C.E.C. Model 21-620 Mass Spectrograph, used for analyzing gases and low boiling liquids up to 150 molecular weight.



Philips X-Ray Diffractometer

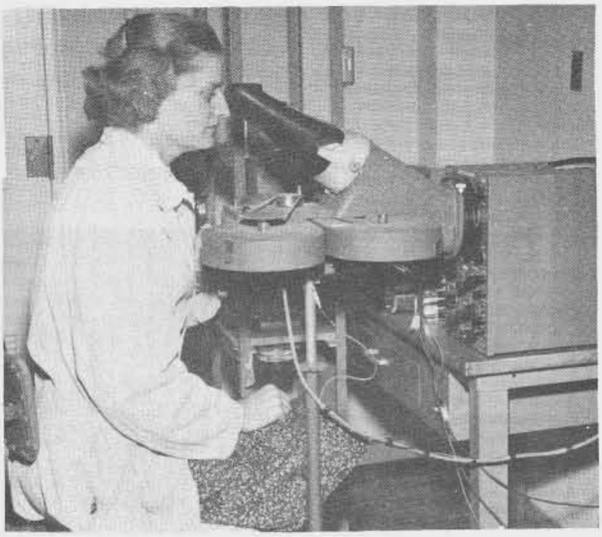
C.E.C. Model 21-620 Mass Spectrograph

Bausch and Lomb Emission Spectrograph, dual grating, medium dispersion, used in the identification of metallic elements.

A Sargent Model XXI Visible Recording Polarograph, designed to measure current voltage curves resulting from polarized electrode phenomena occurring in aqueous and non-aqueous fused salt media.

Perkin-Elmer 21 Spectrophotometer

Several infrared spectrophotometers, including the Perkin-Elmer Models 21, 350, and 137 and Rapid Scan Model 108. Model 21, a double beam instrument designed for operation in the 2.0 to 25 micron wavelength region, is useful in identifying both organic and inorganic compounds, whether solid, liquid, or gas. Model 350, a double beam recording instrument covering ultraviolet, visible, and near infrared wavelength ranges, will deliver extremely accurate photometric data at high resolution and stability. Model 137 is a double beam instrument designed for operation in the 2.0 to 15 micron wavelength region. The Rapid Scan 108 is capable of scanning a spectrum up to 90 times per second, and can be used in examining the exhaust species from a rocket nozzle.

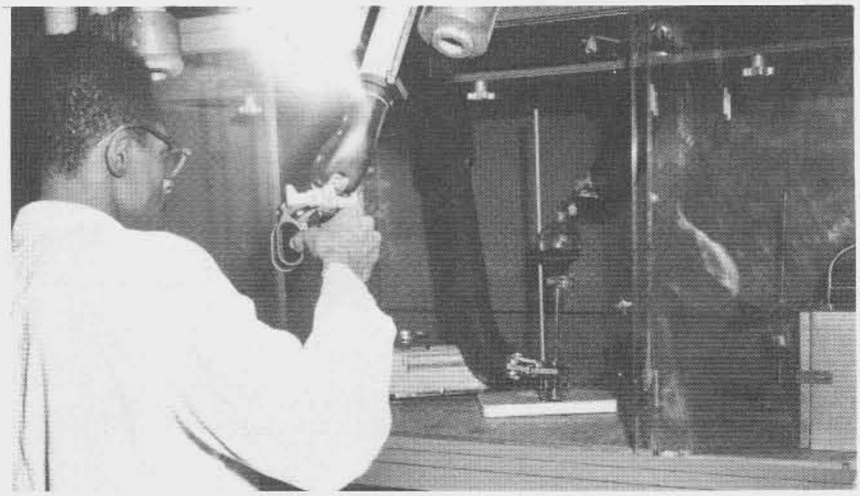


Rapid Scan 108 Spectrophotometer

The <u>1520 Aerograph Gas Chromatograph</u>, useful in the separation of small quantities of organic compounds, positive identification, and characterization of the products from a chemical reaction or mixture. For the synthesis of hazardous compounds, positive identification can be made with small quantities.

1520 Aerograph Gas Chromatograph

Safety devices are provided for personnel protection. Specially built hoods equipped with thick plexiglass shields and mechanical hands are available for use with highly energetic materials.



Protective Hood

## MEASUREMENT BRANCH

*Capabilities:*

The Measurement Branch conducts supporting research and development in interior ballistics of propulsion systems, assessment of detonation hazards, assessment of premature ignition hazards, and effects of propulsion system operation on associated equipment and immediate environment.

Infrared transmitting characteristics of rocket exhaust streams from various propellants are being investigated, based on interest in using this means of transmitting signals to guided missiles which is not easily jammed. Areas covered in this study include: percent transmission of infrared signals through exhaust streams of various rocket motors; effects of various propellant additives and atmospheric conditions; and portions of infrared spectrum most suitable for transmission of signals under adverse conditions.

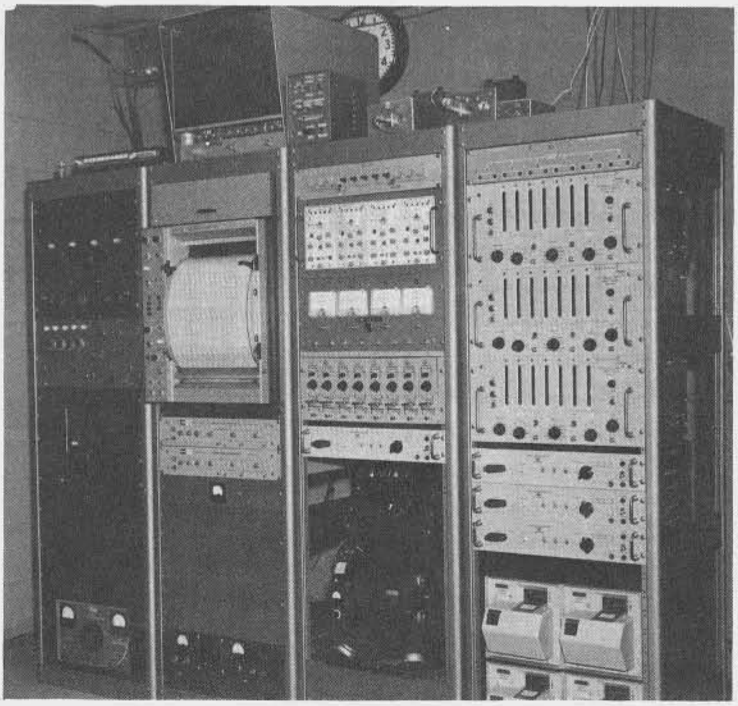
Sources of electromagnetic radiation which could produce premature ignition are detected, identified, and measured by simulating field conditions. Hazards investigated include exposure to rf fields during transport or storage, and electromagnetic fields produced by commercial broadcast stations, communications transmitters, and various types of radar and high frequency sources associated with missile systems.

In the area of radar interference from solid propellant rocket exhaust, a complete signal analysis can be made of AM, FM, or pulse as a function of time as well as of frequency.

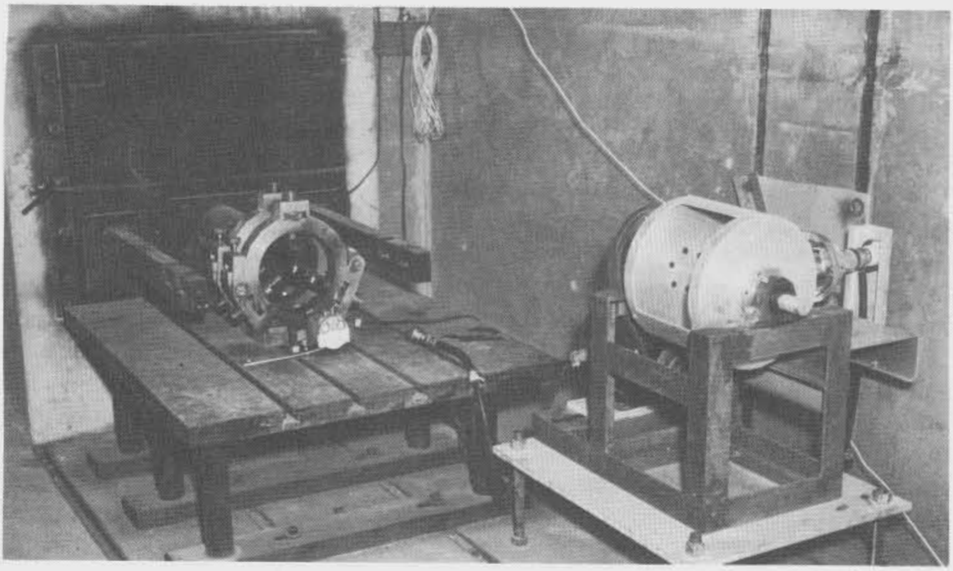
The branch also maintains and operates the more complex and special electrical instrumentation required by other elements of the laboratory.

*Facilities:*

The Static Test Stand is equipped to perform highly accurate and reliable measurements on rocket test motors. Transducers, in combination with a four-arm wheatstone bridge, are capable of measuring thrusts up to 20,000 pounds or pressures to 20,000 psi. High gain DC amplifiers and 20-kHz carrier amplifiers are used to amplify the small output signals of the transducers. Dual-output transducers permit the channeling of one output through a frequency converter to a digital counter, and a recorder capable of immediate recordings of integrated pressures and thrust. Plots of pressure or thrust versus time are recorded with a galvanometer-type oscillograph that employs direct writing photographic paper and can record 36 different events simultaneously or in sequence. Reduction of measured test firing data includes double-checking by planimeter of the values obtained with the automatic readout system.



Inside Static Stand



20,000-Pound Thrust Static Test Stand, with Chopper

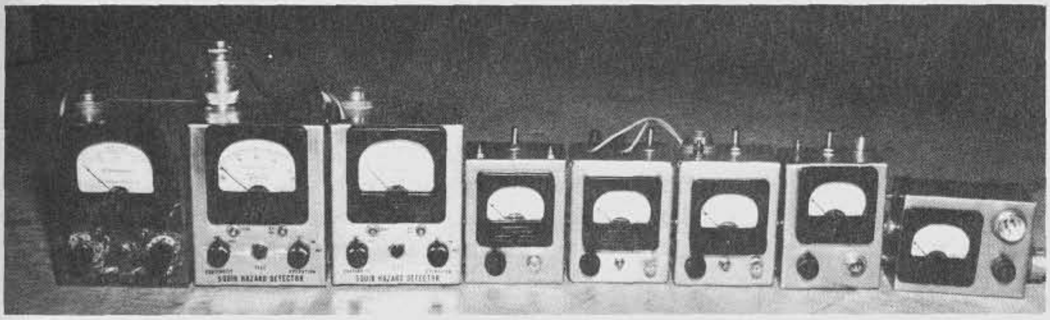
Barnes Radiation Reference Source

A Barnes Engineering High Temperature Infrared Radiation Reference Source, a blackbody type capable of reaching 1000°C, is used to calibrate the tungsten sources for studies in the near infrared (0.8 to 2.5 microns). It can also be used in calibrating thermocouples and other basic research devices. Two other infrared sources are available for the static firing stand -- an intense tungsten lamp with a 2400-Hz chopper, and a 5-inch diameter tungsten lamp with a 115-Hz chopper.

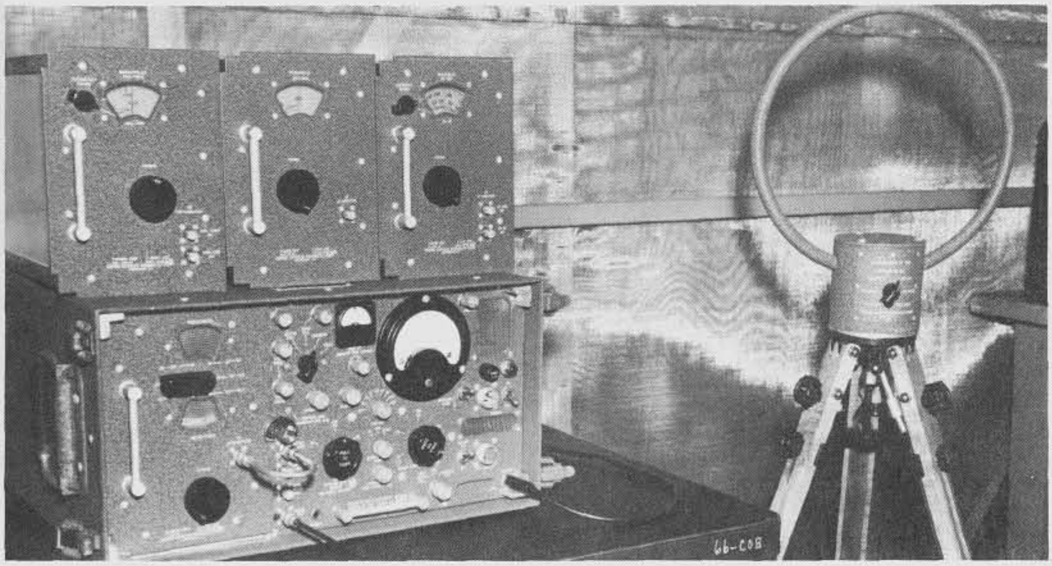
Filters are available for infrared optical systems, with high transmission in the middle of the band and sharp cutoff at the edges. Some of the filters are 6½ inches square and have been used with 6-inch diameter parabolic mirrors.

Thin-glass-sealed lead sulfide detectors, in matched pairs with various sensitivities, time constants, and physical dimensions, are used in the static firing stand. The branch has constructed two different varieties of the preamplifiers which are required for most applications of the detector cells in order to produce a signal sufficient to amplify and record on standard static-firing recording equipment.

The OML Hazard Detector, which was developed in the Propulsion Laboratory, is used to indicate the degree of hazard that exists due to the exposure of missiles to the rf fields present during transportation, storage, and standby situations. The rf energy heats the bridgewire in the detector, which in turn heats a tiny thermistor whose resistance change is monitored by a meter in the instrument. Various modifications have been made to the original design for special applications.



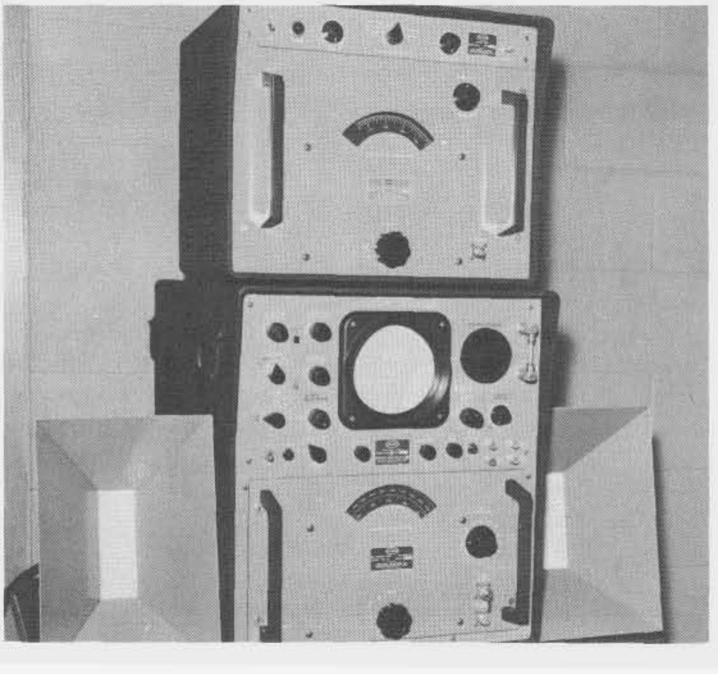
RF Hazard Detector



Screen Room

Equipment is available to produce rf energy from 3.5 to over 1000 MHz, at power levels up to 1000 watts. The laboratory has been assigned five frequencies for radiation of energy within this range, and other assignments have been requested. A screen room, 8 by 18 feet, confines the energy during high frequency tests. Other equipment permits field intensity measurements from 150 kHz to 1000 MHz at levels from 1 microvolt/meter up to 1000 volts/meter. In addition, field conditions can be simulated with respect to the strong electromagnetic fields produced by commercial broadcast stations, communications transmitters, and various types of radar and high frequency sources associated with missile systems.

Special features of the signal equipment used to study the radar interference caused by rocket exhaust streams are: high stability and low incidental AM and FM on CW; internal square wave modulation of 10 to 10,000 pps; minimum pulse rise time and decay time of 0.15 μsec; linear frequency calibration, with UNI-dial tuning of microwave oscillators; noncontracting shorts in tuning cavities, assuring long equipment life and noise-free tuning; self-contained frequency marker for measuring small frequency differences; and video, sweep, and trigger outputs available at front panel jacks. AM, FM, or pulse signals can be analyzed as a function of time (synchroscope operation) as well as of frequency (spectrum analysis operation). Measurements can be made of frequency, attenuation, gain, insertion loss, Q, signal-to-noise ratio, impedance, image rejection, selectivity, conversion gain, and transmission line characteristics.



Spectrum Analyzer

In addition to the specialized equipment, the following are available for general measurement and calibration purposes:

Sierra Electronic Corporation VHF Power Signal Sources covering the frequency range of 25 to 1000 MHz/sec, with a power output from approximately 5 to 50 watts over the frequency range into a 0.5 ohm load.

A Hewlett-Packard Frequency Standard which provides sine wave and pulse signals to 10 Hz, 100 Hz, 1 kHz, and 10 kHz, and sine wave outputs at 100 kHz and 1 MHz. The oscillator's stability and accuracy are not affected by external loading.

A Hewlett-Packard Frequency Divider and Clock, which determines frequency to a high degree of accuracy by means of time comparisons.

A variety of impedance bridges, cathode ray oscilloscopes, sensitive ammeter-voltmeters, high frequency counters, and vibration-measuring and high speed photographic equipment.

## MOTOR PROCESSING BRANCH

*Capabilities:*

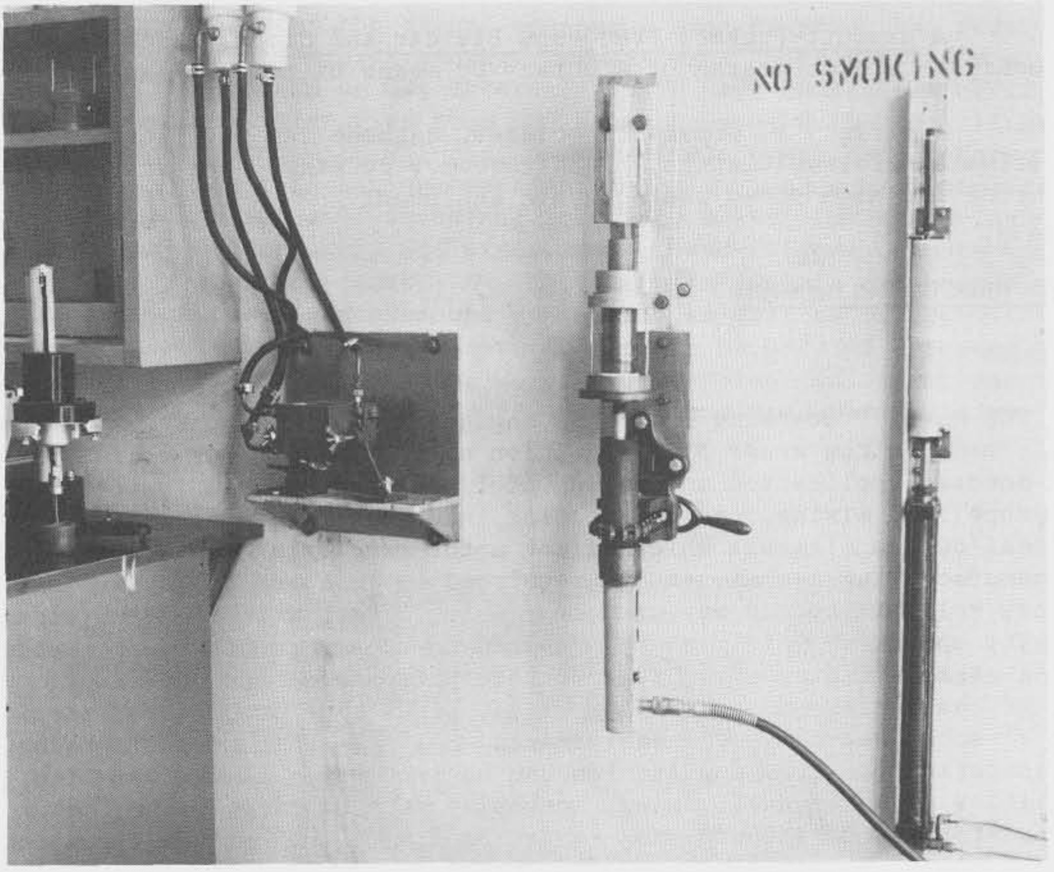
The Motor Processing Branch is engaged in supporting research and development in the areas of preparation of metal parts for solid propellant motors; application and curing of liners and thermal insulation; and propellant mixing, casting, curing, and finishing operations. The critical design elements which affect motor processing are determined, and manufacturing techniques are developed or improved to achieve satisfactory reliability and performance. Using 2-inch motors and physical property specimens which can be prepared in-house, processing parameters can be established to yield reproducible performance and studies can be made of the variations in raw materials, processing conditions, particle size effects, and equipment performance. All types of propellants under consideration for Army application can be processed; remote handling facilities -- barricaded mixing, screening, and casting, mechanical manipulators, and TV monitoring -- are used with the hazardous components and propellant compositions.

A buildup presently underway will provide scale-up polymer facilities and mechanical services for studying process variations in raw materials equipment, design, and processing conditions.

The branch prepares contractual requirements and exercises technical supervision over contract performance in these areas.

*Facilities:*

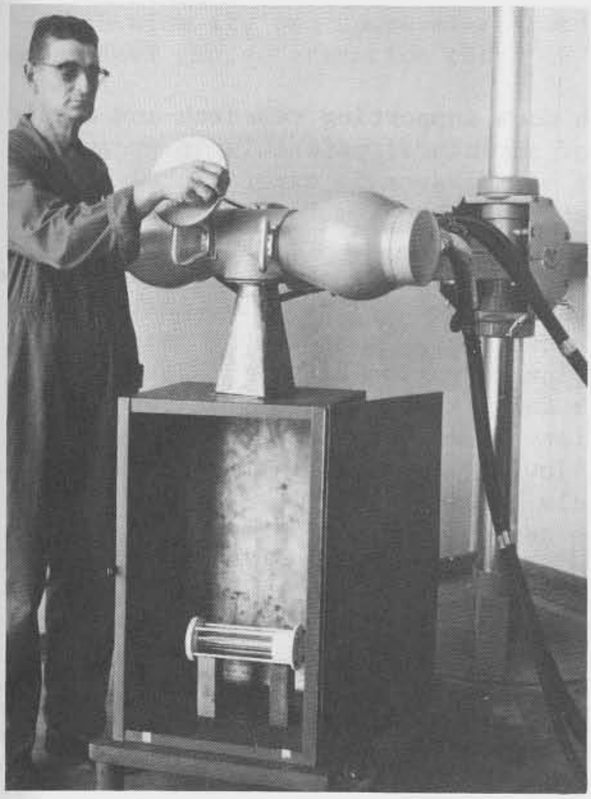
Two Baker Perkins Mixers, horizontal sigma blade type with a 1500-gram capacity, stainless steel construction, jacketed, with variable speed drive and temperature-sensing thermocouple, are used for mixing solid propellant. The mixers can be remotely operated for hazardous materials. Additional equipment includes vertical-type mixer, roll mill, "V" blender, pebble mill, and ribbon blender.




Remote Control Experimental Mixer, Mandrel Extractor, Pressure Motor Casting Device, and Viscometer

Two Viscometers -- a Brookfield type with kilopoise range and a Severs Burrell A200 extrusion rheometer -- are used for viscosity determinations of viscoelastic materials.

A Deaeration Chamber, 6 inches in diameter by 18 inches high, was designed and fabricated in-house to vacuum-slit deaerate propellant and cast into motor case or physical property specimens.

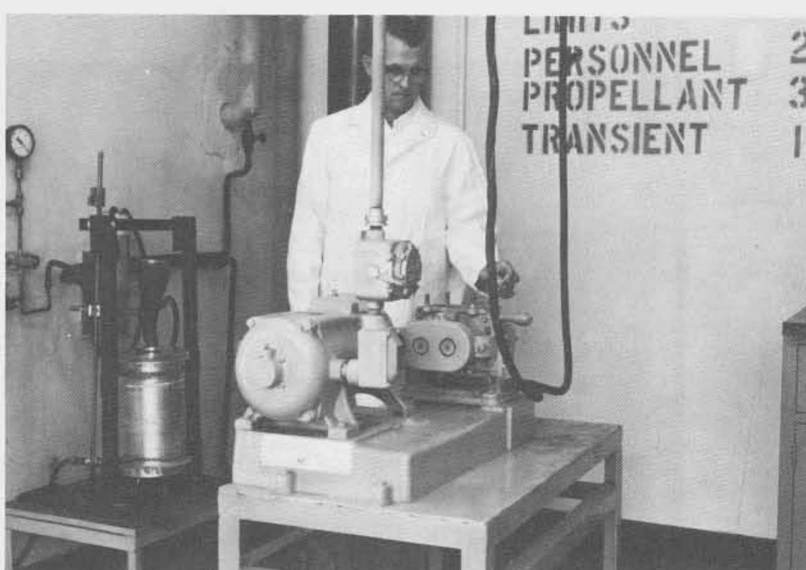


A Brabender Plastograph, 1-pint size and fully instrumented, is available for determining plasticity and curing rates of various propellant compositions.

A Strand Burning Apparatus provides propellant burning rate determinations with small specimens up to 5,000 psi and -40 to +150°F.

A 250-kV X-Ray, industrial design, permits nondestructive inspection of propellant, case, liner, and insulating materials under development, as well as the finished test motor ready to be fired.

250-kV X-Ray for Nondestructive Testing




Propellant Mixer, Deaeration, Casting Apparatus for Small Ballistic Rocket Motors

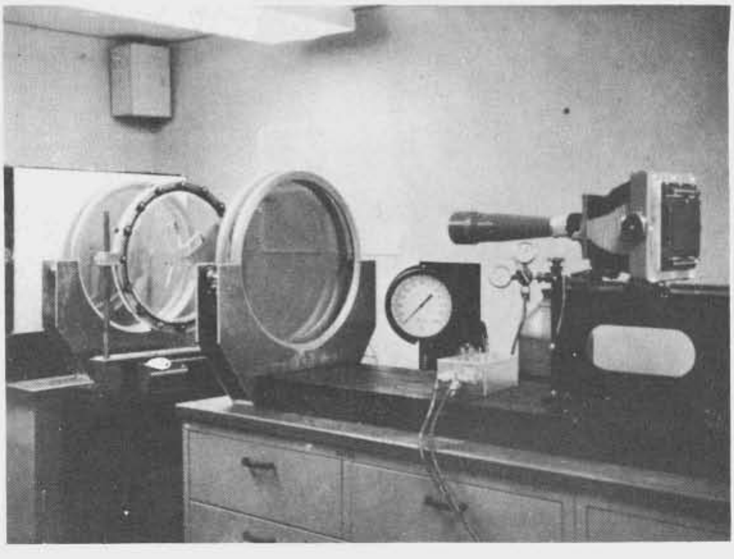
Other equipment includes cure ovens, pressure reactors, pumps, columns, filters, and general laboratory scale equipment.

*Capabilities:*

The Propulsion Mechanics Branch does supporting research and development in the field of application of structural materials to propulsion systems. One of the two major areas of endeavor is experimental evaluation of fracture toughness in high-strength sheet metals for use in solid rocket motor casings. The variables studied are state of stress, rate of loading, temperature, strength level, and metallurgical structure. Tests used in these studies are smooth and notched tensile, instrumented bend, smooth and notched tensile impact, charpy impact, and fracture toughness. The other major area is investigation of the mechanical behavior of solid rocket propellants and structural integrity analyses of the propellant grain under a variety of environmental conditions. These studies are pursued by the following means: the thermo-viscoelastic response of solid propellant materials is determined by means of creep, relaxation, and constant strain rate tests in uniaxial tension; photoelastic models are used to study the effect of strain concentrations caused by noncircular core configurations; strain analyses are performed on specific grain configurations in order to determine the operational and stretch limits of the solid propulsion system; and measurements are made of the changes in mechanical properties of solid propellants brought about by long-time exposure to various environmental conditions.

*Facilities:*

A Diffused Light Polariscope is used to measure stresses and strains on birefringent models of propulsion system components.



Diffused Light Polariscope and Pressure Loading Frame

Three Instron Tensile Testers -- two floor-type and one table-type -- each with its own temperature conditioning chamber, are used to run mechanical characterization tests of propellants and binder materials.

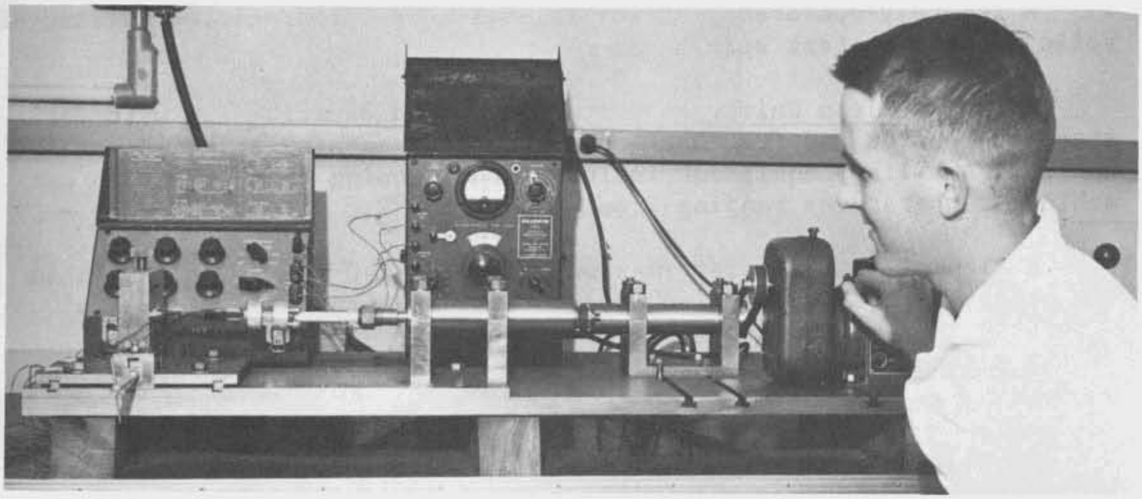

Three types of Dynamic Modulus Testers are available:

(1) Central Laboratories TNTO (Netherlands) Torsion Pendulum, for measuring dynamic shear modulus.

(2) Magnaflux Elastomet, which measures dynamic extensional modulus.

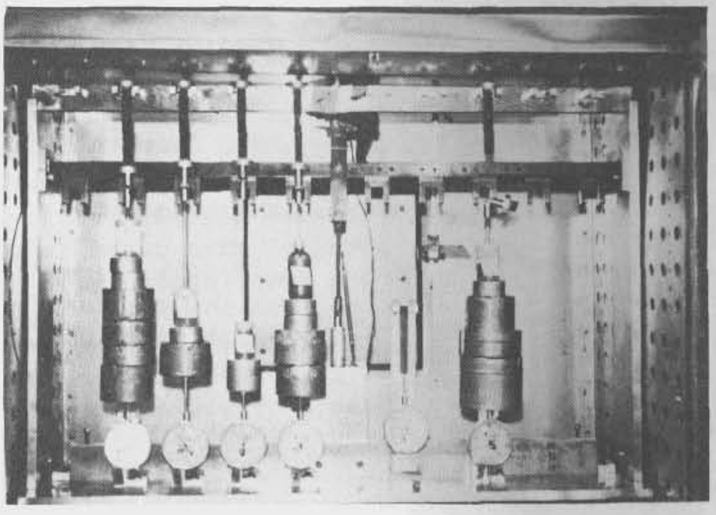
(3) Rotating Beam Dynamic Modulus Tester, constructed in-house, to determine the complex modulus of rigid polymeric materials.

Instron Tensile and Compression Tester with Missimers Temperature Conditioning Chamber



Rotating-Beam Dynamic Modulus Tester

A Creep Facility, fabricated in-house, determines the creep compliance of binders and propellants above ambient temperatures.



Creep Loading Apparatus for Bonded Uniaxial Propellant Samples

A Relaxation Facility, also constructed in the laboratory, can determine the relaxation modulus at temperatures ranging from -100 to 200$^{o}$F; strains can be applied at time intervals of approximately 10 msec.

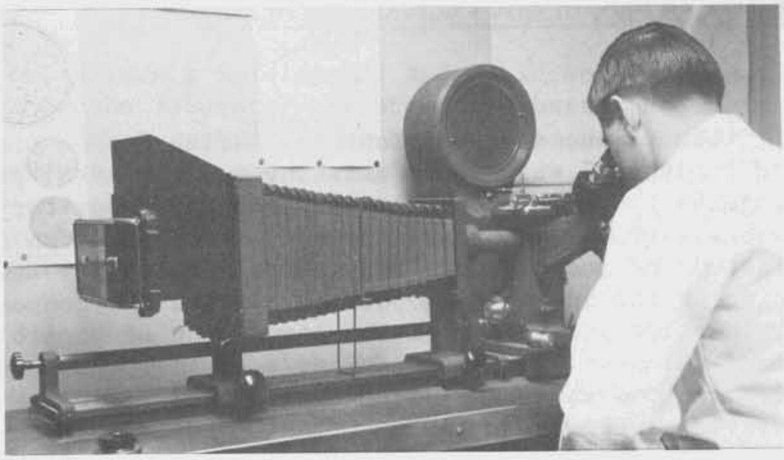
A remotely-operated facility is available for precision milling of solid propellant test specimens.

A Tinius-Olsen Universal Tester, 60-pound capacity, is used for standard tension and fracture toughness tests on high-strength sheet metals. Auxiliary equipment includes conditioning chambers which can achieve temperatures ranging from -100 to 600$^{o}$F.

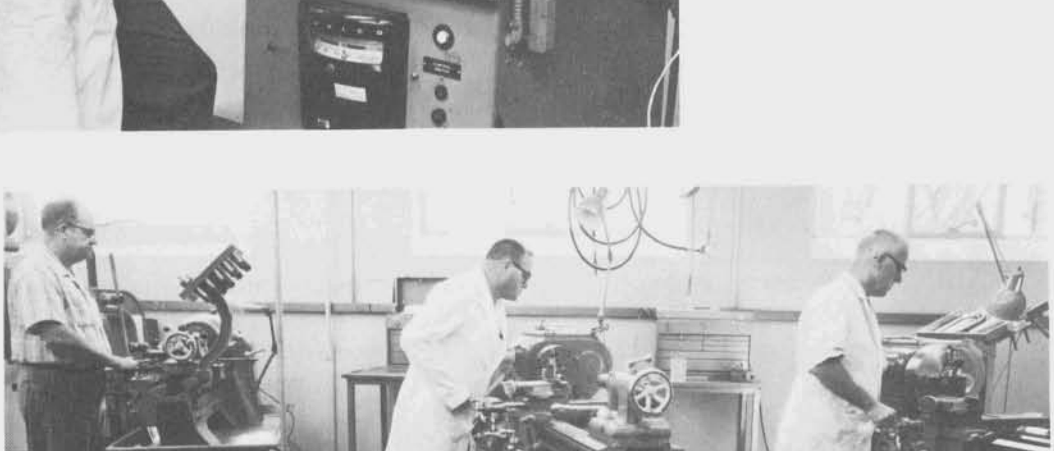
A Riehle Impact Tester, maximum capacity 240 ft/lb, is available for charpy impact and tension impact tests of structural materials.

A Bausch & Lomb Metallograph is used to study the microstructure of metals.

In addition to these specialized items, there are also a series of laboratory hardness testers and furnaces for heat-treating of metals, and a completely equipped laboratory model and instrumentation shop.



Bausch & Lomb Metallograph (above);
Heat-Treating Oven (left);
Instrument and Model Shop (below).



## ADVANCED PROPULSION ENGINEERING BRANCH

*Capabilities:*

The Advanced Propulsion Engineering Branch provides theoretical and analytical support to existing and potential propulsion system projects. Formulas, preliminary design, laboratory computer functions, theories of operation, and schedules for research and development are created and documented. Design and feasibility studies are made of existing and advanced propulsion systems and components. Existing systems are analyzed from the standpoint of possible areas of improvement, validity of specifications, and analytical solutions to problems; advanced concepts, including nuclear and ramjet, are studied for possible application to Army missile systems.

In the course of these studies, detailed analyses are made of performance characteristics of systems and components, interactions of propulsion systems with the missiles, and internal ballistic characteristics such as combustion and gas flow phenomena. The data are correlated in terms of external effects and theory, and design parameters are created for previously unexplained variances.

The branch also develops and applies computational procedures for predicting propulsion performance and future trends in the art of propulsion. Basic and supporting research, component development, and test projects are recommended on the basis of these predictions.

At the present time, the branch is coordinating nationally the design automation (computer utilization) of solid propulsion.

*Facilities:*

An LGP-30 small scale computer and an RPC-4000 medium scale computer comprise the major equipment available for this work.

## MOTOR AND POWER BRANCH

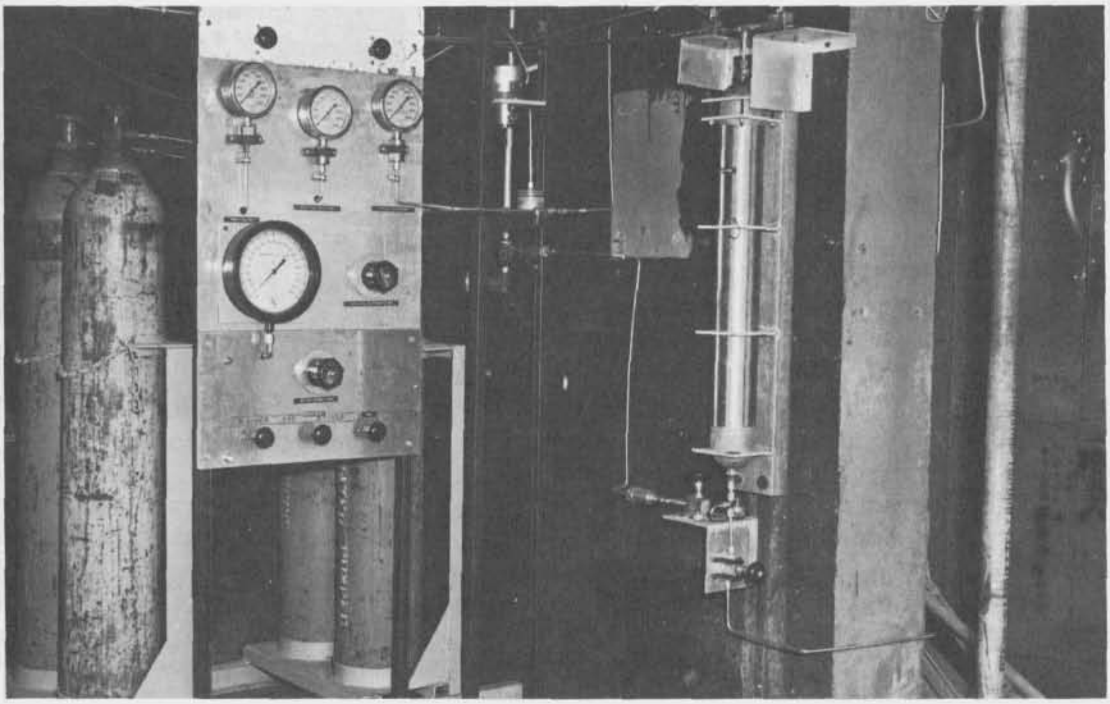
*Capabilities:*

The Motor and Power Branch is engaged in engineering research aimed at identifying and characterizing the more vital design elements of experimental model equipment, including: propulsion and auxiliary power systems; propellant feed systems, mechanical feed systems, mechanical assemblies, and related components; thrust vector and impulse control systems; and separation systems. Research models of propulsion components are designed, fabricated, and tested in-house; plastic components for use in missile systems are designed and constructed. The branch prepares contractual requirements and exercises technical supervision over contract performance in these areas.

*Facilities:*

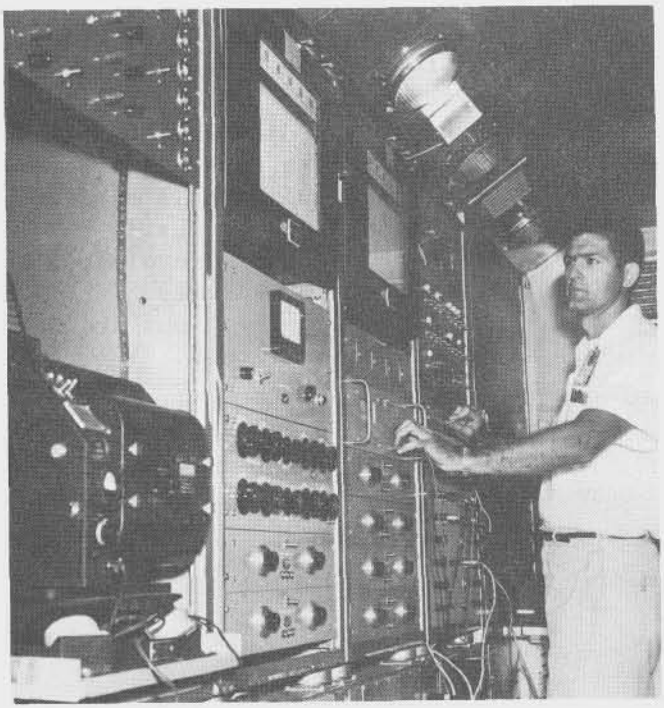
A Hybrid Test Motor, 2 inches in diameter and 21 inches long, was designed and fabricated by the laboratory to study the basic phenomena and parameters of hybrid rocket systems. The motor uses an uncooled convergent-divergent exhaust nozzle and a single oxidizer injector recessed into the head end of the motor. Experiments conducted with this motor are aimed at obtaining data on combustion efficiencies, grain configuration, regression rate, mixture ratio, and throttling range.

The Liquid Injection System used with the test motor, also designed and fabricated in-house, is easily adapted to various operating pressures and flow rates. All tubing, tanks, regulators, valves, and venturis are of a high-pressure, 316 or 304 stainless steel type, and all components are pressure rated to a minimum of 2000 psi. The run tank has a capacity of 0.26 gallon. A high-pressure dry nitrogen system controls run tank and purge pressures. Operational pressure ratings may be easily varied through the use of Maratta electrically-operated solenoid regulators and valves. Flow rates are controlled by cavitating venturis. Most connections are of the AN flare type, and threaded connections are sealed with a commercially available teflon thread sealant.

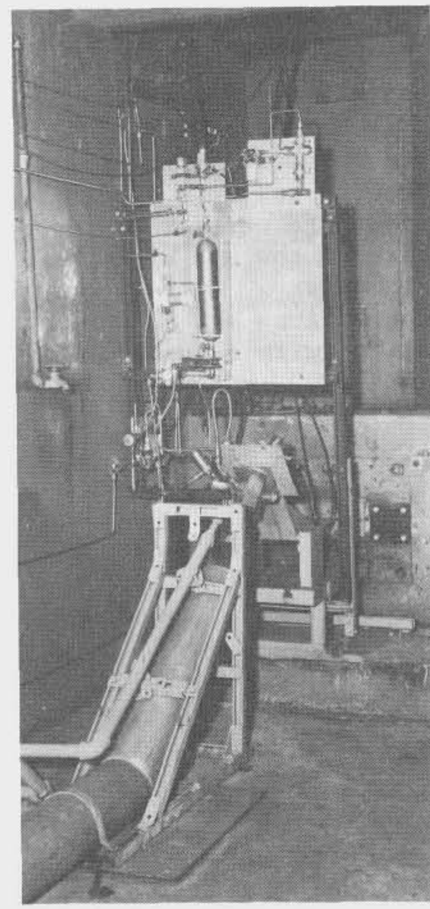


High-Pressure Nitrogen System

The instrumentation used with the test apparatus includes: an automatic sequence timer, with manual override provisions to permit shutoff of the liquid system at any time; Consolidated Electrodynamic recording oscillograph to record pressure and thrust measurements; and closed circuit television for monitoring tests.



Instrumentation Trailer (above)
Thrust Stand for Hybrid Test Motor (right)



The Thrust Stand allows positioning of the test motor at a 48-degree angle to the horizontal to facilitate drainage of the injected liquid in the event of a hang-fire or malfunction of flow control valves.

Other equipment available permits the assembling of small solid propellant test motors, and the injection-molding of plastic items up to 2 ounces.

## PROPULSION SYSTEMS ENGINEERING BRANCH

*Capabilities:*

The Propulsion Systems Engineering Branch is concerned with the design and development of propulsion systems -- solid, liquid, and hybrid types -- and gas-operated auxiliary power systems. The theoretical requirements are established for propulsion components and systems. Analytical studies are made of actual performance data, and the results compared with the theoretical standards. Any corrective action indicated is initiated. Specialized testing programs are formulated and monitored as required. The raw data for these investigations are obtained from other Command elements and from contractors working in these areas.

The branch develops or supervises the development of special equipment for nondestructive testing of such characteristics as grain integrity, liner and bonding of the grain to case walls, and measurement of radar attenuation. Adaptations of existing systems are devised for specialized purposes in the laboratory and in the field.

In addition, the branch prepares specifications and acceptance criteria for propulsion and auxiliary power systems, and provides technical supervision of contractor efforts in these particular areas.

## LIQUID PROPULSION TECHNOLOGY BRANCH

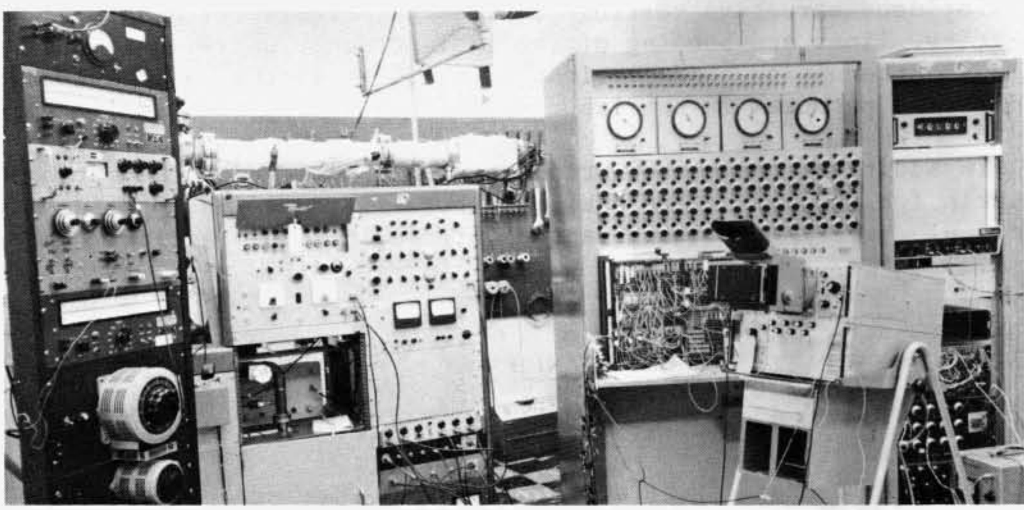
*Capabilities:*

The Liquid Propulsion Technology Branch pioneers basic experimental studies of the physical phenomena of organic and inorganic chemicals and their reactions. The laboratory is designed to work with milliliter quantities of materials. A special competence has been developed in the field of liquid propulsion and high energy chemicals and chemical reactions. Theoretical evaluation of chemical reactions is performed using high speed digital computing techniques.

Mechanics of a combustion process can be experimentally determined and analyzed for effects of progression of free atoms, particles, and molecules during burning. Gas, liquids, and solids can be used. Effects of mixing, instability, and other physical phenomena can be studied in small laboratory apparatus through various stages of small motor firings and large motor testing of liquid propellants. From the results of these tests, parameters of new compositions can be evaluated and propellant characteristics determined, and design criteria can be established.

*Facilities:*

The Bendix Time-of-Flight Mass Spectrometer is primarily used to study high temperature and very fast reactions of potential rocket fuels. The instrument is capable of analyzing 10,000 spectra per second and will accept liquid, solid, or gas samples. Another unique feature of the machine is that it utilizes a straight time of flight for accelerating and separating particles, thus reducing the need for a strong magnetic field. These features allow the researcher to study any free radicals formed when a gas is passed through a chamber maintained at elevated temperatures. In addition, the energy liberated when certain chemical bonds are broken can be studied by varying the electron energy of the ionizing beam.



Bendix Time-of-Flight Mass Spectrometer with Associated Control Equipment

The DuPont Modular Thermal Analysis System is a sensitive and versatile laboratory instrument, suitable for the rapid analytical study of the thermal behavior of small samples of materials. Solid or liquid samples in a variety of environmental conditions can be studied in the range -100 to +500$^{\circ}$C. The instrument is suited for the study of hazardous materials, as only milligrams of material are required for analysis. The thermal analysis system is basically composed of a differential thermal analyzer with associated modules for thermogravimetric, thermomechanical, and calorimetric analyses.

DuPont Modular Thermal Analysis System

Sargent Automatic Titrator

The Sargent Recording Titrator Model D is simply a PH meter, automatic titrator, and Carl Fisher titrator combined in one housing. The instrument may be used in either research or analytical procedures.

The CEC 21-130 Mass Spectrometer is designed to produce and record the mass spectra of gaseous or liquid substances. Accurate analysis of samples can be obtained when only a few millimeters of pressure of the sample are available. It is used to study gaseous products of combustion, reaction products of hydrolysis, other reactions and identification of unknown gaseous mixtures.

C.E.C. 21-130 Mass Spectrometer

A small Perkin-Elmer Infracord records infrared absorption spectra of liquids, gases, and transparent solids. The instrument is used for both quantitative and qualitative analysis of substances related to propulsion research.

The Beckman Model DU Spectrophotometer is used to determine the wavelengths of radiation in the range 210-1000 millimicrons which are absorbed by a substance under investigation. Graphs of percent transmittance/wavelength may be obtained for various materials as an aid in qualitative analysis. The instrument, however, is extremely useful in quantitative analysis where plots of absorbance/concentration are employed.

Perkin-Elmer Infracord

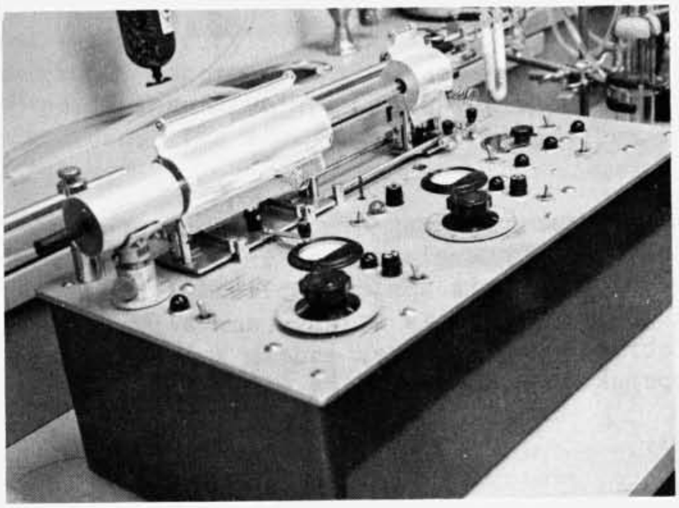
Beckman Model DU Spectrophotometer

The Ferranti-Shirley Viscometer is a cone and plate rotational viscometer which is used to investigate the flow behavior of many types of simple or complex fluids. It is capable of measuring apparent viscosity over a wide range of rates of shear or shearing stress. The instrument may be used to determine rapidly the viscosity of Newtonian fluids, but the Ferranti-Shirley is especially valuable for determining the flow properties of non-Newtonian fluids. For non-Newtonian materials rapid indications of thixotropy, yield-value, shear-rate thinning, and other anomalous flow properties may be obtained. Also, reproducible flow curves may be obtained for shear stress/rate of shear or apparent viscosity/rate of shear. The instrument may be used to construct stress/time relaxation curves.

Ferranti-Shirley Viscometer

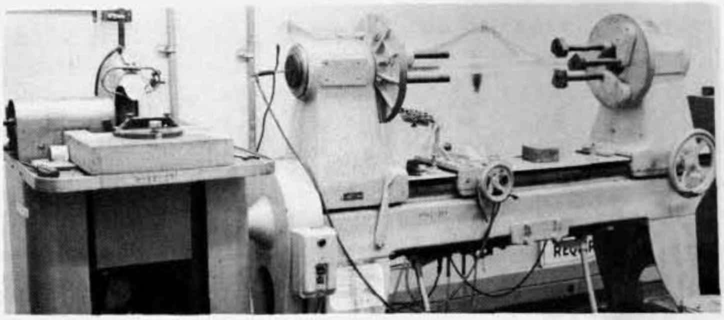
The Sargent Combustion Apparatus is an automatic, micro and semi-micro, combustion apparatus for carbon and hydrogen analysis by modifications of the method of Pregl. Also, the apparatus may be used for the determination of nitrogen, halogens, and sulfur.

The Gas Chromatographs are used in the laboratory for qualitative and quantitative analysis. Three chromatographs are available for laboratory use: the Perkin-Elmer 154 vapor fractometer which has been updated, the F & M Model 720 chromatograph, and the Aerograph Model A-700 preparative gas chromatograph.

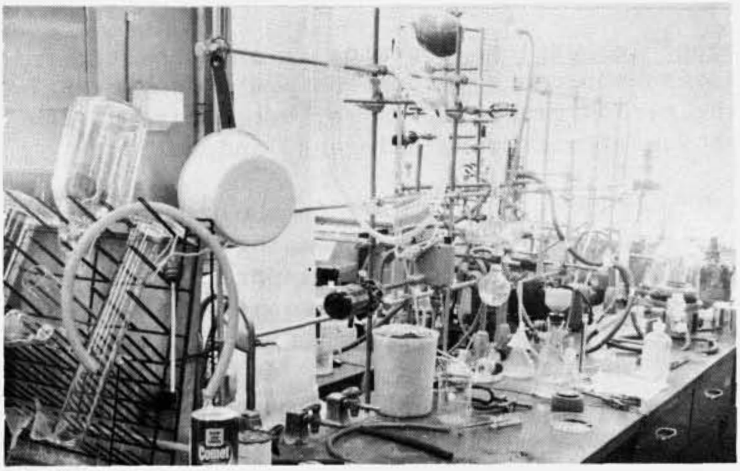


Sargent Combustion Apparatus


F & M Model 720 Gas Chromatograph



Glass Cutting Wheel and Glass Lathe



A Small Section of the General Laboratory Facilities

Glassworking Equipment is an integral part of the laboratory's operation. Basic equipment for use in the glass shop is a glass lathe and glass-cutting wheel. Also, the shop is amply supplied with hand tools and torches for working glass. There is a large annealing oven for the proper treatment of fabricated glassware, and an ample stock of glass tubing, joints, and stopcocks for the building of custom laboratory apparatus.

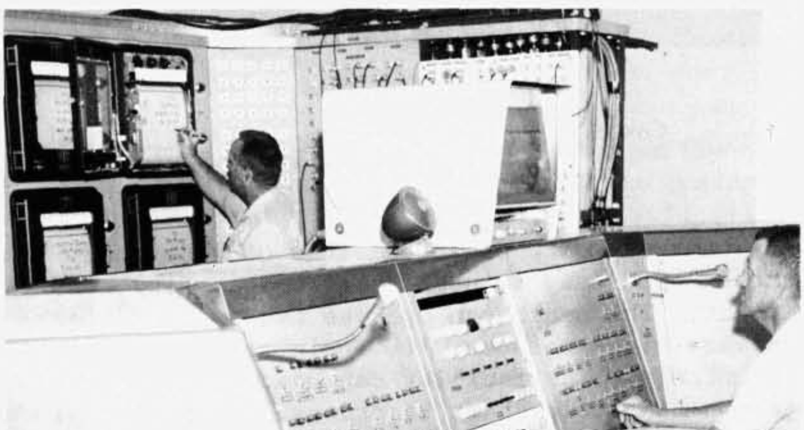
General Laboratory Facilities are available for bench-type laboratory operations. Ample laboratory equipment of a general nature, such as glassware, pumps, and tubing, is available for chemical research. A good supply of semi-micro glassware is kept on hand for experiments with limited quantities of material. A chemical storeroom is well stocked and maintained for support of the research programs.

The Drop-Weight Tester used in this laboratory for liquid propellants is the type recommended by the Joint Army-Navy-Air Force Panel on Liquid Propellant Test Methods. Adaptations of testers used for solid propellants proved unsatisfactory for liquid propellants. The present method uses a 0.03-cc sample enclosed in a steel cup with an O ring in the bottom. A steel diaphragm is placed on top of the sample. A piston which has been torqued to a constant value rests on top of the diaphragm. A weight is dropped onto the piston, and explosion is indicated by puncture of the diaphragm. The data obtained are compared with standards such as nitroglycerine, ethyl nitrate, and n-propyl nitrate, and give a relative compression sensitivity of the material.

The Sargent XXI Visible Recording Polarograph is an instrument designed to record current-voltage curves obtained when solutions of electro-oxidizable or electro-reducible substances are electrolyzed in a cell in which one electrode consists of mercury drops falling from a fine-bore capillary glass tube. From the curves, several reducible or oxidizable substances can be identified and their concentrations determined simultaneously. In some cases, five or six substances present in concentrations ranging from $10^{-6}$ to 0.01 M can be identified from a single current-voltage curve. Both organic and inorganic substances can be analyzed by the polarograph.

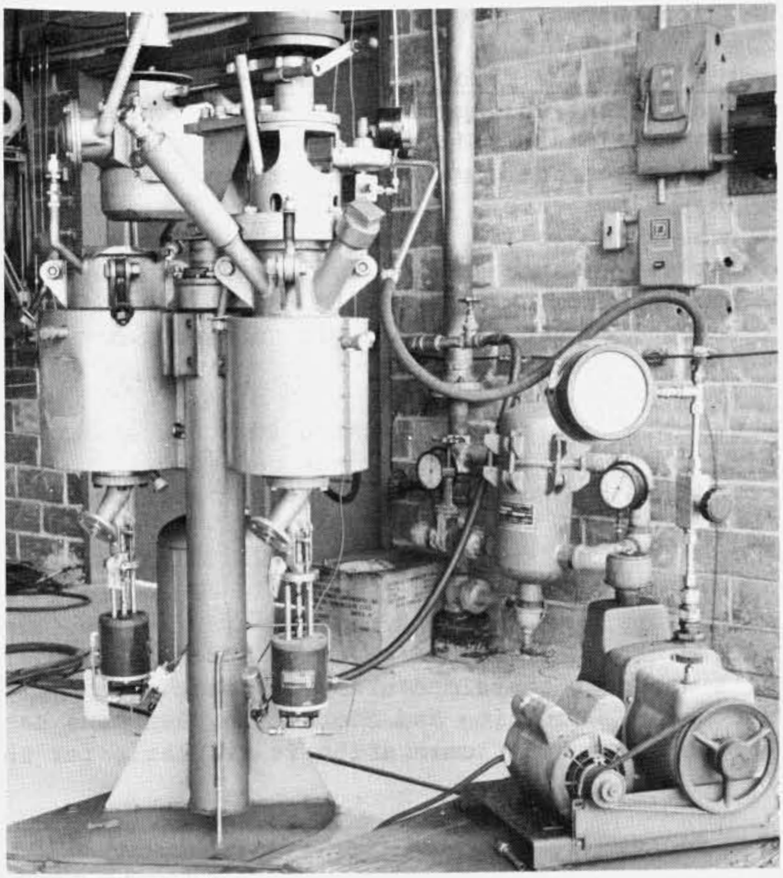
A Burning Rate Combustion Bomb located in the test bay is used to study the burning rate of liquid propellant candidates. A Fastax camera is used to record the burning rate and the test is controlled remotely.

The Propellant Evaluation Facility, consisting of a test cell for four small evaluation motors and two expendable cells, permits the basic studies on liquid propellants which are necessary for propellant evaluation and for determination of design criteria for a particular candidate. The rocket motors used for these measurements range from micro motors to 500-pound thrust units. Ignition and combustion phenomena can be determined. The necessary instrumentation is available for this facility.



Firing Control Center in Test Facility

The Cowles Dissolver is used for the preparation of gels of interest in propulsion research. The capacity of the dissolver is 2-8 quarts, which is sufficient for engineering research uses. The dissolver is so constructed that it may be used with vacuum or pressure and has provision for being thermostatted. Also, mixing operations in the dissolver may be conducted in an inert atmosphere. The output speed range is variable between 1000 and 6000 rpm.



Cowles Dissolver

A Flow Bench with a tank capacity of 150 gallons of water and maximum working pressure of 3000 psig is used to make cold flow studies of hydraulic flow equipment. The bench can operate two systems simultaneously with two auxiliary high-pressure, 1000 psig controls and two auxiliary low-pressure controls. The facility can measure two pressure drops and two flow rates on L&N strip chart recorders. Turbine type flowmeters are used to determine flow rates.

# ADVANCED SENSORS LABORATORY

Within the overall framework of the Research and Engineering Directorate, Advanced Sensors Laboratory is charged with the responsibility of conducting research and development directed toward advancing the application of electromagnetics technology to Army weapons systems. This mission is accomplished by an established in-house capability in all major areas of electromagnetics technology applicable to weapons systems -- radar, guidance (noninertial) and control, and electro-optics. Laboratory programs in these technological areas are accomplished in three branches:

Systems

Radar

Electro-Optical.

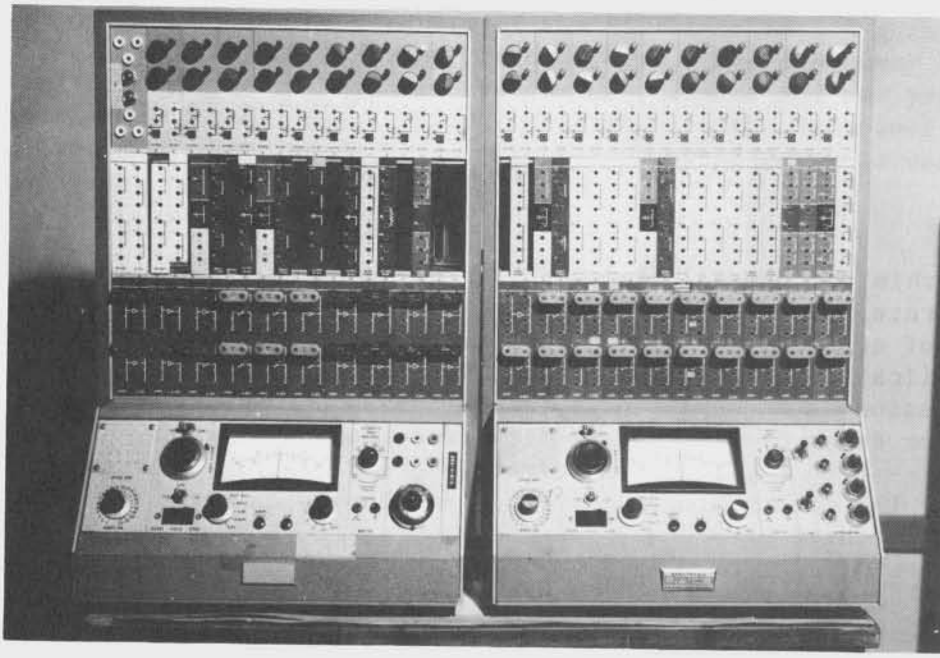
## SYSTEMS BRANCH

*Capabilities:*

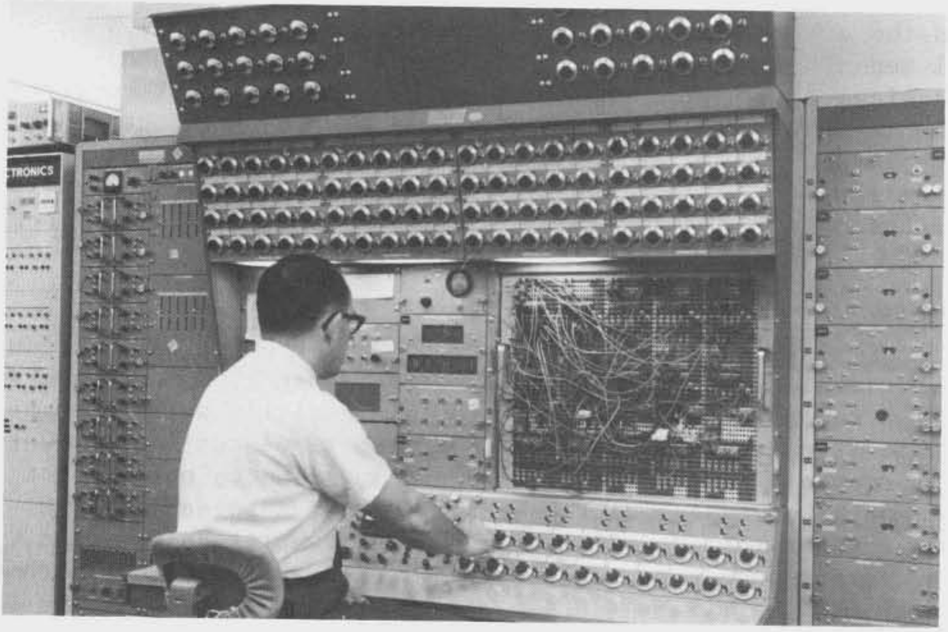
In the Systems Branch, a wide variety of missile guidance and control techniques are analyzed, synthesized, and evaluated. Included are technical systems analysis and design, systems laboratory testing, and planning and control of systems field and/or flight testing. Inherent in the branch operations are real-time system simulation and design of interface signal processing techniques and demonstration hardware used in feasibility testing.

*Facilities:*

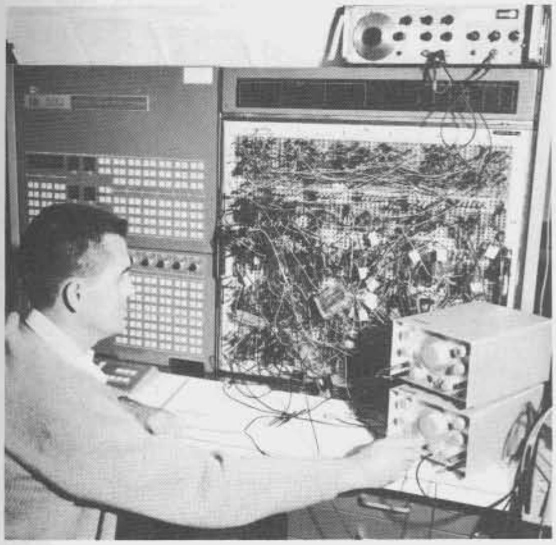
The Simulation Facility consists primarily of an analog simulation computer, complete with nonlinear function generation units and a variety of recording instruments. In this facility a large number of repeatable flight or test conditions can be simulated for evaluating the performance of experimental hardware items which might otherwise require months of expensive flight testing. A three-axis flight table provides angular motions simulating those encountered in flight. This facility permits accurate analysis of missile seeker hardware and other servo systems.



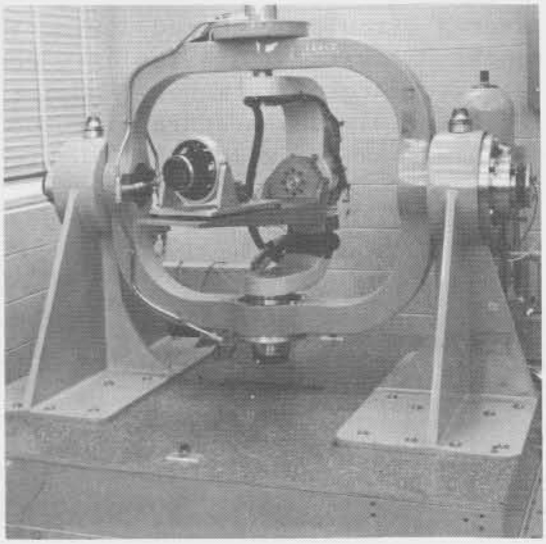
TR-10 Small Portable Analog Computers (three available)



Analog Simulation Computer



High-Speed Analog Simulator with
Patchable Digital Control Logic



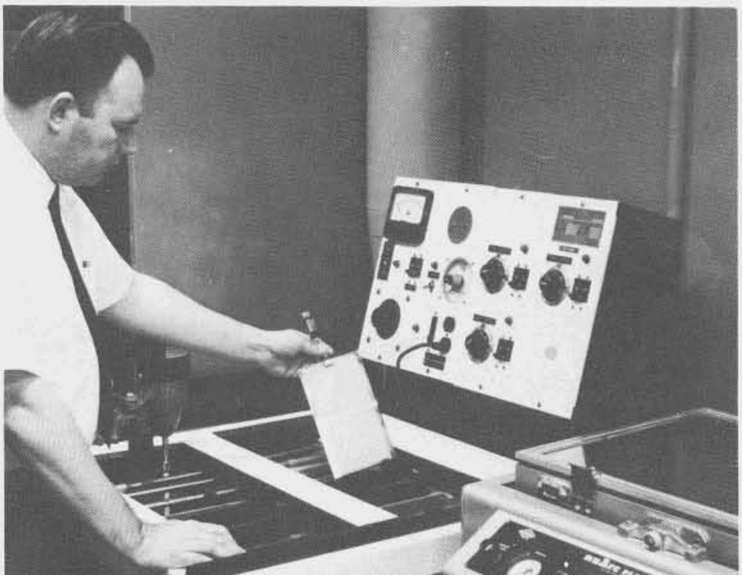
Three-Axis Flight Table

The <u>Three-Axis Flight Simulator</u> is capable of transforming electrical signals into precise angular motions through a three-axis gimbal system. The hydraulically driven gimbals are capable of accurately simulating both the high and low angular rates required in evaluation and testing of missile seekers and other flight hardware. A unique feature of this three-axis simulator is a cutaway middle gimbal that permits an unobstructed field of view for seeker testing. Loads up to 250 pounds may be mounted on the simulator.

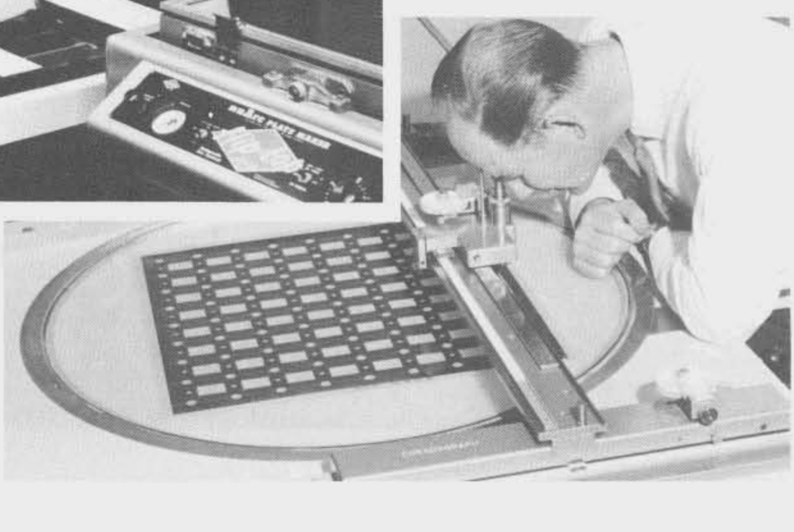
The <u>Esiac Computer</u> is a special purpose computer for plotting root locus diagrams which are used in the analysis of servo problems.

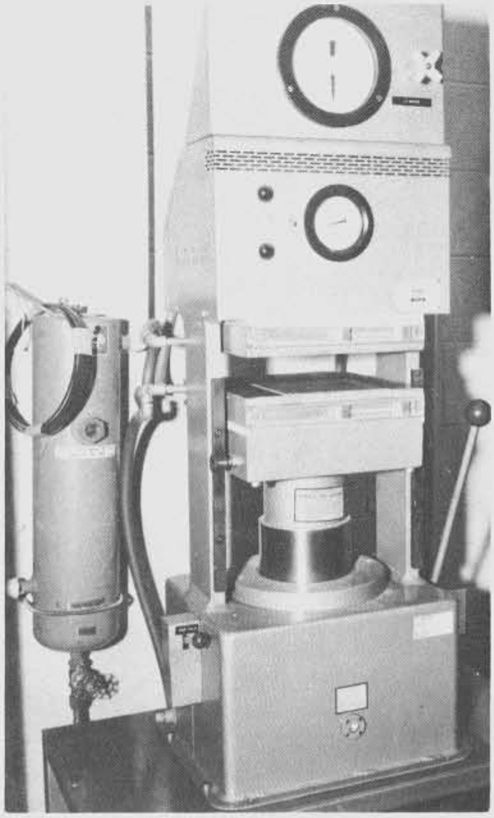

Esiac Computer

The Experimental Printed Circuit Facility is used to produce the printed circuits required during the development and testing of experimental hardware. This facility consists of a Model 610 Chemcut spray-etcher, nuArc plate maker (Model FTO-18A), a small curing oven, Bausch and Lomb inspection stereomicroscope, coordinatograph, Robertson 432 reducing camera, goldplater, Unitek module welder, vacuum potting equipment, multilayer circuit board press, and general purpose auxiliary equipment. Coordinatograph, a precision drafting instrument, is accurate to 0.0015 inch.



Printed Circuit Equipment (left, exposing, plating, and chemical etching of panels; below, coordinatograph)

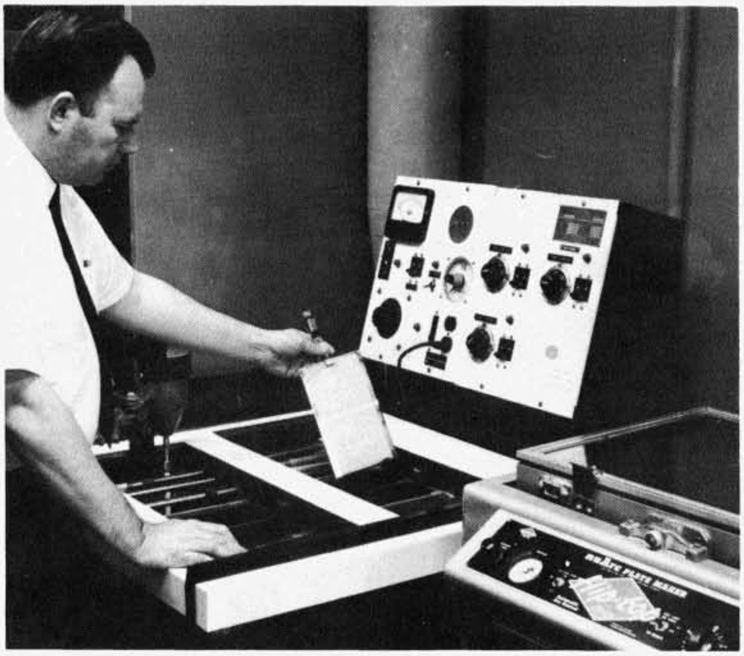




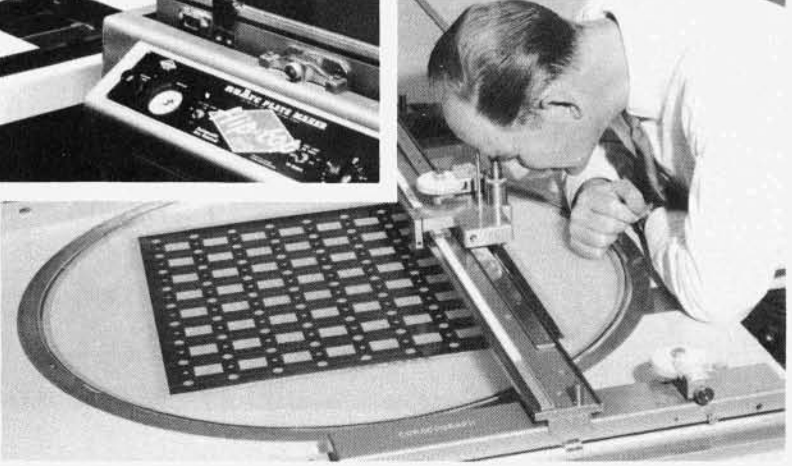
Photographic Darkroom (left) and Press for Multilayer Printed Circuit Board (right)

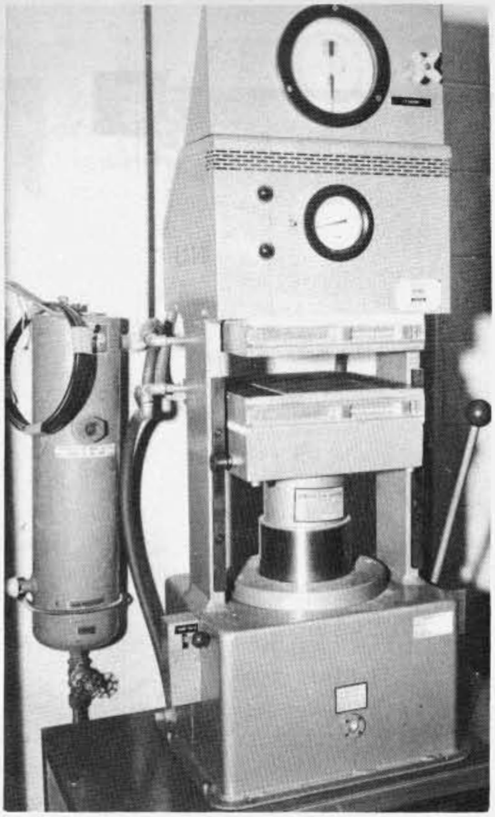
Inspection Area (Electronic Module Welder in Center)

The Experimental Printed Circuit Facility is used to produce the printed circuits required during the development and testing of experimental hardware. This facility consists of a Model 610 Chemcut spray-etcher, nuArc plate maker (Model FTO-18A), a small curing oven, Bausch and Lomb inspection stereomicroscope, coordinatograph, Robertson 432 reducing camera, goldplater, Unitek module welder, vacuum potting equipment, multilayer circuit board press, and general purpose auxiliary equipment. Coordinatograph, a precision drafting instrument, is accurate to 0.0015 inch.



Printed Circuit Equipment (left, exposing, plating, and chemical etching of panels; below, coordinatograph)

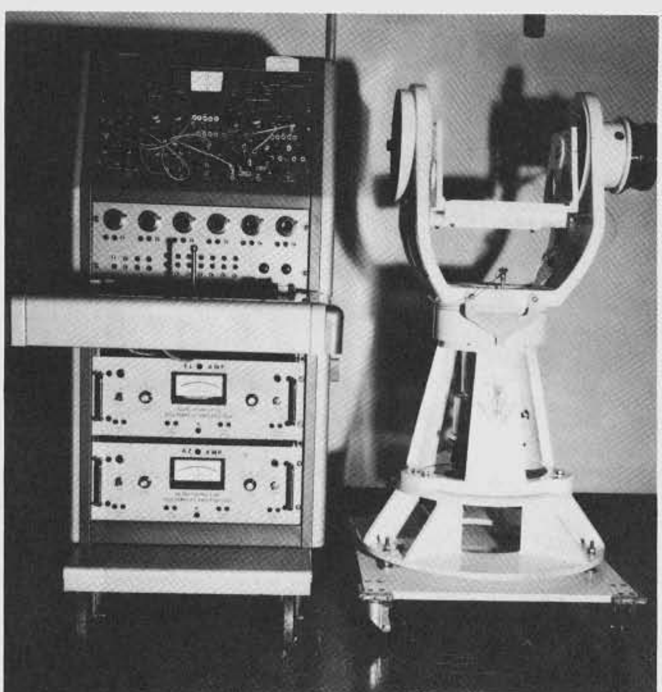




Photographic Darkroom (left) and Press for Multilayer Printed Circuit Board (right)

Inspection Area (Electronic Module Welder in Center)

· Experimental Electronic Systems and Subsystems Fabrication Area



The Two-Axis Tracking Mount consists of a high-accuracy, two-axis, direct-driven gimbal system; also, the required power amplifiers and signal conditioning electronics. Its primary purpose is to provide a portable tracking mount that can be used in the field testing of components, such as seekers.

Two-Axis Servo-Driven Mount
with Control Console

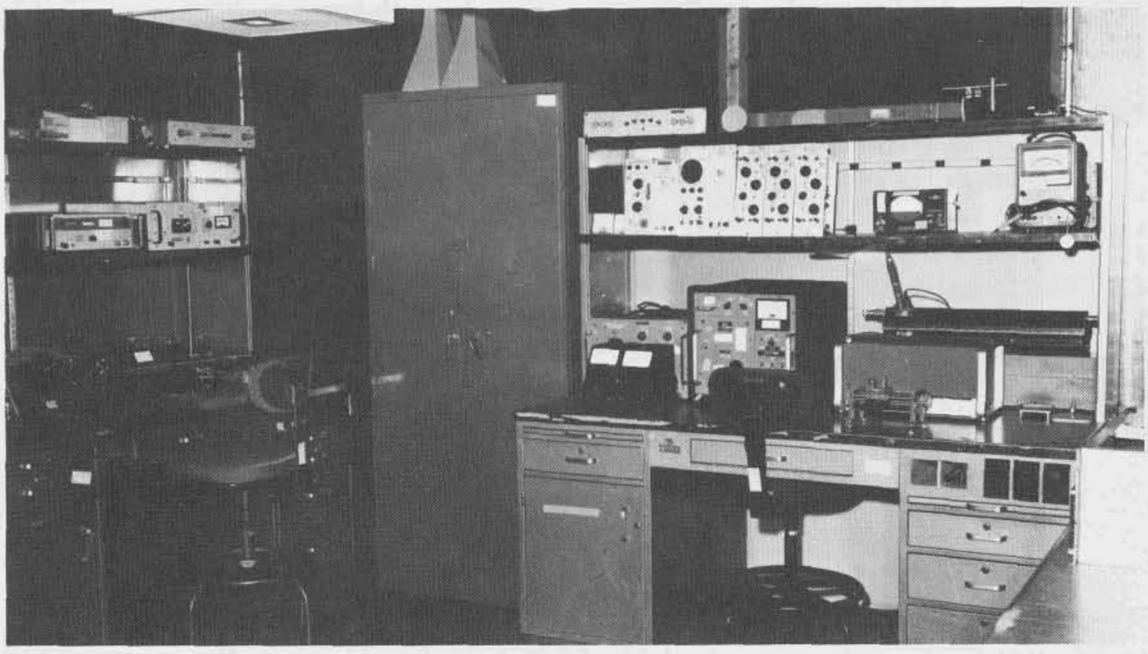
## RADAR BRANCH

*Capabilities:*

The Radar Branch has the capabilities for design, fabrication, and testing of radar transmitters, receivers, antennas (both mechanical and inertialess), feed systems, and signal processing techniques, and adequate measuring facilities to evaluate the feasibility of techniques with respect to systems and/or system components. Specialized capabilities exist in the following areas: advanced solid-state circuits; low-noise microwave amplifiers; microwave phase measurements; signatures, clutter, propagation, ECCM, and penetration aid systems.

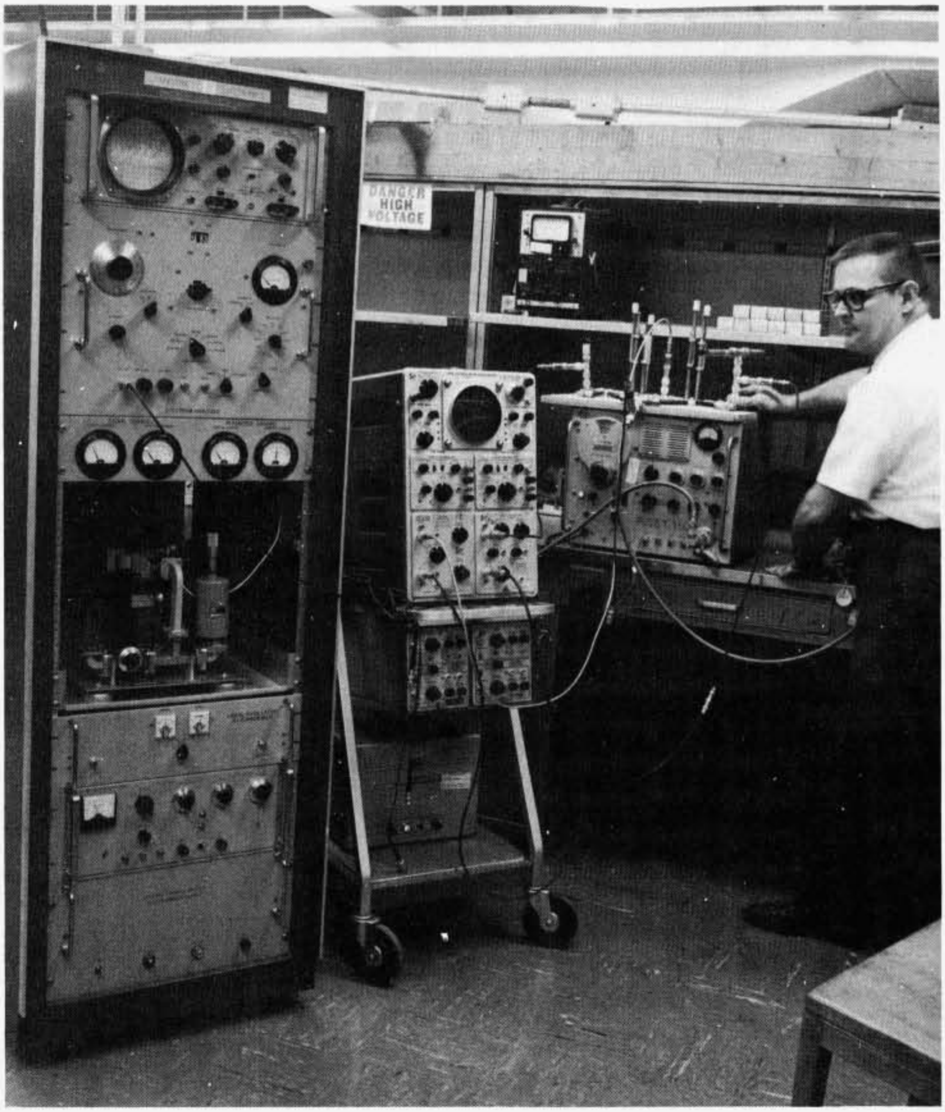
*Facilities:*

Electronic test equipment is available for the design, fabrication, and evaluation of all components of a radar system, and covers the frequency spectrum from subaudio to microwave frequencies. Included are such items as oscilloscopes, signal generators, amplifiers, spectrum analyzers, electronic counters, phase meters, frequency meters, VSWR meters, BWO's, and TWT's. Also available are facilities which allow measurements of all parameters at almost any power level or sensitivity on any electronic component at frequencies through X-band. Specialized facilities exist for similar measurements at K-band and millimeter regions.



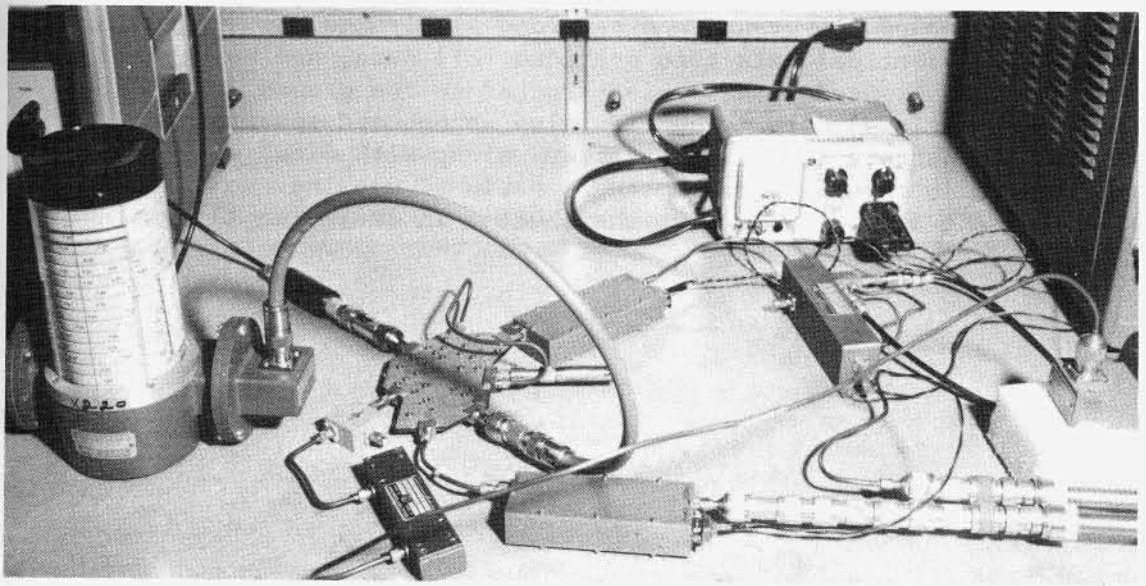
Screen Room Bench Setup

The Transmitter Spectral Analyzer is currently capable of measuring AM noise to levels of 125 dB down from the carrier in a 1-kHz bandwidth; 135 dB down from the carrier in a 100-Hz bandwidth; FM noise to 0.0032 Hz in a 100-Hz bandwidth; a sweep range of 1 kHz to 20 kHz; and a sweep range of 1 kHz to 150 kHz, all in a frequency range at X-band. This facility is being updated to handle signals at C-band, with a change of microwave equipments. Also underway are modifications which will improve and stabilize measurement capabilities. This equipment will make state-of-the-art measurements on any CW transmitter unit within its frequency range.

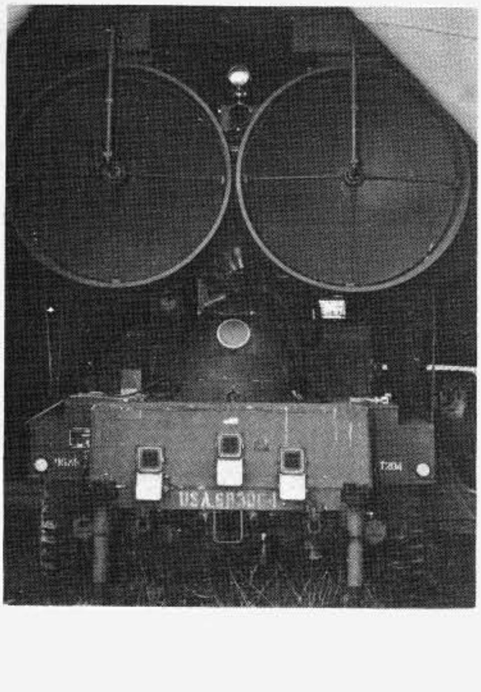



Spectral Analysis Facility

The Screen Room is equipped with necessary filtering on input lines and sufficient internal equipments to allow testing of virtually any transmitter unit except high-power amplifier sections. For reasons of safety, this room is limited to low-power level operations. Adequate access opening is available to move equipment as necessary for test purposes.



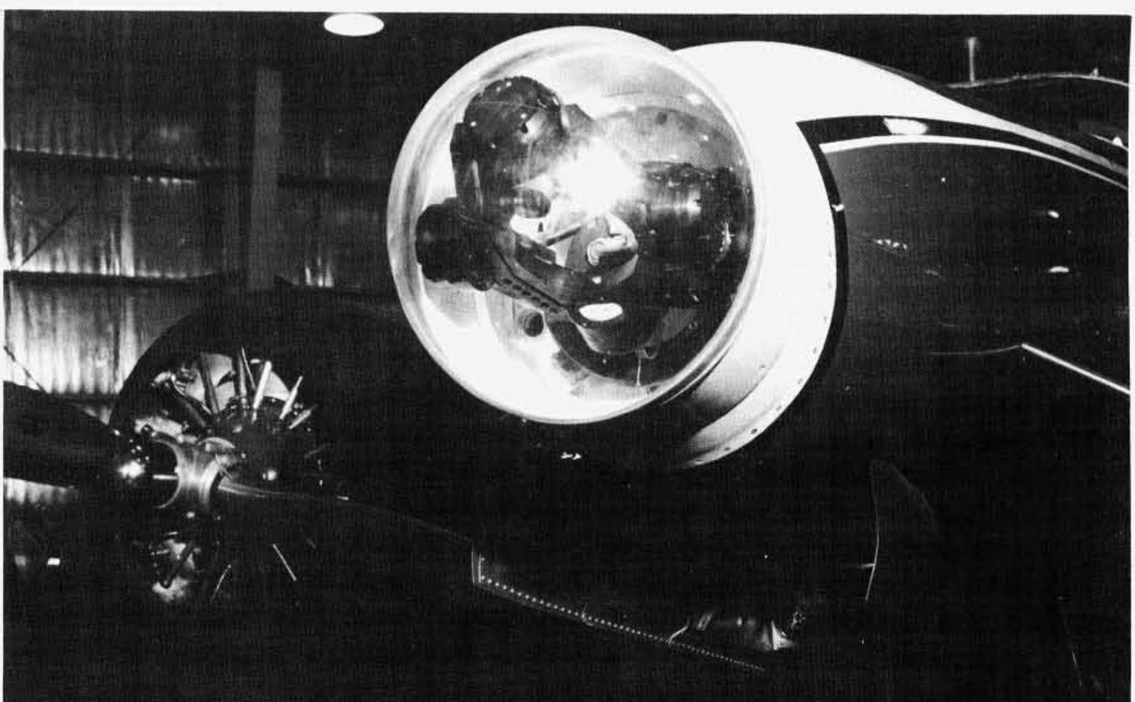
Low-Noise Solid-State Receiver Instrumentation



An X-Band Pulse Doppler Radar is available and has been extensively modified, including additional polarization agility, to make it compatible as a test instrument for a wide variety of testing and data collection purposes, such as tracking of land vehicles and low flying aircraft in extremely high clutter environments. The radar is presently being used to collect data on phase return error (glint) with and without polarization agility.

X-Band Pulse Doppler Radar

Airborne Sensor Measurement Platform. A C-45 aircraft has an optically clear radome mounted on its nose, with a two-axis (pitch and yaw) platform mounted within the radome. The platform contains an optical sensor and an ARM (Anti-Radiation Missile) sensor. The optical sensor is a part of an optical tracking system used to track optical targets on the ground, and the ARM sensor is used to track electromagnetic (microwave) radiation sources (pulse or CW) also on the ground. Both tracking systems are fully integrated with a telemetry transmitter and an onboard 7-channel recording system such that real time data can be transmitted to the ground and recorded simultaneously aboard the aircraft. A vertical axis gyro provides roll data, and an onboard X-band beacon is used with a radar tracker on the ground for precise aircraft positional data. There is also an onboard spectrum analyzer and antenna pattern recording facility, along with electronically synchronized motion picture cameras capable of closing the shutter, advancing the film, and opening the shutter in less than 12.5 ms upon electronic command. A video tape recorder and several video monitors are also on the aircraft, along with an IRIG range timing receiver for real time data.

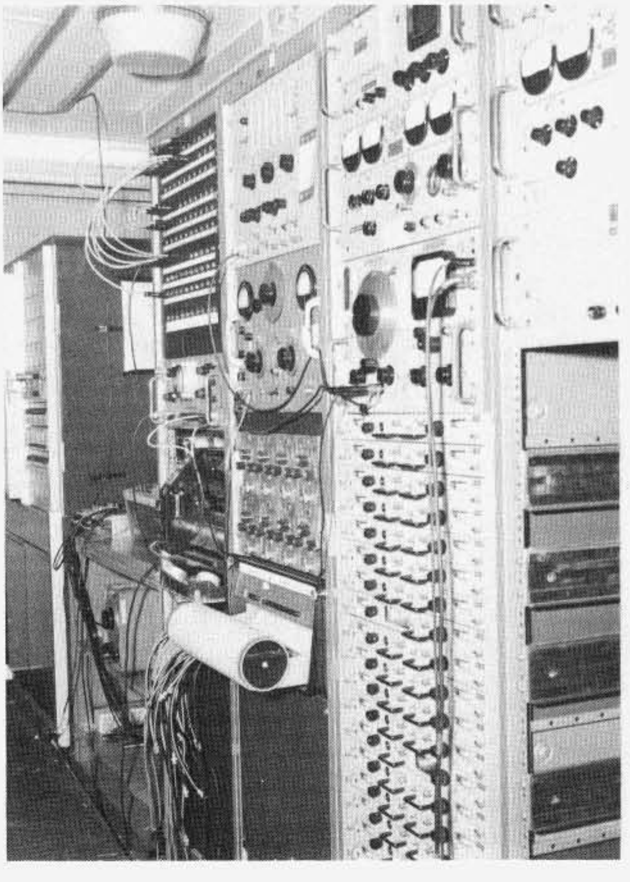


Two-Axis Platform Mounted Within the C-45 Radome

An RF Shielded Anechoic Chamber provides an environment of electrical and magnetic isolation which allows meaningful measurements on highly sensitive components. A wide variety of antennas can be tested wherein true pattern measurements without significant reflections reveal actual characteristics that otherwise would be almost impossible to obtain. The physical dimensions are 49 feet long, 18 feet wide, and 18 feet high. There is 80 dB of isolation from UHF to X-band. The dead zone provides more than 30 dB at 100 MHz, 40 dB at 300 MHz, 60 dB at 400 MHz, and 64 dB at X-band. Backscatter measurements made on scaled-down radar targets are an important capability of this chamber.

Anechoic Chamber (Inner Room)

The Test Range Facility includes a radar test bed for the performance evaluation of radar systems under controlled conditions. A variety of targets, such as the M-48 tank shown, are available. The length of the range is approximately 4200 feet. A 60-foot tower allows the evaluation of midcourse tracking performance of experimental missile seekers. A wide variety of data recording equipment is available for use, such as an 8-channel tape recorder, 14-channel oscillograph recorder, 8-channel pin recorder, telemetry ground station, and other general purpose laboratory recording equipment. Also included in this facility is an antenna pattern range available for use in recording antenna patterns over the frequency range from 30 to 75,000 MHz. Both polar and rectangular pattern plots may be obtained using standard transmitting, receiving, and recording equipment. The antennas under test may vary from small dipoles to very large parabolic antennas. Future plans include modification of this facility to allow performance of the various tests necessary in the design and optimization of inertialess scanning antennas.



Data Recording Equipment

Closeup of Test Tower

Radar Test Bed Facility

The Solid-State Instrumentation used in design and development of circuits and devices employing transistors and other semiconductor elements includes Tektronix 575 Transistor Curve Tracers; Trak Electronics 9129A Tunnel Diode Curve Tracer; Hushed Transistor Amplifier; Tektronix 131 Current Probe Amplifiers; Hybrid Parameter Transistor Test Set, laboratory-built; Fluke 825A Differential Voltmeter; Moseley 2D X-Y Recorder; Solartron Transfer Function Analyzer; General Radio 546-0 Audio Frequency Microvolter; Hewlett-Packard 302 Wave Analyzer with power drive; and a Ballantine 320 True-Root-Mean-Square Voltmeter. There are also a number of special purpose transistor power supplies and general purpose instruments.

In addition to facilities for making standard measurements for voltage, current, power, resistance, admittance, impedance, etc., several items of specialized state-of-the-art instruments are available, such as: a Hewlett-Packard Spectrum Analyzer, Model 851A/8551A, for frequencies from 10 to 40 MHz with a spectrum width from 100 kHz to 2 GHz; a Frequency Engineering Labs Phase Lock Synchronizer, Model KS123A, for microwave device frequency stabilization to one part in $10^8$ per second and one part in $10^6$ per day from below 2 to 12.4 GHz; a Systron-Donner Counter, Model 1037, which provides accurate frequency measurement with direct readout from 0 to 15 GHz; and a Wiltron amplitude, impedance, and phase analyzer covering the frequency range of 4 to 8 GHz.

## ELECTRO-OPTICAL BRANCH

*Capabilities:*

The Electro-Optical Branch concerns itself with the application of optical and electrooptical technology to missile guidance functions. Primary interest is in the conception and development of guidance subsystems such as infrared seekers, television seekers, optical tracking and command links, solid-state and crystal laser and photoemitter devices, and target detection and acquisition units. In this effort, a balanced combination of theoretical analysis, mathematical modeling and simulation, and experimental fabrication and testing is applied. Consulting services are provided to missile system project managers and other government agencies nationwide. Daily technical contributions are made in support of current missile systems which involve optical guidance components -- TOW, SHILLELAGH, DRAGON, REDEYE, CHAPARRAL.

In conducting this work, the branch maintains capabilities in the generation and detection of coherent and noncoherent light (ultraviolet through far infrared), radiometry, target signatures, and all forms of electronic signal processing applicable to electrooptical devices. Occasionally this capability is applied to problems not connected with missile guidance, such as reconnaissance and instrumentation. Typical tasks involve infrared seekers, television guidance systems and optical beacons, and trackers and transmitters for command-guided missiles.

*Facilities:*

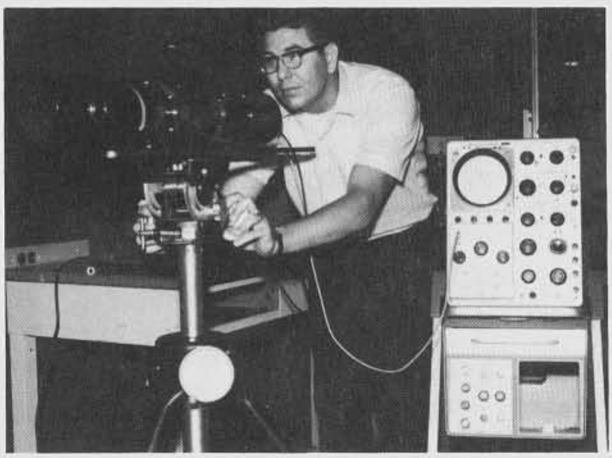
A Television Control Servo System incorporates a two-axis gimballed closed-circuit television system which may be torqued, by applying force to a joystick, to display any portion of a gross $60^{o}$ field-of-view. Various types of television-oriented tracking logics may be evaluated by inserting the logic in this rate gyro stabilized unit and switching from manual to automatic track mode.

Television Control Servo System

The Mobile Electro-Optical Test Facility incorporates only those features basic to performing remote field testing of a wide variety of electrooptical systems. A trailer-mounted 10 kW generator supplies prime power. The van is air-conditioned and heated, has removable rear door viewing panels, floodlights, interior and exterior electrical and communications outlets, and easily removable tables and racks for a variety of recording and test equipment.


Mobile Electrooptical Test Facility

An Infrared Radiometer is used to measure the output power of pulsed infrared sources. The unit uses either a photomultiplier or solid-state sensing element, and will accept pulse widths as low as 50 nanoseconds.



Infrared Radiometer

Infrared Spectrometer

In addition, there is a wide variety of specialized equipment including standard blackbody sources, optical collimators, low level and general purpose amplifiers, wave analyzers, general purpose meters, oscillographs, power supplies, oscilloscopes, white noise generators, bandpass filters, assorted signal generators, two Spectra Pritchard Photometers, two 3-kW portable gasoline generators, two Model 1500 and one Model 660 Ampex Video Tape Recorders, one CP100 Ampex Magnetic Tape Recorder, several types of closed circuit television systems and display monitors, and one infrared spectrometer.

# ADVANCED SYSTEMS LABORATORY

The principal function of the Advanced Systems Laboratory is to evolve and synthesize advanced weapon systems concepts for Army application. Technical approaches are selected on the basis of cost effectiveness and suitability, and subsequent supporting research, feasibility experiments, and component development are recommended, performed, or directed on the basis of the selection. These responsibilities involve comprehensive theoretical and experimental aerodynamic, aeroballistic, radar cross section, and penetration aids research programs in support of existing and advanced weapon system development activities. The organization of the laboratory consists of a Research and Technology Office, a Program Coordination and Administrative Office, and five operating branches:

Concepts Design

System Dynamics

Advanced Concept

Aerodynamics

Systems Evaluation.

Electronics Associates PACE 231-R Analog

The analog and digital computer systems which comprise the major facilities of the laboratory are used by all the branches. Major items of equipment include:

(1) Two EAI 231R analog computers;

(2) An Applied Dynamics PBC analog computer;

(3) Two IBM 1620 20K digital computers;

(4) An IBM 1620 40K digital computer.

## ADVANCED CONCEPTS BRANCH

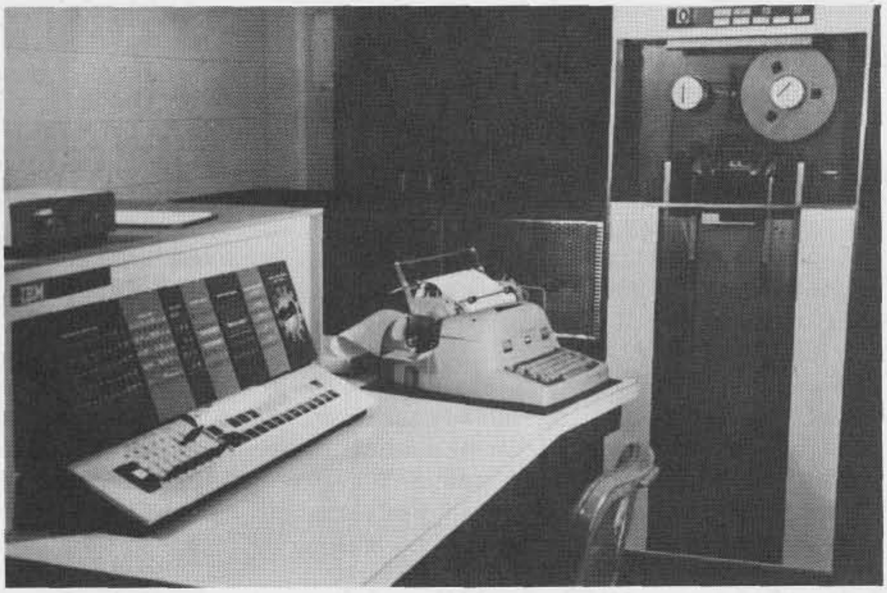
The Advanced Concepts Branch is concerned with insuring that all available technology is properly integrated into new weapon concepts or modifications to existing systems. Prime areas of study are overall system performance, effectiveness threat definition, and parametric costing. Often several systems are analyzed concurrently to determine the effectiveness of the family and to define the contribution of each member. Study methods include operations research and probability application, as well as engineering analysis techniques. Weapon system requirements are interpreted and system parameters defined based on current or projected technology as furnished by the specialty laboratories. Depending on the required results, system capability can be expressed in terms of a single threat and single weapon system, or can be expanded for a complete threat spectrum including multiple weapon systems in a tactical environment. Target and threat analyses are based on an integration of information from various available sources to provide the best estimates for specific system applications. The preliminary concepts, which are formulated from the results of all studies and analyses, are then evaluated and refined with regard to cost effectiveness and other measures of general merit. These studies may result in either further detailed analyses by other branches, or in further supporting research to bolster the technology.

## CONCEPTS DESIGN BRANCH

The Concepts Design Branch performs or directs analytical design studies of specific advanced weapon systems, integrating all applicable subsystems and support equipment. The conceptual designs formulated embrace all component areas such as guidance, fire control, structures, propulsion, warhead integration, launcher, and ancillary equipment. Such designs are normally carried only to the concept stage. The branch also plans and conducts, or directs, analytical studies of hardware operational employment concepts for future missile system application.

## SYSTEMS EVALUATION BRANCH

The Systems Evaluation Branch performs analyses of flight test data, from individual tests or groups of tests, as a basis for optimizing the missile system design and determining the nature and cause of failures. Included are the functions of defining instrument ranges, establishing measurement and test programs, and recommending changes in such programs for systems under development. New techniques are conceived for using high-speed electronic computers in data reduction and evaluation. Computer programs are developed for theoretical evaluation of the aerodynamic parameters and missile dynamics in various environmental conditions for comparison with actual flight data.



IBM 1620 Digital Computer

## SYSTEMS DYNAMICS BRANCH

The Systems Dynamics Branch conducts analytical studies of advanced guidance techniques, the stability of missile control systems, and the dynamic behavior of complete missile systems during flight. Basic guidance equations are developed, and studies and experiments are designed to test their compatibility with actual hardware. The aeroelastic effects of the missile airframe are analyzed to determine the control gains, sensor requirements, and other control system parameters. Digital and analog simulations are employed in the dynamic behavior investigations. This branch also plans and directs, or conducts, supporting research in areas related to flight dynamics.

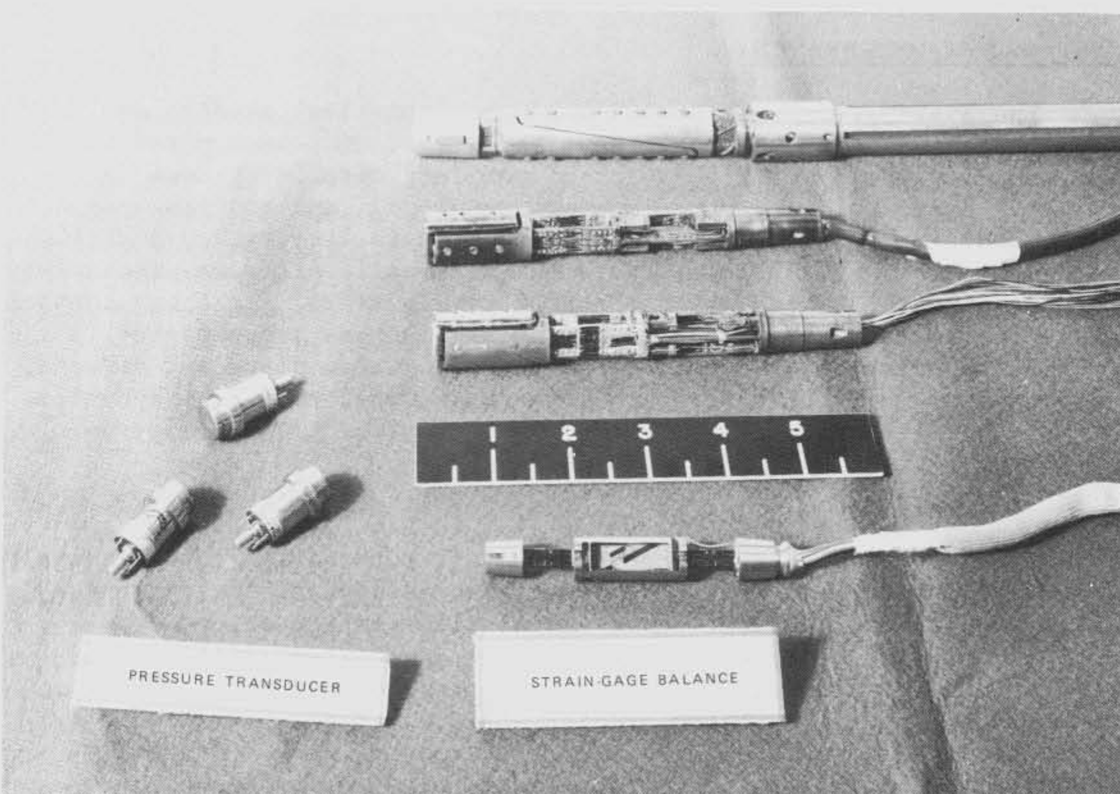
## AERODYNAMICS BRANCH

The Aerodynamics Branch engages in all forms of aerodynamic analysis, from theoretical research to detailed aerodynamic design and experimental verification. External missile configurations are optimized on the basis of desired aerodynamic characteristics, and predictions of aerodynamic coefficients are provided for performance and accuracy studies. These predictions are based on detailed flow field studies as well as parametric experimental data. Generally, aerodynamic characteristics of a selected missile configuration are verified experimentally in either wind tunnel or ballistic range tests.

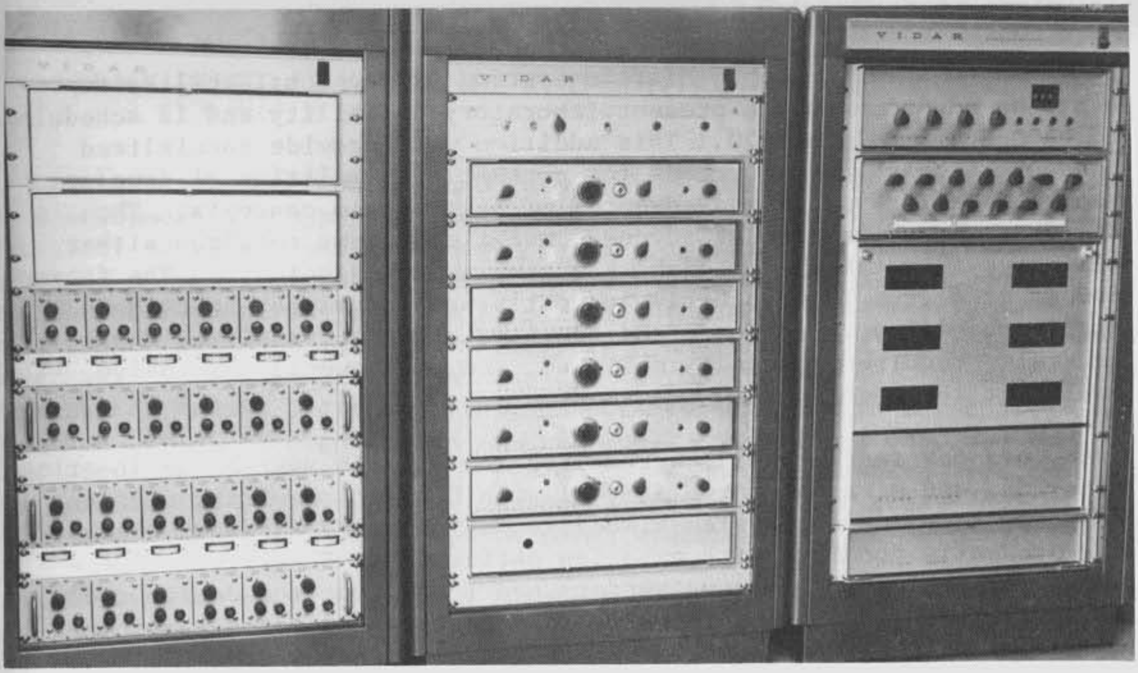
Numerous computer programs are available to support various aerodynamic investigations, and new computer programs and modifications to existing programs are continuously under development to meet the needs of current and anticipated missile system studies.

Specialized instrumentation, specifically suited for small-scale tests of missile configurations is maintained for wind tunnel investigations. A variety of three- and six-component strain gage balances are available with load ranges from 5 to 40 pounds. There is also a portable six-channel data acquisition system which can be used in recording and converting to digital form either steady-state or time-dependent data. A data plotter is used to plot automatically the reduced wind tunnel data.

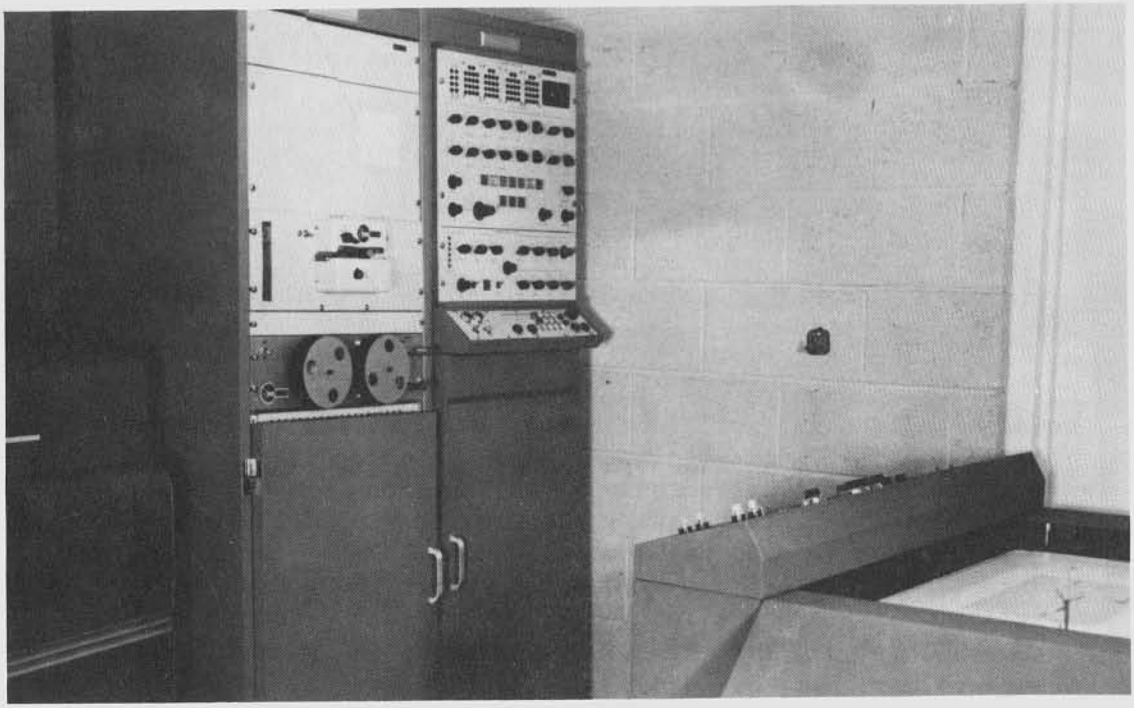
In addition to conducting aerodynamic studies for various missile systems, the branch is engaged in a number of supporting research programs oriented toward developing new and improved design techniques for predicting and improving aerodynamic performance, stability, and control of all types of missiles of interest to the Army.




Strain Gage Balances



VIDAR Data Acquisition System



Electronics Associates Data Plotter

## ADVANCED CONCEPTS MISSILE SYSTEMS DEVELOPMENT FACILITY

The Advanced Concepts Missile Systems Development Facility represents an addition to the present laboratory capability and is scheduled to be operational in 1970. This addition will provide specialized laboratory space and equipment for conducting simulation of developmental missile systems and advanced missile system concepts. The analyses and evaluation of advanced missile systems requires either extensive flight tests or elaborate simulation techniques. The former course of action is prohibitively costly until analyses have shown a high probability of success, and the simulation for analyses has generally required specially designed, and consequently expensive, equipment for each system.

This new facility will accomplish the missile systems engineering functions and mission of the Army Missile Command requiring complex, complete, closed-loop system simulations, including hardware elements not presently possible with existing facilities. It will provide a means for evaluating systems performance throughout the design cycle, and will also serve as an important diagnostic tool for determining causes of malfunction during advanced and engineering development. With this facility, the Missile Command can keep pace with current missile system technology, which has increased in complexity by several orders of magnitude in recent years.

# ARMY INERTIAL GUIDANCE AND CONTROL LABORATORY

The Guidance and Control Laboratory is responsible for the research and development of components and systems for guidance, control, electrical networks, missile-borne tracking, measuring, telemetering, and range safety devices for the Army Missile Command's weapon systems. The laboratory actively participates in all phases of the development. It initiates and performs selected research and component development, integrates the designs into the complete weapon system, and fabricates experimental models and prototypes. Contractor efforts in these areas are given technical support and supervision. Engineering cost and acceptance requirements are established for each component and system, test results are evaluated, and follow-up action is initiated. All design and development steps are thoroughly documented.

The laboratory is organized into a Research and Technology Office, which performs coordinating functions within the laboratory and provides consulting services within and outside the laboratory, and seven operating branches:

Inertial Systems

Electrical Systems

Prototype

System Analysis

Guidance Systems

Control Systems

Instrumentation.

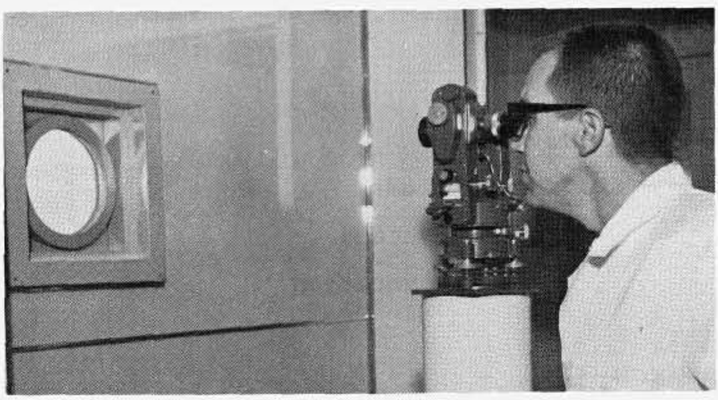
## INERTIAL SYSTEMS BRANCH

*Capabilities:*

The Inertial Systems Branch is responsible for the design, development, testing, and evaluation of gyros, accelerometers, platforms, and applicable servo systems and ancillary control electronics. New designs, techniques, and applications are devised through research, development, and evaluation in-house. The branch is composed of four groups -- Gyro Design, Accelerometer Design, Servo System Design, and Component and Systems Evaluation. Assembly, calibration, and evaluation activities are conducted in a clean room complex containing 100,000, 10,000, and 100 class environments. Evaluation is conducted on precision equipment located on 11 soil-isolated seismic pads, and 8 air-supported pads.

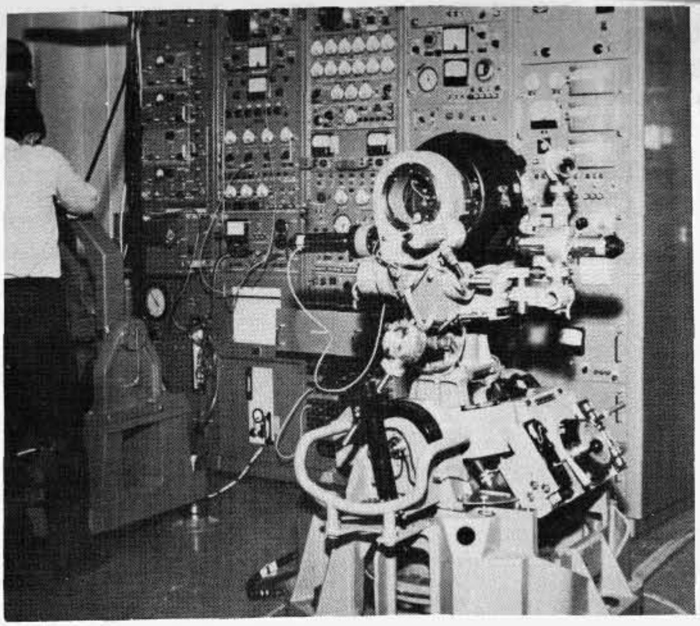
*Facilities:*

The functions of assembly, disassembly, and the several types of evaluation performed on components and systems are conducted in a clean room complex consisting of six operational rooms with ancillary air locks, passageways, storeroom, and change rooms. The air-handling system provides properly filtered and conditioned air to maintain the individual rooms at the proper particulate count level, and at conditions of $72^{o}F \pm 1^{o}F$ temperature and 41% ±2% relative humidity. This area contains the soil-isolated and air-supported seismic pads on which the evaluation equipment described below is located. The air-supported pads isolate in three orthogonal axes to better than $10^{-5}$ g, and maintain level in the horizontal axes to within 2 arc seconds through a unique three-point servoed support system. Optical alignment of the precision evaluation equipment is obtained from transfer points within the laboratory. A first order survey monument is located outside of the laboratory to provide an easily accessible point for external long base triangulation and Polaris sighting. Geodetic latitude and astronomical azimuth are established to the two monuments inside the laboratory by direct line of sight, thus providing the capability to align the precision items to an accuracy of 2 arc seconds directly.



Optical Transfer Stand

Two large Planetary Sidereal Stands, designed in-house, are surveyed into a North alignment within an accuracy of better than 3 seconds, and can be used to drift-test stabilizers that weigh up to 250 pounds. Both stands are equipped with a sidereal time drive, for eliminating earth's rotational effect, that is accurate to $0.001^{o}$ per hour and can maintain this accuracy indefinitely. The stands are environmentally located for temperature and humidity control and are seismically isolated to increase the accuracy factor. There are two turn-tilt stands which give calibrated motions around the three axes of the platform, and test consoles for each system to control the planetary test stands as well as the system under test.

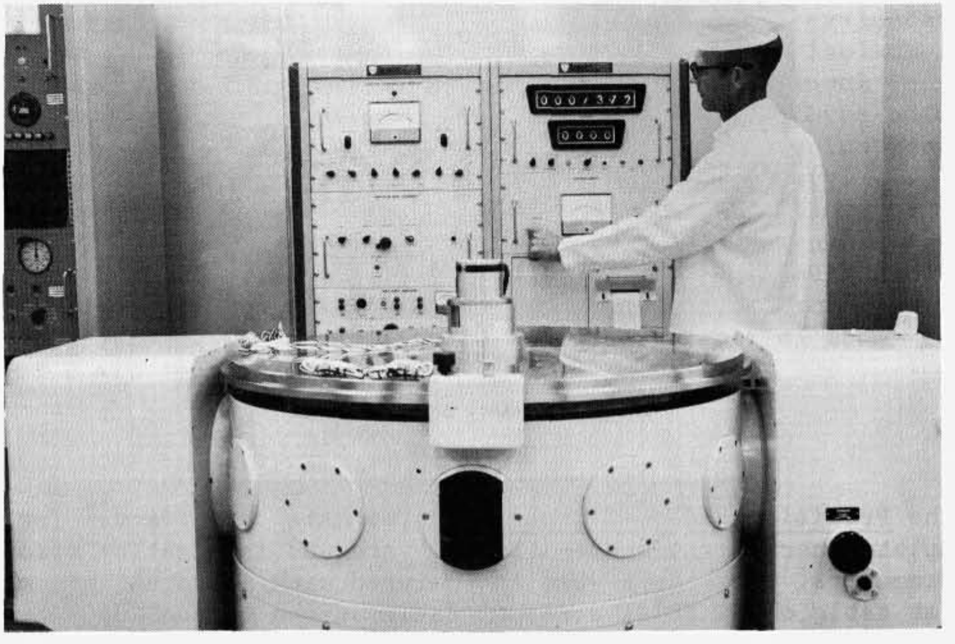


Large Planetary Sidereal Stand

The Precision Sidereal Stand is a two-axis test fixture for testing of complete inertial guidance systems, rate and integrating gyros, and accelerometers. The table axis is equipped with a hydrostatic air bearing. The test table consists of a rotary table driven through $360^\circ$ by a direct-mounted torquer motor. The table is trunnion-mounted in a yoke permitting it to be tipped $\pm185^\circ$. Electrical connections to equipment under test on the table are provided by slip rings and brushes, which contribute no friction to the table. The table is 41 inches high with the tilt axis 33 inches above the base mounting surface. The table top has a diameter of 34 inches and is capable of handling a test package 17 inches high and 36 inches wide. The table has a counterweight capacity of 1300 ft-lb, with a maximum load capacity of 3,000 pounds. The gross weight of the table unloaded is 6,800 pounds. The base alignment device permits $\pm5^\circ$ freedom in azimuth with a provision to align and lock the tilt axis within ±1 arc second to any preselected direction. Leveling of the base to ±1 arc second is achieved by means of three lockable screws.

The table axis can be manually positioned around the trunnion axis $\pm185^\circ$ from vertical. A clamp and tangent screw is provided for precision positioning of the trunnion and positive locking to eliminate backlash and creep during extended functional testing. The tangent screw permits fine adjustments to ±1 arc second. The tilt axis runout is less than ±0.0005 inch. Coarse and fine readout are provided. The trunnion axis coarse readout consists of a graduated dial and vernier with a resolution of ±30 arc seconds. For fine readout a Gurley Unisec Optical Readout is provided and has a resolution of ±1 arc second and an accuracy of ±2 arc seconds.

Six levels are provided on the tilt axis to indicate discrete positions within ±5 arc seconds. These angles include the polar axis at this latitude. The table axis is orthogonal to the trunnion axis within ±3 arc seconds at any position of the table and trunnion axes. The wobble of the table axis is less than ±½ arc second with loads counterbalanced around the tilt axis and with the center of gravity at the table axis. The table axis runout is less than ±0.0001 inch.

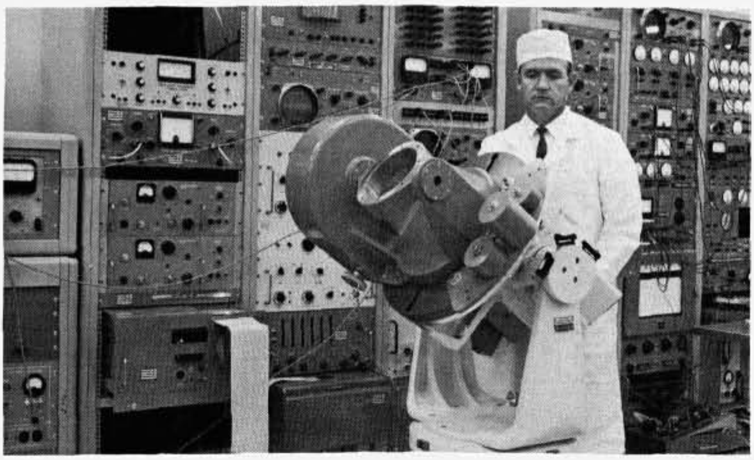


*Precision Sidereal Stand*

A direct-mounted AC torquer motor is provided to drive the table. The AC unit is used to provide complete mechanical isolation of the table and to prevent any stiction, frictional, or drag torques. Normal servo-following capability is up to $60^{\circ}$ per second. The moment stiffness of the air bearing is 400 ft-lb per arc second. The table top is flat to within 0.001 inch. The top face wobble is less than ±6 arc seconds. Table axis readout is provided by a 720-pole inductosyn of ±0.5 arc second accuracy. The inductosyn is mounted on the table shaft to provide a precision reference for position and rate readout. A course resolver is supplied for the table axis (on the slip ring assembly) to provide course angular position data to resolve the inductosyn ambiguity.

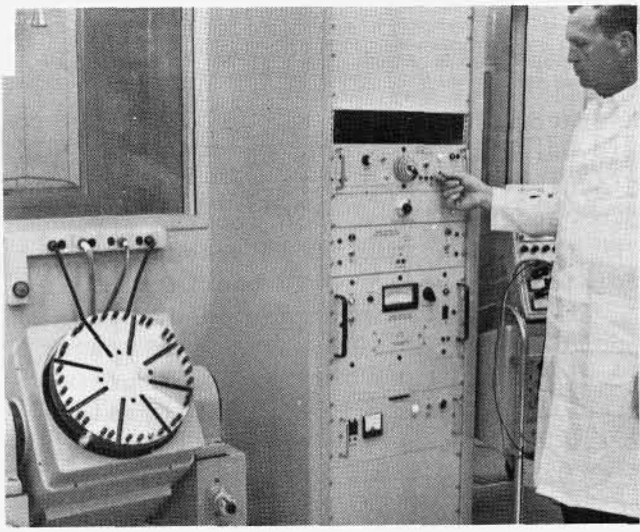
Fifty (50) slip ring lines are available in a connector recessed in the table top for electrical connections. Each line is capable of carrying 3 amperes at 115V. Slip ring noise is less than 50 μV at 10 mA current. The slip ring subassembly is servo driven by a DC torque motor to eliminate the friction effects of the slip ring assembly.

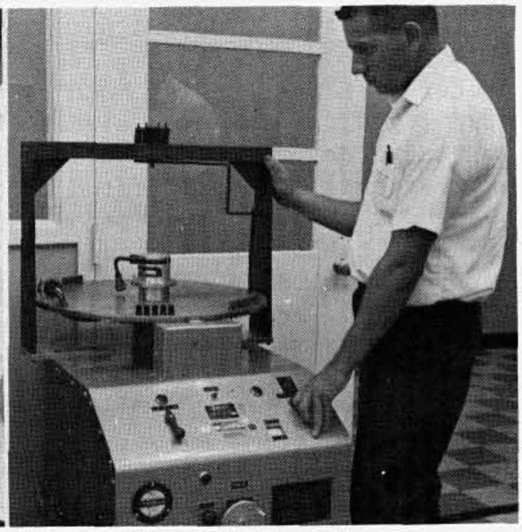
The Two Axis Sidereal Rate Table is a two-axis multimode fixture highly suitable for testing inertial components such as gyros and accelerometers. Either one or both of the two axes may be slaved by the output signal of the gyro signal generator. Both axes may be operated in a rate mode providing continuously variable speeds up to 75°/hour. The first axis may be operated in a synchronous mode with the axis being driven by a 60-hertz synchronous motor at earth rate, 150°/hour. The first axis table top is orthogonal to the drive axis to 10 seconds of arc. The drive axis rotates on precision preloaded taper bearings at the upper end, and on a ball bearing at the lower drive gear end. The table is capable of accepting 100-pound loads. The 60-hertz synchronous and 400-hertz servo motors drive through a 360-to-1 worm gear, accurate to ±5 seconds of arc. Sidereal correction is provided by a gear train which uses a ratio accurate to 0.02 second of time per day. The output is provided by a 4-pole microsyn which supplies positional information such that one revolution is equal to 56.92 arc minutes of table rotation. The microsyn sensitivity is 52.7 mV per arc second of table rotation near the microsyn null. The microsyn linearity is 0.5 percent to 20°, having a useful range of ±35° of shaft rotation.



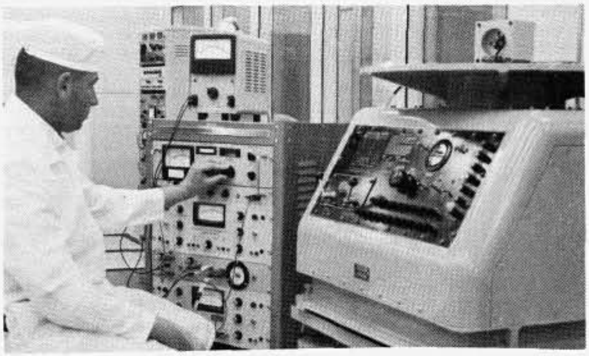
Two-Axis Sidereal Rate Table

The Wide Range Rate Table is capable of bidirectional operation between 0.02°/sec to 1500°/sec with a long term stability of ±0.05%. The table can be accelerated at a maximum rate of $1000^{\circ}/sec^2$, and will maintain wow and flutter better than ±0.005%. Remote presetting permits automatic hysteresis tracing. These performance characteristics are obtained by means of an air-bearing shaft support. Air-bearing components may be evaluated since the design incorporates a high pressure (500 psi) supply at the table. Thirty (30) slip rings are available for power and signal transmission, and an optical shaft encoder permits precision control and makes table position data available.





Wide Range Rate Table (above left)
Standard Rate Table (above right)
Precision Rate Table (right)

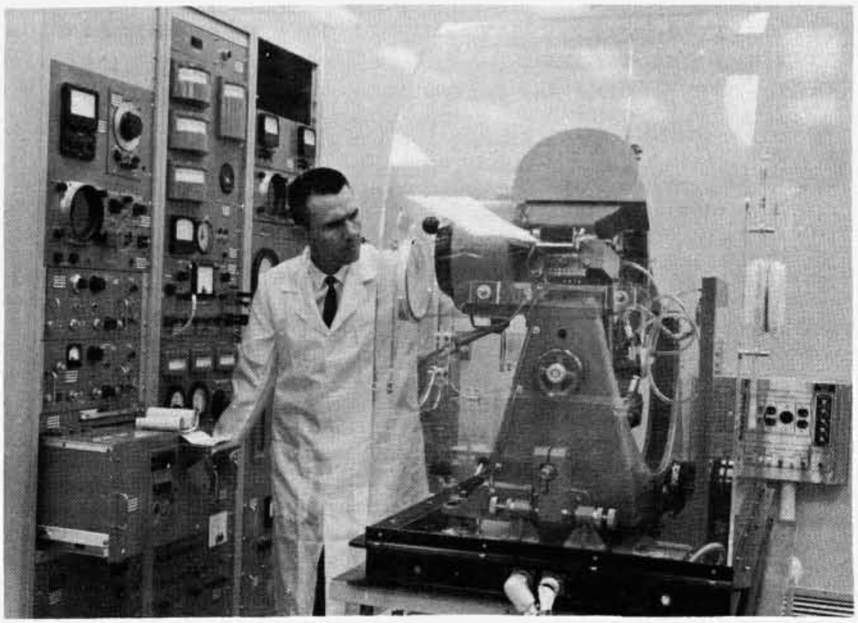


A Precision Rate Table is used for calibrating and testing equipment such as gunsight systems and rate gyros, which require an accurate angular displacement check. The front panel of the unit contains the switches and mechanical controls to stop and start the table, to control the direction of rotation, and to select the rate of turn. Various jacks and receptacles are provided to connect power and test circuits to the turntable and through the turntable to the equipment being tested. The speed capability of the table is from 1 through 700 mils/sec at the following ranges: 1, 3, 4, 5, 25, 50, 75, 100, 125, 140, 150, 200, 250, 420, 560, and 700 mils/sec.

A Standard Rate Table, with a range of 0.01°/sec to 1200°/sec, is available. The angular velocity is constant within 0.1%, and the preset rate is accurate to within 1%. Unique features installed in-house include additional instrumentation slip rings, and an attachment to provide clean air to the rotating table to permit the evaluation of air-bearing components.

The Gyro Sidereal Stand (AB-5 FCO) is designed to perform a drift test and a rundown test on gyros. This equipment consists of four major components -- the sidereal test, the filter cabinet assembly, the cable and air line assembly, and the AB-5 final checkout console. The AB-5 sidereal consists of a planetary test stand, heat enclosure and enclosure base. The sidereal stand is used to mount the gyro and provide a test frame free from the effects of earth's rotation. The heat enclosure is made of plexiglass and is used to retain heated air around the planetary stand and to keep out dust particles. The enclosure base surrounds the planetary stand and supports the heat enclosure. The filter cabinet assembly supplies filtered, heated air to the gyro air bearing. The cabinet contains the air shutoff petcock, the metallic poro-mesh type air filters, and the electric controls. The FCO console is used for applying the proper excitation voltages and monitoring the outputs of the gyro under test. The manufacturer rated accuracy on the sidereal stand is as follows:

| | |
|---|---|
| Time Drive | $\pm 0.005^{\circ}$/hr (0.12 sec of time) |
| Polar Axis | ±30 arc sec of true North |
| Angular Displacement of Gimbals | ±4% |
| Gimbal Bearing Trueness | within 36 seconds |
| Gyro Mounting Surface Flatness | ±0.00005 |

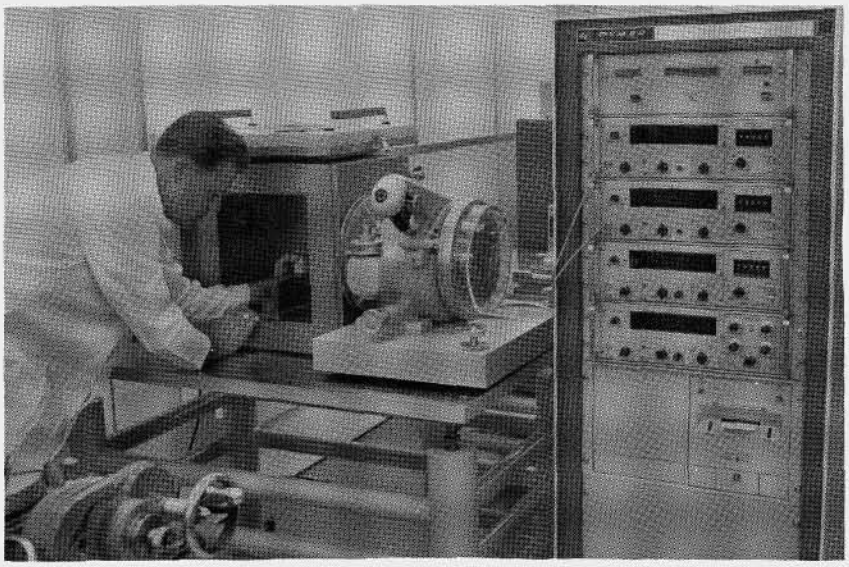


Gyro Sidereal Stand

Two Vinco Optical Dividing Heads, which have been modified in-house to give any angular position within 0.5 sec of arc, are used to calibrate and evaluate air-bearing, pendulous, and integrating accelerometers in a 1-g field. The spindle axis of the dividing head is aligned North-South within 10 sec of arc and perpendicular to the local vertical within 10 sec of arc. The accelerometer mounting bar, used for accurate and repeatable positioning, is leveled to within 2 sec of arc in the zero position, horizontal plane. The accelerometer is mounted against the mounting bar on the South side of the dividing head disc. By rotating the head, the attitude of the accelerometer is changed in relation to the local gravity vector, and it is then possible to determine the scale factor, constant bias, side balance, servo error, and pivot alignment of the unit.

The Temperature Control Chamber, which has been modified to use with the Vinco dividing heads, makes possible the measurement of accelerometer parameters under controlled temperature conditions and also the measurement of the temperature gradient sensitivity of the parameters.

The Dymec Accelerometer Test System includes a versatile combination of components to enable the outputs of digital devices to have 8-place accuracy over a wide range of output levels. With this equipment as many as four digital signals can be measured over a specified period of time, ranging from 0.001 second to several hours, using internal or external time sources. Once the setup is fixed, the measurement can be made repeatedly without attendance and the results printed out, with identification, on a single tape.

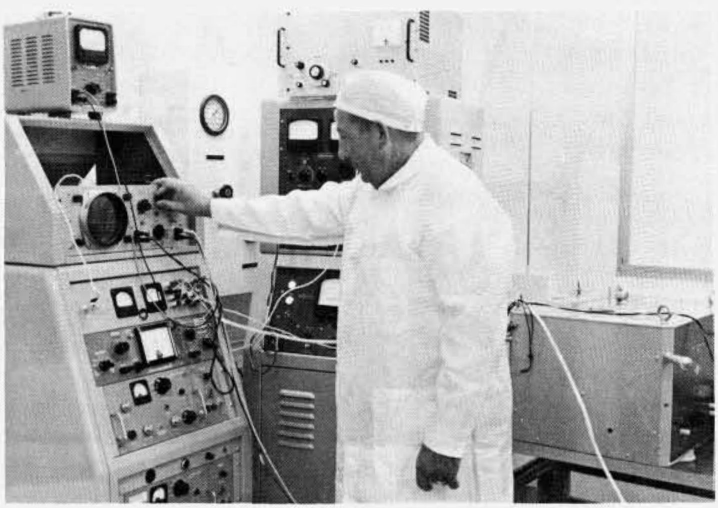


Vinco Dividing Head with Temperature Chamber and Accelerometer Test Console

Evaluation Vibration Equipment

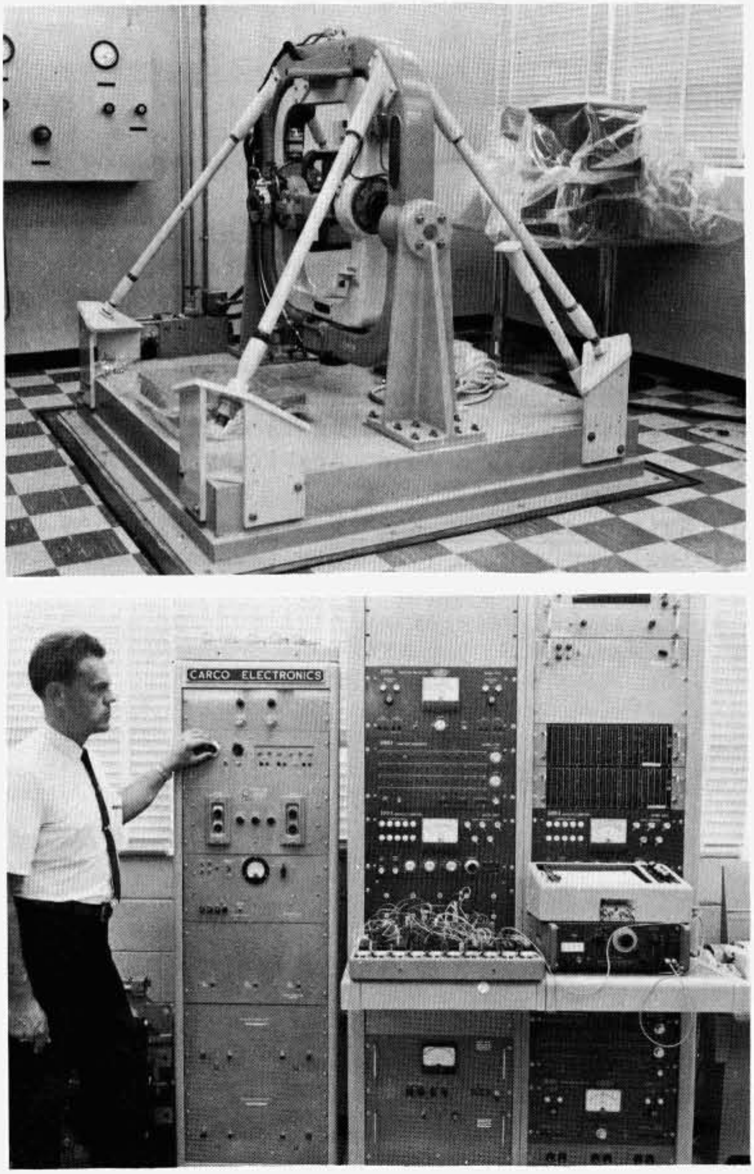
The Evaluation Vibration Equipment, contained within the clean room complex, is utilized to provide an environmental input to a component under evaluation to facilitate the observation of gimbal or float response by stroboscope or by film techniques. (A vibration machine for true vibration performance testing is available in the environmental laboratory.) Calibration of some instruments, and vibropendulosity evaluations are also conducted on this equipment. The shaker is equipped for sine spectrums only up to 9,000 cps, and has a load capability of 100 force pounds.

The Single Axis Oscillating Rate Table is primarily useful in the performance of single axis gyro frequency response determination. The table has a maximum displacement of $\pm 5^{\circ}$, a maximum angular rate of $200^{\circ}/sec$, and an angular acceleration of $1800^{\circ}/sec^{2}$. The usable frequency is DC to 60 cps.



Single-Axis Oscillating Rate Table

A Three-Axis Dynamic Test Stand is used in conjunction with a Donner function generator to provide the dynamic environments required to evaluate components and systems. The inner gimbal can be operated in continuous roll up to 12 rps, and clean air or gas can be supplied to the component or system for evaluation of air-bearing instruments. All gimbals can be operated to an acceleration level of 100 rad/sec$^2$ with a load inertia of 3 lb-in-sec$^2$; and reference position is indicated to within 30 arc seconds through the encoders. Sixty (60) slip rings to the inner gimbal provide adequate power and signal leads.




Three-Axis Dynamic Test Stand

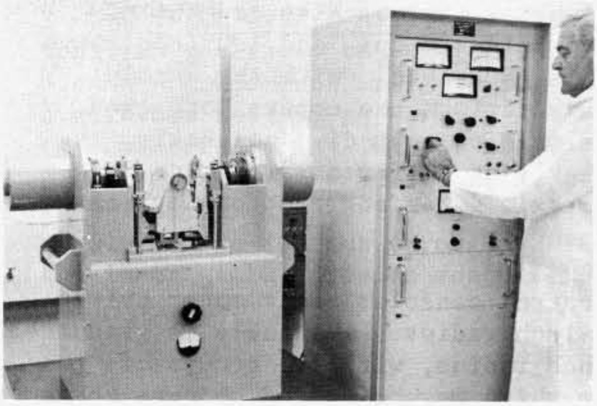
A Two-Axis Oscillating Rate Table has a maximum displacement of ±5°, a maximum angular rate of 200°/sec below 30 cps, and 100°/sec above 40 cps. Maximum angular acceleration is 1800°/sec², with the usable frequency range from DC to 60 cps. This performance covers both axes. Operation may be conducted with either axis on an individual basis, or both axes simultaneously and independently at different amplitude and frequency settings. Evaluation of two-axis gyros and platform systems is greatly simplified with this equipment.

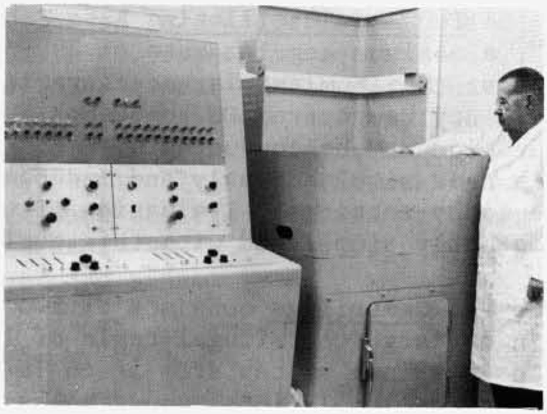
The Centrifuge consists of two control consoles and a motor driven main or large centrifugal table of 17-inch radius. The table is graduated into 44 ¼-inch spaces from 5- to 16-inch radius, with two groups of diametrically 3/8-inch tapped holes to which may be bolted objects to be tested, with the necessary counterbalances. On the large centrifuge table are two satellite tables 6 inches in diameter at 12-inch radius from the main table's center and driven by a separate motor. They are independent of the main table; by conversion, they can be made to stay directionally motionless while the main table revolves, or both the main table and satellite tables may be made to revolve independently of each other in either direction at different rates of speed.

In the center of the main table is a hub on top of which is mounted a swivel air fixture for the purpose of the conduction of air from a stationary source of supply to gyros or other equipment revolving on the centrifuge tables and requiring air. Around the circumference of the hub are conductor connectors with conductors leading through slip rings to the two control consoles -- eleven (11) to each, plus grounds. One console controls the rpm or speed to the main centrifuge table, and the other the speed of the two satellite tables. A tachometer generator connected directly to the main table actuates a direct rpm reading E-Put meter on one console. Photocells actuate the direct rpm reading E-Put meter on the other console from one satellite table.

The centrifuge assembly has a steel enclosure, the upper part of which acts as a protection from possible material thrown outward from the centrifuge table. A higher additional safety enclosure has a hinged section which may be folded back for easier access to the tables. The accelerator is designed to operate at speeds up to 550 rpm, and is capable of accelerating a 2.5-pound test specimen to 100g while the specimen itself is rotating in the centrifugal field at frequencies from 0 to 30 cps.

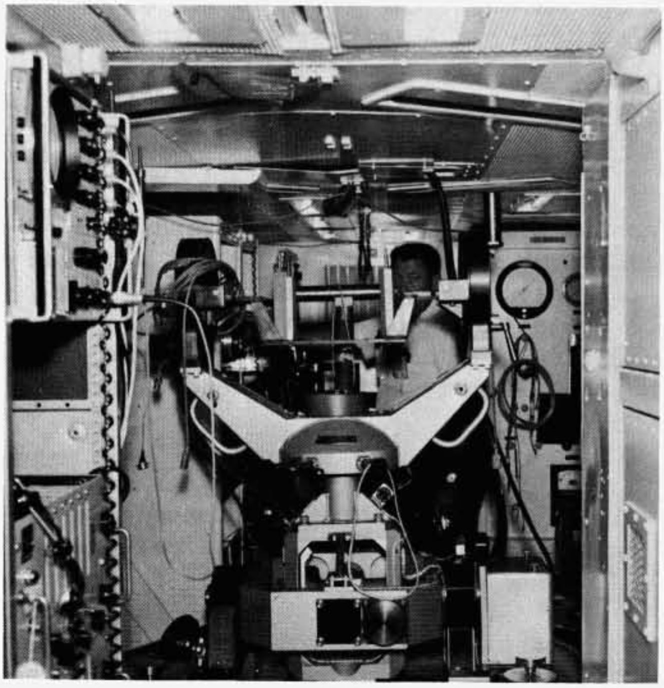
The Mobile Inertial Evaluation Van is utilized primarily as an economical dynamic simulator by which inertial systems and components may be thoroughly evaluated. After laboratory evaluation and calibration is completed, the most feasible and economical means available to produce the complex movements and velocity inputs is to employ a van. The systems can be operated, at several closely controlled speeds on good highways to several first order survey points, to simulate flight conditions. The van design is versatile and permits gyro, accelerometer, platform, and computer evaluation for any type of analog or digital design, and for any type of application through modular conversion techniques.





Two-Axis Oscillating Rate Table

Centrifuge

Mobile Inertial Evaluation Van (lower view showing Planetary Test Stand inside)

The van is supported on air with isolation below 5 cps, and contains a planetary sidereal stand which is accurate to 1/75,000. Power is available within the van by means of a diesel 60-cps generator. A motor-generator set, inverters, and precision current and voltage supplies form the basic source of any power required. Monitoring equipment such as scopes, voltmeters, and a tape deck, form the basic installation of six (6) isolation-mounted consoles. Air-conditioning and a heating system maintain the environmental conditions, while an intercom system and radio provide communications contact with the tractor driver, the laboratory, and the tracking aircraft.

A Mathatron Calculator, with an auxiliary program storage unit and a PTP mathatyper, is available within the laboratory. This calculating device is used to perform scientific and engineering calculations that are too complex to be run on a mechanical calculator without repeated reentry of intermediate results, but too small to be programmed for larger electronic data processing systems. These calculations are simplified in that numbers and formulas are typed directly into the Mathatron using ordinary mathematical notation on a direct input keyboard. The Mathatron then automatically calculates and prints the solution with the decimal point in its correct mathematical position.

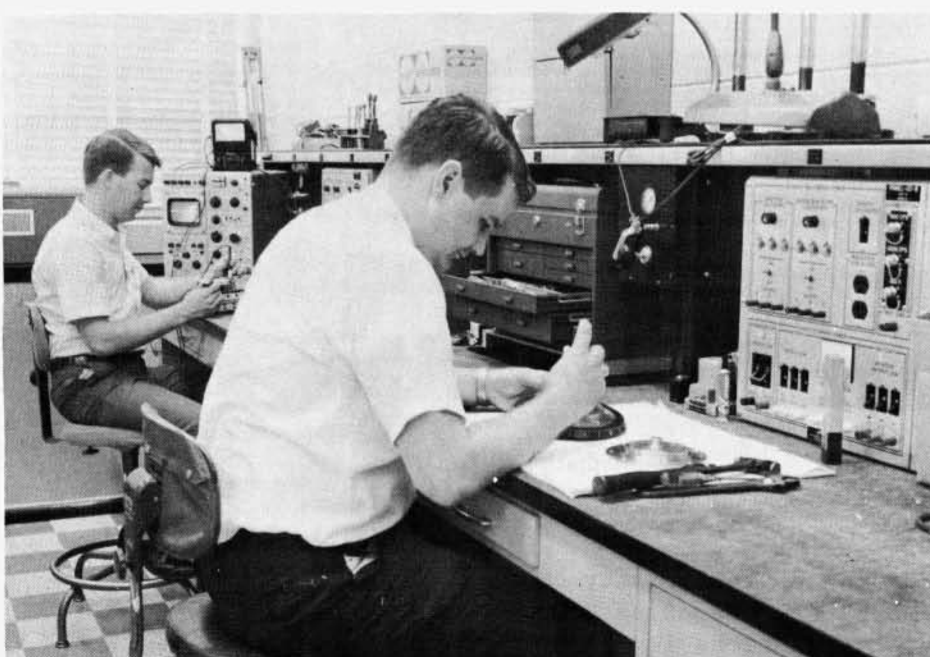
Mathatron Calculator

In addition to its ability to perform simple arithmetic calculations, the basic Mathatron possesses a memory and storage capability which allows a sequence of operations in a problem to be memorized. After a problem or formula has been worked once, all recorded operation steps are repeated automatically by pressing a single button on the keyboard. Only variables which cannot be defined by a mathematical process need be entered manually.

The auxiliary program storage unit provides the Mathatron with a storage capacity of 480 steps of program memory and 48 storage registers. Each storage register can store a ± number containing 9 significant digits multiplied by $10^n$ where n is equal to or greater than -41 and equal to or less than +49. The Mathatron is also equipped with a PTP mathatyper which allows program instructions to be punched on paper tape. This punched tape can later be fed into the paper tape reader, which then loads the proper sequence of operations into the Mathatron memory. After the variables are entered into the Mathatron via the keyboard, the Mathatron performs the necessary operations stored in the memory and types out the answers.

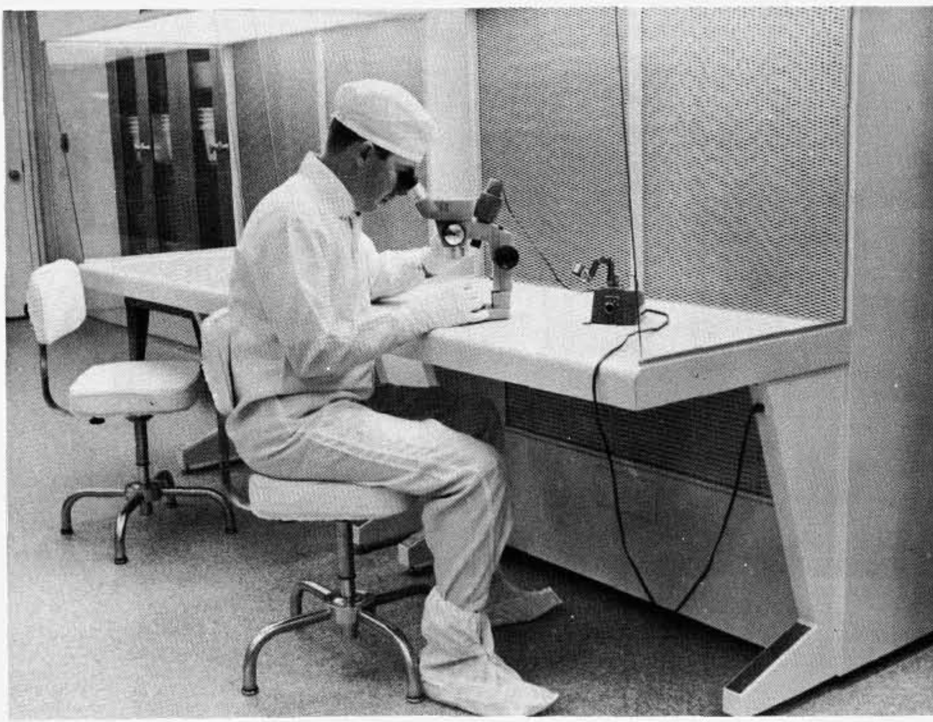
Typical problems the Mathatron is capable of solving include: raising numbers to any power; the solution of cubic quadratic and fifth degree equations; the evaluation of polynomials; determination of standard deviations; solution of simultaneous equations (up to 10); and many other similar complex problems.

An Electronics Laboratory work area is available outside of the clean room complex to facilitate the buildup of breadboard electronics, calibration of fixtures, cable makeup, etc. Each bench work area provides clean air, plant air, high pressure gas, and a power panel from which a wide range of precision AC and DC power is available as well as an instrument ground and standard frequencies.



Electronics Laboratory

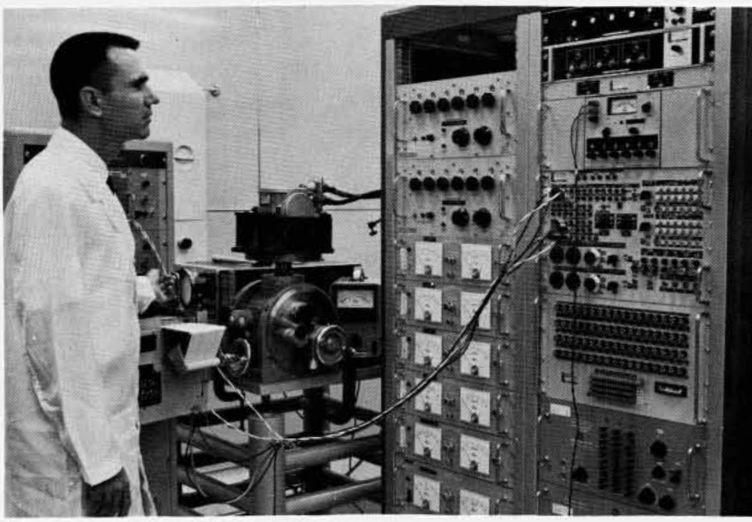
There are several Class 100 Assembly Inspection Areas containing laminar flow work benches for use by laboratory personnel in disassembling, assembling, repairing, or inspecting instruments. R&D evaluation normally entails periodic design changes, calibration, and inspection of the items under test, and the placement of the laminar flow work benches insures that these vital operations will not permit the introduction of contaminants into precision gyros, accelerometers, or platforms.



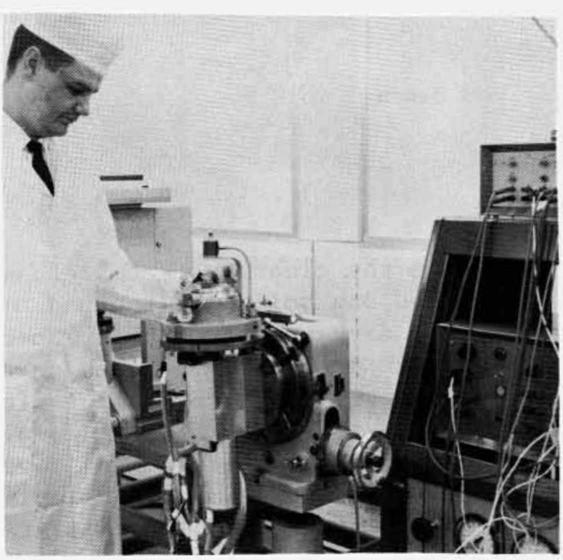
Laminar Flow Work Bench

An Optical Dark Room is located within the clean room complex. It is equipped with an air-isolation pad and one soil-isolated pad. A sidereal test stand is located within the dark room to provide special test capability for stabilized light and heat trackers, in addition to stellar navigation, and optical sight trackers. A 4-by-6-foot granite surface plate is located on the air-supported isolation pad. A complete optical bench with a multitude of light sources is available for developing and testing of optical alignment equipment for aiming and laying of inertial sensors. Transmissibility measurements can be made over a wide range of light wavelengths for geometric as well as polarized and twist collimator paths.

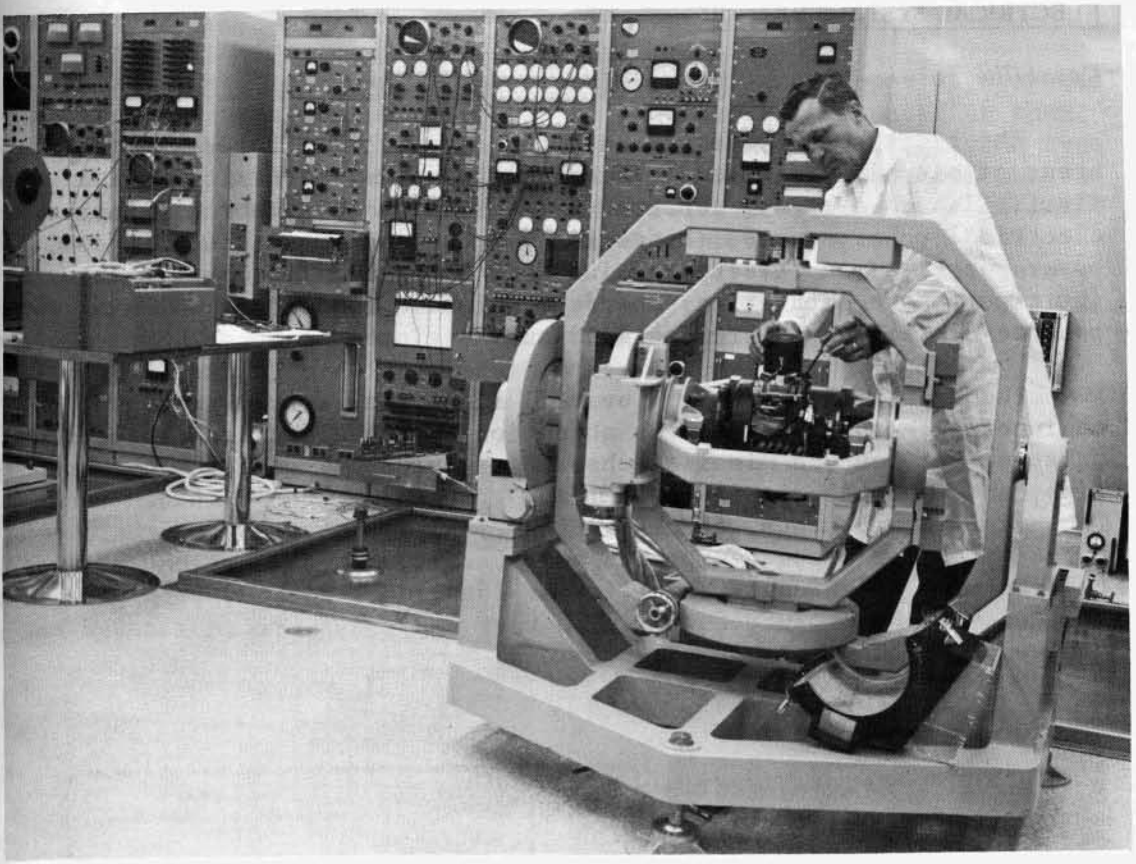
General laboratory equipment consists of such items as P&W dividing heads (accuracy of 2 arc seconds), Leitz dividing heads (accuracy 1 arc second), three-axis precision tilt stands (position accuracy 2 arc seconds), and in-house designed and built spin/pitchover fixtures used to simulate the general environment of a spinning missile in steady or varying pitch positions. Also available are those equipment items commonly in use in laboratories of this type -- precision current and voltage supplies, scopes, analog and digital electronics and tape decks, laboratory standards, etc.



Leitz Dividing Head



Spin and Pitchover Fixture



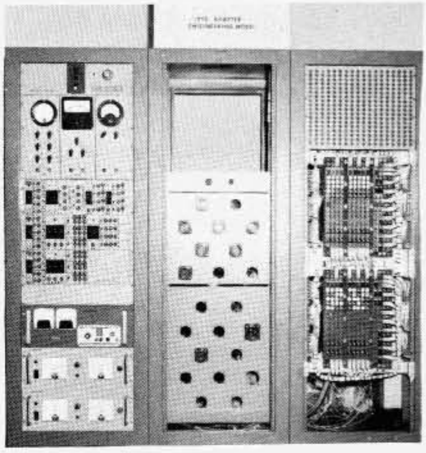
Three-Axis Tilt Stand

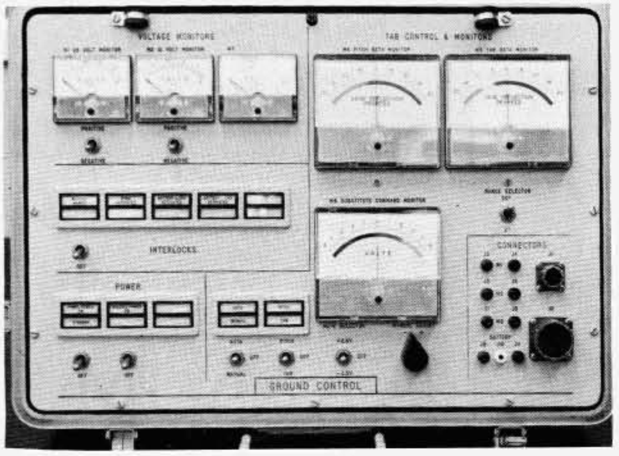
## ELECTRICAL SYSTEMS BRANCH

*Capabilities:*

The Electrical Systems Branch plans and conducts research in the areas of missile and ground electrical networks, electrical power systems, missile launch test and checkout systems, missile airborne primary electrical power sources (batteries), precision regulated AC and DC power supplies, and electrical initiation systems for missile motor ignition, stage separation, and other missile functions. Special components or techniques are designed and developed in-house when required.

The branch also performs overall electrical systems integration engineering, paying particular attention to the electrical interfaces existing between the missile subsystems, guidance, warhead, and propulsion, and also the missile system and ground electronic launch systems. Technical requirements, specifications, and acceptance criteria are established for these equipments and systems, and evaluations are made to determine technical feasibility or functional adequacy. Engineering breadboards and prototypes of field test equipment are fabricated and tested under the branch's supervision.

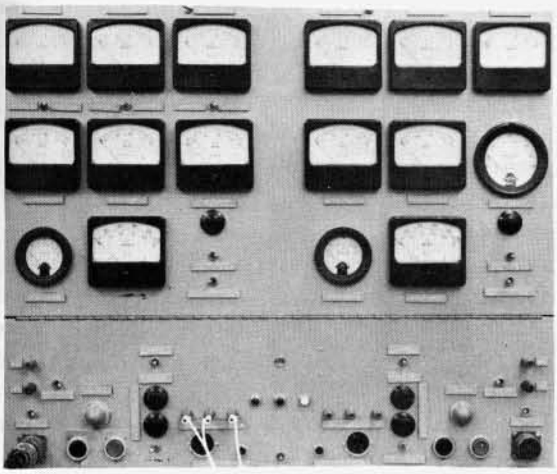


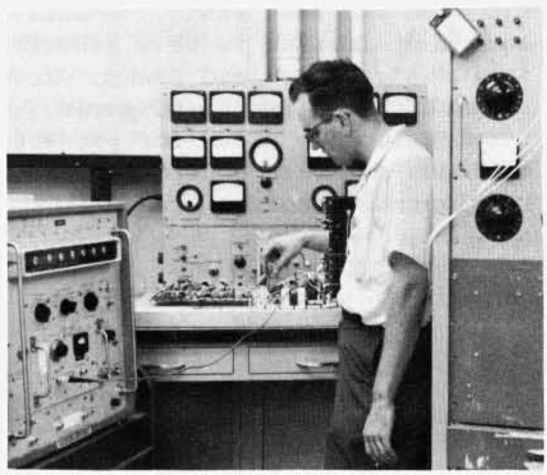



Engineering Breadboards and Prototypes

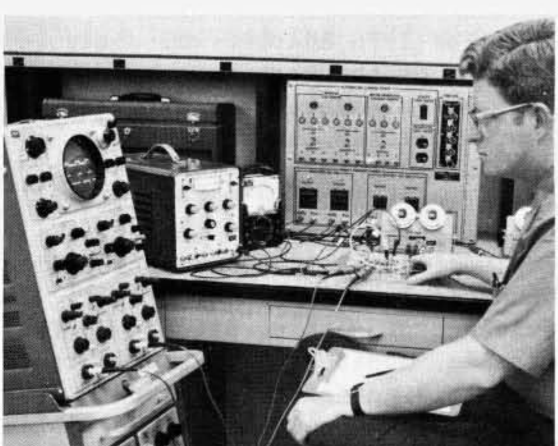
*Facilities:*

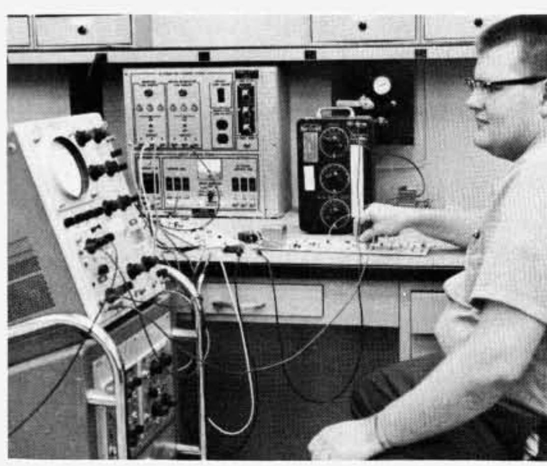
The <u>Inverter Design and Checkout Laboratory</u> is equipped with special panels that have the controls for two DC generators terminated on them. These controls permit the test engineer to vary the DC voltage, the type of regulation (local or remote), and the line resistance between the source and the load. The control panels provide measuring devices for DC input voltage and current, output voltage and current for 3-phase 3-wire units, and the phase rotation of the inverters. This laboratory is also equipped with load bands that permit changing the inverter load resistance and the load power factor. Other equipment provides the capability of making precise frequency measurements.





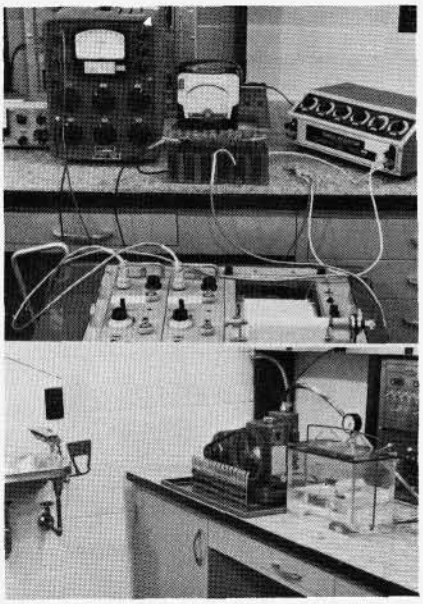
Inverter Design and Checkout Laboratory



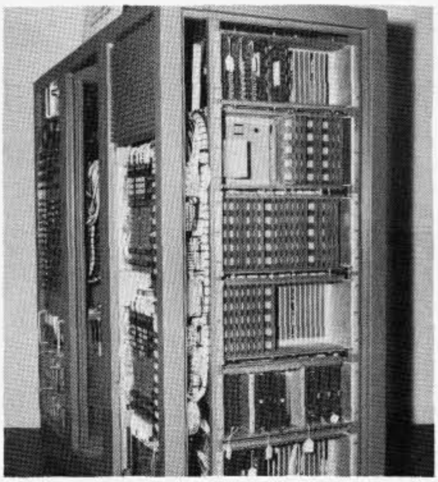


The Electronics Laboratories are equipped with special electronic test equipment -- recorders, oscilloscopes, precision AC and DC meters, transistor testers, and materials for breadboarding and testing electronic circuits. Each laboratory is equipped with panels that provide DC power, battery, and rectifier; AC power, 400 Hz and 60 Hz; and frequency standard signals. These electrical power and frequency standard signals are obtained from a common building power system.

The Battery Laboratory is equipped with many safety features required for safe handling and testing of batteries, including eye wash and wash basin. Special equipment located in this laboratory includes various load banks, vacuum activation equipment, DC power terminations to allow for presetting of loads and test equipment, and refrigerated storage area.



Battery Laboratory



IPTS Adapter

The IPTS Adapter was designed as part of the test, checkout, and launch equipment for a missile system. It is controlled by a general purpose digital computer. Operating together, they have the capability of controlling and monitoring missile functions during launch operations, providing guidance presetting signals to the missile, monitoring voltage output of ground and airborne power supplies, and monitoring the system to insure safe operation. With change of computer programs, this equipment could be used with many missile systems.

## PROTOTYPE BRANCH

*Capabilities:*

The Prototype Branch plans and conducts research on nuclear radiation effects on electronics. Special computer programs are utilized as aids in determining the permanent and transient effects on circuit performance. Experimental data on the electronic component's and circuit's response to nuclear radiation are gathered from tests arranged at Government radiation laboratory facilities or from coordinated field tests. The planning and research efforts in the nuclear weapons effect research program are coordinated with all segments of the laboratory.

Other research is aimed at the development of advanced electronic packaging techniques and the application of new techniques and materials for the manufacture of precision instruments. Welded modules, flat cable connectors, and module connectors are developed and evaluated in-house. Studies are made to determine the potentials of micromodules, thin film, and microelectronics, and advanced electronic packaging and interconnection techniques are investigated.

The branch also performs the following service functions for the laboratory: prepares drawings, specifications, and other required engineering documentation; fabricates and assembles prototype equipment of a peculiar nature; environmental tests of components during the design phase. Drawings and drawing sets prepared by the laboratory and contractors are reviewed for conformance with Ordnance standards, and modifications made as required. Laboratory-wide design standards are established. Many precision testing instruments are designed and constructed. The environmental test facilities can simulate wide ranges of temperature, humidity, vibration, acceleration, and altitude.

*Facilities:*

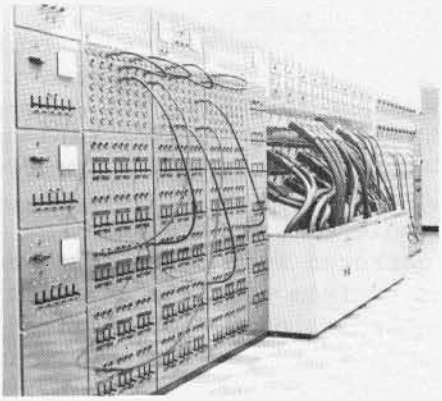
The Weld and Cable Connector Fabrication and Testing Equipment available includes the following:

Power Supplies - Weldmatic Models 1026 (0.2 to 80 watt-sec energy storage range) and 1016 (0.1 to 40 watt-sec); Sippican 1A (0.4 to 40 watt-sec); and Raytheon 60 C (0.1 to 63 watt-sec, 3 capacitor settings, series or parallel primary and center-tapped secondary).

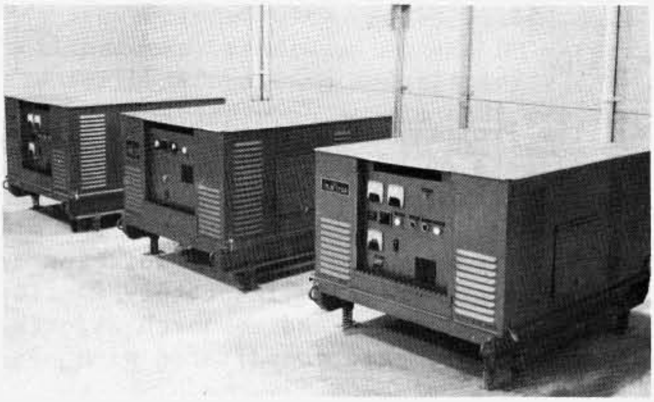
Welding Heads - Weldmatic miniature 1032 (4 oz to 15 lb electrode pressure range, 80 watt-sec); Sippican Pincer 12A (½ to 5 lb); Sippican Vertical 16 (½ to 12 lb).

Weldmatic MP-100 Mylar Film Punch - including punch and die sets for 0.016, 0.028, 0.035, 0.040, 0.062, and 0.125 inch diameters.

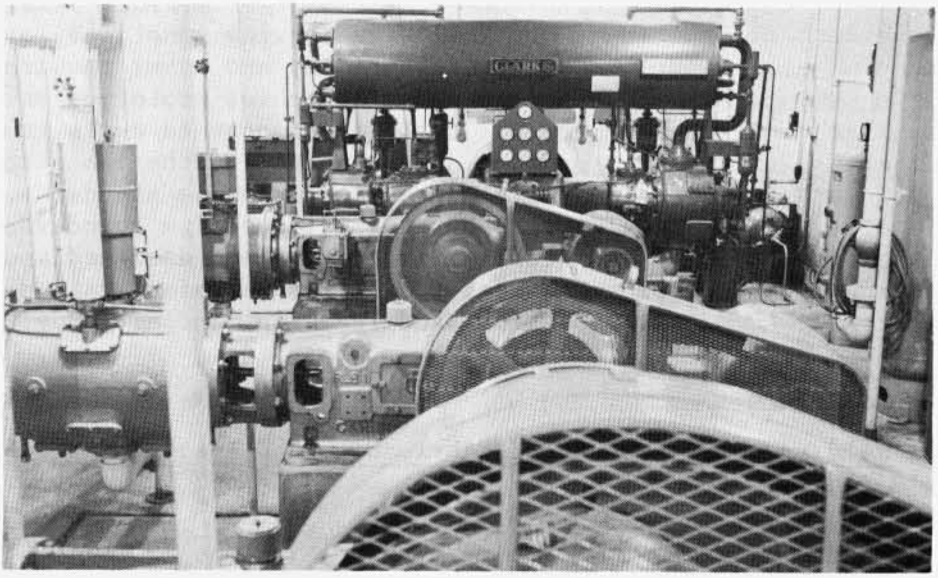
Hunter Spring TTH100 Tensile Tester - with 0-20 lb or 0-50 lb force gage ranges.



Master Control Patch Panel for
Laboratory Power



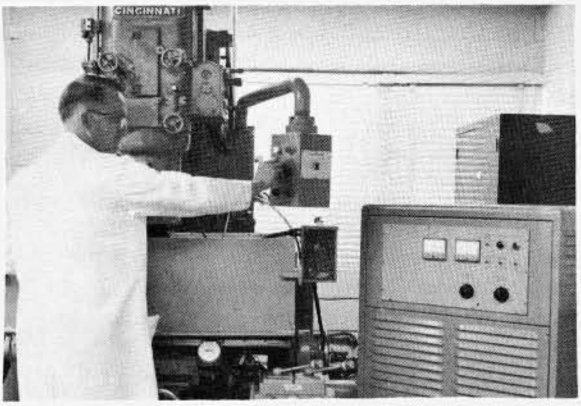
Motor-Generator (400-hertz)



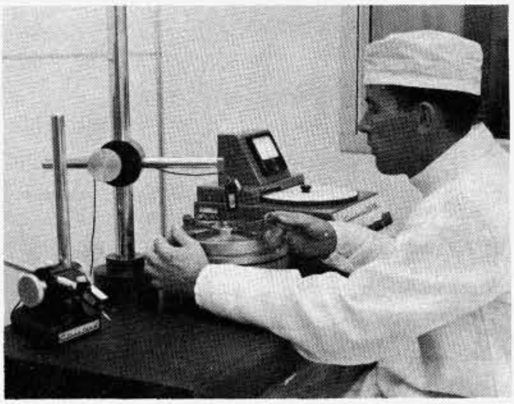
Compressor Room for Laboratory Air and Vacuum

Duffers 272 Weld Current Monitor - with air-core toroid pickup, 1000 to 100,000 ampere range.

Keithley Inst. 502 Milliohmmeter, 0.001 to 1000 ohm range, full scale.



Electrical Discharge Machine Used for Shaping Conductive Materials

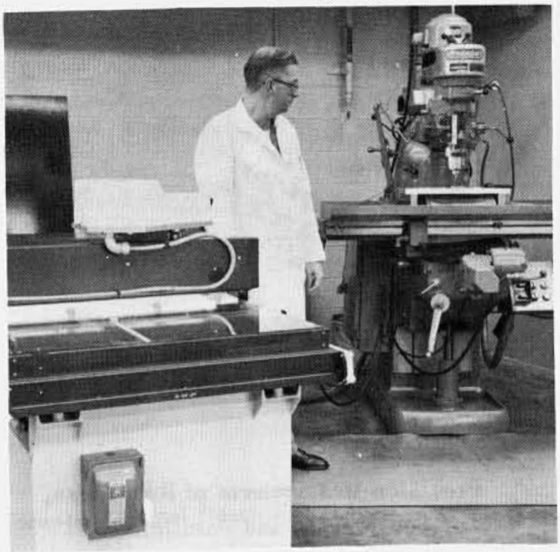


Precision Measurement of Roundness, Squareness, and Parallelism

Precision Prototype Fabrication Facility

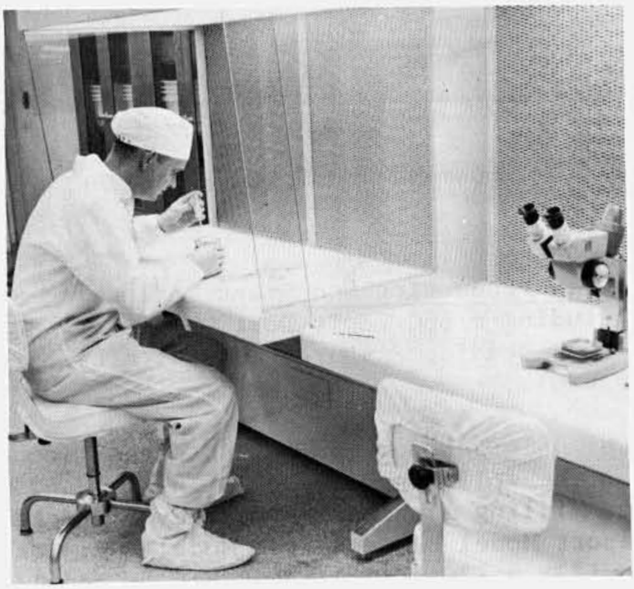
Prototype Module Production Equipment includes: S. S. White Model C Air Abrader, including a 66C Torit Dust Collector; RCA MMK-201 Process Control; RCA MMK-204 Abrading Fixture; and all necessary jigs, molds, ovens, parts, and tools.

Equipment available for developing and assembling special prototype equipment includes the following: Pratt & Whitney and Moore jig borers and cabinets; four milling machines -- Kearney & Trecker Model D and Universal, Bridgeport Model BR, and Tree Model TUV; Gorton three-dimensional Pantomill; a 12-inch flat lap and 6- and 12-inch roll laps; Do-All G-1 surface grinder; Brown & Sharpe No. 2 cylindrical grinder; Wilson 5JR Hardness Tester; Bendix Ultrasonic Washer, Rinser, and Dryer; Pratt & Whitney Electrolimit Internal Gage; Kodak Contour Projector; Gorton precision grinder; Dracon power Punch; furnace, 0-600°F ±2°; band and hack saws; tool room lathes -- Hendy 14-inch, Monarch and Hendy 10-inch, and Harding 6-inch; Master-Mike Tool Room Microscope, tool post grinders, and drills; an optical line tracer with slaved milling machine; an electrojet machine for precision milling of conductive metals; and a variety of equipment for precision measurements of round surfaces, flat surfaces, and parallelism.



Optically Controlled Line Tracer and Slaved Milling Operation

Ultrasonic Cleaning Operation



Clean Bench Assembly Operation

Six Clean Rooms are maintained by the branch -- two each of 10,000 level (particles per cubic feet) with maximum dust particle size of 0.5 μ, and four each of 100,000 level (particles per cubic feet) with maximum dust particle size of 0.5 μ.

For Environmental Testing, the following equipment is available:

Vibration System - consisting of an Electronics 4200 MB system, MB amplifier, T388 automatic equalization console; C50 oil-cooled exciter; Allied Research ARA 30-30 Vibra-Plane.

Sine Performance - 5-3000 cps Frequency Range, 70 in/sec velocity, 10-inch total displacement, 5000-lb force vector, and 10g - 455 lb, 20g - 205 lb, 30g - 120 lb maximum table loads.

Random Performance - White Noise 15-2000 cps, 4000-lb RMS force, 12,000-lb peak force, and 30g peak/10g RMS 355 lb, 60g peak/20g RMS at 155 lb, 90g peak/30g RMS at 85-lb maximum table loads.

Acceleration - Genisco Model A1030 g-accelerator, 0.1 to 175g acceleration range, 10-400 rpm speed range, 10,000 g-lb arm rating (100 lb to 100g, 55 lb to 175g), two mounting baskets for maximum 18-inch cube test package, 16-circuit slip ring system, 5-amp rating each.

Altitude - Conrad Model FH-30-3-5 Altitude Temperature Chamber, ambient to 250,000-ft altitude range with ambient temperature, -100°F to +300°F from ambient to 65,000-ft temperature range, semiautomatic controls, 24 x 24 x 24 inch chamber.

Humidity - Conrad Model FD-10-2-2 Temperature Humidity Chamber, 20% to 98% humidity range, 35°F to 185°F; dewpoint limits 5% at 185°F, -100°F to +300°F temperature range; hold 85°F with 400-watt live load; hold 70°F with 650-watt live load; cam controlled; 24½ x 23½ x 22½ inch chamber.

## SYSTEMS ANALYSIS BRANCH

*Capabilities:*

The Systems Analysis Branch performs preliminary system design studies, performance analyses, and simulations in conjunction with the hardware related activities of the other branches within the AIG&C Laboratory. In addition, it performs analyses and evaluations for the missile project managers of the Army Missile Command as well as supporting the IGMTC (Inertial Guidance Management and Technology Center) in "state of the art" studies and evaluations of proposals for Army inertial systems originated by agencies outside MICOM. The broad range of tasks has included inertial fuzing analysis, optimum guidance equations, antitank, air defense, and ballistic missile analysis, aircraft navigation problems, and strapped down platform programs.

The branch has pursued a simulation program which permits it to maintain progressive analog and hybrid simulations of guidance and control systems from the preliminary design phase of a weapon system through flight test, production, and product improvement. In almost all cases simulations are scaled in real time, and a block-by-block correspondence with G&C hardware is maintained. At appropriate phases of the weapon system development cycle, major portions of the system mathematical model are replaced with breadboard or flight hardware. This approach results in analyses which are strongly hardware and performance oriented, and permits the closest possible relationship between the hardware designer and the system in which his hardware will be used. The evolutionary development of simulations in parallel with weapon system evolution enables the branch to support project managers throughout their program rather than just during the R&D phase. The maintenance of simulations enhances their support in such activities as the following:

- Design verification flight testing
- Performance evaluation flight testing
- Evaluation of system design changes and fixes
- Studies of new applications of the original system or extensive system modifications for new missions.

In addition to the capabilities described above, the branch maintains several digital programs which are used in the MICOM Computation Center. These programs are designed to accommodate extensive variation of the G&C systems represented, and are amenable to limited reprogramming by branch personnel. Typical programs include:

- Inertial instrument error analysis
- Generation of trajectory cutoff partial derivatives
- Strapped down inertial platform coordinate resolution programs with several computational algorithms
- Inertial fuzing configurations
- Aircraft navigation system data formatting program.

*Facilities:*

The Systems Analysis Branch facility is a simulation facility designed to permit implementation of the philosophy outlined in the preceding discussion. The facility, although in appearance similar to conventional computation facilities, is in many ways unique because of the extensive hardware support and interfacing provisions tailored to the demanding requirements of inertial G&C hardware.

Simulation Room: The simulation area is approximately 80 by 100 feet. One end of the area is divided from the other by a steel and glass partition to avoid noise problems and to insulate the analog simulators from undesirable hardware related problems. Ten-foot-wide doors are used for access to the area. A door to the outside of the building has been provided, and a major area is maintained free of permanent equipment to permit ready introduction of missiles into the simulation area. Missiles up to the 10,000-lb class can be accommodated.

The floor of the simulation area is partitioned and raised above the subfloor, permitting cable runs within the room without causing safety problems. Electrical and pneumatic power is available at panels below the floor in six locations and at three bench locations. The air supplies and electrical power are controlled to the same tolerances as in the hardware laboratories. Provision has been made to introduce hydraulic power from a hydraulic test stand on an as required basis. Windows have been positioned in such a fashion that direct sightings can be made on a first order survey marker located several miles from the laboratory, thus permitting the introduction of highly accurate survey lines for setting up inertial reference equipment.

In addition to special provisions for operation of inertial G&C hardware within the simulation facility, the area is also provided with an extensive system of trunk lines to appropriate hardware laboratories. Hardware may be used in a simulation while located in a pecular environment which economically could not be duplicated in the simulation area, e.g., inertial equipment in a clean room environment or on a special test stand, hydraulic equipment which requires very short supply lines, or a large remote digital computer.

Simulation Facility

Simulation Equipment: The analog simulation equipment is composed of two Pace 221 and one Comcor C15000 analog simulators. The machines are all fitted with extensive nonlinear equipment and special cabling and interfacing for introducing hardware signals. The two Pace machines are cabled together and may be operated independently or as a single machine. The Comcor C15000 is a powerful analog machine with provisions for a substantial amount of digital logic. It can be readily adapted to hybrid operation.

A Carco hydraulic three-axis flight table is located in the area partitioned from the main simulation room. The table has been extensively modified to permit operation with inertial hardware. Provision has been made to introduce clean air through the gimbal system to a component in simulation. The gimbals have been fitted with 20 arc/sec Wane-George encoders. The outputs of these encoders are formatted and interfaced to a tape recorder by a device designed in the Guidance Systems Branch. This equipment provides the capability to generate component and table data formatted for reduction by 7094 equipment available in the MICOM Computation Laboratory. The table has also been fitted with a continuous-roll inner gimbal which permits "hardware on the loop" simulations of missile systems which spin, and is used for accuracy improvement.

In addition to the above major equipment, the simulation area contains an IBM card punch, a Recomp II desk-type digital computer, an Esiac root locus computer, and a complement of plotting tables and recorders.

## GUIDANCE SYSTEMS BRANCH

*Capabilities:*

The Guidance Systems Branch conducts research in and establishes requirements, design, and testing for digital computers in missiles, aircraft, ground checkout systems, and air defense systems. Capabilities include logic design, computer system design, computer system requirements, programming analysis, and digital computer programming. Items or assemblies proposed or produced by vendors are evaluated as to adequacy and feasibility for use in current or future weapon systems. Commercially-produced digital integrated circuit modules, for example, are tested to determine such operation characteristics as effect of power supply variations, temperature effect, loading limits, drive capabilities, and noise sensitivity. Digital computing memory units are being evaluated for possible use in both airborne guidance computers and ground computing devices. Types being tested will include a thin film magnetic memory, core memory, and other advanced memories.

*Facilities:*

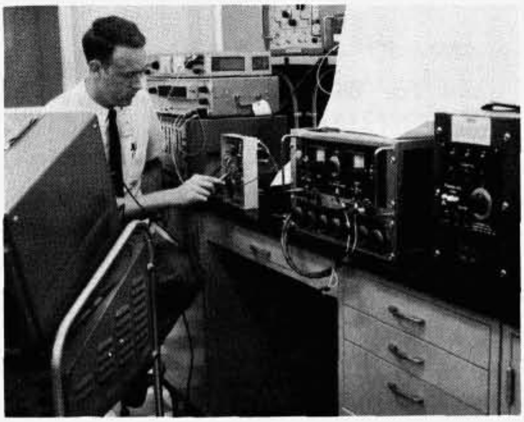
A General Purpose Digital Computer, used for digital simulation and evaluation of advanced testing techniques, has an operating speed of 250 kHz, 8192-magnetic-drum memory, 40-bit word length, and 320-μsec cycle time.

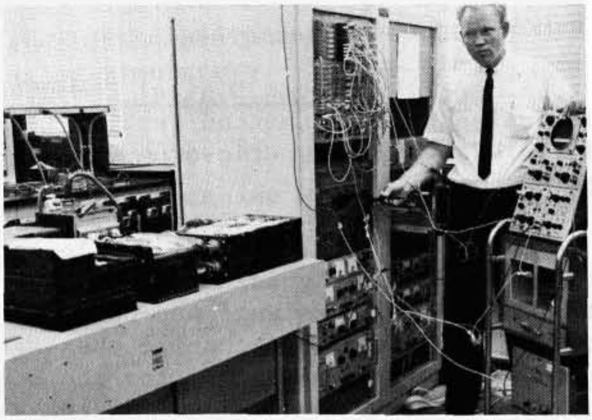
An engineering model of the Incremental Digital Computer used for solving range axis guidance equations for a medium range ballistic missile has been designed and constructed in-house. Commercial digital modules were used to mechanize the logic design, and its operation was tested by a program written for the General Purpose Digital Computer. The model is used to evaluate advanced memory elements such as thin film, delay line registers, and new designs of input/output circuits.

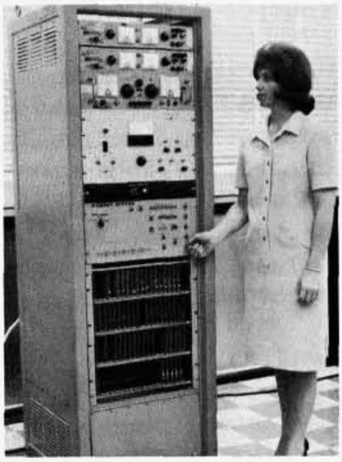
An engineering model of the improved Common Digital Computer for PERSHING and SERGEANT will be installed in the fall of 1966. This unit will be used to evaluate engineering changes, system operation, and self fault isolation on the computer system. This same computer will be used in the improved SERGEANT ground firing set. The computer is a parallel, integrated circuit, core memory machine with a 4-μsec cycle time, memory expandable from 4,000 to 24,000 words, 24 bits long. Input/output devices will include tape reader, typewriter, tape punch, and magnetic tape unit.

General Purpose Digital Computer

Mockup of the Improved Common Digital Computer for PERSHING and SERGEANT







Primary Voltage Reference Equipment (above, left)

Hughes General Purpose Digital Computer and Test Set (above, right)

Memory Buffer (left)

A Hughes General Purpose Digital Computer for use in Aircraft Navigation problems is set up with the necessary input/output equipment for loading memory, checking individual registers, and general fault isolation. The computer is presently being used in conjunction with an inertial platform as part of an aircraft navigation system.

A Memory Buffer along with the General Purpose Digital Computer makes up a Computer Controlled Memory System Exerciser used for laboratory analysis and testing of prototype memory systems. The memory buffer is capable of testing memory systems with capacities up to 4096 words, word lengths up to 18 bits per word, and memory cycle times down to 1.0 μsec.

A Primary Voltage Reference (Model SCO-106) and a Julie Research Laboratories DC precision voltage source (Model DVS-106) are being used to supply precision input voltages to analog-to-digital converters under evaluation. The DVS-106 is calibrated with the three standard cells of the SCO-106 and has a full-scale output range of -1200 VDC to +1200 VDC with an accuracy of 0.0025% of setting +0.0001% of full scale. The equipment is capable of supplying voltages as small as 1 μV.

Instruments employed in the design and development digital circuits include the following: Electro Instruments DVX-400 Digital Voltmeter, with power supply, A-1 converter, and printer control unit; Tektronix 585 Dual-Trace Oscilloscope; Hewlett-Packard 522B Electronic Counter; Hewlett-Packard 202A Function Generator; General Applied Science Lab PSG-1 Pulse and Square Wave Generator; Electro Measurements 290R Impedance Bridge, with 400-Hz, 10-kHz plug-in unit; Tektronix 555 Dual-Beam Oscilloscope with power supply; Systron 1031 Electronic Counter and Timer; Hewlett-Packard 523B Electronic Counter; Honeywell 906C Visicorder Oscillograph; Kintel 202B Microvoltmeter; Hewlett-Packard 201C Audio Oscillator; Tektronix 661 Pulse Sampling Scope; generator, 100 Hz to 15 MHz and 10 to 100 nsec pulse width; pulse generator, 100 Hz to 10 MHz and 5 to 25 nsec pulse width.

## CONTROL SYSTEMS BRANCH

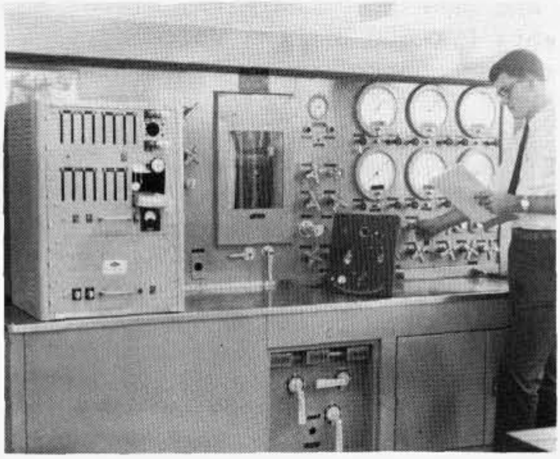
*Capabilities:*

The Control Systems Branch plans and conducts research in the areas of missile control actuating devices, including hot gas and digital actuators and fluid amplifiers; servo systems including electromechanical, proportional, relay, hydraulic, and pneumatic; electronic circuitry for control systems and special control equipment; and programming devices used to vary control system gain and other parameters as a function of flight time. Technical requirements, specifications, and acceptance criteria are established for this equipment, and evaluations are made to determine technical feasibility or functional adequacy. Inner-loop control systems and special components and techniques are designed and developed in-house.

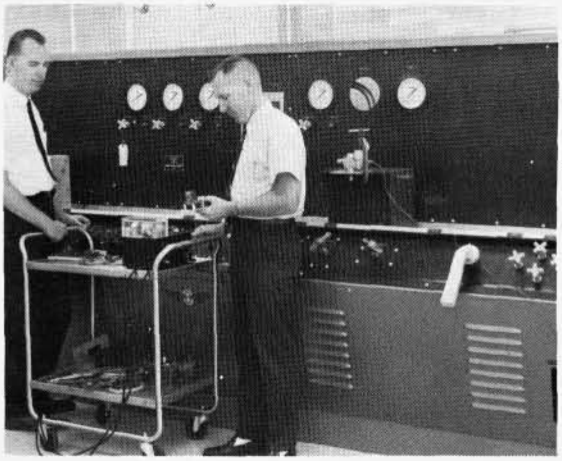
*Facilities:*

The Nankervis Hydraulic Test Bench is equipped with an external, high pressure pump capable of supplying pressures of 0-3000 psi and flow rates of 0-20 gpm. The bench is instrumented to operate with a servo valve analyzer and provides 3-micron hydraulic oil filtration. It utilizes MIL H-5606 hydraulic fluid.

The Greer Test Bench is a high flow rate test bench equipped with an internal, high pressure pump (0-5000 psig, 0-60 gpm). The test stands, which can be adjusted to control inlet and outlet pressure and flow rates, contain pressure gages, flow meters, and temperature sensors to determine and control the test bench operation. An automatic particle counter monitors and controls the contamination level of the hydraulic oil (MIL H-5606) during stand operation. Test equipment and instrumentation are available to monitor the inputs and outputs of the components under test.



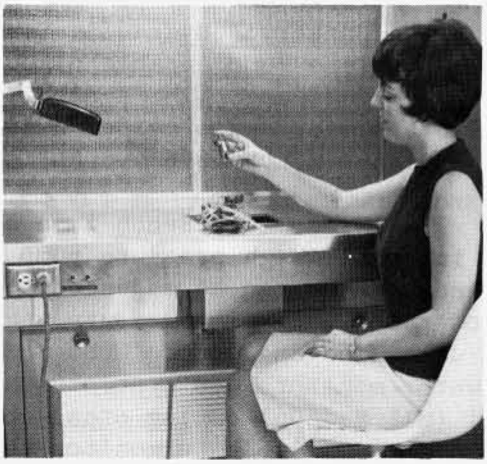
Nankervis Hydraulic Test Bench



Greer Test Bench

A Hydraulic Clean Room (class 100,000), houses both hydraulic test stands, and is isolated from surrounding areas by an air lock. Contamination is controlled to 100,000 particles, 0.5 microns and larger, with no more than 700 of these particles 5 microns or larger per cubic foot. In addition, controlled temperature and humidity is provided with a positive pressure above adjacent lower class sections. Within the clean room is a class 100 work station provided by the Heilamat laminar flow stand.

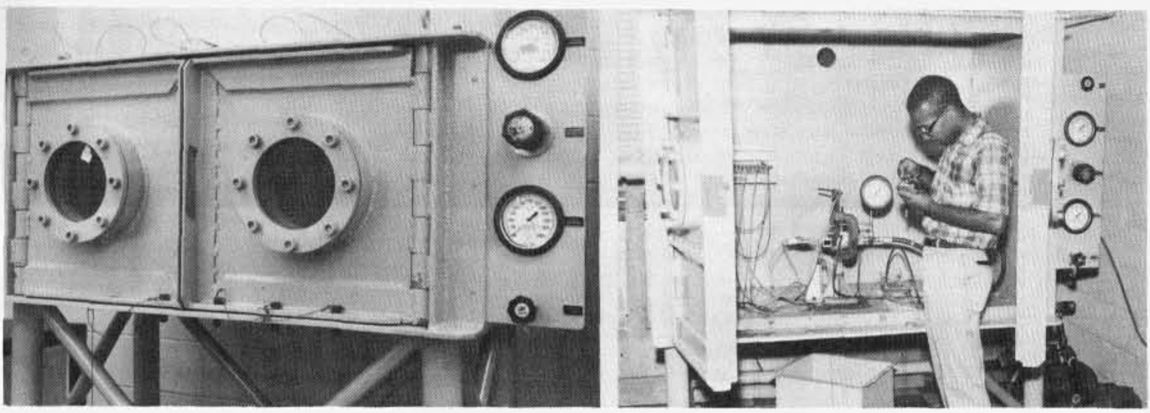
Hydraulic Clean Room



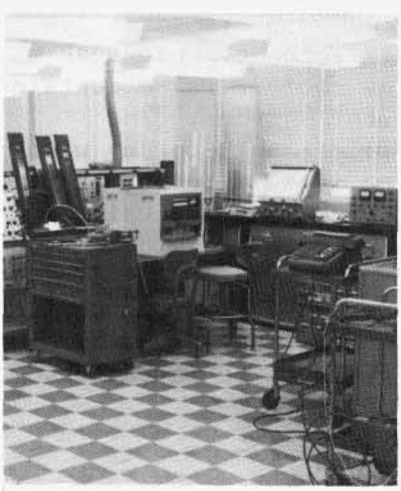
Heilamat

Explosion-Proof Pneumatic Test Cells are available in both the Electronics Laboratory and Pneumatics Laboratory. These test cells will withstand 3500 psi plus safety factor, and provide special power connections and exhaust external to the building.

The Pneumatics Laboratory is equipped for quantitative and qualitative evaluations of pneumatic components, and can be adapted to liquid operation. The facility contains a Water Table to simulate compressible and incompressible flows in designing and developing pure fluid control components; the table has a 5-by-11.5-foot working test section so that components can be cascaded, and a pumping system with a maximum capacity of 4 inches of water flow over the test section. Other equipment includes a smoke tunnel, which is used to study compressible flow problems at low Reynolds numbers and to assist in visualizing flow through pure fluid components; manometers; flow meters; and a complete range of pressure transducers to evaluate pure fluid components.

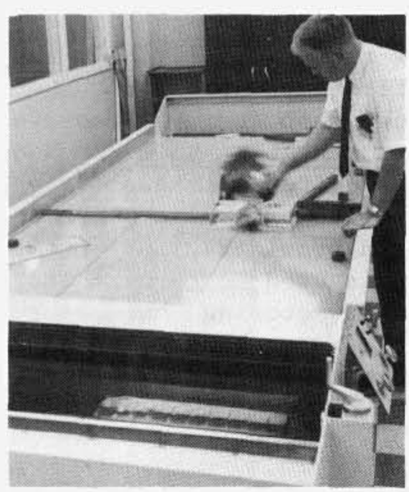


Explosion-Proof Test Cell (Pneumatic)

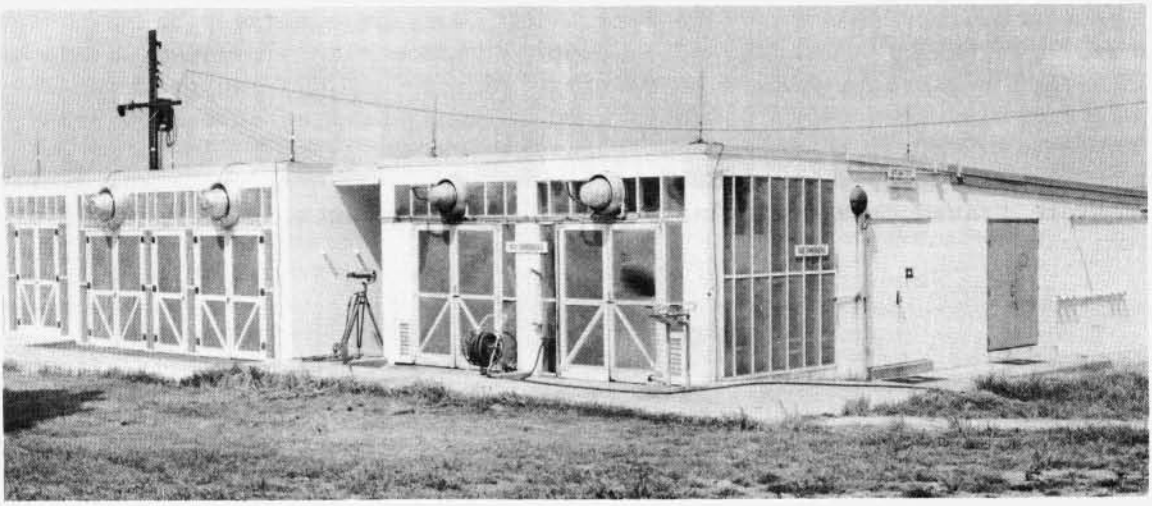


Pneumatics Laboratory (left)

Water Table (right)

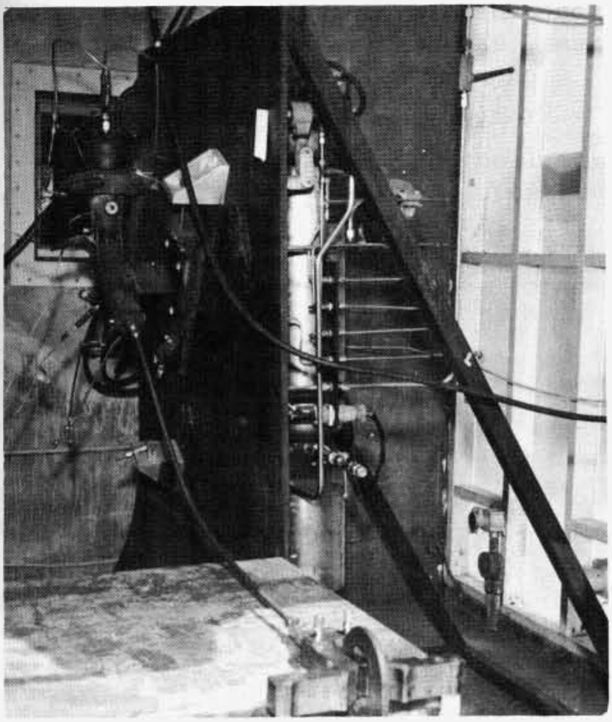


The Hot Gas and Pneumatic Test Facility contains two small (10 x 10 ft) and one large (12 x 25 ft) test cell, designed to handle a maximum of 15 pounds of explosives. These cells, and the compressor room, are contained within 12-inch reinforced concrete walls and roofs.

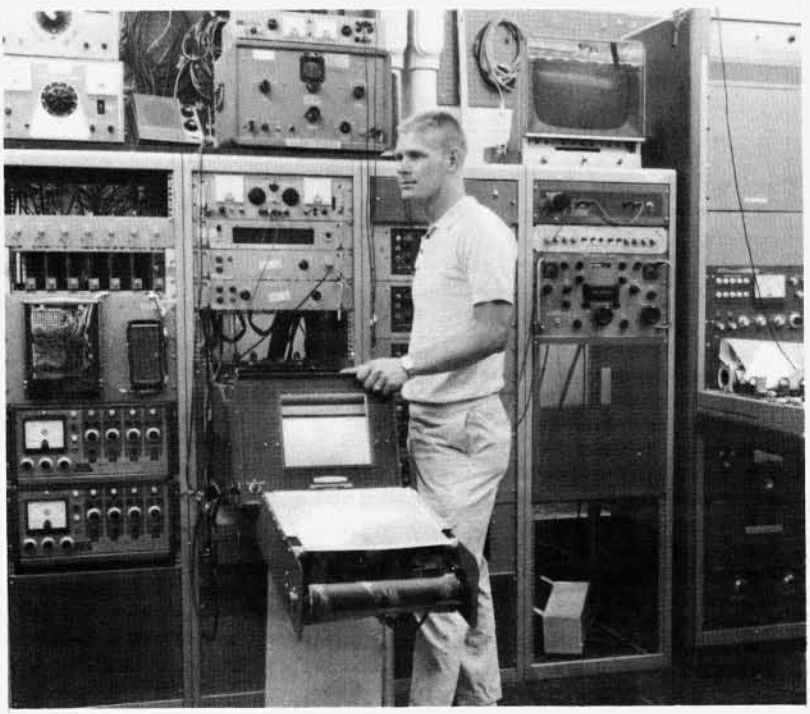


Hot Gas and Pneumatic Test Facility

The Liquid Hot Gas Generator Test Cell contains a monopropellant hydrazine hot gas generator capable of delivering 1000 psi at 17000°F with a hot gas flow rate of 1 lb/sec. The flow rate can be adjusted from 0.05 lb/sec to 1 lb/sec. This generator can be operated at low flow rates for several minutes to permit investigation of heat soak problems associated with hot gas operation. The facility also contains a work shop area, office area, and an instrumentation room. The Instrumentation Room contains a 36-channel oscillograph recorder with the required data conversion equipment. A patch panel with permanently installed trunk lines connects to the test cells. Closed circuit television provides visual monitoring of hazardous operations. This installation is used to develop and evaluate hot gas control systems utilizing thrust vectoring, hot gas actuators, secondary injection, and pure fluid control components. An additional air compressor delivering 25 SCFM at 5000 psi with a 100-cubic-foot storage capacity, is to be installed.



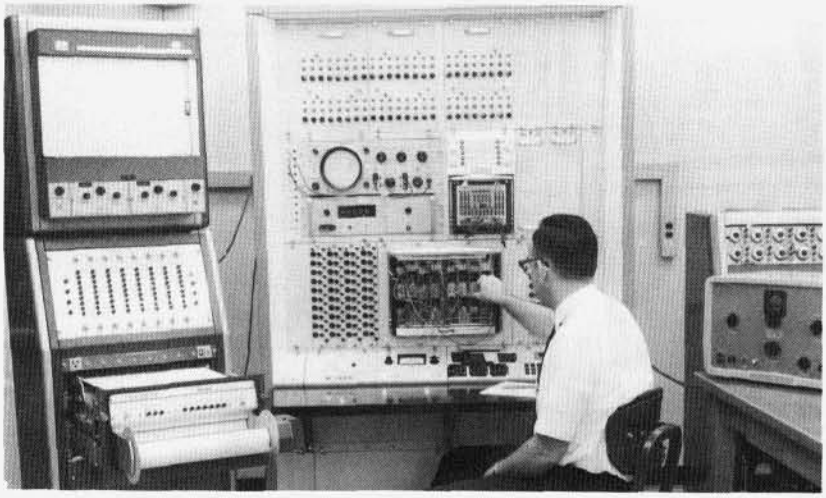
Liquid Hydrazine Hot Gas Generator



Instrumentation Room

The Electronics Laboratory contains all electronics equipment necessary in the design, development, and testing of missile control electronics systems. Provided at each work bench is a power panel with 60 and 400 hertz at 115 VAC, 2, 4, 6, 12, 24, and 60 VDC, a vacuum attachment, and 120-psi air outlet.

Electronics Laboratory



Applied Dynamics PBC-64 Analog Computer

The Applied Dynamics PBC-64 Analog Computer is a 64 amplifier computer with patchable digital logic. It also contains track-hold units, 15 nonlinear functions, (multipliers, $X^2$, log X, sine and cosine generators) as well as 6 variable diode function generators. The computer has considerable expansion capabilities in the nonlinear area. Associated recording equipment includes an 8-channel mark 200 Brush Recorder and EAI Variplotter 1110. The computer is used in control hardware design and development, control system dynamical studies, and research in methods of nonlinear analysis.

## INSTRUMENTATION BRANCH

*Capabilities:*

The Instrumentation Branch collects requirements for on-board flight information from design laboratories, develops plans to acquire such information with maximum utilization of hardware, and publishes a measuring program for each flight round. Design and development work includes: techniques and devices to convert missile parameters to electrical analogs and to convert these analogs to signals suitable for transmission to ground station; telemetry subassemblies and component parts to meet particular requirements; tracking and nontactical command systems such as destruct and maneuver; and missile-borne antenna systems. The telemetry systems include frequency modulation (FM/FM); pulse amplitude modulation (PAM); pulse width modulation (PWM), sometimes called pulse duration modulation (PDM); and pulse code modulation (PCM).

Research in advanced antenna systems covers the areas of ground station seeking arrays; automatically tuned antenna systems; plasma studies as associated with reentry bodies; RF power distribution systems, including diplexers, filters, and isolators; and broadband antenna systems. Specifications are established and evaluations made of such RF systems as command destruct receivers, UDOP transponders, DOVAP transponders, C-band radar systems, S-band radar systems, and altimeter systems.

The branch also designs and maintains standards, test stands, and other equipment necessary to evaluate the performance of instrumentation devices such as transducers, power supplies, and signal conditioners. Evaluations, including environmental testing, are made of both in-house and commercially-produced devices.

*Facilities:*

The Genisco Rate Table, used to calibrate linear accelerometers, rate switches, and rate gyros, has a range of 0.01 to $1200^{\circ}$/sec. Calibration precision is assured by the use of a light cell in conjunction with a light source, and an electronic counter to measure the period of revolution of the table to the 4th and 5th place. The period can be converted to degrees per second for the rate gyros or to acceleration for an accelerometer or rate switch when the radius arm length is known.

The Tenny Environmental Test Chamber, with a range of -90 to $+240^{\circ}$F, is one of several temperature chambers which may be used for calibration of temperature sensors or to subject components to varying temperature environmental conditions to check test performances.

The MB Shaker has a frequency range of 5 to 10,000 Hz. The machine may be used to shock-test or random-motion-test, and has variable automatic frequency scanning. It can be operated at a constant displacement, velocity, or acceleration level. It is used to calibrate vibration pickup and as a forcing function to enable the study of dynamic response characteristics of linear accelerometers. It is also used to study vibration environmental performances of transducers, signal conditioners, and various electronic packages.

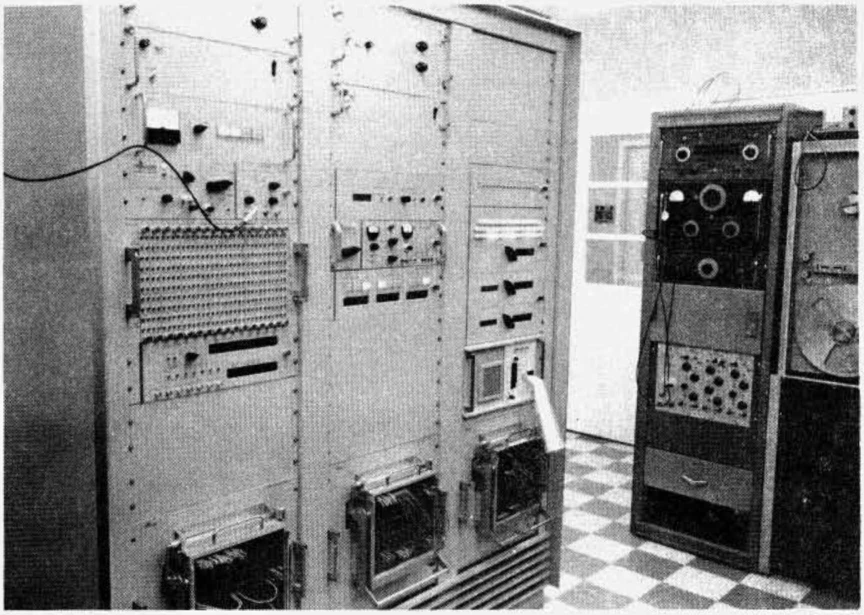
The Pressure Console, which allows for pressure ranges of 0-30 psia, and 0-3000 psig, consists of two precision Wallace & Tiernan absolute pressure gages and six precision Heise pressure gages, connected to use a common air supply. The console was designed and built for the calibration, checkout, and investigation of drift characteristics of pressure transducers, and can simultaneously calibrate several transducers with different pressure ranges.

The Primary Pressure Standard, a Consolidated Electrodynamics high accuracy dead-weight tester, can be used to calibrate absolute and gage-type pressure measuring instruments. The pressure ranges vary from 0.3 to 500 psi, with an accuracy of 0.015% of full scale.

The Trans-Sonics Equibar Pressure Meter, which consists of a differential pressure sensor and its associated circuitry, is a differential micromanometer which operates over eight full scale ranges from 0.01-30 mm of mercury, with a meter reading accuracy of +3% full scale of selected range. The meter may be used for a wide variety of measurement, recording, and control applications, including dynamic vacuum pressure measurements.

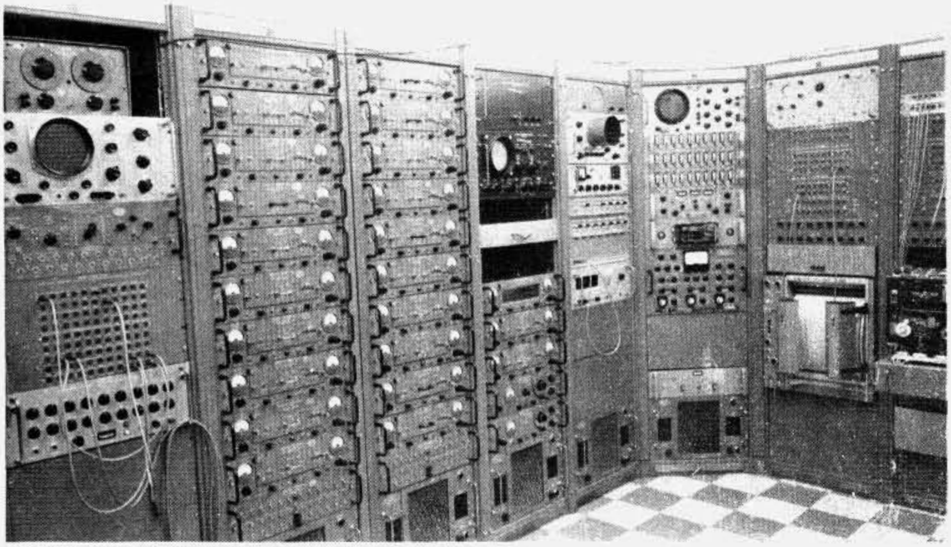
A Manometer-Absolute-Controller (Ideal-Aerosmith) is an absolute (Cistern type) mercurial manometer equipped with electromechanical devices to assist in scale readings. Indicators automatically follow the mercury level and indicate on a meter when the reader is precisely in line with the mercury level. The controller varies the mercury level and the pressure in the transducer under calibration to match predetermined check points. The assembly is used to measure and control very accurately the pressure of gases from 0 to 32 inches of mercury.

Specialized Radio Frequency Equipment -- checkout sets, signal generators, and related equipment -- is available within the laboratory facility for the complete evaluation of RF tracking equipment such as radar altimeters, command destruct receivers, UDOP transponders, radar transponders, and DOVAP transponders.

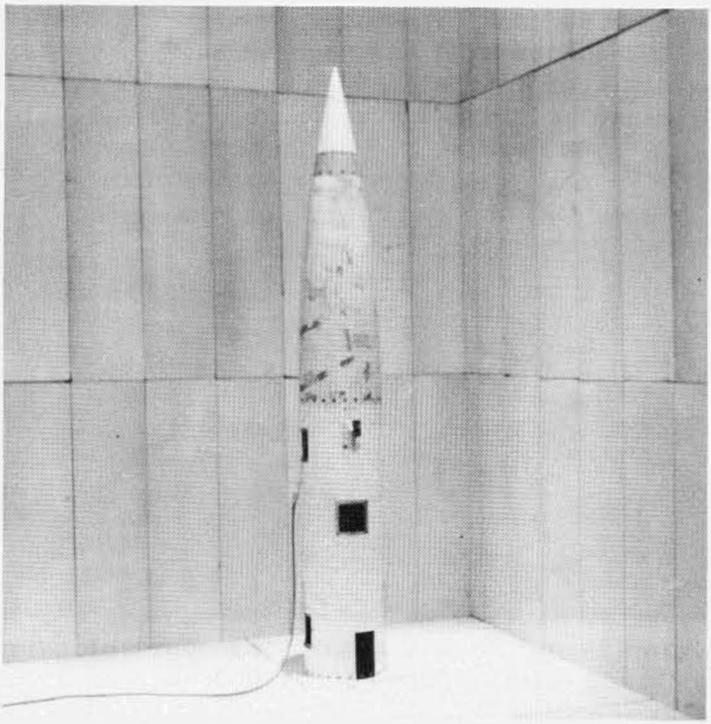


Pulse Code Modulation Telemetry Ground Station

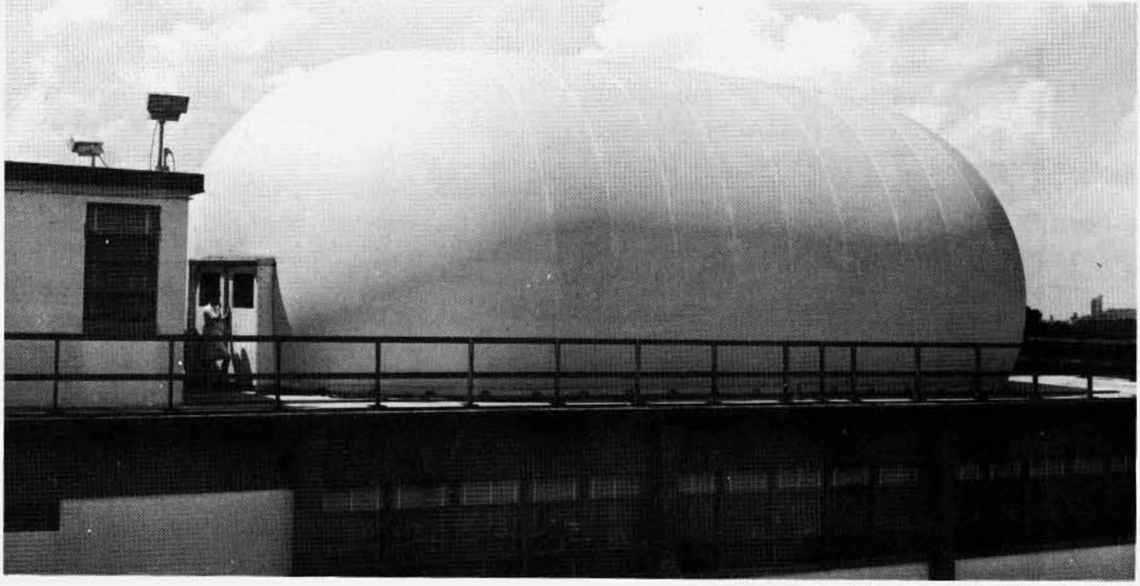
A Telemetry Ground Station, installed in an air-conditioned room, is used to check out different telemetry components and evaluate instrumentation performance in missile flights.



FM/ FM/ PAM Telemetry Ground Station



Anechoic Chamber



Antenna Pattern Range

The Anechoic Chamber is located in the basement of Building 5400, and is designed to have an intrinsic impedance of 377 ohms. The chamber absorbs all RF radiation above 200 MHz without reflections. This allows the checking of antenna bandwidths and impedance characteristics without interference from surrounding objects.

The Antenna Pattern Range is located on the roof of Building 5400 and consists of an air-supported structure approximately 60 feet long, a control room with receiving and recording equipment, and the necessary positioning equipment. The range is used in developing antennas for use on various missiles, as well as in determining the best locations and phasing arrangement for the most desirable radiation patterns. Antenna patterns are made using both full size and scaled missile models and antennas.

Antenna High Altitude Test Chamber

The Antenna High Altitude Test Chamber is designed to check the power-handling capabilities of transmitting antennas at altitudes up to 400,000 feet (0.5 μ). It is equipped with a 56-inch plastic bell jar for minimum interference with the electrical characteristics of an antenna. Coaxial connectors are provided in the base plate for providing power to the antennas and also for making impedance measurements during the test. The mechanical pumps used in the system require no warmup or cooling-off period, as do diffusion pumps.


HUNTSVILLE
TEST AREA 7
TEST COURSE AREA
TEST AREA 3B
TEST AREA 3
TEST AREA 3C
OBSERVATION BUNKER
TRACK NO. 3
TRACK NO. 1
TEST AREA 1
CONTRAVES NO. 2
CONTRAVES NO. 3
SYSTEM ENVIRONMENTAL LAB
BLAST TEST AREA
TARGET TRACK 2
CONTRAVES NO. 1
DATA & INSTRUMENTATION
TEST AREA 2
TEST AREA 4
TEST & RELIABILITY EVALUATION LAB
COMPONENT TEST AREA
CONTRAVES NO. 4
TEST AREA 5
N
TEST & RELIABILITY EVALUATION LABORATORY

# TEST AND RELIABILITY EVALUATION LABORATORY

The Test and Reliability Evaluation Laboratory plans and conducts or supervises experimental and development test programs on weapon systems or components, and as required, service tests of tactical equipment. There is a complete complex of flight, static, and environmental test facilities, which occupy a total of approximately 13,000 acres, or 28 percent of the Arsenal. The facilities can handle both inert and hazardous items, and can test for system as well as component reliability. The rockets and missiles flight-tested during the 18 years the laboratory has been in the missile testing business have ranged in length from 9 inches to 30 feet, and static tests have been performed on much larger vehicles. Supporting services -- computers, shops, and photographic laboratory -- are all available. The laboratory is primarily concerned with fulfilling Army R&D test requirements, but work can be, and has been, performed for other government agencies and private industry.

The facilities and capabilities are shared by the laboratory's six operating branches, and are presented here under five major categories -- static test facilities, flight and track test facilities, system environmental facilities, component test equipment, and analytical services.

## STATIC TEST FACILITIES

The three major facilities for static firings of rocket motors -- the Big Block, the Liquid Engine Test Stand, and the Dual Position Test Stand -- are located in Test Area 5. A Central Control Blockhouse, also in this area, serves all three test stands. Other features in the static testing category are the Plume Signal Radio Frequency Effects Test Facility, located in this same area, and the Hazard Test Site, situated in the southwest portion of the Arsenal.

Central Control Blockhouse. This facility serves as a central control and data-handling point for all the static test operations in Test Area 5. The two-storied concrete building contains approximately 16,000 square feet of floor space. It is directly connected (hard wire) to the Big Block and the Dual Position Test Stand by walk-through concrete tunnels, and to the Liquid Engine Test Stand by an underground duct bank.

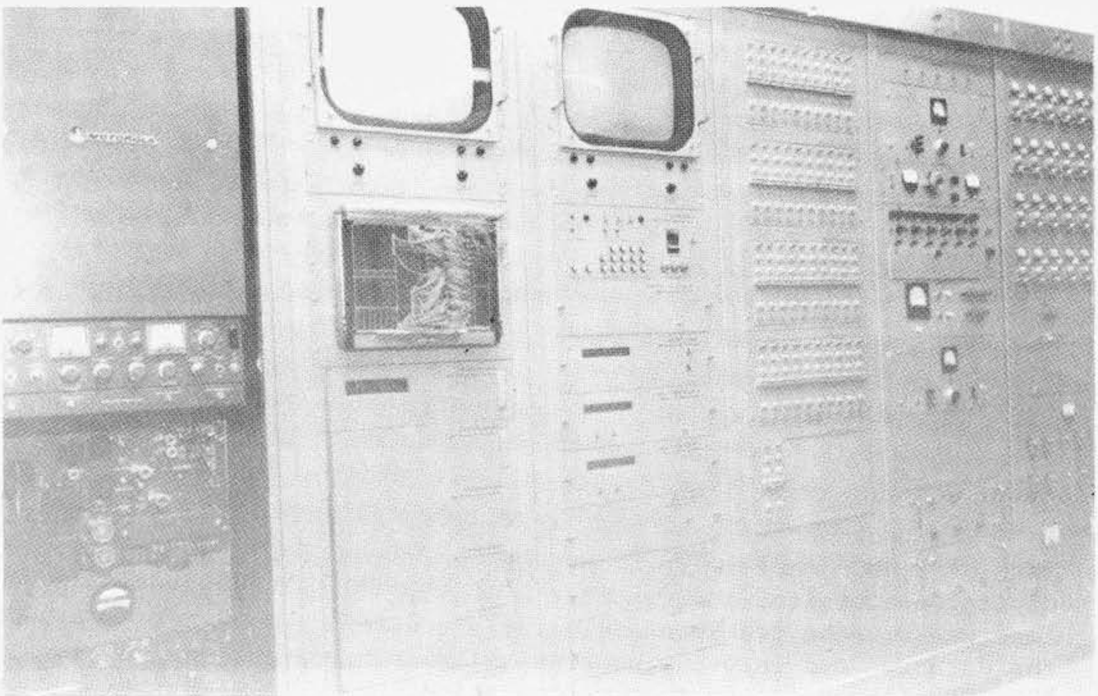

Test Area 5
(1) Big Block; (2) RF Receiving Tower; (3) Central Control;
(4) Dual Position Test Stand; (5) Liquid Engine Test Stand

Within the blockhouse, each of the stands has its own bank of controls. Two consoles serve the Liquid Engine Test Stand, and are connected to the stand by 360 unshielded No. 16 wires, 300 shielded No. 16 wires, and 60 unshielded No. 10 wires. Any predetermined function requiring 5 amperes or less can be controlled from these consoles. Available at the stand itself is 500 amperes of dc power, which can also be controlled from the blockhouse. The Dual Position Test Stand is served by three consoles, connected to the stand by 820 unshielded No. 16, 820 shielded No. 16, and 80 unshielded No. 10 wires. Functions of the Big Block are controlled from two consoles. There are 160 unshielded No. 16 and 20 unshielded No. 10 wires connecting these consoles with the terminal room at the Big Block; 500 amperes of dc power for event control and 500 amperes of dc power for firing circuits are available.

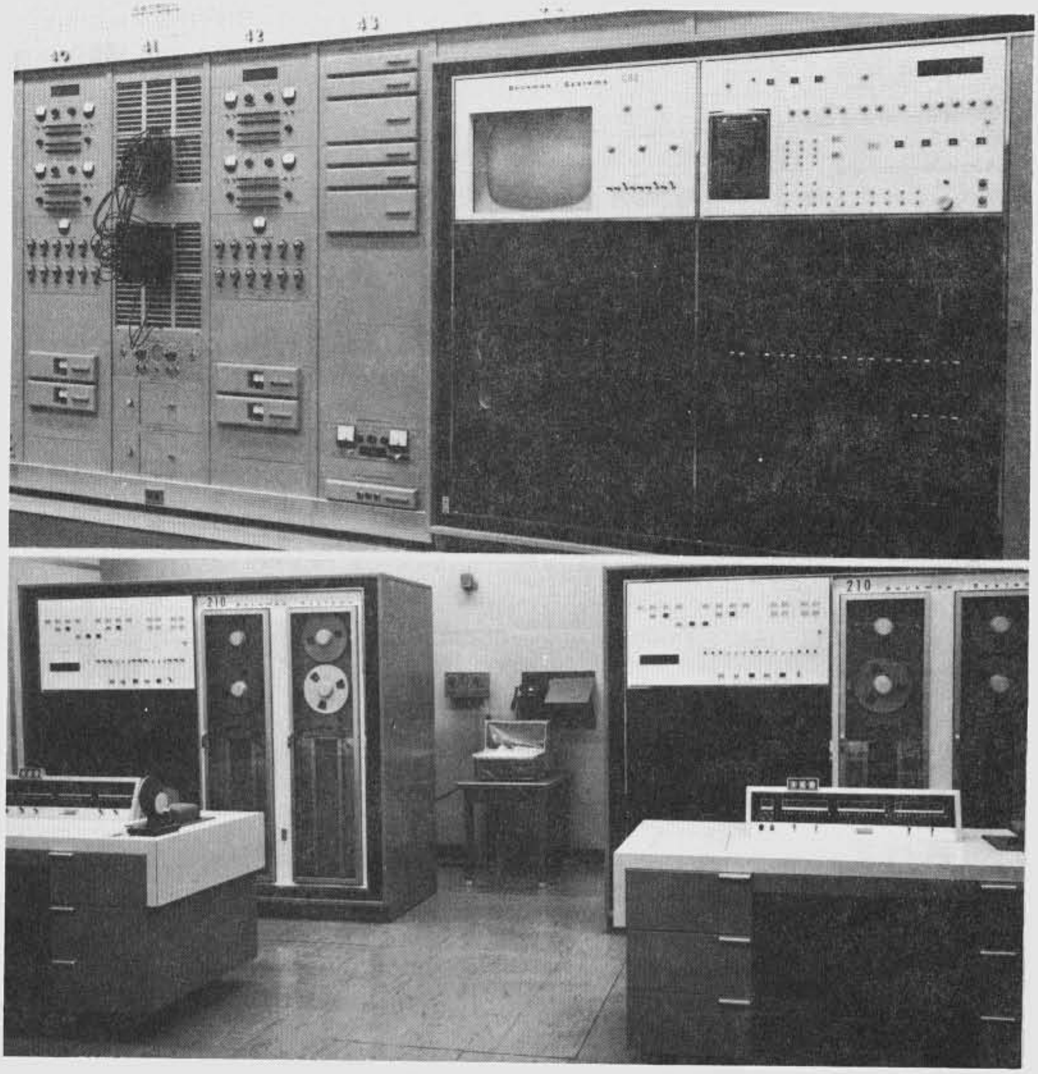
The blockhouse also contains highly specialized supporting equipment. There is a programmer capable of controlling a firing circuit at each test stand, plus 48 programmer relays which can be programmed to function in 0.2-second increments from -100 to +500 seconds. Twelve event recorders can monitor and record a total of

240 events -- any dc signal can be monitored and recorded. Sound-powered communications exist between the blockhouse and all test stands. The PA system operated from the blockhouse can be heard throughout the area. There are closed circuit TV capabilities for each test stand, and slave monitors located throughout the blockhouse.

In addition to approximately 700 channels of normal analog recording techniques (oscillograph, strip chart, tape), the control blockhouse has two special data-handling facilities -- a Packard-Bell system and a Beckman 210 data processing system. The Packard-Bell system takes analog transducer signals directly from the test stands by cable, amplifies them and converts them to digital form, and transmits them by microwave link to the Army Missile Command's Computation Center on the Arsenal, where the data are automatically processed by an IBM 7094. At the present time the Packard-Bell system can handle 144 channels of instrumentation. Sampling rates now available are 1,000, 200, 100, and 20 cycles per second (or any even multiples of these rates), with an overall maximum of 15,000 samples per second. Each sample is a 14 binary bit number plus a sign indicator. Overall accuracy of the system is 0.1 percent. Twenty of the 144 channels may be flagged for printout by the 7094 computer at the rate of 600 lines per minute, while the information on all 144 channels is recorded on magnetic tape for further processing.



Packard-Bell Analog-Digital Equipment

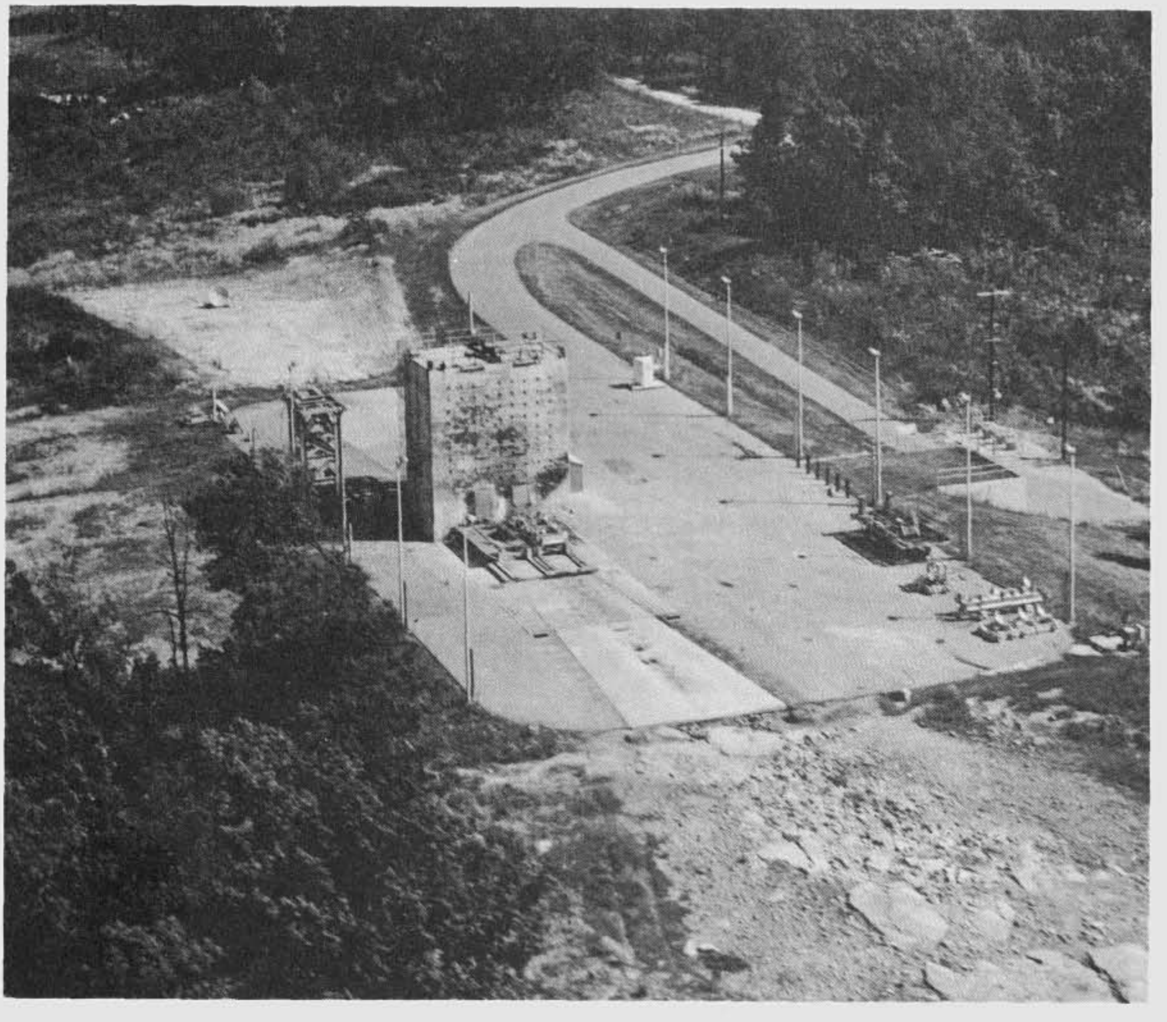



Beckman Data-Handling Equipment
(Above, Control Equipment; Below, Computers)

The Beckman system can handle 198 channels of analog data at a rate of 5,000 samples per second per system, perform an analog-to-digital conversion, and record the digital data on magnetic tape. This tape can then be fed into a digital processor (in the building), and the data reduced into engineering units or recorded on magnetic tape in IBM 7094 format for further manipulation.

These pieces of equipment represent some of the most advanced test data processing techniques available, and eliminate weeks of the computation time formerly required when a system was static-tested.

Big Block. The large horizontal test stand, known as the Big Block, is designed so that motors may be tested against either face. The thrust block itself is reinforced concrete, 30 feet wide, 18 feet thick, and 36 feet high. The keyed foundation supporting the block is 134 feet long, 30 feet wide, and 10 feet thick, and provides a nominal horizontal thrust capability of 10,000,000 pounds on either face of the block. To facilitate hardware and equipment mounting, each face of the block has 117 attachment points (shown as square sections in the photograph below). There are tie plates in the base slab for installation of 24-by-28-foot vertical test stands on each side of the thrust block. These towers would have a vertical thrust load capability of 4,920,000 pounds each.



The Big Block

Plume-Signal Radio Frequency Effects. The Plume-Signal RF Effects Test Facility is designed to gather data to establish, by experimental methods, the magnitude of attenuation and the phase shift of an rf signal by a rocket motor exhaust plume.


Plume-Signal RF Effects Setup
(Transmitting Antenna at Lower Right)

The RF attenuation measurements of rocket motor exhausts require that the exhaust gases expand in the atmosphere in such a way as to preclude plume distortion by obstacles in the flow field external to the nozzle. It is further necessary that surface dust and particles due to aspiration during firings be prevented from contaminating the plume. This static test pad meets both of these requirements by providing for the horizontal firing of full-size rocket motors at an elevation of 30 feet above the ground.

The transmitting antenna is a pillbox type, specifically designed to minimize reflections at the receiving antennas, and is mounted on a ground plane above the test motor. To obtain attenuation data, 6-foot parabolic dish antennas are aligned along the ground and up the length of a 200-foot tower located approximately 1,000 feet downrange behind the motor. Simultaneous coverage for eight aspect angles, from $+10^{o}$ to $-9^{o}$, is provided in a single rocket motor firing. At present the facility is instrumented for data collection in the S and L frequency bands.

Liquid Engine Test Stand. The Vertical Test Stand was designed primarily for the static testing of liquid-fueled engine systems. The basic structural steel tower measures 12 feet 7½ inches square and 55 feet in height, and has a vertical thrust capacity of 160,000 pounds. Engine exhaust is directed into a water-cooled flame deflector suspended from the engine platform level. There are over 100 remote control valves on the test stand which are used for controlling propellant flows, pressures, purges, flushes, and on-stand firex systems. The test sequencing valves open or close in 0.01 second. All of these functions are controlled from a console in the blockhouse.

Over 250 instrumentation lines are available at the stand for measuring pressures, temperatures, flows, thrusts, vibrations, and strains. In addition, there are 11 camera positions, each of which has three motion picture timing outlets. The 15,000 watts of lighting available on the engine level enables high quality motion pictures under all ambient lighting conditions.

The stand is equipped with a six-component thrust measuring system with capacities of 60,000 pounds axial force and 1,000 pounds orthogonal force.

There are two propellant feed systems, each with its own propellant tankage and gaseous nitrogen storage tank, and its own systems for pressure regulation, purging, flushing, temperature conditioning, and flow control. Each feed system has a propellant tankage capacity of 250 gallons, with the capability of supplying 1,000 gallons per minute to the engine at pressures up to 2,000 psi. Two 75-cubic-foot, 5,000-psi storage tanks located by the stand supply the gaseous nitrogen for pressurization and purges. A 3,500-gallon, deionized water tank, which supplies flush water, is shared by the two feed systems.

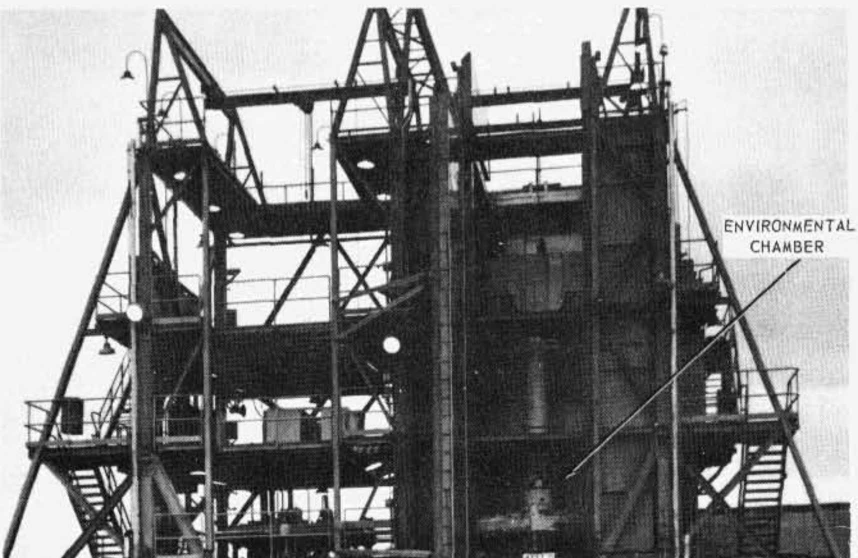
Each propellant system has two pressure regulation systems -- one system is a bank of remotely controlled dome loaded regulators, and the other uses a pressure feedback loop, pressure programmer, electronic controller, four gaseous nitrogen makeup valves, and a vent valve. Both use gaseous nitrogen as the pressurizing medium. The propellant pressure can be controlled at the engine inlet to produce varying flows and to follow a pressure-time profile.

Liquid Engine Test Stand

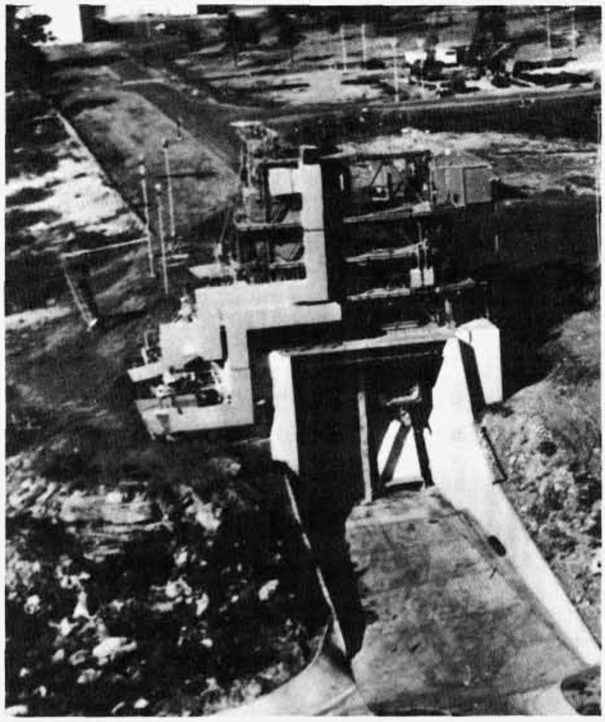
Three independent temperature-conditioning systems on the stand give the capability of conditioning the propellants and the engine at different temperatures, ranging from $-80^{o}F$ to $+180^{o}F$.

Dual Position Test Stand. The Dual Position Test Stand is the laboratory's most comprehensive static test facility. It was originally designed for a complete simulated flight of the PERSHING missile system, including stage and warhead separation. Capabilities of temperature conditioning, utilizing the environmental chamber, and flight vibration, utilizing a soft mount, are provided. The test stand can be adapted to static-testing of both solid and liquid rocket systems.

The dual position complex consists of two structurally identical steel superstructures -- one designated B-2, is enclosed and insulated, and contains a temperature environmental system capable of maintaining temperature environments from -80°F to +180°F for an indefinite period of time; the other, B-1, is an ambient facility. Both B-1 and B-2 are structurally capable of constraining 450,000 pounds of static thrust. The exhaust deflector cooling system for the stands has a total flow capacity of 10,000 gallons per minute maximum, with a head pressure of approximately 180 psi gage. Water for the stand is supplied from a 500,000-gallon storage tank. The stands are equipped with firex systems on each of the four working levels, converging on the center line of the thrust axis; the nozzles can be adjusted from extremes of spray to stream with all levels operating.




Dual Position Test Stand (front view)



Dual Position Test Stand
(Rear View Showing Exhaust Deflector and Water Spillway)

Each of the test stands is equipped with 1,200 control terminals and 700 instrumentation terminals which connect to the terminal room located underneath the B-2 environmental test stand. From the test stand terminal room the cables extend through a walk-through tunnel to the blockhouse terminal room, and are easily accessible for inspection or replacement. The instrumentation cables are separated from the control cables throughout the tunnel run to the blockhouse. Measurement capabilities cover pressure, thrust, temperature, strain, sound, flow, and vibration, and all electrical measurements from dc through 500 kHz. Cable types available are 130 coaxial, 470 four-wire, and 100 six-wire. Power supplies available to both B-1 and B-2 are two 400-Hz, 30-amp, three-phase generators; two 500-amp dc generators; two 500-amp dc battery banks; and a regulated 200-amp, 115-volt ac power supply. The generators, batteries, and regulators are located beneath B-1. The test facility is equipped with two separate nitrogen sources (10 cubic feet each) which terminate at centrally located panels. Each panel is complete with pressure range regulators from 100 pounds per square inch gage to 6,000 pounds per square inch gage. Other systems available on the stand include low pressure air, breathing air, and high pressure (3,000 psig) MIL-H-5606 hydraulic power.

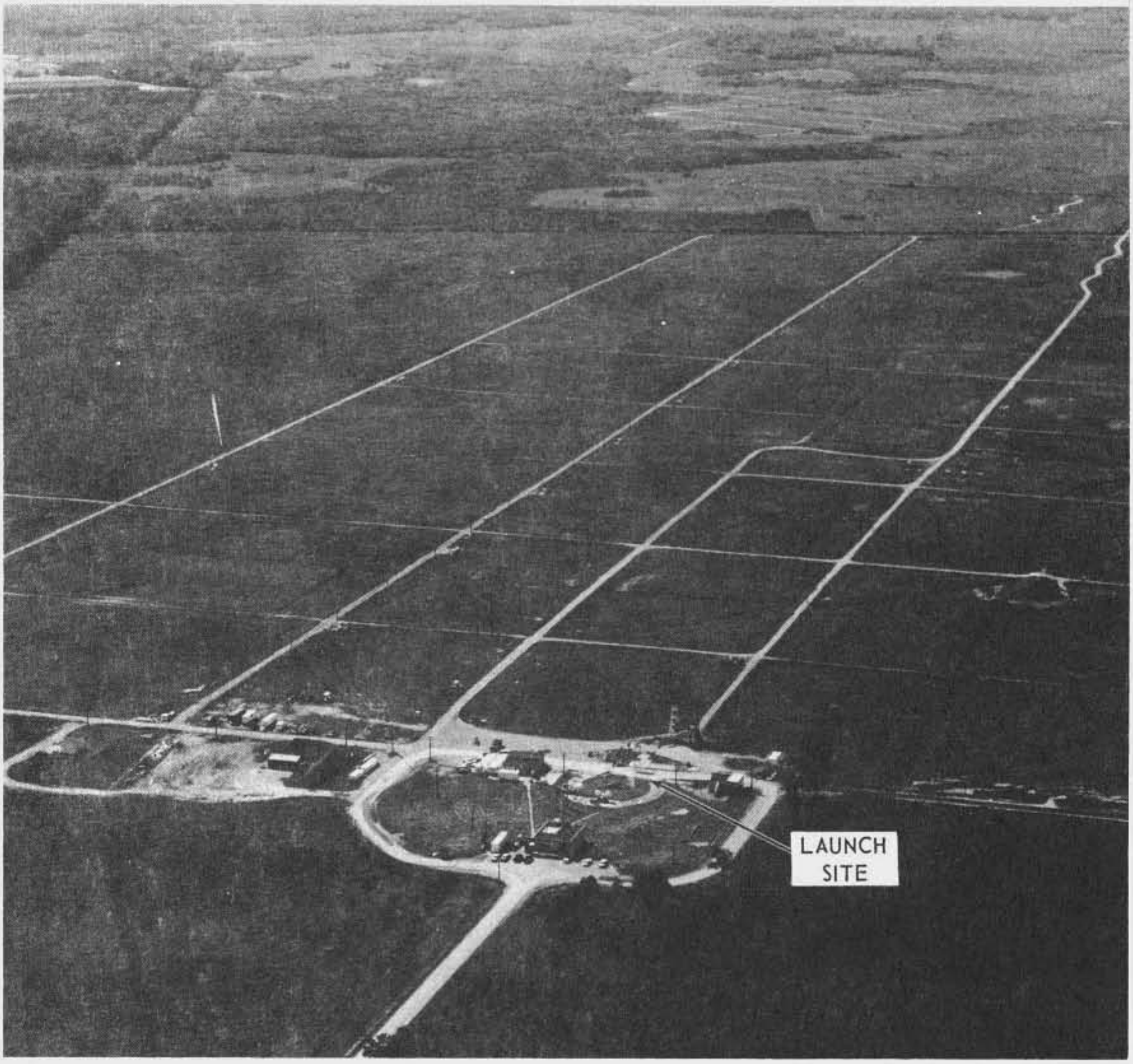
Both B-1 and B-2 are capable of measuring six components of force and moment on propulsion systems or motors. Axial force or thrust is limited to 60,000 pounds, and side force limits are 5,000 pounds; both forces can be resolved with precisions better than 1 percent. The thrust axis is equipped with a dual range load cell (0-5,000 pounds and 0-50,000 pounds) that permits high resolution force measurements with a 10-to-1 booster-sustainer thrust ratio. The bias errors inherent in this type of system have been defined by complete interaction analyses.

Hazard Test Site. The hazard test site is remotely located in the southwest portion of Redstone Arsenal, just west of Bradford Mountain. The site is used to obtain data for the hazardous classification of rocket motors and explosive components. These data are used by the military and the Interstate Commerce Commission to determine the safety criteria for the transportation and storage of explosive items. An air-conditioned control blockhouse, situated behind a protective earthen mound, is equipped with a function control programmer and oscillograph and tape recorders for data acquisition.

Hazard Test Site

## FLIGHT AND TRACK TEST FACILITIES

Test Area 1. Test Area 1 contains a flight test range approximately 8,200 meters long with a 45-degree safety angle. The photo below shows the launch site and some of the camera roads and emplacement at the beginning of the range (for extent of range, see map on page 130). Temperature conditioning facilities, film processing equipment, and assembly buildings are all available in this area.

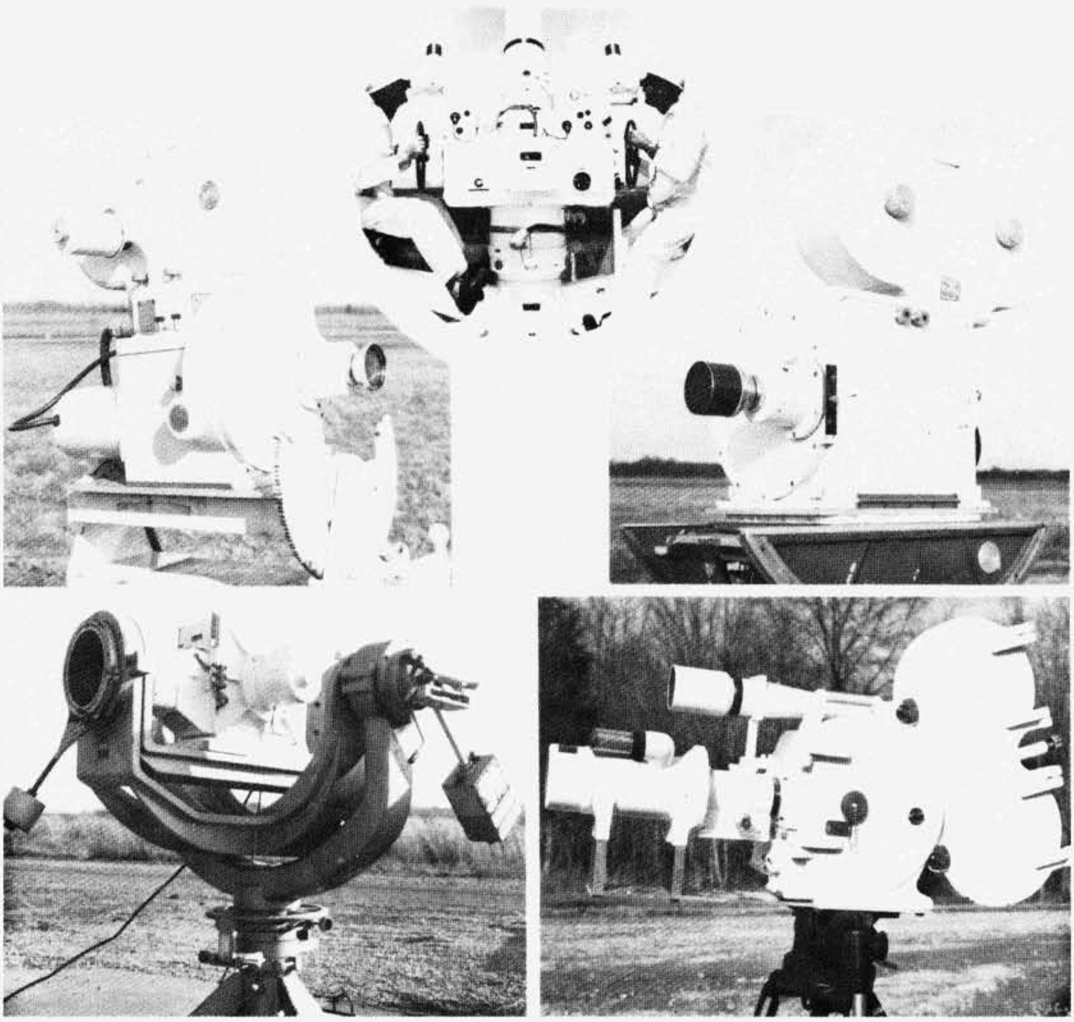



Test Area 1
(Range Boundary at Upper Left)

Interior of Instrument Control Building

This range is one of the most completely instrumented flight ranges in the country for short-range testing. The instrument control building contains a ground telemetry station, oscillograph recorders, 14-channel magnetic tape recorders, and the sequencing equipment necessary for the downrange instrumentation.

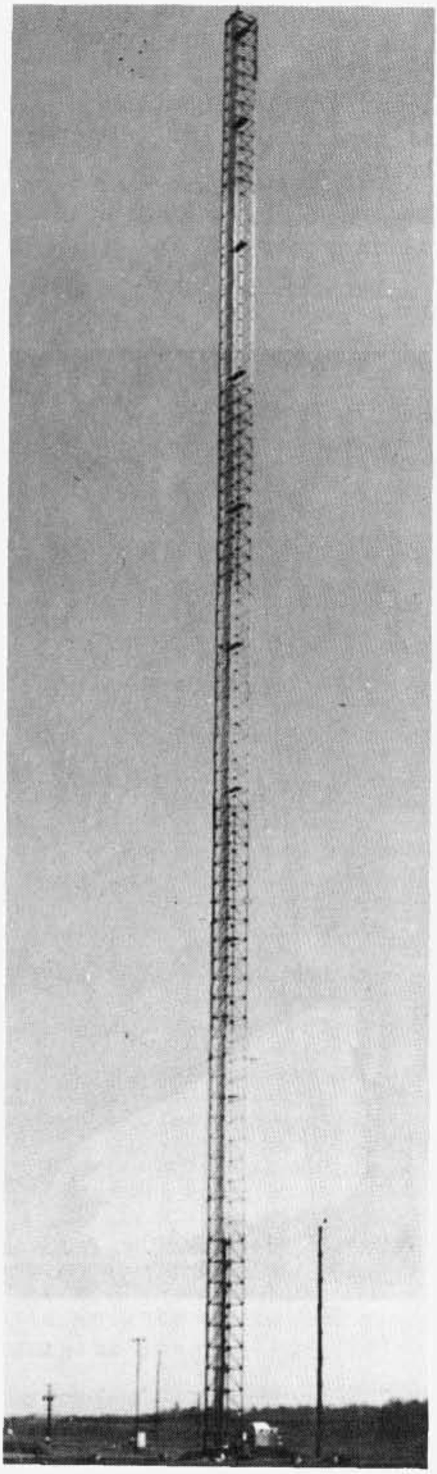
Optical Instrumentation. In order to meet the increasing demands for optical data coverage, the laboratory is engaged in continually updating its metric photographic equipment and techniques. Sufficient optical instrumentation is available to handle the most demanding data requirements. Equipment includes the following cameras: Bowen-Knapp ribbon frame, 32; 70mm, 12; Fastax (high-speed), 32; Contraves tracking cinetheodolite, 4; "Smear" type, 11; 35mm, 10; 16mm Milliken, 3; and a complement of lenses from 25mm to 100mm focal length for most of these cameras. Range timing and programming are available for all cameras.



Typical Cameras

The approach to optical instrumentation has been to emphasize the acquisition of accurate data using the latest optical techniques, and to maintain flexibility in optical setups to meet the varying requirements of development agencies.

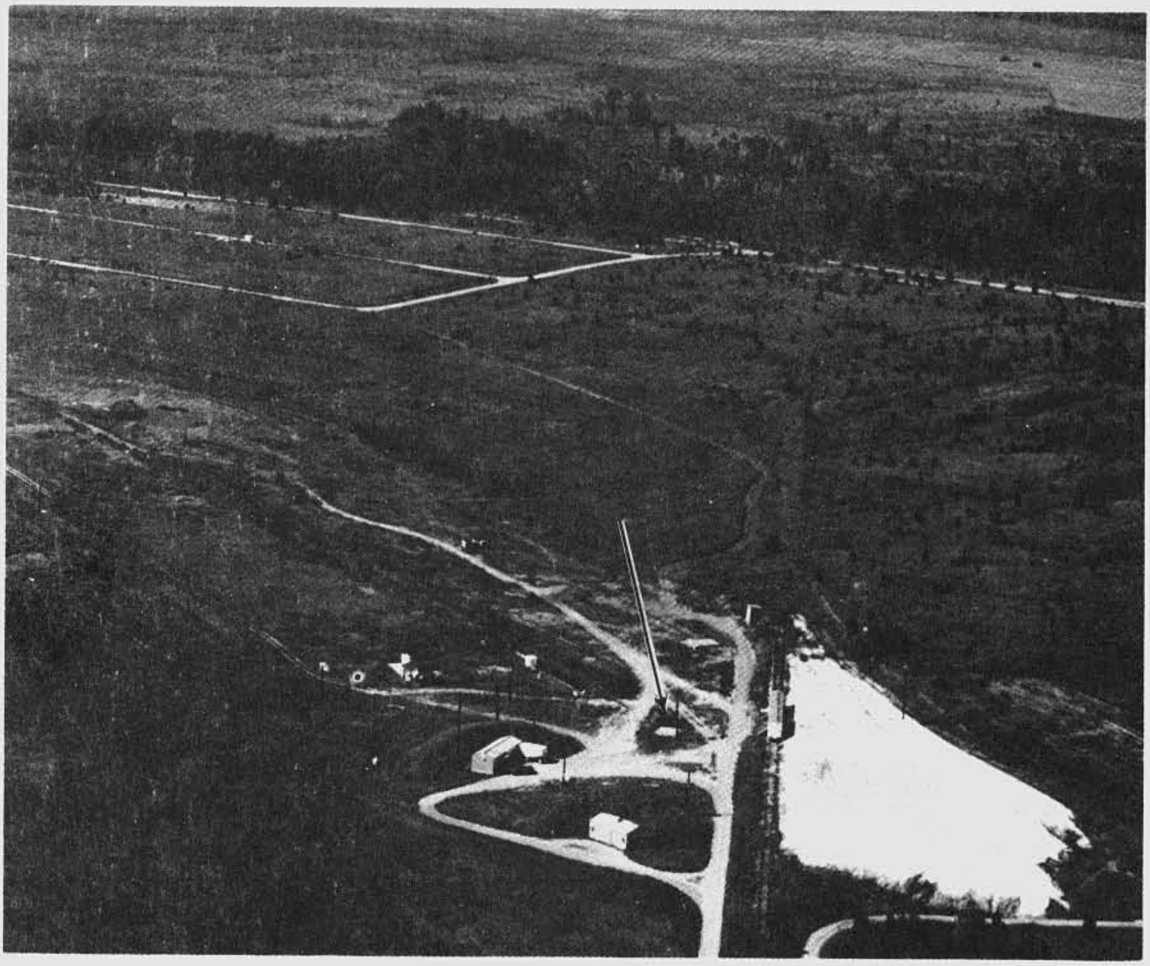
Telemetry and Electronic Instrumentation. Test Area 1 is equipped with a mobile ground station capable of receiving all standard IRIG, FM/FM, and PCM telemetry transmissions. Forty-two channels of magnetic tape are available. In addition, there are 100 channels of oscillograph recording equipment, which has been used extensively for strain gage and load cell instrumentation in making launcher dynamics determinations.



Camera Tower (400-foot)

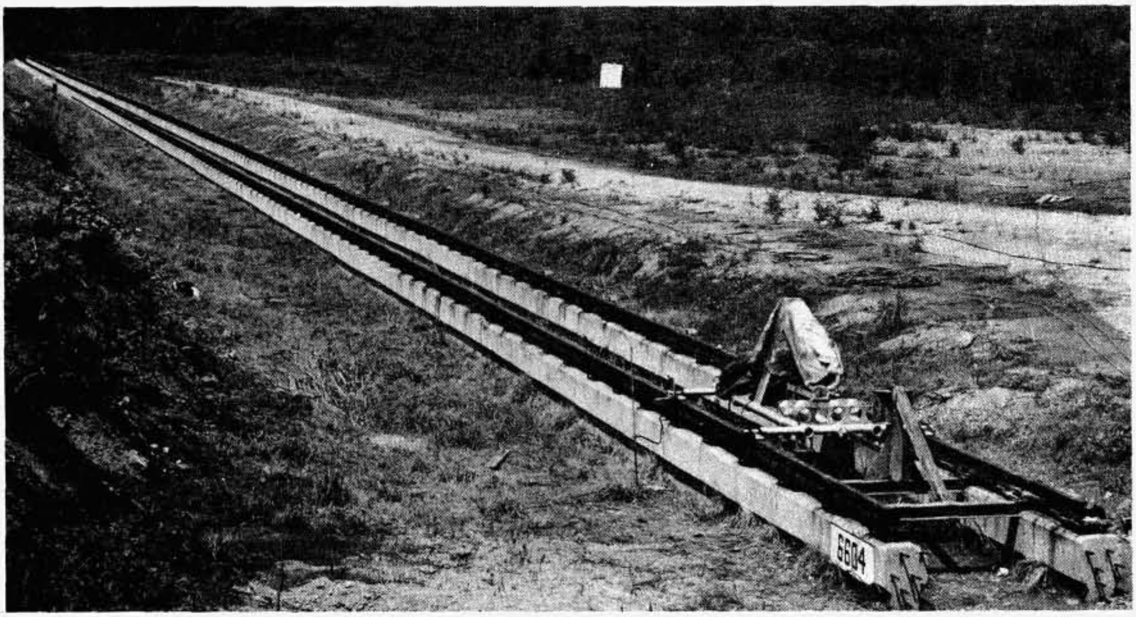
Camera Tower. During the development testing of missiles, the acquisition of accurate flight performance data is of prime importance. Obtaining an adequate description of the complex motion of the missile presents a problem, particularly in the case of low-flying vehicles. One solution is to position cameras above the line of flight to obtain yaw data. For this purpose, a 400-foot "yaw" tower (shown at left) has been installed on the flight range. Using three 70mm cameras or two Bowen-Knapp cameras on an elevator platform permits downrange coverage to 600 feet. Measurement of yaw on a missile 4 to 5 inches in diameter to an accuracy of 5 to 10 mils has been achieved.

Test Area 4. The Test Area 4 range is about 5,000 meters long and extends to the Arsenal boundary (aerial view shown below). At 2,500 meters, Bradford Mountain rises 160 feet above the ground. The location of this test area makes it ideal for testing warheads and fuzes. It is also used to test short range missiles to relieve the demands on the larger, more complex facilities. Permanent instrumentation equipment is available in this area, as well as facilities for temperature conditioning test items prior to night firing.



Test Area 4
(Arrow Points to Launch Site and Control Building)

Test Tracks. Rocket and missile testing inevitably requires sled testing (warheads, acceleration effects, moving targets, and aerodynamic characteristics). To meet this requirement, there are two horizontal sled tracks on Redstone Arsenal. One of these tracks is 1,250 feet long. Since hazardous conditions and resultant damage are involved in many of the tests, the track construction was kept simple to facilitate repairs. Construction consists of two continuous reinforced concrete piers, with rail alignment devices at 3-foot intervals along each pier. Rails are ASCE 80-pound crane rails with a track gage of 56.5 inches. As a further safety precaution, the track is so located that its "muzzle" points toward a bluff on the range.

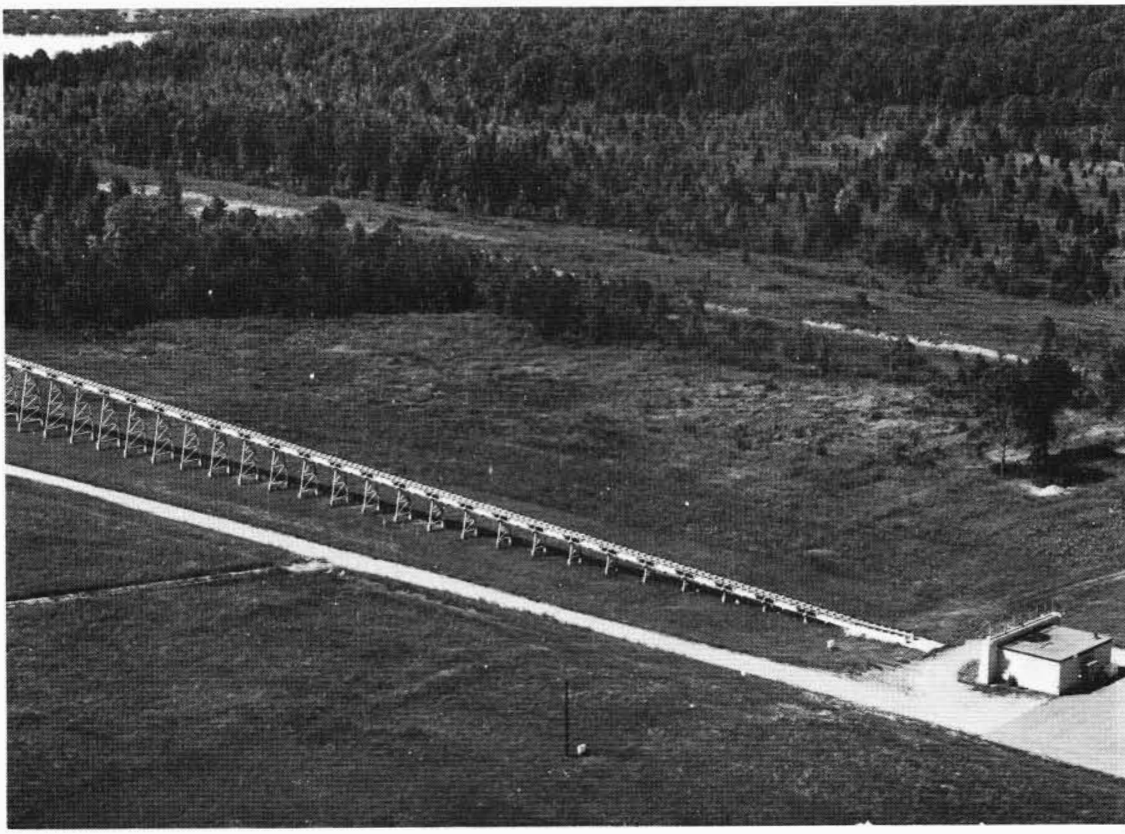



Test Track (1250-foot)

The other track consists of a 4,250-foot section of modified railroad track useful for velocities up to 1,000 feet per second and sled weights up to 600 pounds. This facility has been used for such tests as laser illumination and tracking of fast moving targets.

A mobile instrument van and ground telemetry station are available, along with ballistic and high speed cameras.

Ballistic Ramp. This range provides a 600-foot-long, 3-degree precision ramp, used to test missiles at simulated aircraft speeds. Either a monorail or a two-rail sled may be mounted on the ramp and accelerated to a given velocity.



Ballistic Ramp (600-foot); Control Building at Lower Right

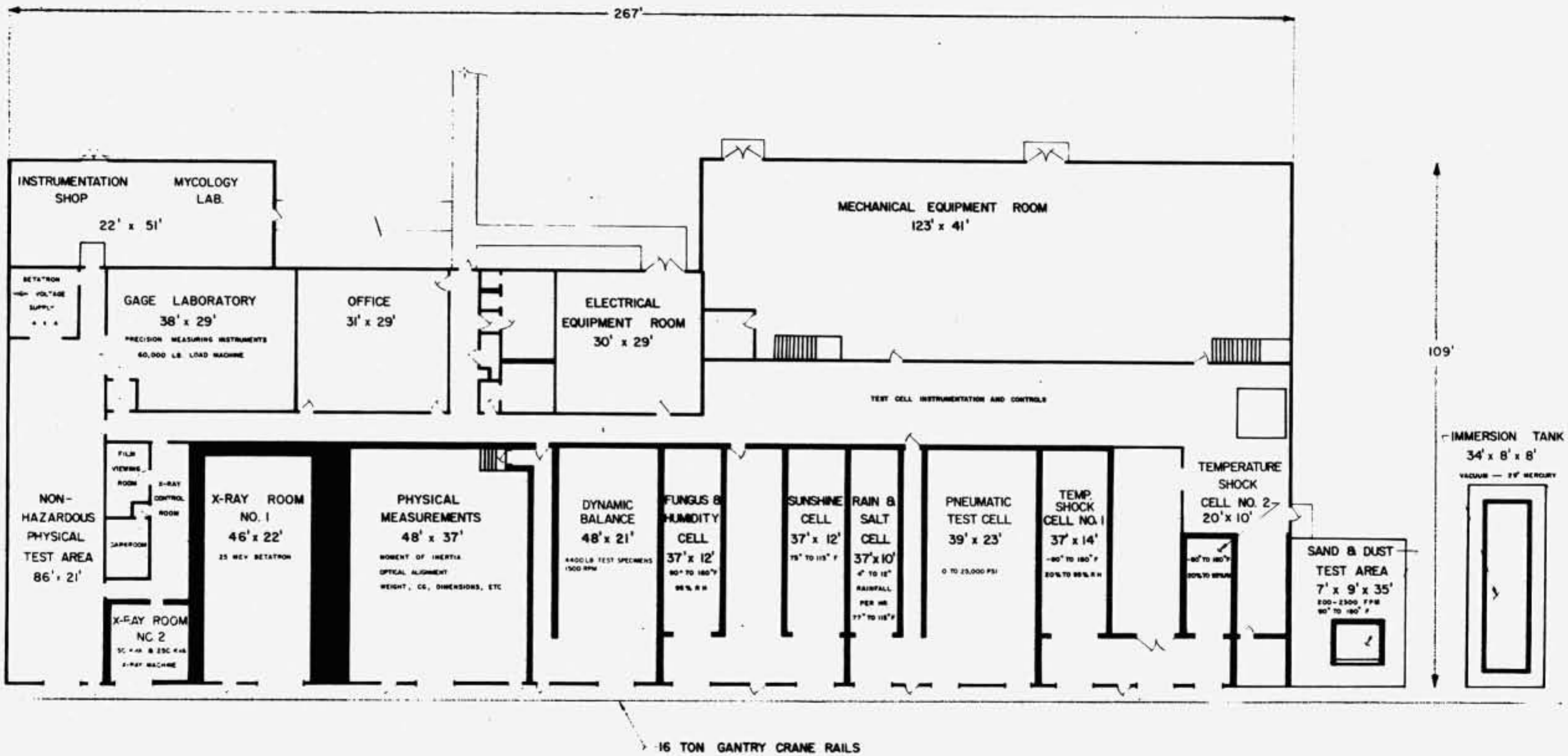
The ramp is oriented so that rockets may be fired at any horizontal angle up to 12 degrees to the left of the centerline of the track and at elevations up to 45 degrees. Primary instrumentation facilities consist of ballistic cameras, radar, and telemetry.

## SYSTEM ENVIRONMENTAL FACILITIES

A wide range of system environmental testing is provided in various structures scattered throughout the Arsenal. The major facility is the Environmental Testing Laboratory located in Test Area 2; others include the Motor Conditioning facility, also in Test Area 2; the Altitude Simulation and the Climatic Chambers in Test Area 5; a Test Course area; Radiography facilities; and an Aircraft Modification hangar located at the Arsenal airport. There are also various isolated sites within Area 2, which are specifically designed for environmentally testing liquid propulsion missile systems.

Environmental Testing. The Environmental Testing Laboratory, located in Test Area 2, provides a 25,000-square-foot facility in which a thorough environmental test program may be conducted on hazardous or inert items (see diagram on following page). The expected operating conditions for any particular weapon can be duplicated here. These tests may be conducted separately to ascertain individual effects, or in combinations. Test results are evaluated by visual, radiographic, x-ray, or ultrasonic inspections, as well as by static or dynamic firings.


Environmental Laboratory

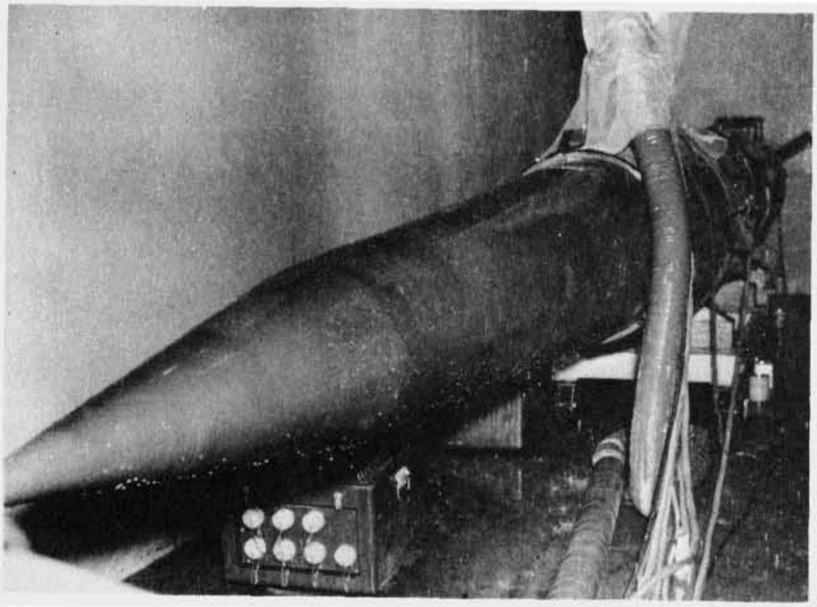



Floor Plan of Environmental Laboratory

Electrodynamic and hydraulic shakers are available for sinusoidal or random vibration testing through the range of 5 to 5,000 hertz, with force outputs ranging from 5 to 100,000 pounds. Combined vibration and temperature conditioning tests can be performed.

The shock testing facilities provide drop tests on systems weighing up to 12,000 pounds, and drop heights up to 25 feet. There is a small shock test machine for testing items weighing up to 100 pounds. Wave shapes, pulse durations, and acceleration levels may be varied. A large shock machine provides 200,000 pounds force with a five-inch piston stroke.

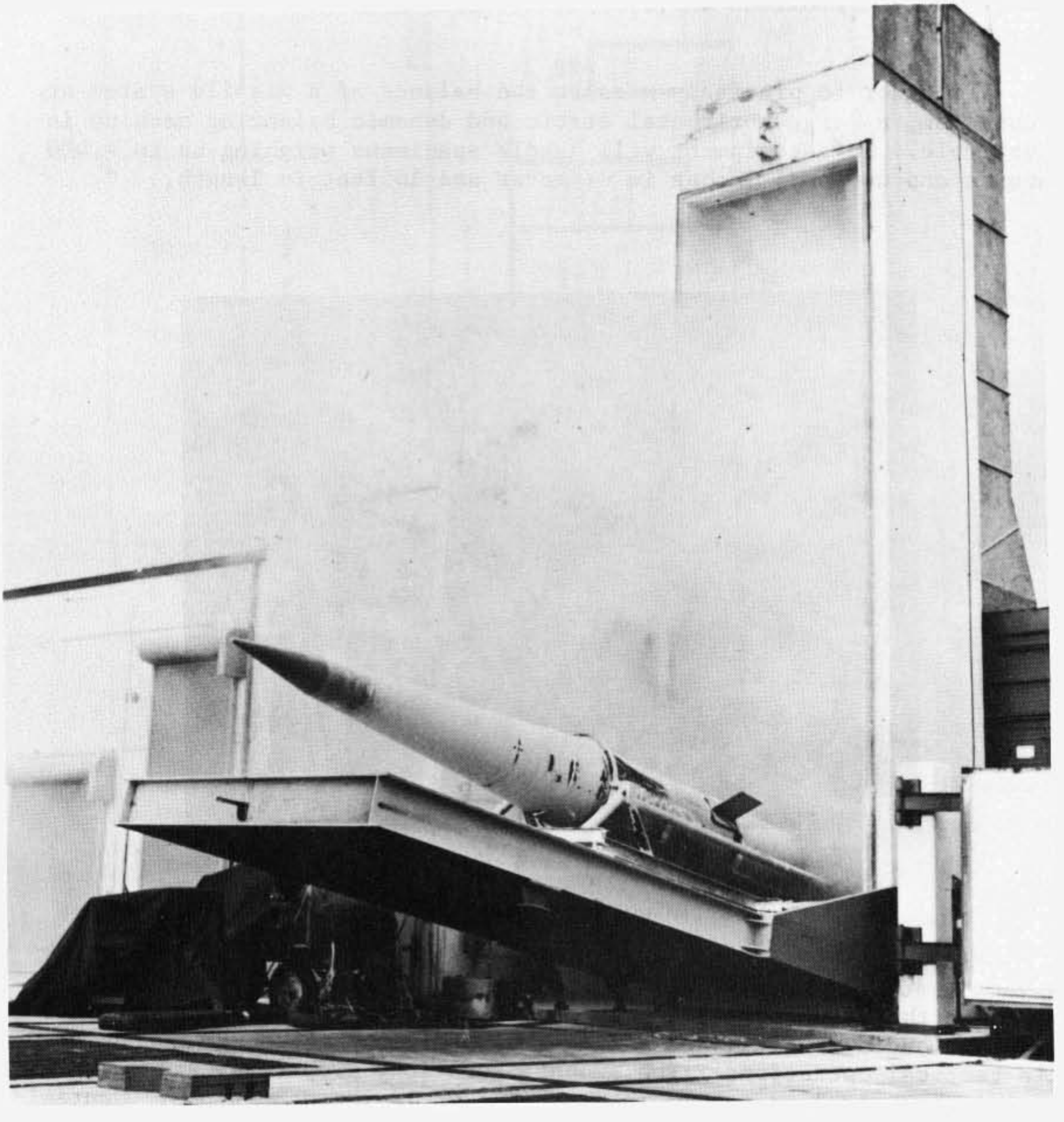
In order to precisely measure the balance of a missile system or subsystem, a large horizontal static and dynamic balancing machine is available. This equipment will handle specimens weighing up to 4,400 pounds and up to 71 inches in diameter and 16 feet in length.



Missile Undergoing Rain Test

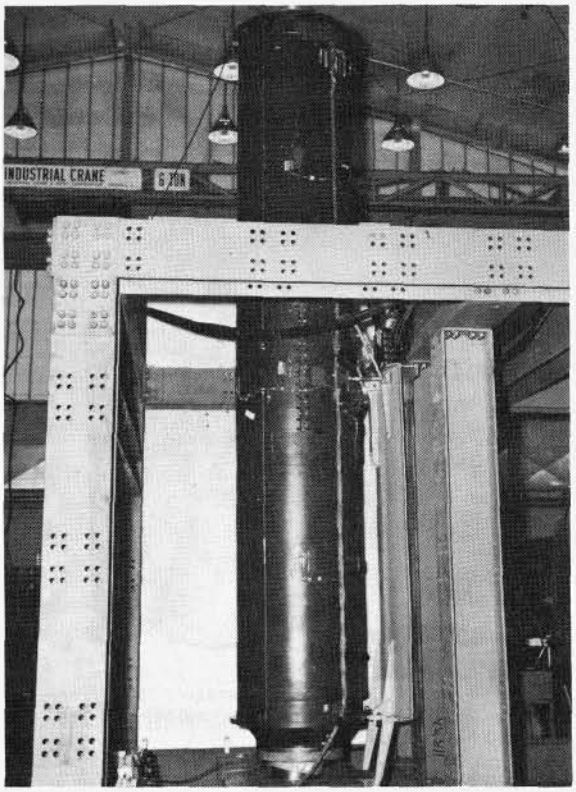
In the rain and salt spray facilities, test items are exposed to the prolonged rainfall and salt spray conditions which are encountered in tactical operations. The amount, duration, drop size, and temperature are controlled to simulate typical worldwide conditions. Contaminants, such as coral dust, can also be provided as a test condition. The immersion facility allows large missiles, component parts, and containers to be immersed in water and leak-tested for a specified period of time.

Missiles, rockets, or components may be subjected to a sand and dust environment, with varying temperature conditions, particle size, concentration, and wind conditions (from 200 to 2,300 feet per minute). The test items, including missiles, are mounted on the 30-foot test door.



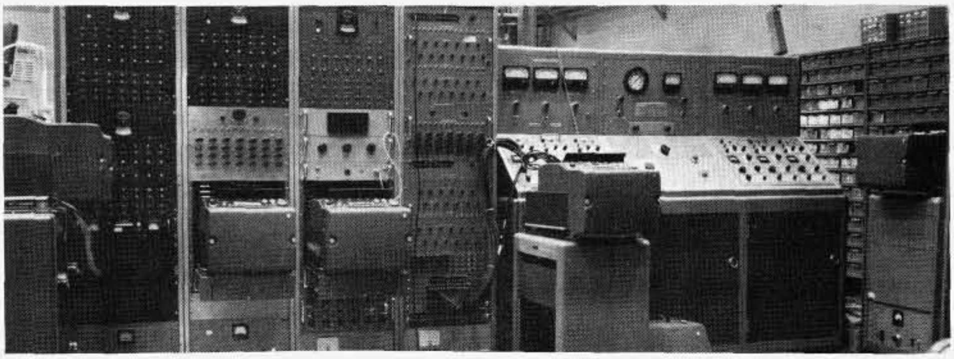
Missile Being Removed After Sand and Dust Test

The fungus and humidity facility simulates environments encountered in tropical climates. The test item is sprayed with a suspension of mixed spores prepared from five types of fungi, as described in MIL-STD 810.



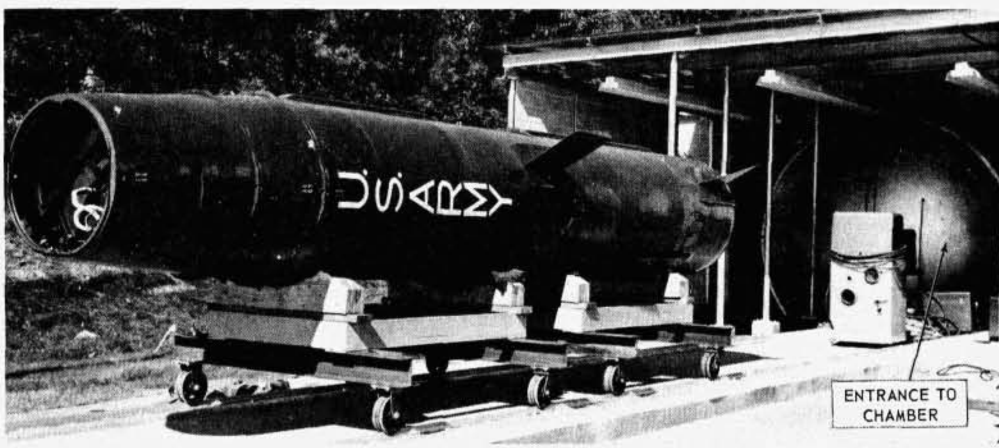

The multicomponent thrust simulator equipment simulates the static and dynamic thrust loads experienced by a missile in post-launch environment. Loads ranging up to 100,000 pounds force (axial) in tension or compression may be applied directly, as well as combinations of the six load component vectors.

Solar radiation is duplicated in a 12-by-37-foot chamber, utilizing ultraviolet, visible, and infrared sources at a temperature range from 75 to 115°F.



Multicomponent Thrust Simulator
(Top, Missile Structure Test; Bottom, Instrumentation Console)

Altitude Simulation. The Altitude Simulation Chamber, located in Test Area 5, comprises a stationary 12-foot-diameter structural steel tank section, 16 feet long, with removable heads at each end. Longer test specimens may be accommodated by moving an additional 35-foot unit into position and clamping the sections together. Interior floors are provided with integral tracks, permitting test specimens to be rolled into the chamber from the unloading area. The chamber may be used to simulate altitude environments up to 200,000 feet, and can also serve as a liquid propellant booster drying facility. The 16-foot section may be evacuated to an absolute pressure of 0.16 mm Hg, while 10 mm Hg may be reached using the complete 51-foot chamber. Fully automatic controls and recording equipment to support the test operations are permanently installed.




Missile System Being Installed in Altitude Chamber

Temperature Conditioning. The complement of temperature conditioning chambers cover a range from -80 to +200°F. The chambers vary in size from a maximum of 26 by 52 by 14 feet high, to small boxes of 2 by 2 by 2 feet. Some chambers provide either high or low temperature conditioning only, while others cover the entire temperature spectrum.

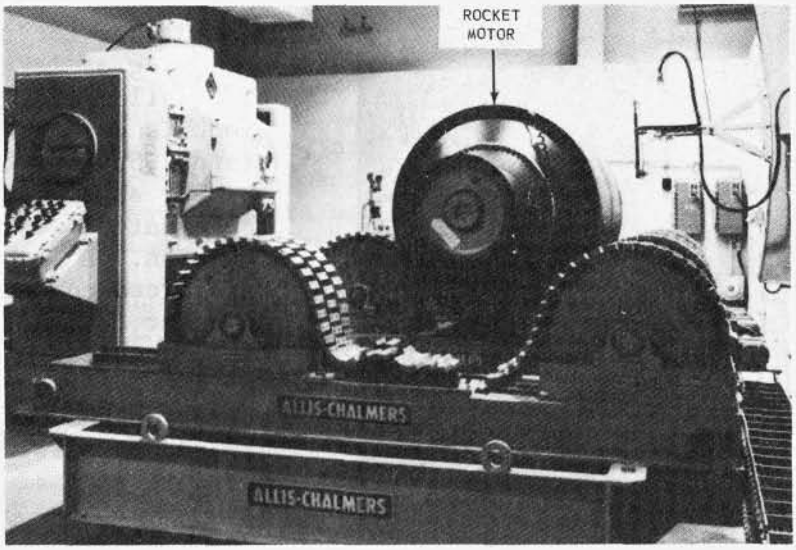
Climatic Effects. The Climatic Chamber, also in Test Area 5, is a large temperature-controlled cell, 26 by 52 by 14 feet high, providing temperatures from -80 to +200°F. It is used in temperature conditioning large systems and in conducting "operational" tests on smaller classes, permitting the systems to be exercised at high and low temperature by operating personnel. This type of testing has proved invaluable in detecting design problems prior to conducting expensive real-environment Arctic testing. The smaller missiles may be actually fired in the chamber.

Arctic Test in Climatic Chamber

There is a thrust block in the chamber for the preconditioning of large missiles or missile motors. The block is designed to withstand 1,500,000 pounds of thrust, as a precaution in the event of accidental ignition. A 40-by-18-foot reinforced concrete room, adjacent to the temperature cell, provides a safe area for personnel during the operation and control of hazardous tests. On the opposite side of the cell is a 43-by-36-foot room which is used for special power and conditioning equipment. These areas are all housed within the main building, which is a prefabricated, steel-framed, metal-covered structure. A support building, in the immediate vicinity, provides office and test equipment storage area.

Radiography Facilities. The industrial radiography facilities consist of a 25-MeV betatron, three x-ray machines -- a 250-kV, a 150-kV, and a portable 140-kV -- and a Budd multitron cobalt-60 unit. They provide the capability to x-ray almost any item from the smallest to a 20-inch thickness of steel.

The entire betatron installation, which includes a specimen handling carriage, can be remotely controlled. The betatron has a focal spot size of 0.5 mm, and when tested with a steel block 10 inches thick shows a sensitivity of 0.5 percent. This results in x-ray photographs which show small details very distinctly. The instrument operates at a frequency of 180 hertz, with a burst of x-rays occurring once every cycle. It has an energy output which may be varied from 2 to 25 MeV, and is rated for continuous duty at all energy levels. At 25 MeV the instrument produces at least 150 roentgens per minute and can penetrate up to 20 inches of steel. The carriage and other specimen handling equipment can handle a wide variety of items, including rocket motors up to 6 feet in diameter and 20 feet in length.



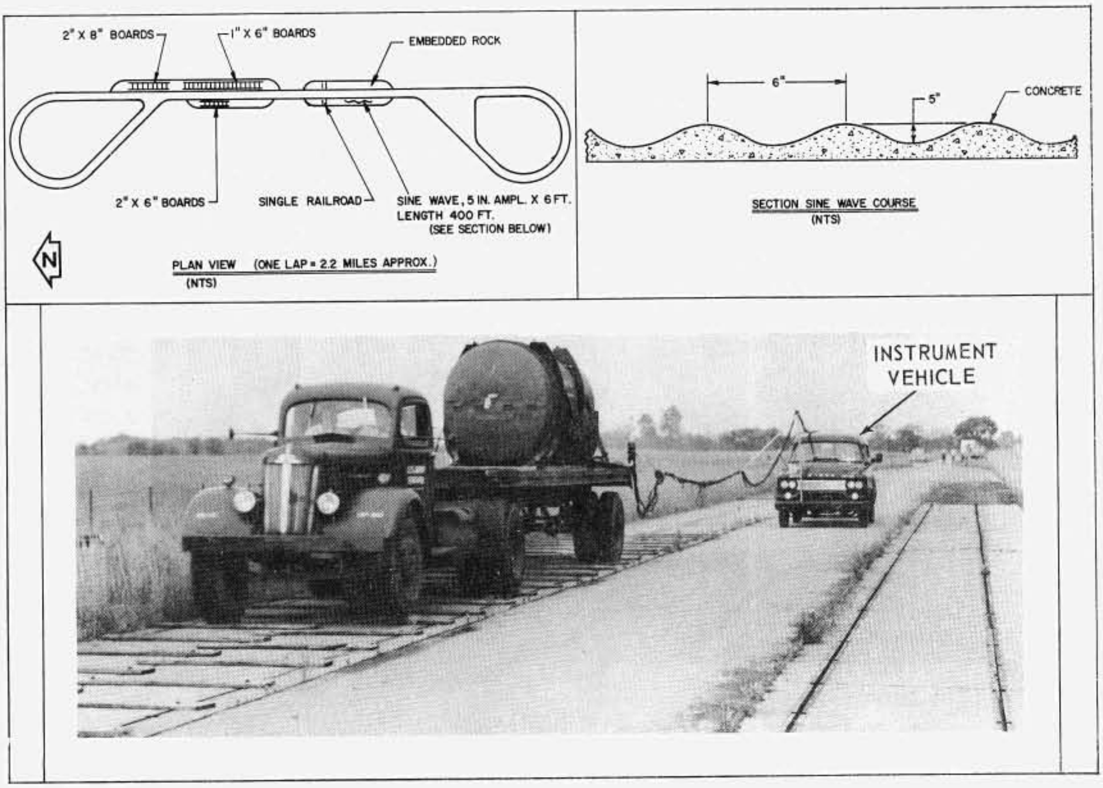

25-MeV Betatron

Both the 250-kV and the 150-kV x-ray machines have variable energy outputs, together covering the energy range from 30 to 250 kV, and can x-ray items as small as transistors or as large as steel castings 2 inches thick. For items that cannot readily be brought to the inspection facility, the portable x-ray machine, with an energy range of 30 to 140 kV, is brought into use. It can be easily and rapidly transported to remote sites, and is suitable for x-raying up to a 1-inch thickness of steel.

The cobalt-60 equipment has a significant advantage in that the radioactive capsule can be placed inside a specimen in a small space not accessible to an x-ray tube. Its x-ray capability includes steel thicknesses from 2 to 6 inches.

Test Course. The 2,700-yard, all-weather driving course simulates a variety of road surface conditions normally encountered during noncombat movement of vehicles and mobile equipment. Its location was chosen to permit the testing of hazardous items. Included as permanent road conditions are an elevated railroad crossing, sinusoidal dips, crushed rock configurations, and suspension systems test pad. Selected sections are designed to incorporate special road surface configurations in the basic test course as required. Improved, unimproved, and cross-country courses are located adjacent to the main test course.

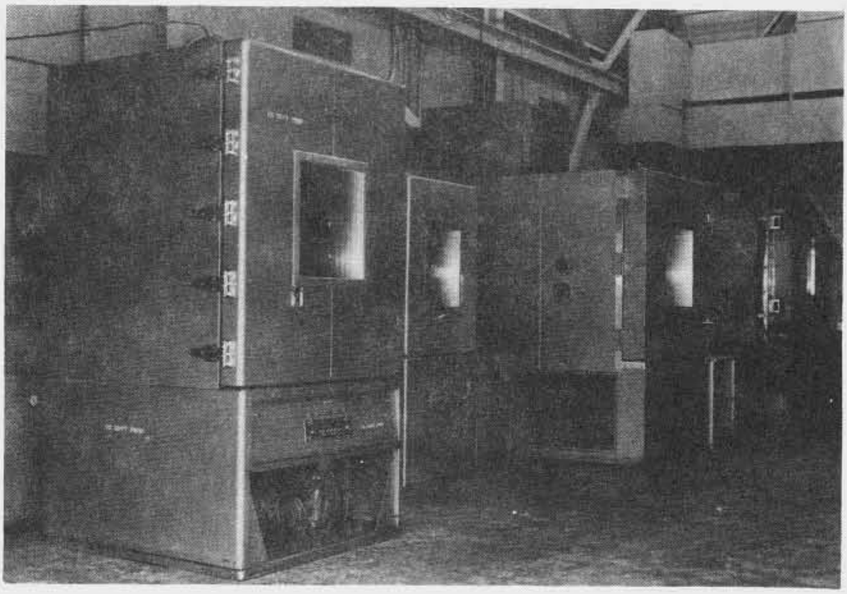
Vehicles, equipment, and equipment mounts may be fully instrumented to provide shock and vibration frequencies and magnitudes, for evaluation and further studies. Photographic coverage is available to record the behavior of items during test performances.



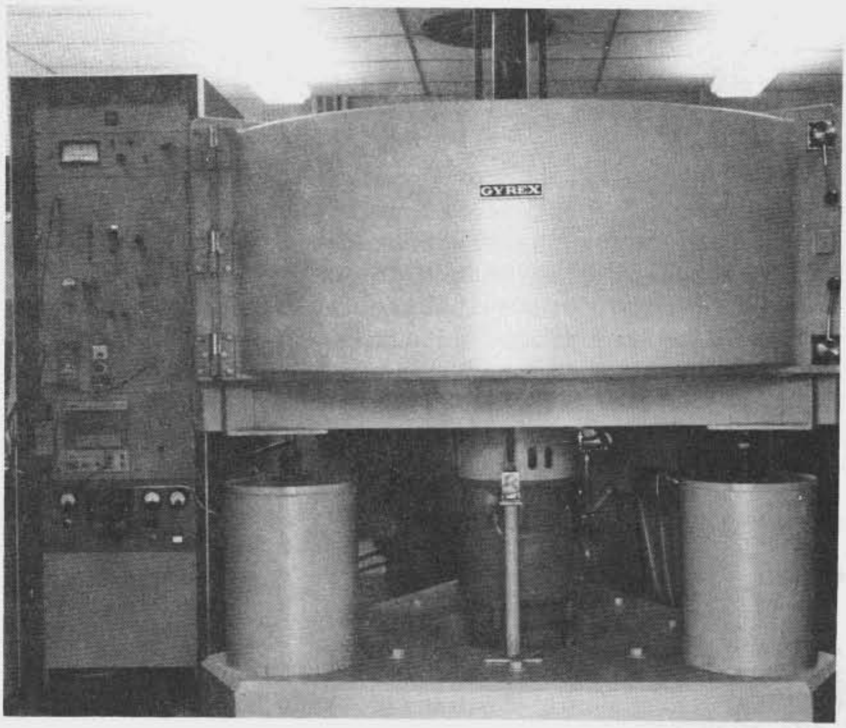

Test Course
(Top, Rough Road Layout; Bottom, Missile Equipment Under Test)

Motor Conditioning. The Motor Conditioning Facility, located in Test Area 2, consists of three separate chambers, each 8 by 10 by 30 feet, and provides operating temperatures ranging from -60 to +180°F. In addition to preconditioning motors for static test firings, this facility can also be used for evaluating the effects of prolonged storage periods. Complete ground handling equipment is available for installing and moving test items.

Aircraft Modifications. A hangar facility, located at the north end of the Redstone Arsenal Airport, is equipped for aircraft modifications and tests. It will accommodate aircraft measuring up to 85 feet in length, 100 feet in width, and 25 feet high. The available floor area is 12,000 square feet, of which 10,000 is hangar area and the remainder is for office, shop, tool room, and laboratory use. Special features available throughout the hangar, shop, and laboratory include aircraft power, heating, lighting, and compressed air.



Environmental Chambers

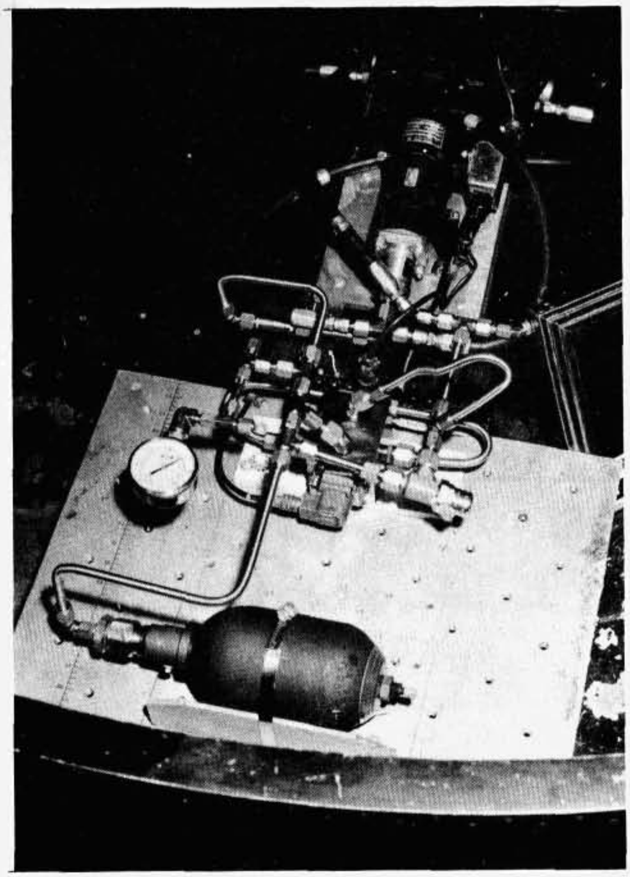



Precision Centrifuge (10,000 g-lb)

## COMPONENT TEST EQUIPMENT

Climatic Environment. The laboratory has the equipment available to simulate any climatic environment that a missile component might be expected to undergo -- high and low temperature (-100°F to +500°F), altitude (to 150,000 feet), humidity, rain, solar radiation, salt spray, sand and dust, ozone, and fungus.

Acceleration. The major item of acceleration equipment is a precision centrifuge capable of 10,000 g-pounds force, with 600g or 50 pounds being the limiting factor. The rotor is air-bearing supported, and the rotational speed is controlled to within ±0.001 percent. "Wow" is held to less than 0.005 percent at low speeds and is not measurable at higher speeds. Nominal radius is 24 inches.



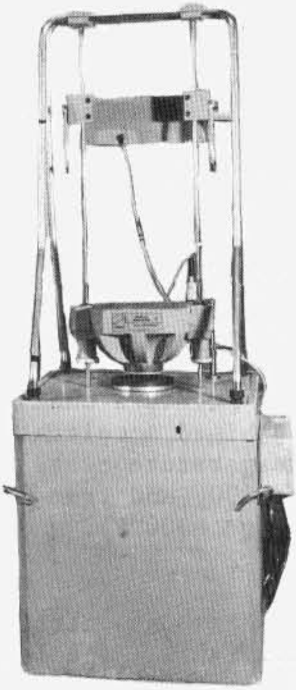
Component Acceleration Test Setup
(2,000 g-lb Centrifuge)

The instrumentation system is NBS traceable to 0.001 percent accuracy. There is a temperature chamber for combined acceleration and temperature tests (up to 200g and from -100°F to +300°F).

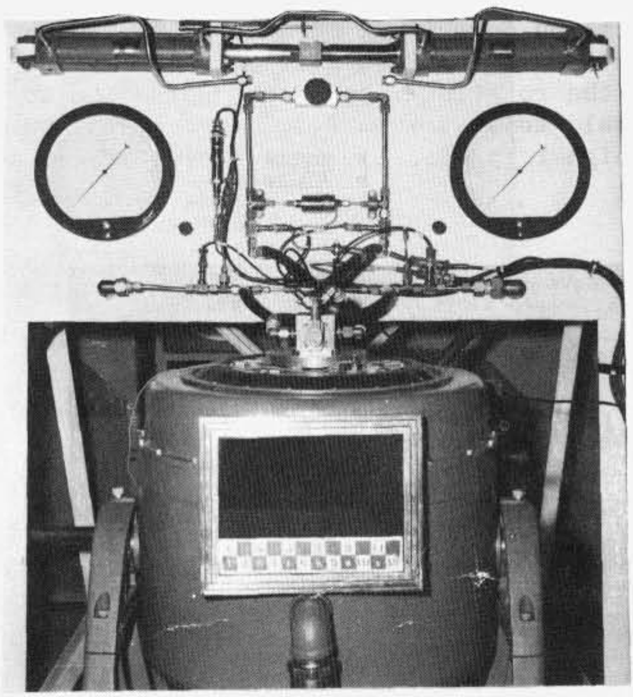
Two other centrifuges are available. The larger has a capacity of 2,000 g-pounds (78g maximum). Maximum specimen size is an 18-inch cube weighing 100 pounds. The photo shows a 3,000-psi servo valve set up on this centrifuge to operate under acceleration.

The smaller machine will accommodate a 7-inch cube weighing 25 pounds.

Shock. There are three shock test machines, with varying capabilities. The first has a capacity of 4,000 g-millisecond and ½ sine pulse with a 25-pound test item; the second has a capacity of 1,000 g-millisecond and ½ sine pulse with a 100-pound item; and the third is capable of a 100g, 11-millisecond, ½ sine pulse, or a 100g, 6-millisecond, sawtooth pulse, either with a 100-pound test specimen.



Shock Tester
(1,000 g-ms)

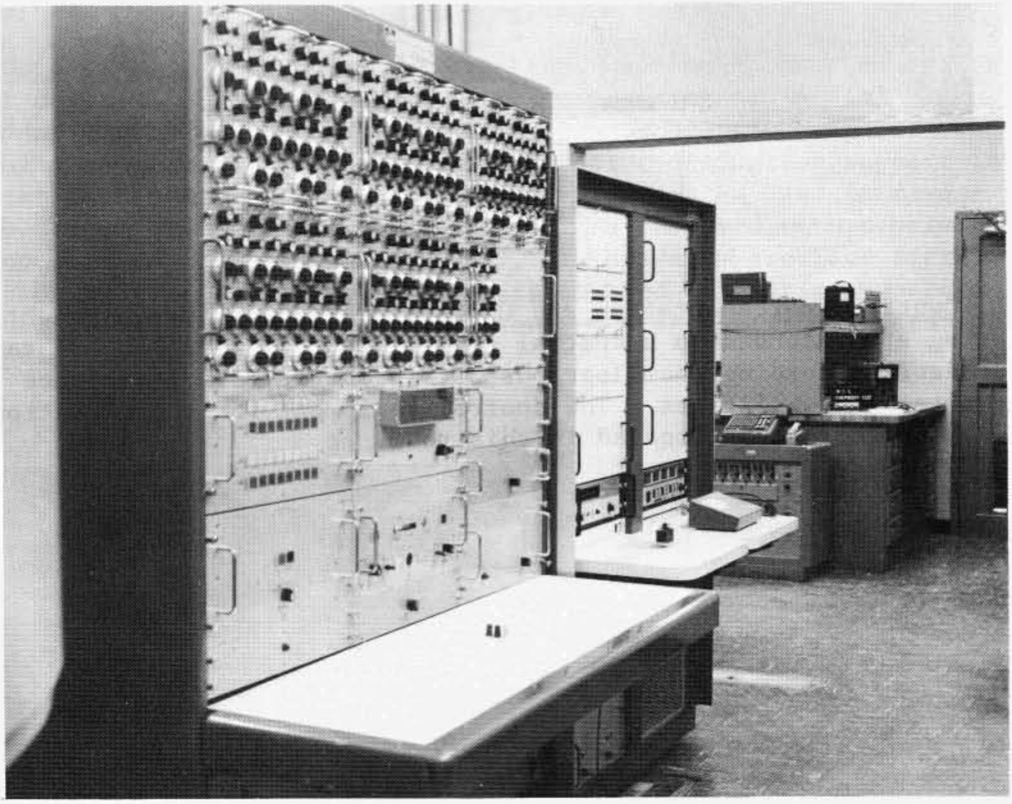


Vibration Test Setup

Vibration. Several electrodynamic shakers are available, ranging from 50 pounds force to 6,000 pounds force, and producing both sinusoidal and random noise vibration. Conditioning shrouds are used to provide combined temperature and vibration environments.

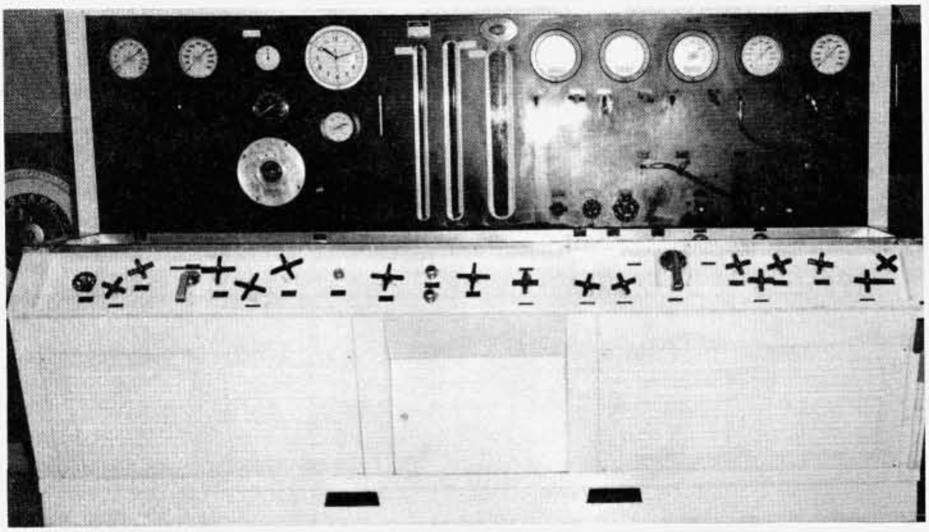
Acoustics. Acoustical tests are performed in a reverberation chamber, 50 feet by 26 feet by 13 feet high, using five acoustical horns with a frequency range of 10 Hz to 40 kHz and a total sound power level of 170 dB (reference $10^{13}$ watts). Each horn is capable of 2 kW of acoustical power output.

Piece Parts Laboratory. Some of the equipment available for piece parts testing is shown in the photograph below. Illustrated are the Fairchield 4000-M integrated circuit tester, sequential mechanism for automatic recording and testing (of transistors), and the Systron Donner "Systrak" multichannel digitizer recorder. These items comprise the heart of the facility and are centrally located among dynamic and climatic environmental test equipment, which permits efficient and economical testing of minute parts -- numbering in the thousands -- for each major qualification program.



Piece Parts Test Equipment

Hydraulic Test Bench. The two hydraulic test benches have similar characteristics. The stand pictured below has a flow capacity of 35 gallons per minute at 3,000 pounds per square inch, or 20 gallons per minute at 5,000 pounds per square inch. Static pressure of 10,000 pounds per square inch is available. All measurements associated with hydraulic component testing are available. Adjacent to the stand is a laminar flow clean work station. It is possible to combine functional operation of hydraulic or electronics components with temperature and vibration environment.



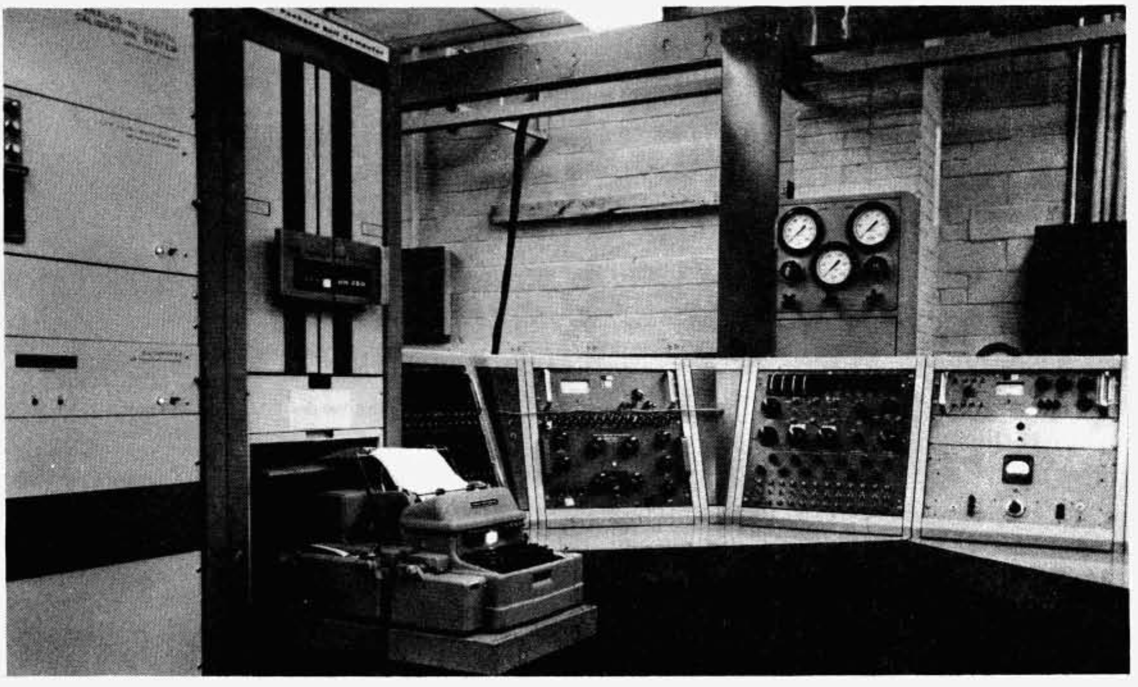
Hydraulic Test Bench

Central Instrumentation and Control. All data for component testing are recorded in a central control room. Available are tape recorders, recording oscillographs, strip charts, bridge balance circuits, and amplifiers. The control equipment for the vibration and shock testers is located in this room.

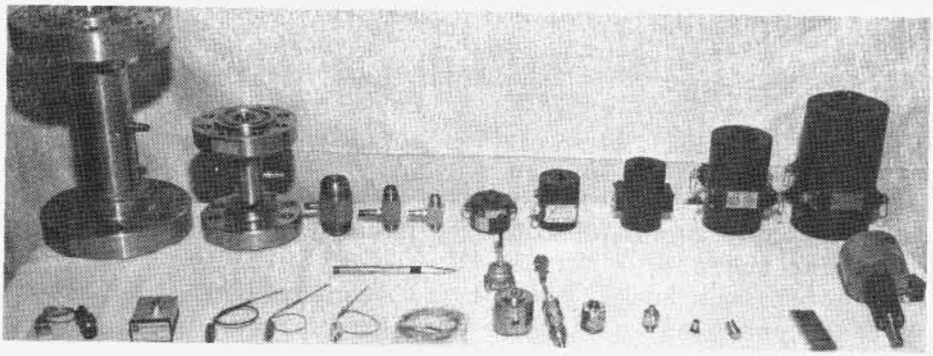
Component Testing Instrumentation and Control Equipment

Special Instrumentation Development. The special instrumentation support has always been emphasized within the laboratory, and a small staff is charged with the responsibility for continuously updating the instrumentation and data gathering capabilities. The skills of this group have resulted in successful development of a variety of systems or devices -- highly accurate dynamic six-component force measurement systems, optical techniques for resolution of in-flight attitudes of missiles to precisions better than 1 milliradian, in-flight instrumentation systems, and blast over-pressure impulse measurement system. A prototype development and fabrication group lends support to this effort.

Gage and Transducer Error Evaluation. Although instrumentation itself cannot be considered a facility, a grouping of specialized equipment represents a special capability. Such a grouping has been assembled to provide gage and transducer error evaluation support for all test operations within the laboratory. A system used to assess the characteristics of a field transducer as compared with a primary or secondary reference is shown below. This system provides signal conditioning, analog-to-digital conversion, and automatic computation of shunt equivalents to transducer inputs for the particular transducer undergoing test.



Calibration Data Processing Equipment



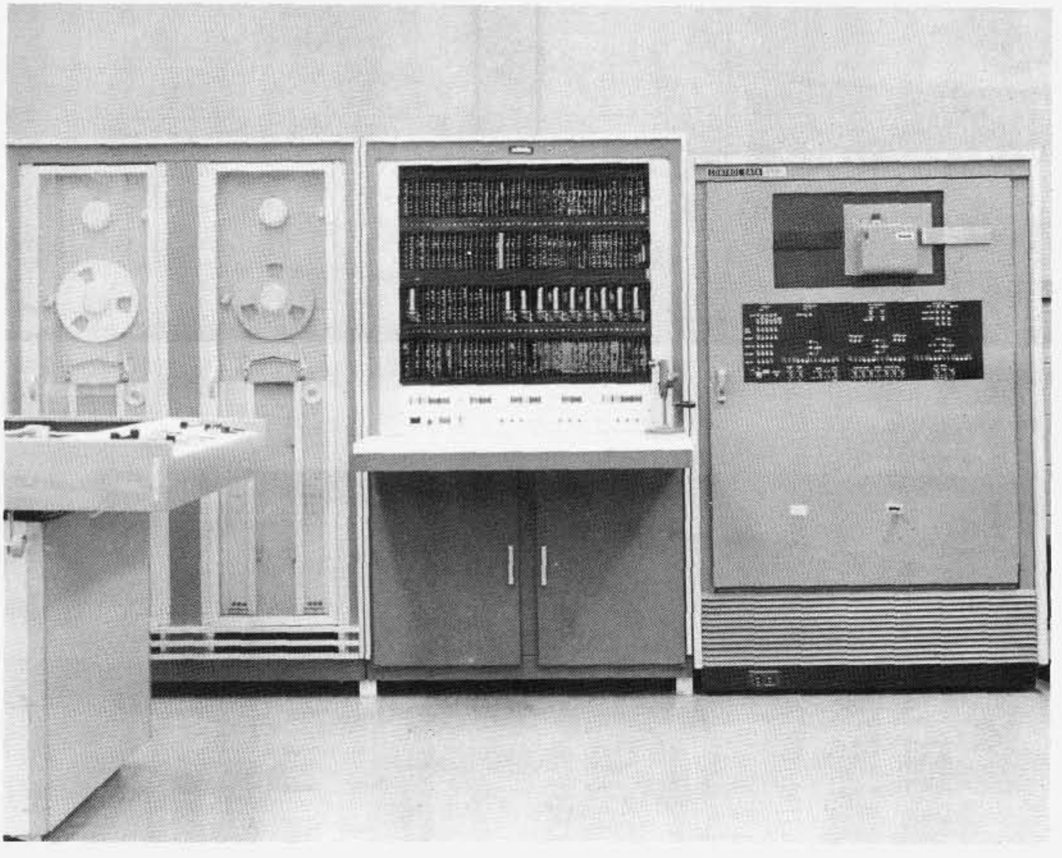
Typical Transducers

The equipments and capabilities available include the following:

- 12-channel analog-to-digital calibration system and signal conditioning
- Pressure calibration
  - 0-3000 psi (Ruska), ±0.02% accuracy
  - 0.01-100 psia, ±0.1% accuracy (Wallace and Tiernan)
  - 0-10,000 psi, ±0.1% (Ashcraft)
  - 0-100,000 psi, ±0.1% (Aminco)
- Pressure measurement, 0-1 psia through 0-50,000 psi
- Force calibration, 1 oz. to 1,000,000 lb, ±0.1%
- Force measurement, 1 oz. to 1,000,000 lb
- Strain measurement, current state-of-the-art
- Acceleration measurement, 0-1g through 0-1,000g
- Acceleration calibration, 0-1,000g
- Vibration measurement, 0-10,000g
- Vibration calibration, 1-100g, 20-10,000 Hz
- Temperature measurement, -300°F to +4000°F
- Temperature calibration (per NBS-prepared millivolt charts)
- Multicomponent force calibration and measurement
- Flow calibration and measurement, 0-5 through 0-1,200 gpm
- Blast pressure calibration and measurement, 0-1 through 0-500 psi
- Noise calibration, 134 dB
- Noise measurement, 125-192 dB

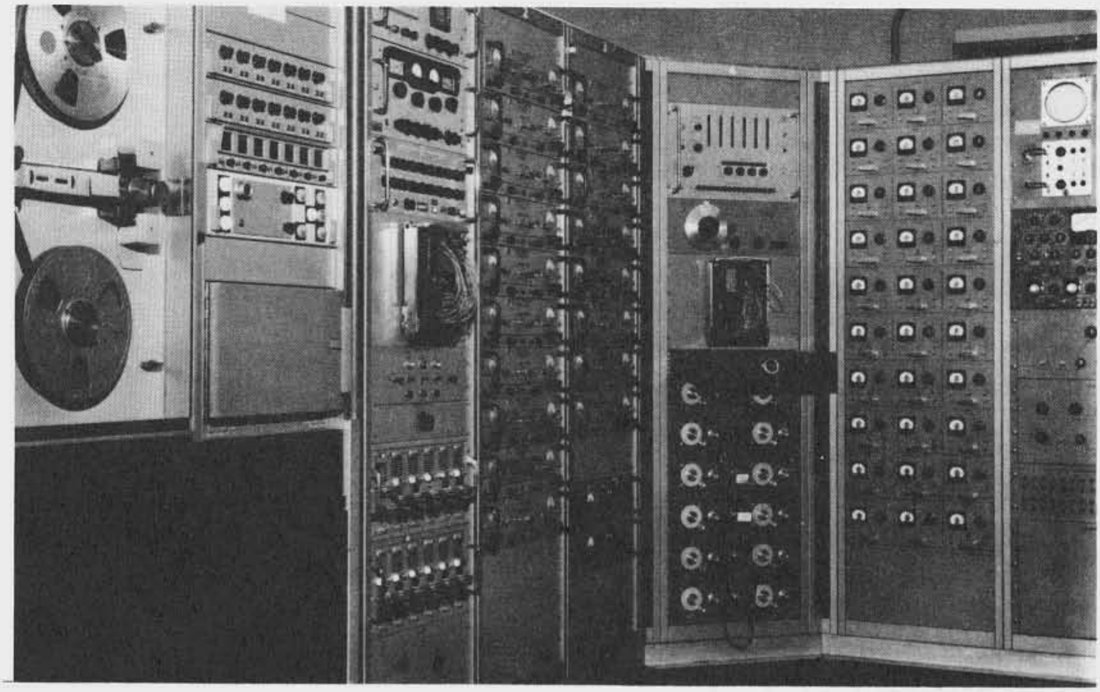
The laboratory also has the capability for designing and fabricating special missile telemetry packages for the in-flight measurement of missile parameters.

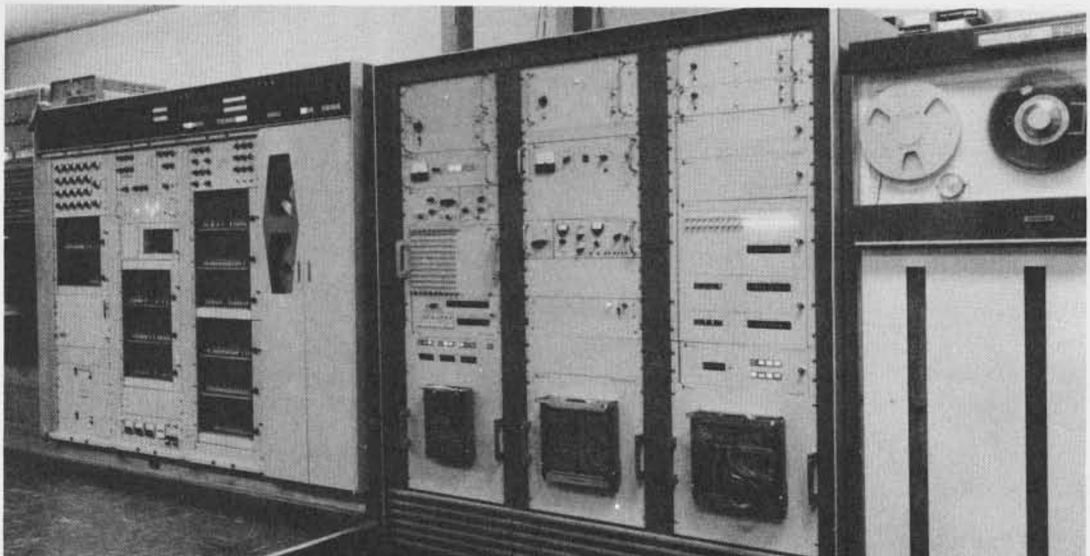
Data Reduction. An FM/FM system and a PCM system are used in the reduction of flight telemetry data (illustrated on the next page). These systems jointly provide the capability for processing telemetry data acquired and multiplexed by all conventional techniques except constant bandwidth. The complex includes a high-speed analog-to-digital system with front-end gear especially adapted to the various telemetry formats; its output is a computer compatible tape. In addition, there are oscillographic recorders for analog recording of the discriminated data signals.



Digital Data Processing Equipment

Digitally acquired data are similarly processed for conversion to engineering units tabulation and replotting, and when it is required are formatted for large scale computer (IBM 7094) analysis of complex test data. The X-Y plotters used are high-speed, digitally-commanded plotters, which may be operated under computer, punched card machine, or manual control.



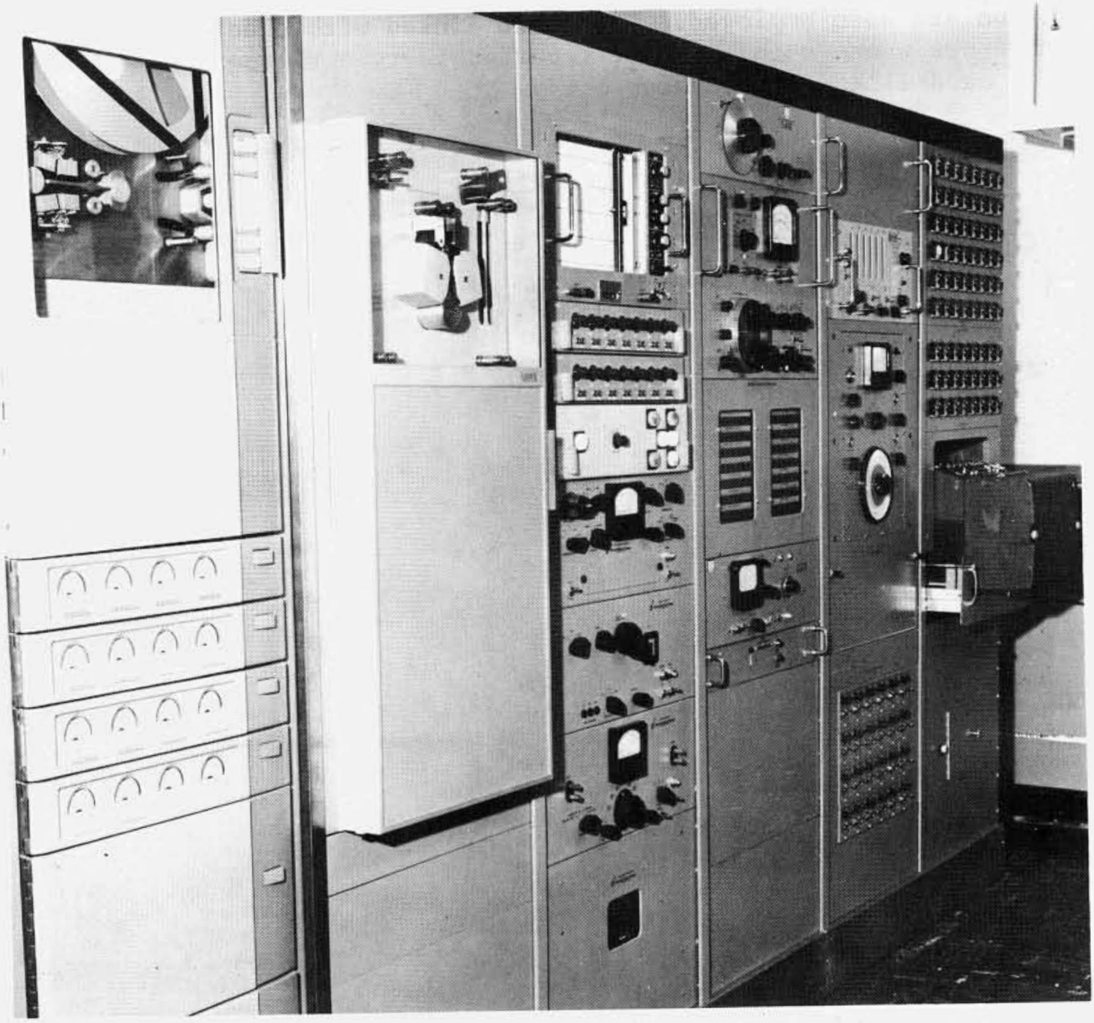


Data Handling Equipment – Telemetry

A number of readers equipped for film and oscillographic record reduction are also employed. These are linked with electronic counting accumulators whose output can be recorded in typewritten form or on punched card files for computer entry.

Visual Record Reduction Equipment

Standard programs (or especially developed programs if required) are used to derive reduced data or to perform test data analysis. These include ballistic parameters, launch studies, and flight trajectory analysis. Additionally, several comparators, essentially traveling microscopes, are used for high accuracy measurements; one is equipped with electronic counting accumulators and automatic output.



Frequency Analysis Equipment

Other special purpose data processing systems are on hand. Typical among these is the frequency analysis system used to assess the frequency characteristics and energy levels for complex signals obtained from vibration and acoustic transducers. Another is the system applied in the processing of data acquired by a Doppler-type radar -- when fully updated it will accommodate the improved Doppler (tracking type) radar planned for the flight ranges. When the radar and data processing system are fully operational, much of the flight trajectory data can be obtained without the use of costly optical techniques.

## STRUCTURES AND MECHANICS LABORATORY

The Structures and Mechanics Laboratory performs research in and establishes criteria for missile structures and mechanical components in the areas of structures design, mechanics design, structural stress and thermodynamics analysis, structures dynamics analysis, and materials engineering and development. Capabilities required in this work cover a broad spectrum of scientific and engineering disciplines, including thermodynamics, mechanics, materials, hydraulics, pneumatics, mathematics, physics, electricity, and chemistry. The laboratory's research and engineering are aimed at improving existing systems, assuring integration of any technological advances, and designing advanced missile systems and components.

The laboratory is organized into a Special Projects Branch and four operating branches:

Dynamics Analysis

Materials Engineering and Development

Stress and Thermodynamics

Missile Design.

### DYNAMICS ANALYSIS BRANCH

*Capabilities:*

The Dynamics Analysis Branch performs analytical and experimental investigations in the fields of flight and fluid mechanics, aerospace engineering, and structural dynamics. Areas of endeavor encompass aerodynamic, inertia, and net or total loads for such conditions as blast encounter, resonance, aeroelasticity, and maneuver. Linear and nonlinear response due to such modal excitations as wind-induced oscillations, flutter, shock, and thrust buildup are additional areas of concern. Criteria are determined for selecting structural design conditions, as well as for establishing requirements for future design. Analytical studies in these areas are performed in support of the various Army missile and antimissile systems, as well as in support of in-house research tasks.

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*Facilities:*

In support of the analytical programs, concepting capability is required in addition to those facilities at the Computation Center. Available within the laboratory are the following:

1620 Digital Computer with expanded storage.

Benson-Lehner Incremental Plotting Device, which is an on-line digital plotter.

Gerber Data Reducer, which is an off-line machine with adjacent analytical card punch and typewriter.

TR-10 Analog Computing Consoles for the solution of small dynamic problems.

Offner 8-Channel Graphical Recorders for displaying the output of the analog's solutions.

## MATERIALS ENGINEERING AND DEVELOPMENT BRANCH

*Capabilities:*

The Materials Engineering and Development Branch is concerned with all aspects of selection, application, and evaluation of materials, both metallic and nonmetallic, for use in missile and rocket systems fabrication. Standards and specifications are established, and special materials and processes are developed as needed or as deemed desirable to provide deterioration-proof components and systems and to afford maximum reliability. Design and consultation services are provided; contractor and in-house drawings are reviewed for materials compatibility. The extensive tests required are performed by the branch, or by contractors under the supervision of the branch. The reviews and tests cover a multitude of areas ranging from the selection of ultrahigh-strength steels to proper coatings for fasteners, adequate isolation of dissimilar materials, and specification changes on plastic parts callouts.

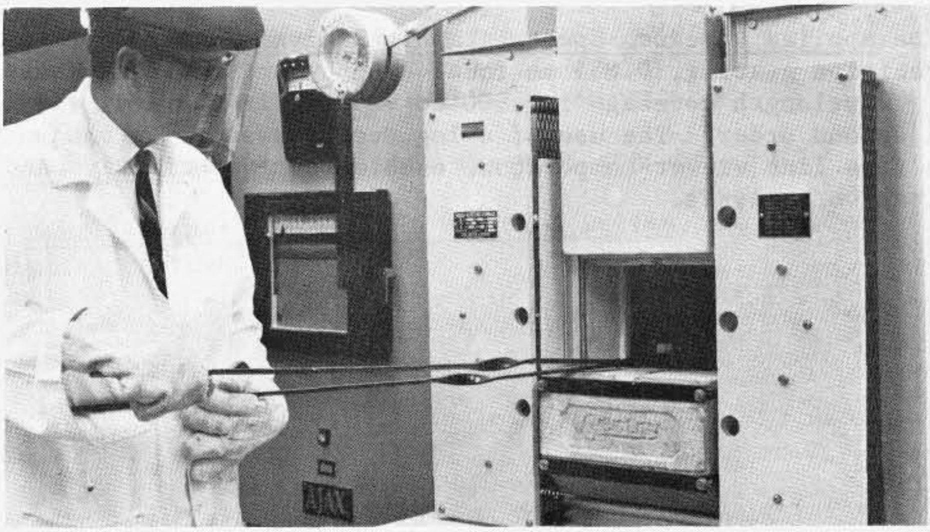
Specific problems handled include development of superior potting compounds for the insulation of electrical connectors, study of effects of variables on structural adhesive systems, application studies of low temperature elastomers and RF barrier materials, investigation of the effects of simultaneous rapid heating and loading on materials, stress-corrosion studies, and development of ceramic flame-shield materials.

*Facilities:*

The Applied Research Spectrographic Analyzer has a 960 lines/mm B&L precision grating, 0.855 mm focal length, and modified Wadsworth mount. Wavelength coverage is 4500 to 9300 Å first order, and 2250 to 4650 Å second order. The use of a log sector system, in conjunction with a fine line viewer-comparator, enables semiquantitative and quantitative analyses.

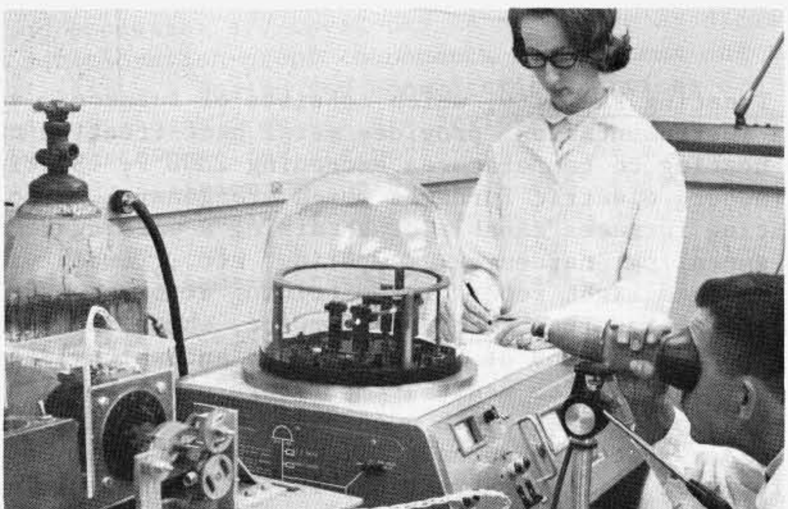
Spectrographic Analyzer

The Heat Treating Facility, which consists of furnaces, accessory equipment, and instrumentation, provides metal heat-treating capabilities for protected heating to temperatures exceeding 2300°F. Specific furnaces include two Lindberg electric furnaces which are general purpose laboratory heat-treating furnaces capable of attaining a working temperature of 2200°F for annealing, hardening, tempering, etc.; Temco furnace modified with special gas-tight retort for nitriding at temperatures from 800 to 1000°F; Lindberg crucible or pot furnace, which is electrically-heated and has pot dimensions of 8 x 15 inches, and which is a versatile heat-treating unit for low to medium temperature use with liquid heat operations such as oil or salt bath quenching, martempering, and austempering. Ajax salt bath furnace, with a salt chamber of 12 x 24 inches, used for salt bath heat-treating, including carburizing and nitriding, to 1900°F; Sentry atmosphere furnace, a protective atmosphere furnace for heat-treating to temperatures above 2300°F, with a chamber size of 12 x 8 x 20 inches, used for austenitizing and normalizing high strength alloy steels.




Sentry Atmosphere Furnace

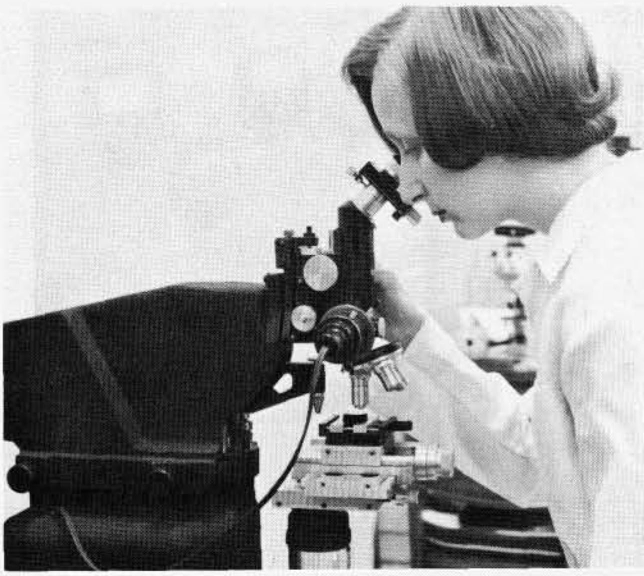
The Kinney High Vacuum Bell-Jar Evaporator system is capable of producing vacuums to the $10^{-9}$ torr range in less than eight minutes. In conjunction with accessory heating and gas (argon, hydrogen, helium, etc.) induction facilities, the unit is used to study material responses to heating under various degrees of vacuum, vacuum coating and metal sputtering, thin film evaporation, and cathodic metal etching.



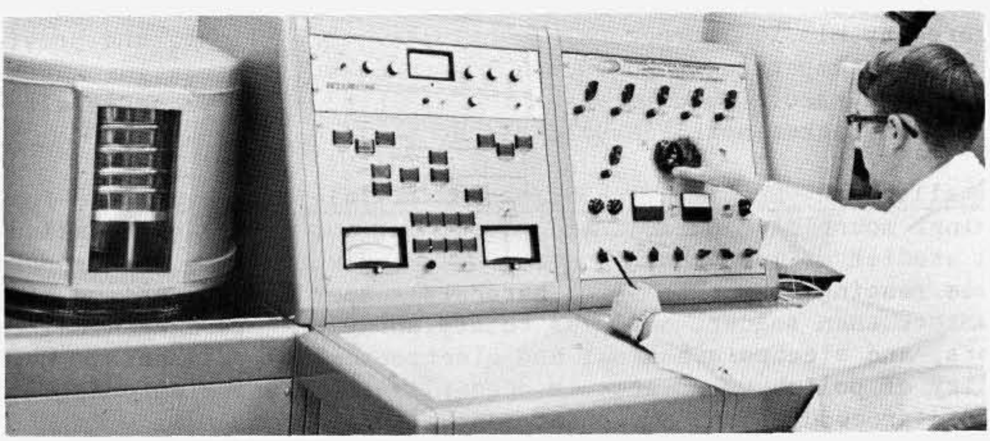
Bell Jar Evaporator

A Tukon Microhardness Tester is used for determining the hardness of metallic and nonmetallic materials at a microstructure level of accuracy. Items such as fine wire, small precision parts, thin metals and foils, shallow depth surface treatments, plastics, and glass materials can be tested without damage. It is also used in research work for the study of surface phenomena and for hardness tests on specific individual crystals, inclusions, and particles within a basic microstructure.

The Thermo-Physics Combination Thermal Conductivity Instrument is employed to obtain highly accurate thermal conductivity data at temperatures from -325 to 1200°F. Thermal conductivity, expressed as Btu/hr-ft$^2$-F°/ft, can be determined under conditions of vacuum ($10^{-5}$ torr) or inert atmosphere by either the guarded hot plate or cut-bar method.

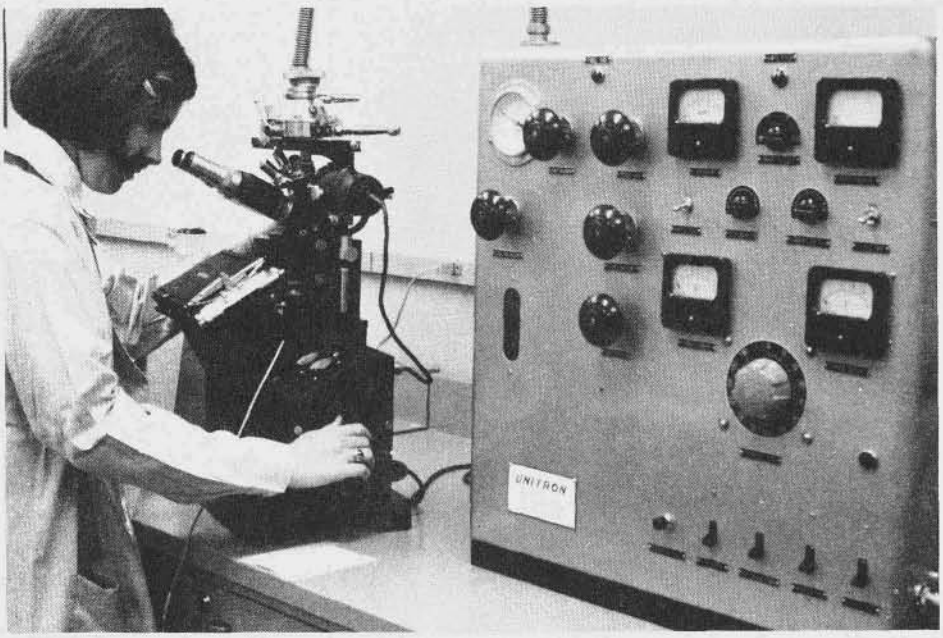


Tukon Microhardness Tester



Thermal Conductivity Instrument

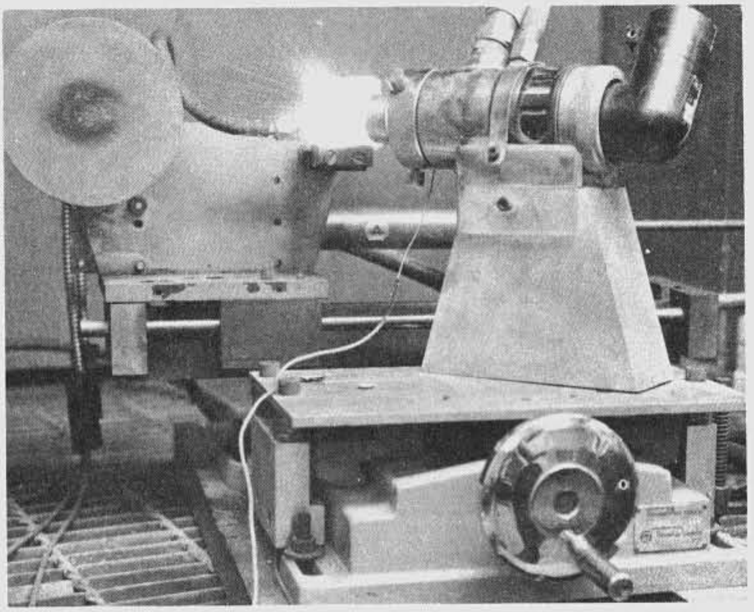
A Unitron Vacuum Hot-Stage Metallograph is used for the high magnification study of the microstructure of metals at high temperatures. Capable of attaining temperatures exceeding 1500°C and vacuums to $5 \times 10^{-4}$ mm Hg, the instrument can also be used for positive pressure studies to a level of three atmospheres. Various gases can be introduced into the system for quenching, etching, and compatibility studies.



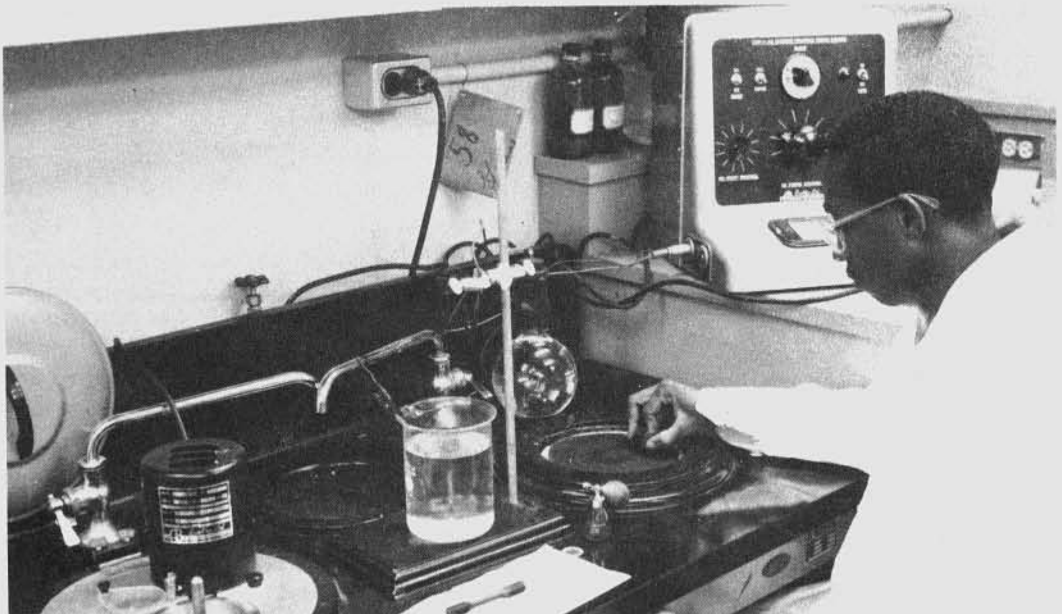

Unitron Metallograph

The Plasma Test Facility is used to simulate thermal environments encountered by missile structures in high velocity flight, and provides plasma stream temperatures to 30,000°R with associated heating rates up to 2500 Btu/ft$^2$-sec. Specific uses include evaluation of materials for nose cone and rocket nozzle applications.

Metallography Specimen Preparation Facilities are available for sectioning, mounting, and polishing specimens for high magnification optical studies of microstructures. Polishing apparatus, for preparing materials ranging from those with hardnesses approaching diamond to those softer than solder, includes rotary and vibratory mechanical polishers, and electromechanical and electrochemical polishers. Reproducibility of polished surfaces is accomplished by using automatic and programmed procedures and equipment controls.

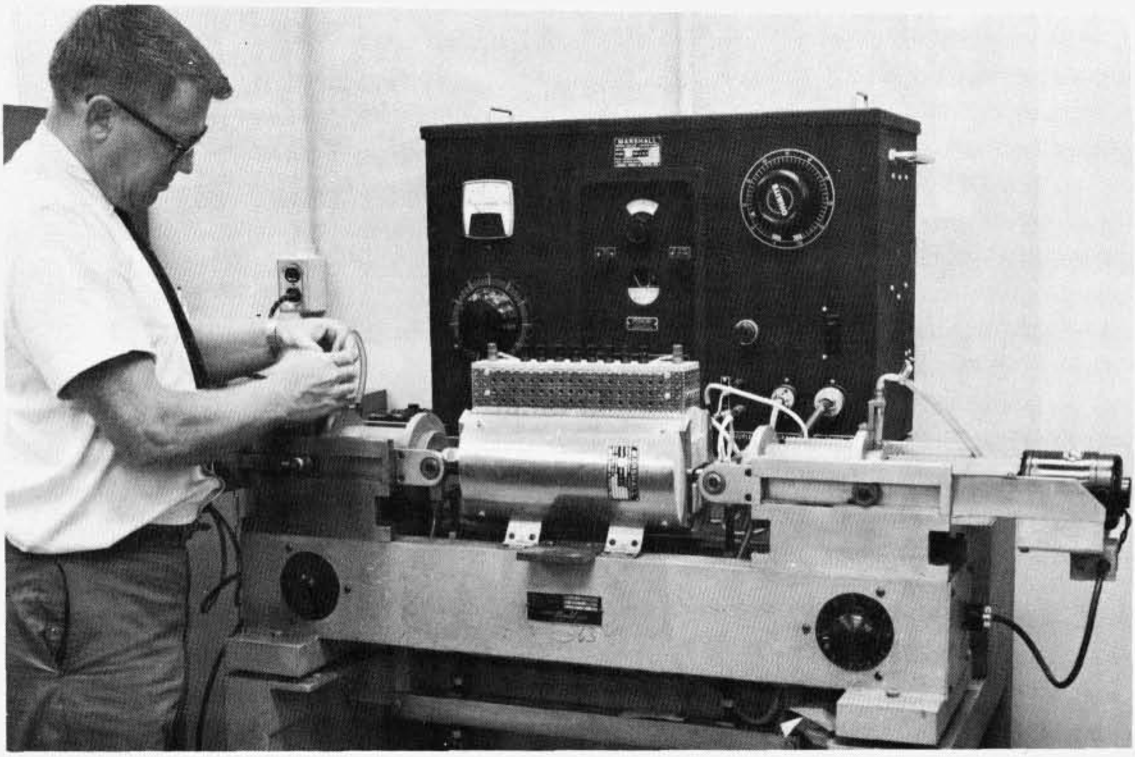


Plasma Test Facility



Metallography Specimen Polishing Equipment

A Budd Rotating Beam Fatigue Testing Machine (850 inch/pound) combines the advantages of high speed testing with an elevated temperature environment. Loaded as a simple beam, the specimen is driven from both ends through high-speed spindles by two variable-speed, series-wound electric motors. Dead weight loading is applied to the specimen by a lever system and is independent of specimen position and rpm. The electric furnace and temperature controller facilitates testing at temperatures from ambient to 1800°F. Low temperature testing to -325°F can also be accomplished by substituting an $LN_2/N_2$ chamber for the furnace.



Rotating Beam Fatigue Testing Machine

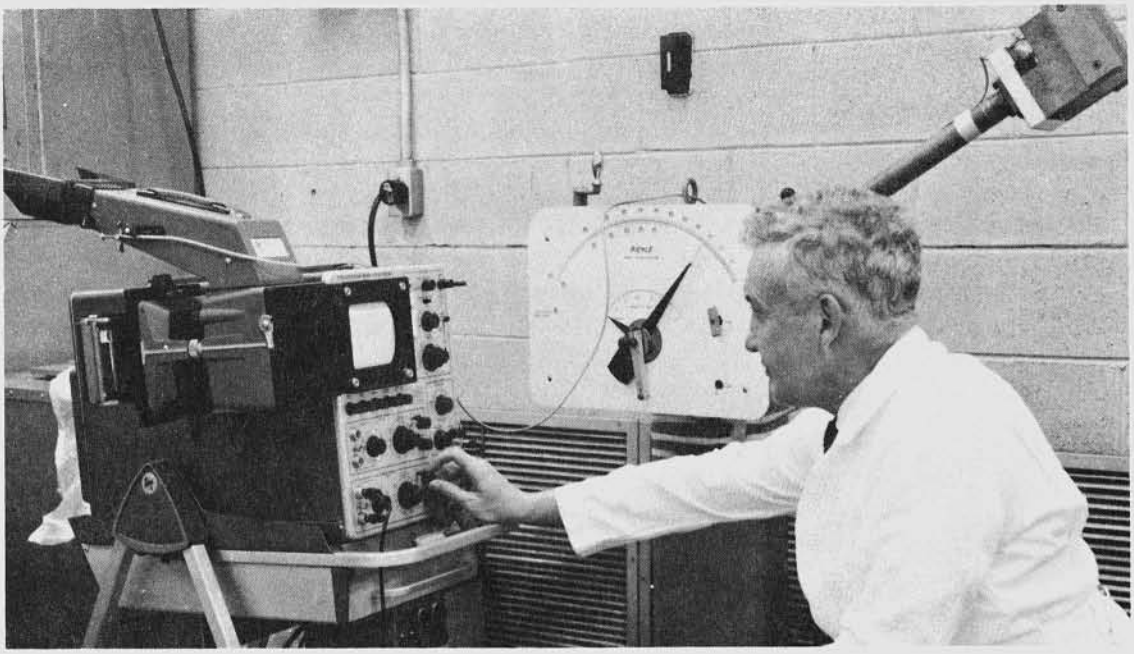
The Harrop Thermal Analyzer is a precision instrument for conducting thermal analyses of materials relative to physiochemical properties versus temperature. Basic analytical procedures employed with this equipment are differential thermal analysis (DTA) and thermogravimetric analysis (TGA). Maximum operating temperature of the instrument is 1600°F, controllable to ±2% at the higher temperature level. Applied environments include vacuum, nitrogen, argon $CO_2$, etc. Weight recording sensitivity to 0.001 mg is attainable for thermogravimetric analysis.

Harrop Thermal Analyzer

The Instrumented Impact Testing Machine, employing strain gauges and oscilloscopes, offers a new approach to evaluating the toughness of steel which is to be used under shock-loading conditions. When the pendulum strikes the specimen on which the strain gauges are located, a change in EMF produces a trace on the screen, triggered at the moment of impact, which is similar to the curve of a stress-strain diagram.

The Temperature-Humidity Environmental Chamber has a capacity of 8 cubic feet and can be programmed for automatically controlled (continuous) temperature/humidity testing, meeting the requirements of MIL-E-5272. Operating specifications for this test chamber are as follows:

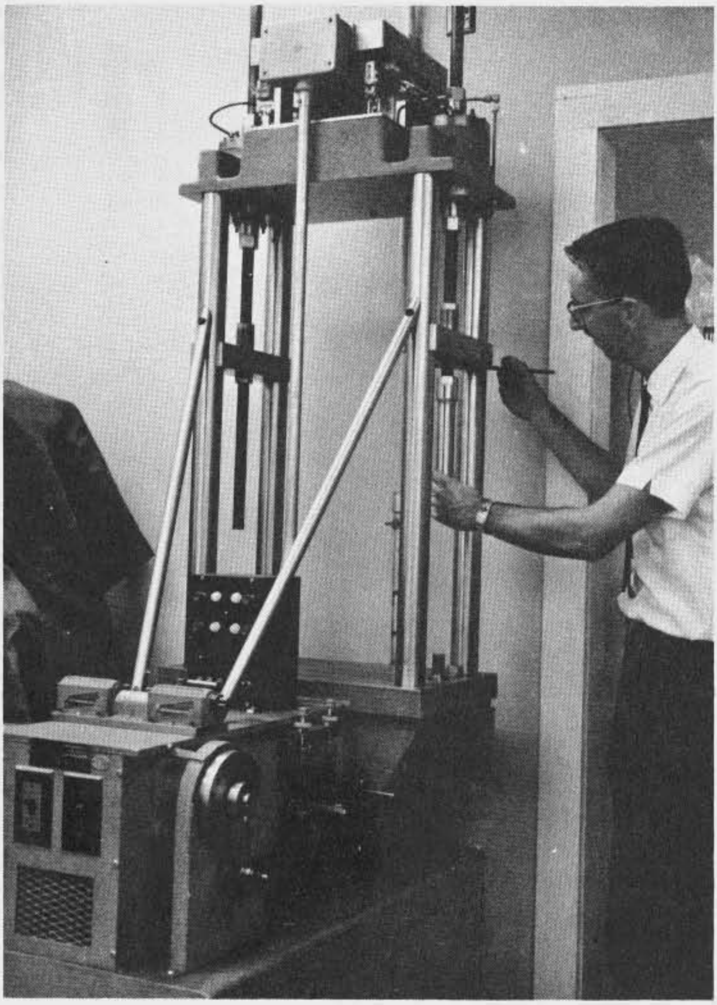
| | |
|---|---|
| Cooling: | Ultimate low: $-100^{o}F$<br>$+70^{o}F$ to $-70^{o}F$ in 55 min.<br>$+70^{o}F$ to $-100^{o}F$ in 85 min.<br>$+300^{o}F$ to $+700^{o}F$ in 30 min. |
| Heating: | Ultimate high: $+300^{o}F$<br>$-100^{o}F$ to $+70^{o}F$ in 25 min.<br>$+70^{o}F$ to $300^{o}F$ in 25 min. |
| Humidity Range: | 20% to 95%<br>$35^{o}F$ and $185^{o}F$ dewpoint limits<br>5% at $185^{o}F$ |



Instrumented Impact Testing Machine

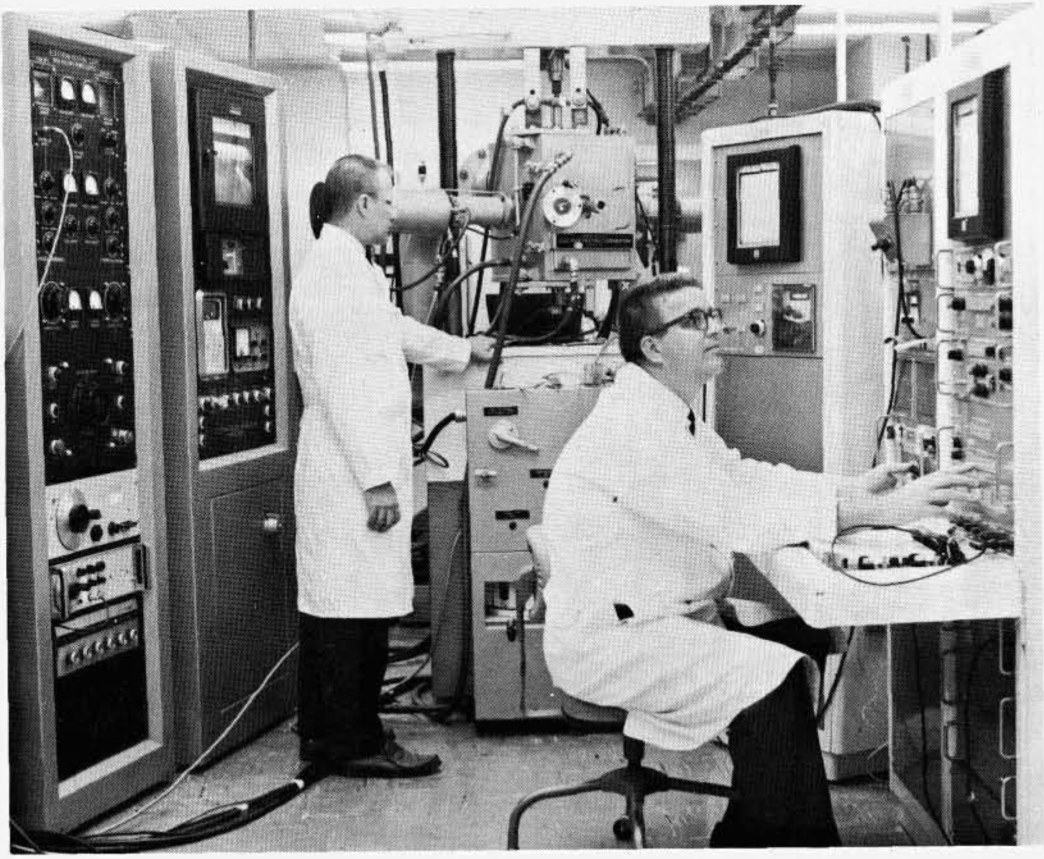
Environmental Chamber

The Dual Column Direct Stress Fatigue Testing Machine is an axial-loading (specimen) fatigue tester. Column construction provides excellent axial specimen alignment. Electromechanical in operation, the tester has a 5000-pound maximum load capacity and a cyclic speed (tension-tension) of 1500 cpm. Additional features include: (1) dual testing capabilities, i.e., two specimens may be tested simultaneously with independent test modes; (2) each test head exerts a variable sinusoidal force to the maximum 5000-pound limit; (3) automatic load maintainer facility accurately maintains preselected loading parameters through test; (4) dual test heads can be linked together for single specimen testing to 10,000 pounds.



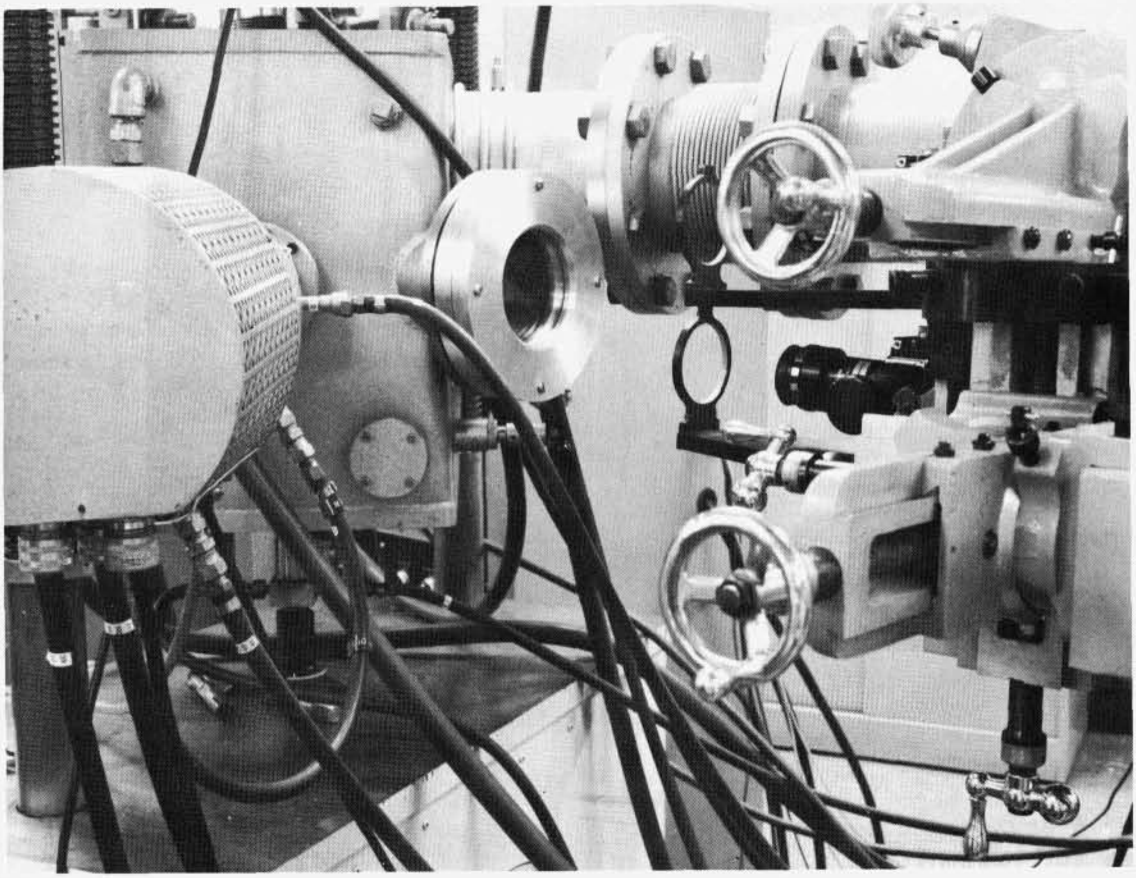
Fatigue Tester

The Marquardt TM-6 Universal Testing Machine, a fully automatic, high speed tester, is used for acceleration/simulation testing of structural and nonstructural materials. Control modes for testing are extension, load (stress), and table position. With a table loading speed of 20 inches per minute maximum, the unit can be employed for dynamic testing at speeds approaching impact. In conjunction with rapid-rate resistance and electron-beam heating facilities, the equipment is employed to duplicate the harsh load and thermal environments of missile launch and flight. Tension-compression or fluctuating loading for fatigue or hysteresis testing is possible at rates up to 1000 cycles per minute. Both loading and heating may be controlled individually or simultaneously, and control may be either manual or automatic. Programming instrumentation included in the test complex permits an entire test program (cycle) to be pre-programmed for unidirectional, bidirectional, or cyclic operation.



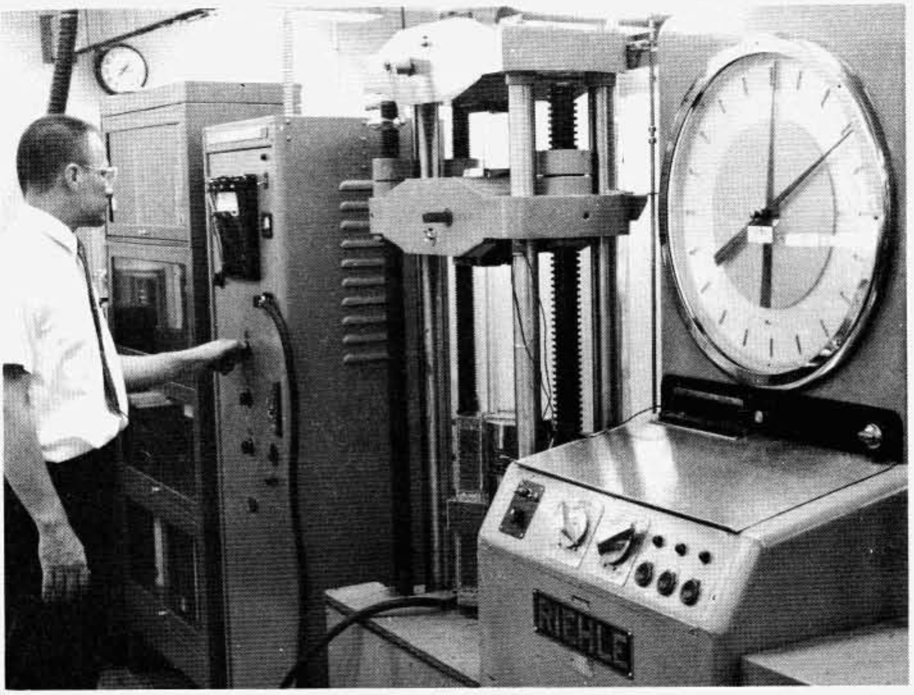
TM-6 Universal Tester

The Electron-Beam Heating Furnace is a two-gun high vacuum system capable of heating rates in excess of 1000°F per second. The furnace chamber has inside operating dimensions of 12 x 12 x 15 inches, and low vacuum attained is $2 \times 10^{-5}$ torr. The electron-beam guns have an individual rating of 20 kW and can be operated and controlled either separately or together. Controls for beam emission, focus, and sweep (vertical and horizontal) permit concentrated beam-heating of areas ranging from less than a square millimeter to approximately four inches in diameter. Coupled with an optical extensometer, the unit is used with a Marquardt TM-6 universal tester for rapid heating and loading studies.



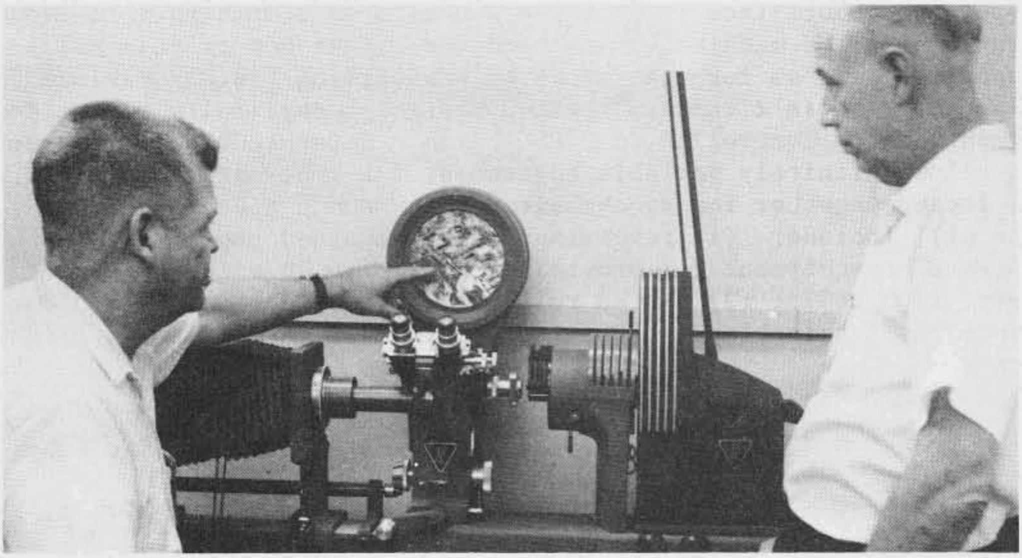
Electron Beam Heating Furnace

A Riehle Universal Testing Machine, rated at 60,000-pound maximum tension/compression loading, has mechanical (screw) loading with electronic strain-rate control. Direct load figures are indicated by the transmittal of crosshead force through a level weighing system to an electro-balance indicating unit. Stress-strain curves are produced by the transmittal of force and extension data to a servo-balance unit, which records in graph form. In conjunction with applicable accessories, this piece of equipment is used for a variety of tests including flexure, ductility (sheet), bend, shear, hardness, and compression. In addition, with equipment available, thermal environments from -326°F to 1500°F can be obtained.



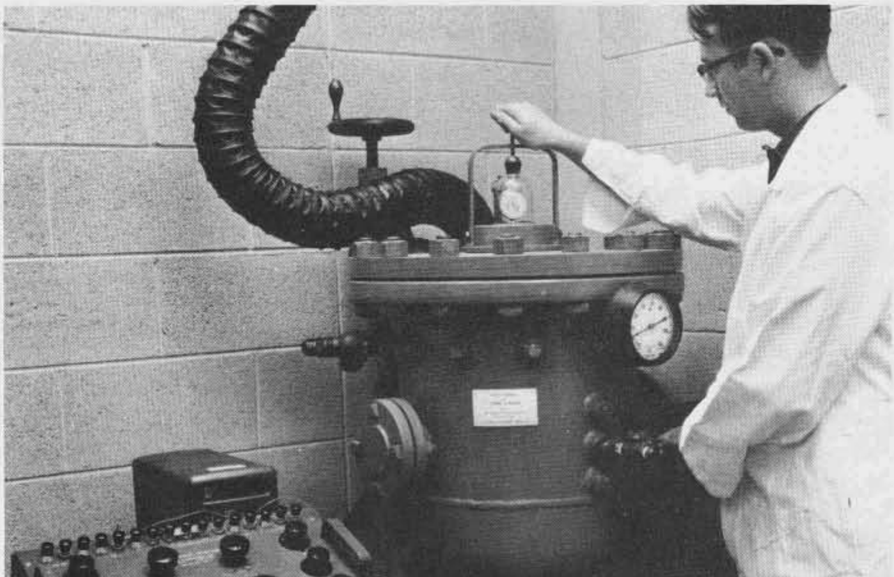

Riehle Universal Tester

A Bausch and Lomb Balphot Metallograph provides microscopic facilities for optical and photomicrographic examination and documentation of materials substructures and microstructures at magnifications from 25X to 1500X. Examination parameters include bright field, dark field, phase contrast, oblique lighting, and automatic centering and focusing. Photographic accessories include equipment for exposing black and white metallographic plate film, black and white and color cut-and-roll film, and cut-and-roll Polaroid picture material. Metallographic support equipment includes a B&L "L" camera, Unitron BU-11 metallograph, A&O microstar, microscope, and various low power optical examination and photographic equipment.



B & L Balphot Metallograph

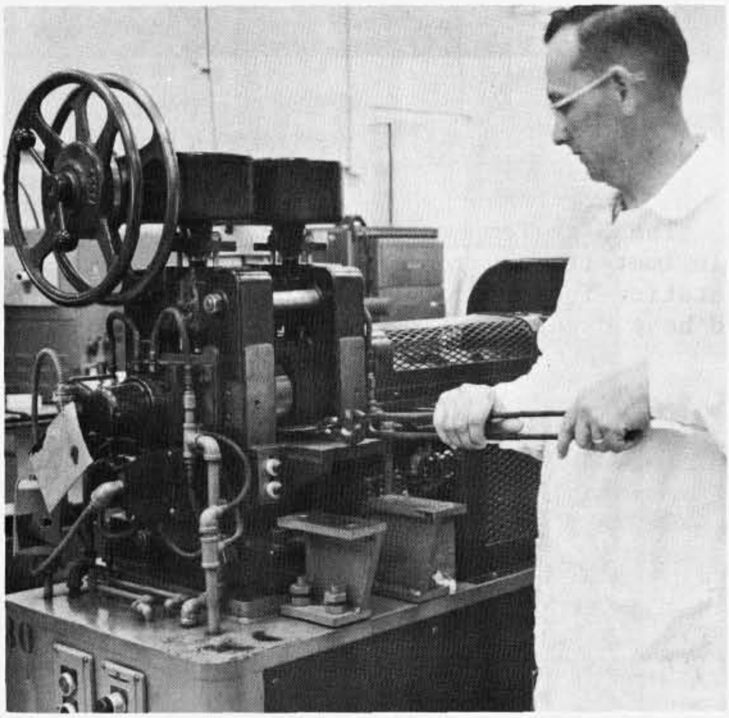
The High Temperature Thermal Property Facility includes the furnaces, calorimeters, environmental systems, power supplies, controls, and instrumentation for the determination of thermal conductivity, thermal expansion, and heat capacity of materials at temperatures from ambient to 5200°F.



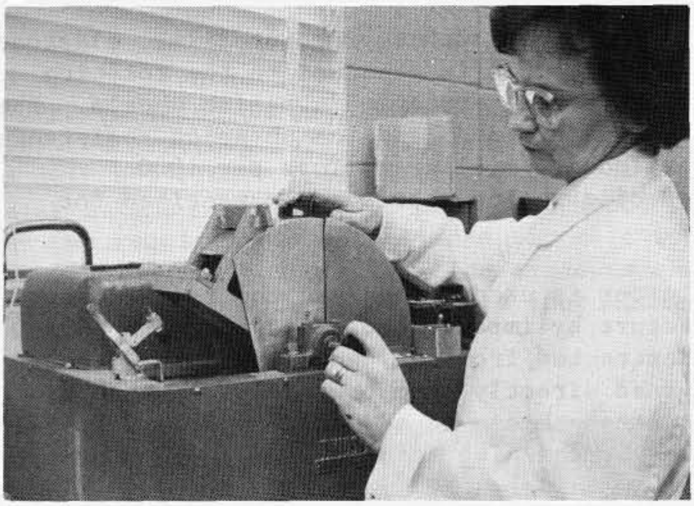
High Temperature Thermal Expansion Furnace

The Stanat Precision Rolling Mill (4-inch), a backup driven, torque arm type, can be utilized in either a two-high or four-high roll configuration. The machine can be used for either hot or cold rolling of shapes, as well as for flat stock on a reversing basis. Maximum two-high roll gap is 2 inches, maximum four-high gap is 1/4 inch. Roll adjustment can be controlled to 0.0001 inch. Separate bearing control wheels allow infinitely variable adjustment for roll parallelism, or can be locked together for synchronized screwdown. Special accessories for the mill include: (1) reversing, self-contained pay-off and recoiler; (2) conversion equipment for providing the mill with either wider or narrower width rolls; (3) heated rolls, with temperatures to 1000°F at roll surfaces attainable; (4) continuous circulating, bearing lubricating oil system.

Stanat Precision Rolling Mill

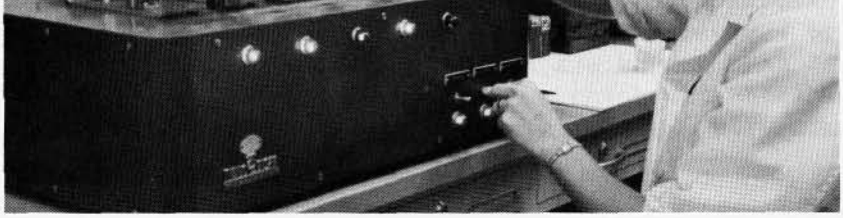


The Brittleness Tester is a completely inclosed instrument used to determine the brittleness temperature of nonmetallic materials by impact in accordance with ASTM-D 746-57T. This test is most applicable to rubbers and elastomers, and the results obtained are a measure of the stiffness or brittleness of the material at low temperatures. Although "dry ice" is generally used, almost any refrigerant would serve the purpose.



Brittleness Tester

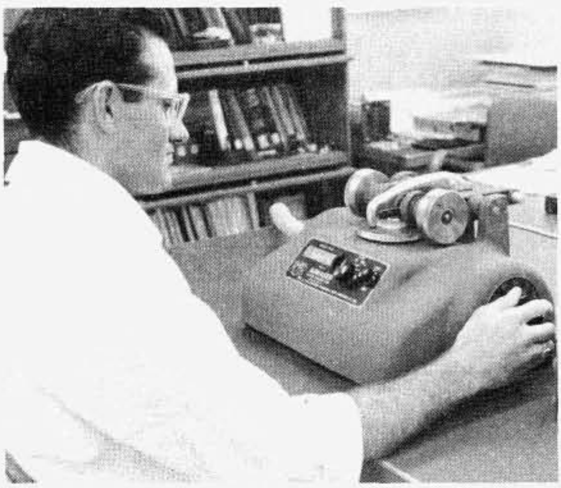
A Heat Distortion Tester is available for studies of the characteristics of nonmetallic materials under load when heated. From one to five test specimens (0.5 x 0.5 x 0.5 inches) can be tested simultaneously. The specimens are loaded as a simple beam with a predetermined fiber stress, and the deflection of the specimen is observed while being heated. Each of the five units is completely equipped with an automatic deformation indicator and thermometer, and a pilot light which indicates when a predetermined deformation is reached. The unit is heated at a constant rate of 2°C per minute, by immersion heaters in a continuously circulating bath of an appropriate heat transfer medium. All of the requirements for testing heat distortion characteristics of ASTM-D 648-56 are met by this equipment. It is possible to purchase an inexpensive conversion kit for one or more of these units, which will then measure Vicat softening point in accordance with ASTM-D 1525. Vicat and heat distortion points can be determined concurrently.



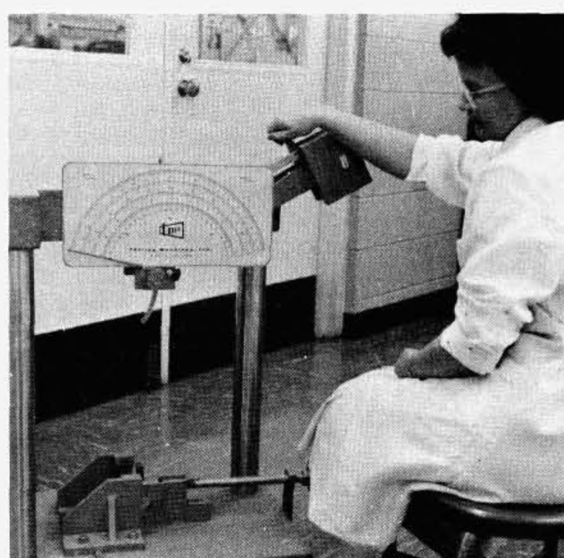
Heat Distortion Tester

The Taber Abraser measures the resistance of paint films, elastomers, plastics, etc., to abrasion. The sample is attached to the rotating table and abraded by two weighted freely-rotating abrasion wheels. The loss in weight of the sample is determined, and its abrasion resistance is usually expressed as "Wear Index" (milligrams loss per 1000 revolutions). Varying grades of abrasion wheels are prescribed for different types of materials.

An Izod-Charpy Impact Tester is used to measure the resistance of nonmetallic materials to fracture by impact, in accordance with ASTM-D 256-56. The kinetic energy extracted from the pendulum in the process of breaking the specimen is read directly from the dial. Ranges for either Izod or Charpy impact strength can be adjusted to 0-2, 0-5, 0-10, or 0-30 foot-pounds full scale by changing to different weights or types of pendulums.



Taber Abraser

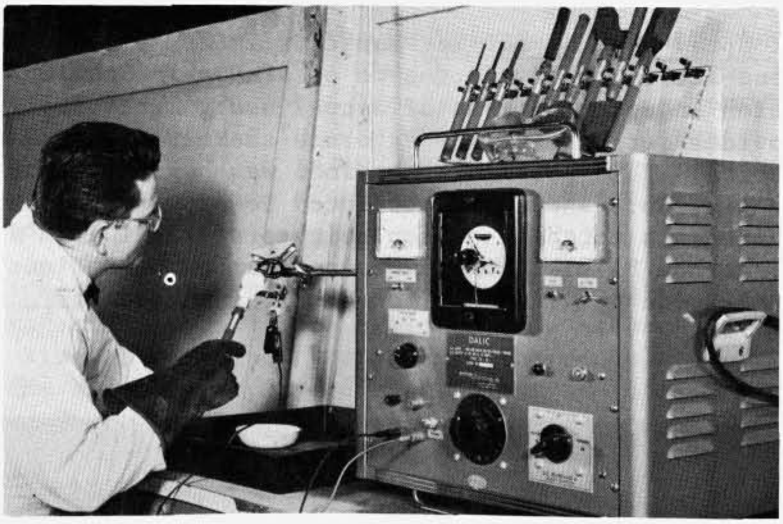


Izod-Charpy Impact Tester

The Salt Spray Testing Cabinet subjects materials and finishes to the accelerated action of a salt fog to obtain an indication of resistance to deterioration under conditions of actual use. Essentially, the apparatus provides for heating the exposure chamber and for atomizing the salt solution. This particular cabinet was built by Industrial Filter & Pump Mfg. Co., and was constructed to provide conditions which meet the requirements established for salt spray testing in MIL-E-5272 (MIL-STD-151, Method 811.1). The exposure chamber dimensions are approximately 25 inches wide by 47 inches long by 34 inches deep.

Salt Spray Testing Cabinet

In Selective Electroplating, the work is connected cathodically to a rectifier and the coating is applied by brushing the work with a solution-soaked swab wrapped around an anodic stylus. Relatively small areas are generally plated. The coatings are characterized by extremely low porosity, and have a higher density and are harder than bath deposits; however, the deposits are not bright and the thickness obtainable for certain metals is limited. The rectifier is mobile and requires much less space than the bath-type unit.



Selective Electroplate

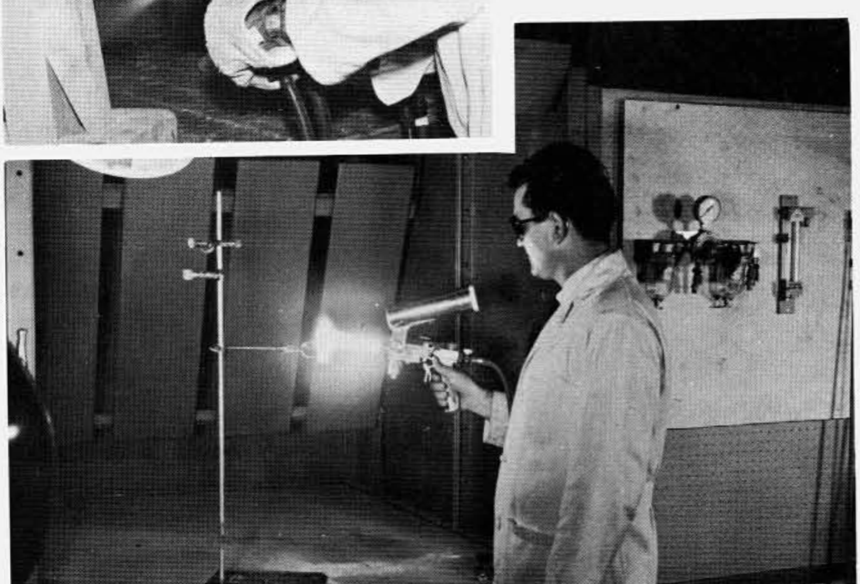
A Laboratory Hydraulic Press is available for general laminating, molding, and testing of nonmetallic materials. Its 12 x 12 inch platens are electrically heated and individually controlled at temperatures up to 600°F. Pressures up to 30 ton (ram) are achieved through a two-stage manual pump. This press is frequently used for molding of test specimens, reinforced laminates, and rubber items.

In the Flame Spray Facilities, a plasma arc or oxyacetylene flame is used to spray molten particles of metal or ceramic materials in the manner of paint to form continuous metal/ceramic coatings. With the plasma arc, the coating materials are fed into the flame in the form of wire or powder, melted by the high temperature flame, and propelled out of the gun at high velocities by the combined forces of combustion heating and applied gases. The material fed into the oxyacetylene flame is also in the form of wire or powder, and is melted by the flame and blown against the surface to be coated. The molten particles solidify at the instant of contact and form a tightly adhering coating. These coatings are used to protect rocket nozzles, bearing surfaces, flame shields, and any other components or portions which require protection from abrasive wear, erosion, and extreme temperatures. Almost any material can be sprayed by these processes if it is obtainable in wire or powder form. Steel, zinc, aluminum, tin, lead, brass, nickel, chromium, tungsten, and molybdenum are among the most commonly sprayed metals. The use of ceramic spraying is increasing, and includes materials such as alumina and zirconia.

Hydraulic Press

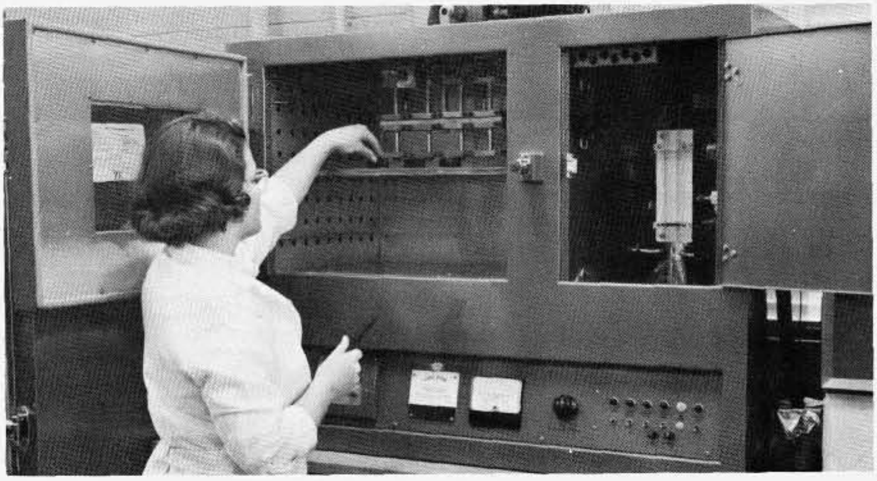
Plasma Generator

Oxyacetylene Flame Sprayer

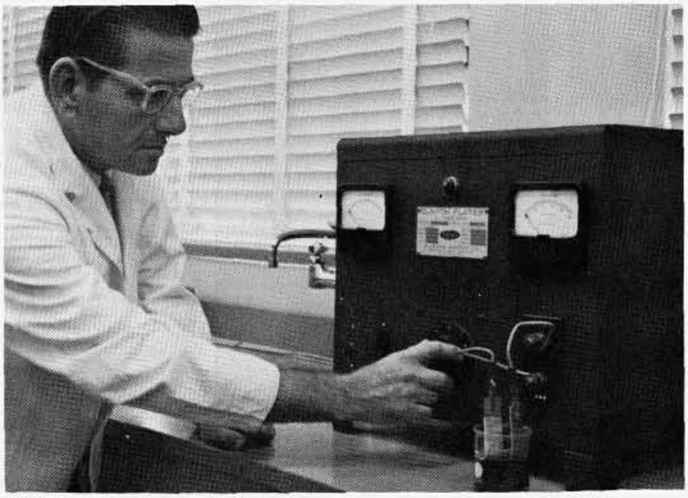


The Ozone Test Chamber is used to determine the resistance of organic materials to ozone deterioration. This equipment is capable of generating and controlling ozone concentrations accurately between 15 and 1000 pphm.

The Clinton Electroplater is rated at 0-9 volts dc, and has a current capacity up to 150 amps. The unit is classed as laboratory size -- limited to parts with a total surface area of approximately 1 square foot. Plate metals deposited with this unit include copper, nickel, cadmium, tin, zinc, and chromium. Plating solutions are not maintained as in a production facility, but are made up as the requirement arises. Tanks and other associated hardware necessary for complete operation are standard chemical laboratory equipment.

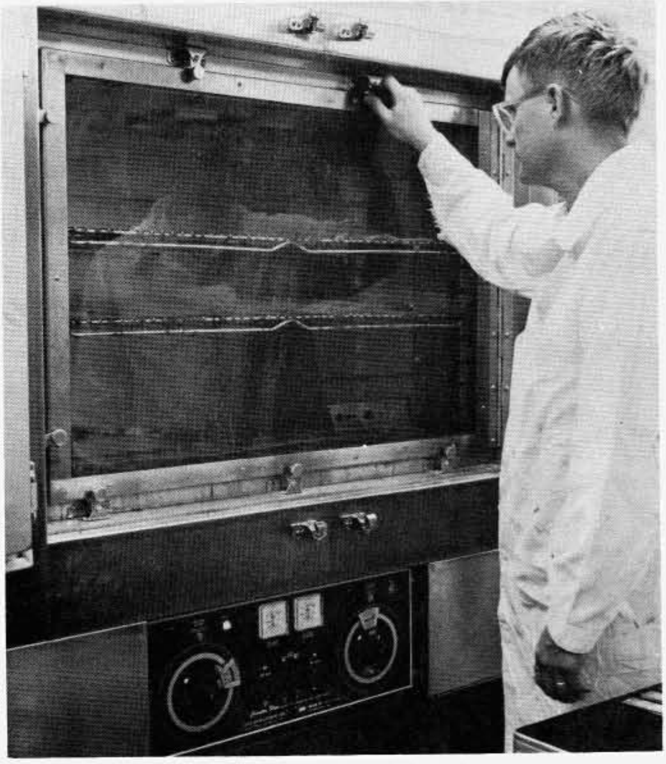


Ozone Test Chamber



Clinton Electroplater

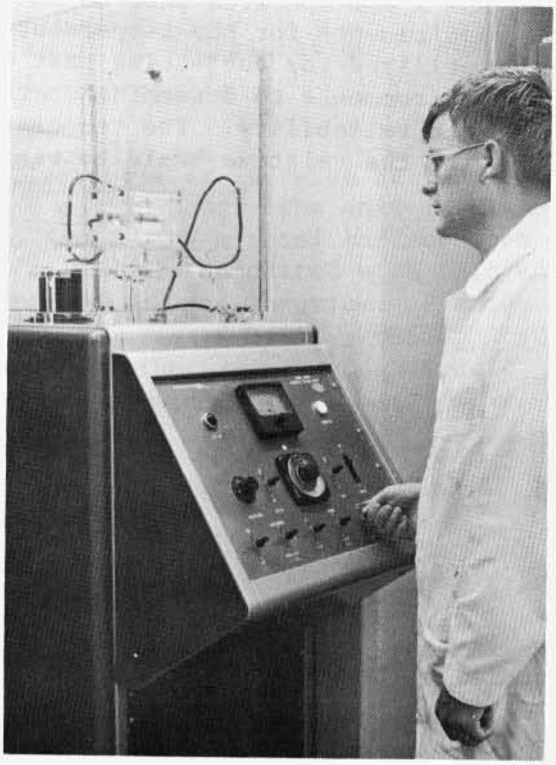
The Humidity Chamber has a cam-operated program controller that conforms to MIL-STD 202B requirements for the temperature and humidity cycles. This equipment is utilized for subjecting test components to various simulated natural environments to determine operational capabilities, life expectancy, and reliability. The temperature range for the unit is -10°C to 93°C with the relative humidity range from 20 to 98%.



Humidity Chamber

The Hypot Materials Tester is used for determining dielectric strength of insulating materials such as tapes, varnishes, oils, electrical cord insulation, film, and sheeting. It is capable of producing a potential of 50,000 volts between two electrodes. Voltage may be increased manually or automatically at a rate of up to 1000 V/sec. Other controls allow the voltage to be decreased or held constant. When the test specimen fails, automatic circuit breakers de-energize the circuits, and a memory circuit indicates the breakdown voltage.

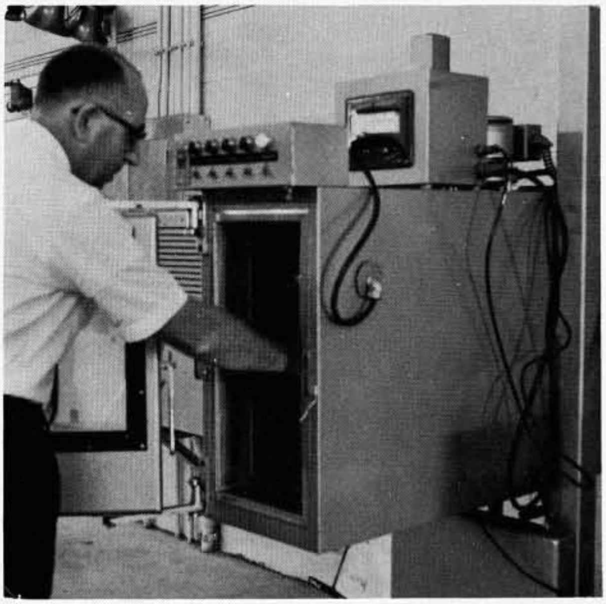
A Two-Roll Rubber Mill, laboratory size, is utilized for blending small size batches of rubber. Its 5-inch-diameter by 12-inch-long rolls are heated or cooled, as needed, by the heat exchanger-pump assembly seen at the left.



Hypot Materials Tester


Rubber Mill

The Missimers Test Chamber is a portable chamber that is used with the Instron Test Machine to provide high and low temperature test capability. The temperature range of this chamber is $-100^{\circ}$ to $1000^{\circ}F$ with a temperature gradient of 5 to $7^{\circ}$ after stabilization. The heat-up rate is from $80^{\circ}$ to $1000^{\circ}F$ in 45 minutes, and cool-down rate is $80^{\circ}$ to $-1000^{\circ}F$ in 30 minutes.



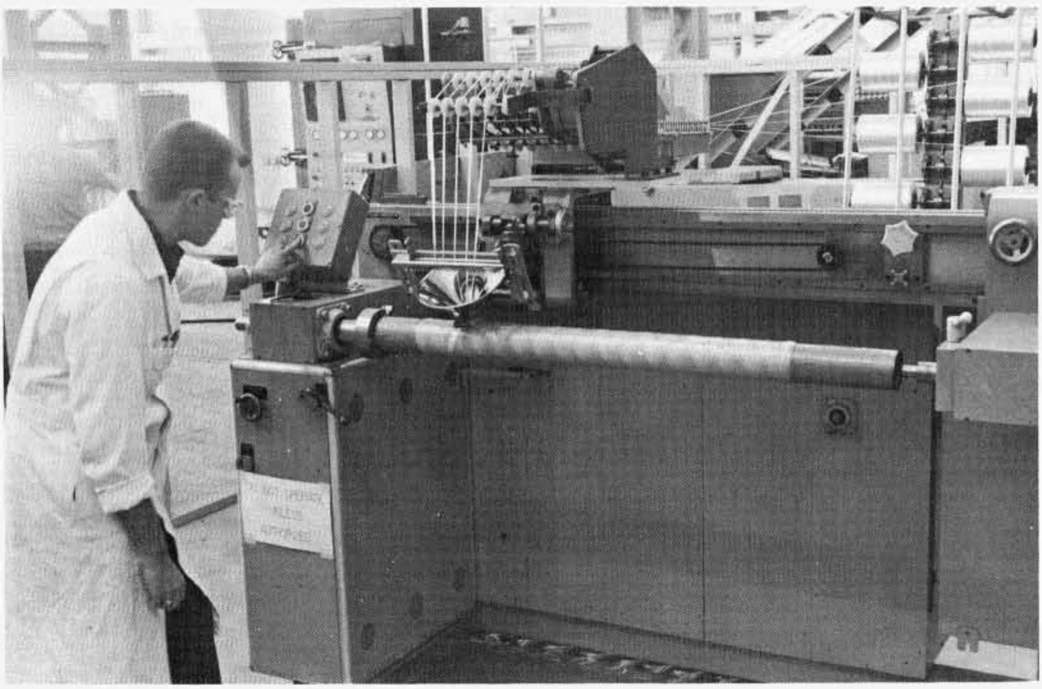
Missimers Test Chamber



Hydraulic Press

A Laboratory Hydraulic Press is available for heavy duty general purposes such as molding and laminating of nonmetallic materials. The press is equipped with electrically heated platens variable between 0 and $800^{\circ}F$. These platens measure 12 x 15 inches, and the maximum force between the platens is 100,000 pounds. The pressure may be preset and is maintained automatically even when working with compressible materials. Maximum adjustable opening between platens is approximately 20 inches.

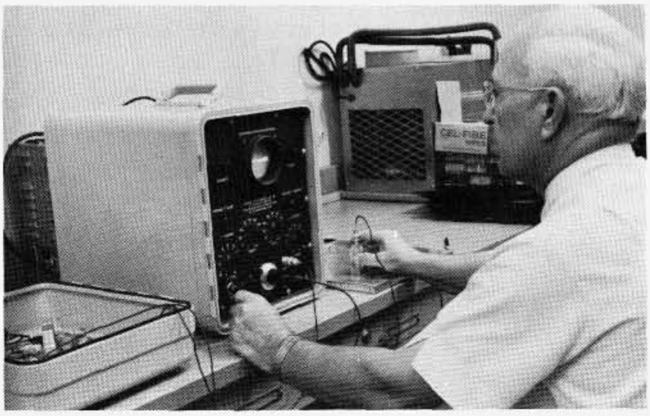
The Filament Winding Machine has the capacity to wind numerous shapes up to 22 inches in diameter by 60 inches long as well as ASTM, NOL, and 18-inch-diameter ABL-type pressure vessels and test specimens. Fiber delivery can be made from up to six spools of either single-end yarn or 8-, 12-, 20-, 30-, or 60-end roving (wet or pre-preg) up to a 1-inch-wide band. The machine includes full console for manual and semiautomatic control, with special attachments for programmed stopping after predetermined circuits or layers of fibers, programmed carriage reversal, additional wetting system for maximum fiber wetting, separate carriage delivery programming for variance from helical and geodesic paths and for local buildup without loss of pattern.



Filament Winding Machine

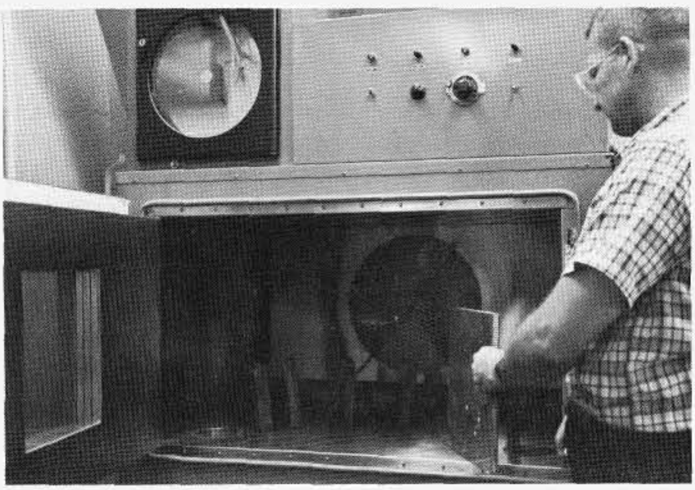
The Coinda Scope Ultrasonic Inspection Instrument is a portable, self-contained instrument engineered for efficient testing of bonded and welded structures. The circuit has been especially designed for inspection of adhesively bonded structures, and offers the advantage of simplicity of adjustment and operation. A piezoelectric crystal is driven by a variable frequency current of constant amplitude. The voltage developed across the face of the crystal is proportional to the amplitude of the crystal's vibration, and is displayed as a function of the frequency on the face of the oscilloscope. Thus, the pattern shown on the oscilloscope relates characteristics of the crystal's vibration.

When the crystal is acoustically coupled to a bonded panel, information regarding the panel's vibration and resistance to vibration, and therefore its physical characteristics, are shown on the oscilloscope. This instrument can also be used to check the strength and quality of certain spot welds and to inspect brazed honeycomb sandwich panels in restricted applications.



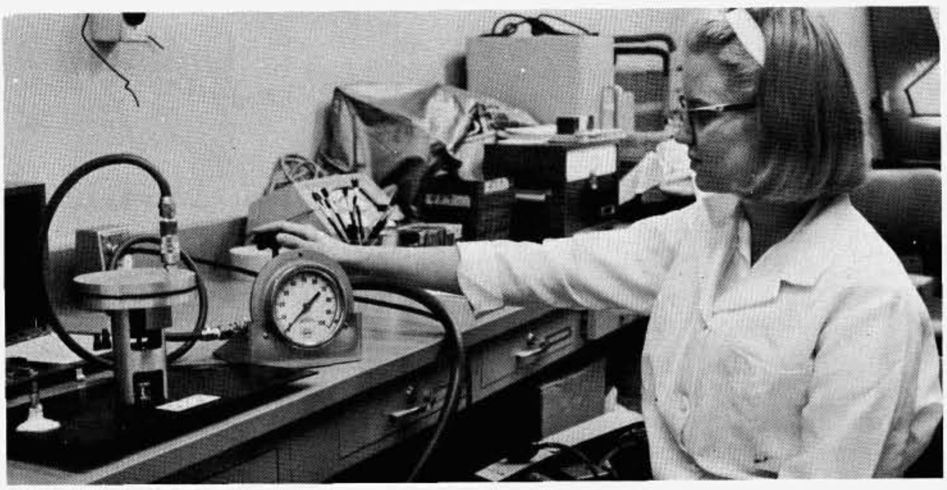
Coinda Scope

The Hotpack Temperature Chamber has a range from -100° to 400°F, and will maintain any temperature in that range to ±5°F. The chamber size is 36 x 24 x 20 inches, which will allow small components as well as test samples to be aged at a particular temperature or cycled over the temperature range.



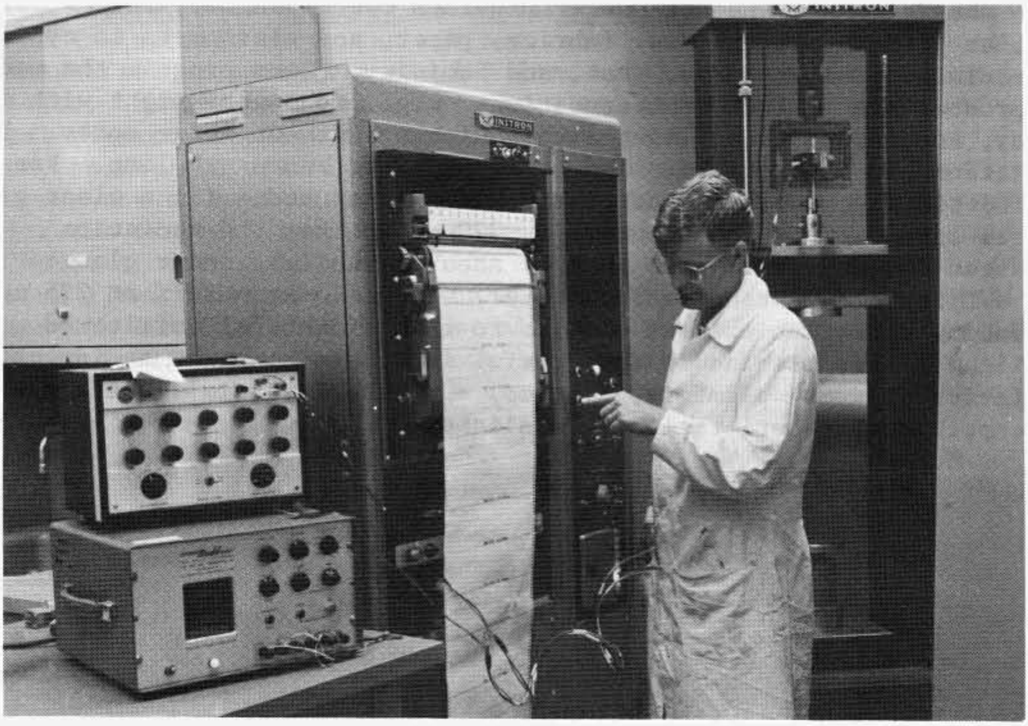
Temperature Chamber

The "Porta Pull" Fillet Quality Tester is a semi-nondestructive fillet quality testing apparatus used for determining the quality of bond between the outer skin and the core of an adhesively bonded honeycomb panel. This is accomplished by applying a progressively greater tension on a test button cemented to a 1-square-inch round coupon of the skin until separation is achieved. The pressure gage is constructed so that the reading at separation is recorded. This apparatus can also be used in testing brazed panels in a similar manner, except the coupons are not cut out of the skin. Predetermined loads are applied to the adhesively bonded buttons, and if the load does not separate the skin from the core the panels are considered acceptable.



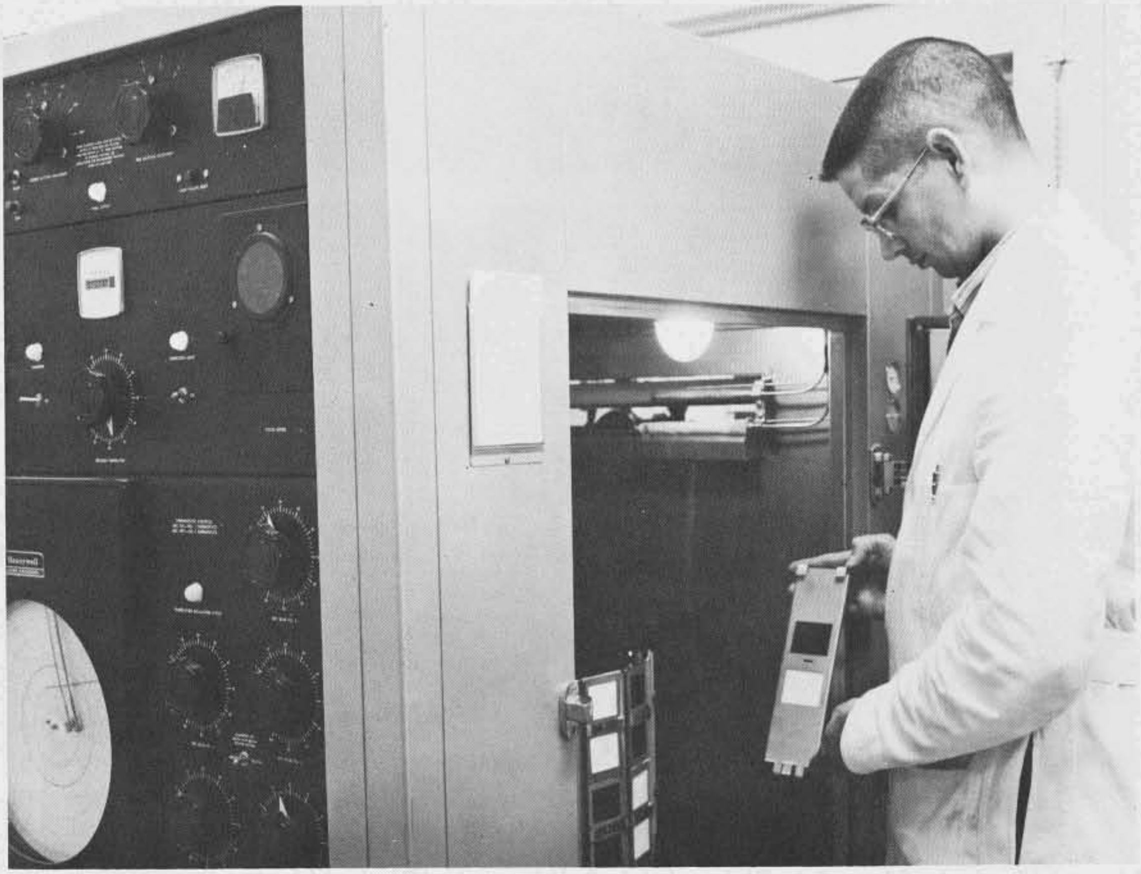
"Porta Pull" Tester

Two Instron Universal Testing Instruments are available, one a floor model, split console design and the other a single unit type. Both have a 10,000-pound capacity; by interchanging load cells, a multiple selection of load ranges -- down as low as 2 grams full-scale -- can be obtained. Testing speeds range from 0.02 to 20 inches per minute, and chart speeds from 0.2 to 50 inches per minute. The large assortment of jaws and jaw faces makes it possible to hold most materials and structures for testing. This instrument is especially suited to the testing of adhesives, laminates, rubber, and other elastomeric materials, but it can be used in metals testing and in an almost infinite number of special tests which require compression or tension.



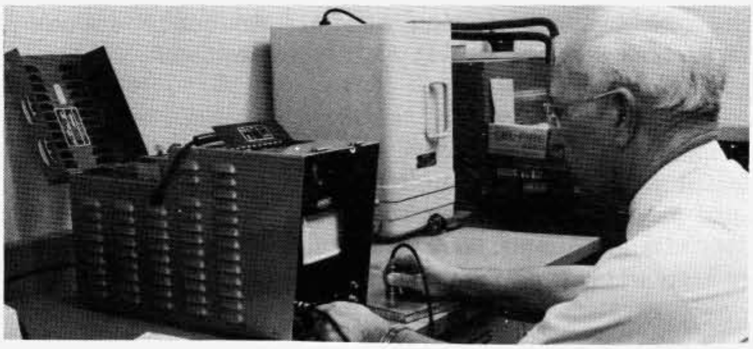

Instron Universal Testers

The Xenon Arc Weather-Ometer provides the capability for exposing samples of plastics, paints, fabrics, paper, and elastomers to cycles of radiation, water spray, heat, and humidity. Cams program the machine to produce the desired test conditions, e.g., no light, light with water spray, and period of no light either with or without water spray. The radiation and heat are supplied by a 2500-watt xenon arc lamp. For normal testing, two types of glass filters are used: (1) a clear glass filter tube, with a lower cutoff at 320 mμ so that the radiation produced is very similar to that of natural sunlight under glass; (2) a Pyrex or UV transmission filter, with a lower cutoff at 275 mμ, producing radiation that is similar to that of natural unfiltered sunlight. This machine is also useful in determining the fading characteristics of dyes, pigments, fabrics, and other materials which are susceptible to deterioration by sunlight.



Weather-Ometer

The Sonoray Flaw Detector is an ultrasonic instrument which employs sound at frequencies above the audible range, and is used for nondestructive inspection of materials ranging from metals to organic tissues. It detects, locates, and evaluates flaws and certain structural and physical characteristics, and measures thickness. It is a lightweight, compact, portable, versatile, sensitive, rapid, and economical instrument which presents no radiation hazards. It is essentially a flaw detector, used for the internal inspection of any material capable of propagating sound waves at frequencies above 400 kHz/sec. It can be utilized in detecting flaws by straight beam or angle beam, or through transmission or immersion testing. The Sonoray, although slightly more difficult to adjust and calibrate than the Coinda Scope, is considered to be a more versatile instrument in that there are many accessories available as attachments for specialized testing.



Sonoray Flaw Detector

STRESS AND THERMODYNAMICS BRANCH

*Capabilities:*

The Stress and Thermodynamics Branch is concerned with the performance of highly technical and intricate stress analysis of thin-shelled spherical, conical, and elliptical structures, and of other bodies of revolution. Analysis is performed on monocoque, semi-monocoque, corrugated, composite, or beam system structures, all of which may be subject to bending loads, internal or external pressure, shear, inertial forces, and external loads. Consideration is given to discontinuity stresses resulting from variations in shape, thickness, composition, and thermal environment of materials. Theoretical calculations and mathematical derivations directly concerned with the thermodynamics and heat transfer problems of high-speed missile structures are computed and substantiated experimentally. Accomplishments include the production of original programs necessary for complete design. Research is performed in these areas to maintain a capability of structural design for the most severe conditions, including hypervelocity vehicles in a nuclear environment.

## MISSILE DESIGN BRANCH

*Capabilities:*

The Missile Design Branch designs and develops missile airframes, protective structures, and mechanical and electrical components. Exploratory development involving analytical methods and experimentation is aimed at developing design techniques which can be automated. Capabilities include developing a design from preliminary theoretical calculations and feasibility studies through coordinating fabrication and assembly of components, establishing an experimental program, conducting experiments, and evaluating component performance. Preliminary working drawings and mass characteristics data are provided to other elements. The results of the combined study are coordinated into design prototype configurations. If the project is accomplished in-house, detailed design of the prototype is started; if the program is to be carried out by a contractor, a technical development plan is derived from the preliminary design study. Adequate documentation is maintained to assure reproducibility in production.

*Facilities:*

The available equipment includes a hydraulic actuated static load fixture, 1500 psi capacity; a pneumatic test bench; experimental stress equipment for strain gage applications; and oscilloscopes, pressure gages, etc. for use with this equipment and breadboard experimental setups.

# GROUND SUPPORT EQUIPMENT LABORATORY

The Ground Support Equipment Laboratory, as the name denotes, is concerned with the research, engineering, and development of missile ground support equipment. Quoted here, to indicate the scope of its mission and functions, is the definition of ground support equipment that is recognized and used by the laboratory's scientists and engineers: "The technology and hardware required to support a missile system from the time the missile leaves its place of origin until its mission is accomplished."

The laboratory is required to deal with whole Army weapon component systems and with very small components. It evolves and analyzes new system concepts and performs research and development leading to the advancement of technology in functional support areas, and provides all such support required to maintain the functional operating status of the weapon system. Missile system requirements in specialty areas are developed and evaluated from the standpoint of technical feasibility and functional adequacy, for future as well as current systems. Such evaluations are based on technical and test requirements and acceptance criteria established by the laboratory. If required, component systems in these specialty areas are designed and developed. In its assigned areas, the laboratory also prepares contractual requirements, evaluates proposals, and exercises technical supervision over contractor efforts.

The laboratory is organized into a Research and Technology Office, which assists the Director by developing overall plans and coordinating all technical programs within the laboratory, and eight operating branches:

Preliminary Design

Aircraft Weaponization Design

Launch Systems

Electrical Design

Launch and Handling Equipment Design

Requirements and Analysis

Container and Auxiliary Equipment Design

Test and Checkout Equipment Design.

## PRELIMINARY DESIGN BRANCH

The Preliminary Design Branch plans and conducts design studies and performance evaluations of system concepts for use in advanced missile system syntheses and feasibility studies in surface-to-surface and surface-to-air areas. It plans and conducts or directs supporting research and component development effort internal to the laboratory, and performs or directs preliminary designs in GSE areas. Other responsibilities include establishing the key criteria for advanced weapons systems and their relative weights for trade-off studies in areas such as cost, weight, accuracy, reliability, safety, and performance. The branch also coordinates requirements and design criteria for advanced weapon systems with other branches in the laboratory, and serves as the central point for design synthesis for such systems.

## AIRCRAFT WEAPONIZATION DESIGN BRANCH

The Aircraft Weaponization Design Branch conducts studies to maintain cognizance of the state-of-the-art. It recommends, initiates, and determines concept areas of aircraft weaponization for developmental or research programs. It participates in formulations of command, R&ED, and laboratory policies on aircraft weaponization, modifications, or missile system aircraft utilization. It performs research, design analysis, detail layouts, component design, system studies, and development programs with respect to aircraft-mounted missile weapon systems less the missile. These functions are also performed for the aircraft interface functions of other aircraft-mounted equipments in support of the other laboratories of R&ED. Research, concept, design, and development are performed for optimized missile reload systems for both aircraft- and surface-mounted missile and rocket systems.

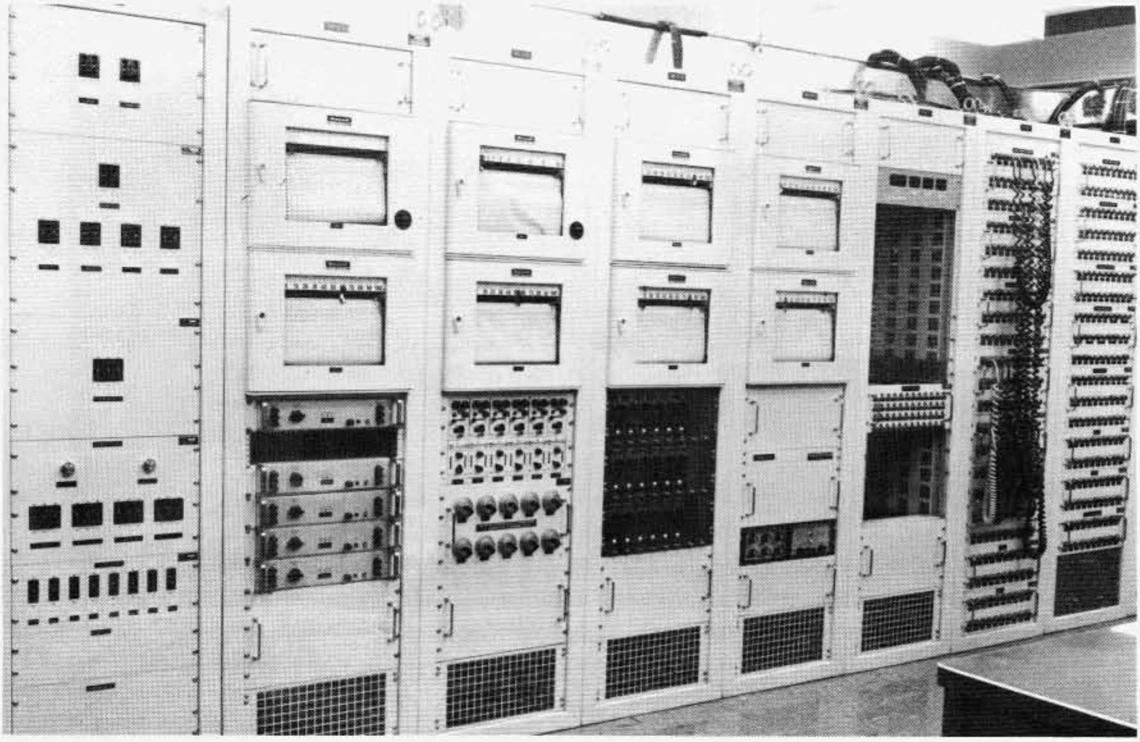
## LAUNCH SYSTEMS BRANCH

*Capabilities:*

The Launch Systems Branch is responsible for assembly, checkout, modification, operation, and evaluation of weapon systems; operation and assignment of Crane Bay Space (Building 5400) for R&E activity. This also includes installation, calibration, and operation of the instrumentation complex (Building 5400) in support of GSE Laboratory and other laboratories. The organization prepares operational procedures on prototype weapon systems and special hardware. A field shop is maintained for minor fabrication and for modification of prototype launchers and other hardware for checkout and evaluation purposes.

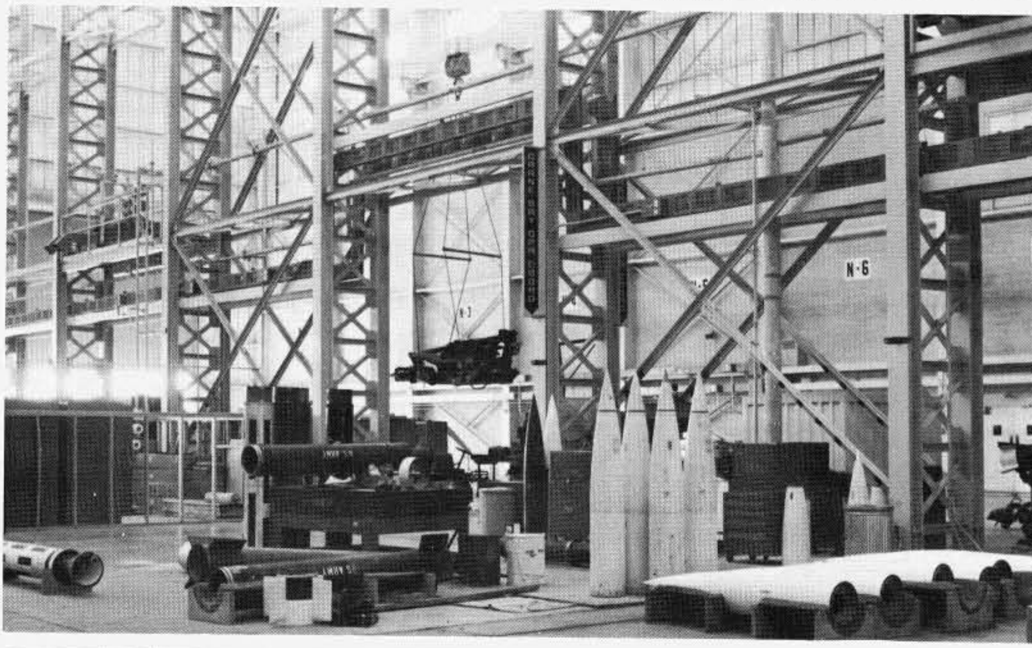
*Facilities:*

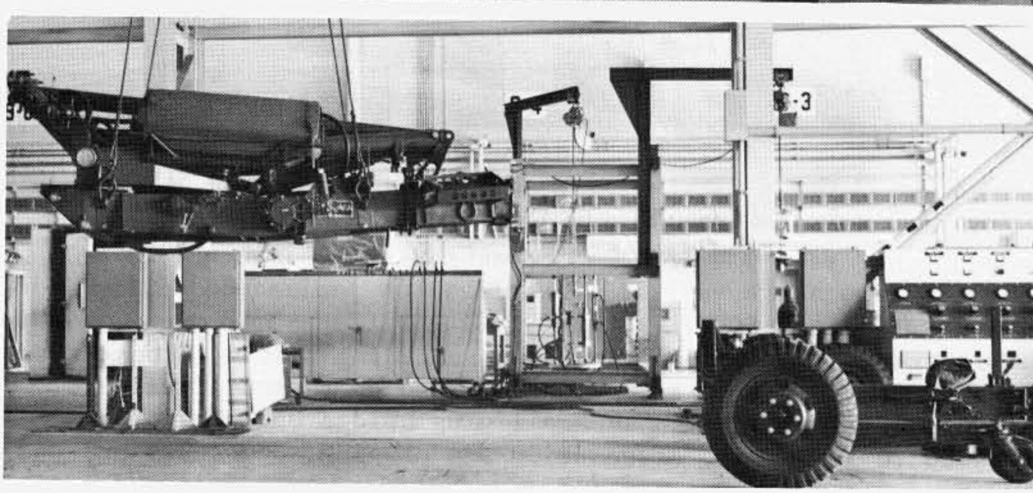
The Crane Bay, in Building 5400, houses the general checkout and assembly area. Total usable floor space is 420 feet long by 120 feet wide (50,400 sq ft). A total of five 20-ton overhead cranes, spanning 60 feet, are used to support activity in this area. Four cranes with 50-foot hook height are located in north and south bays (2 each). One crane with an 80-foot hook height services an area 60 feet by 60 feet in the northwest corner of the north bay. Access is provided by 35-by-35-foot roll-up doors at each end of both bays, as well as by normal personnel doors.



Recording Instrument Center Showing Amplifiers, Signal Patching System, and Power Distribution Center

The instrumentation complex has two recording systems, located on two different floors (first and second). Through the utilization of the various conditioning media -- amplifying bridge balance, thermocouple reference junctions, attenuation and damping, demodulation, and filtering -- and the various means of recording -- oscillographs, tapes, analog-to-digital, and strip chart -- the system has a testing capability of 300 channels of data. Consoles are provided at several locations for connecting instrumentation leads to items undergoing tests.

Views of Crane Bay

A source of compressed air is available from pneumatic console taps for pressures up to 5000 psi, as well as a hydraulic facility for up to 300 pounds of pressure and 3 gallons per minute.

Power outlets are provided in all areas of the Crane Bay, with the following types of power available: 440/220, 60 cycle; 208/110, 60 cycle; 208/110, 400 cycle; 28 volts dc (General Service and Precision).

A Staging Area facility, located approximately 500 yards east of Building 5400, consists of 12,360 sq. ft. of building area and 64,900 sq. ft. of open area enclosed by a security fence. This area is used for the retention of those components and subassemblies adaptable to multisystems development programs and modification of systems during the R&E phase, which is essential to a quick response capability. This facility also accommodates the placement of system hardware between tests and firings. In addition, it is used for special operations, and serves as a field shop for the modification and integration of GSE missile system items.

## ELECTRICAL DESIGN BRANCH

*Capabilities:*

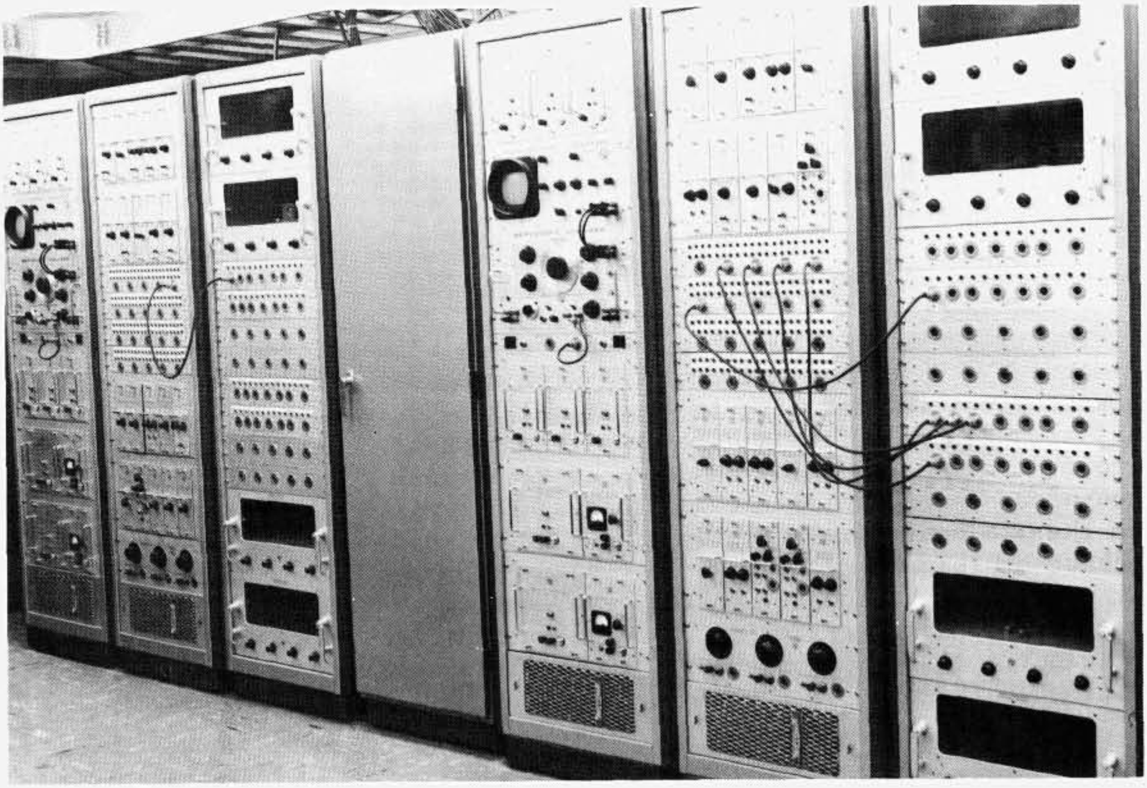
The Electrical Design Branch does feasibility studies, advanced and engineering development, prototype system and subsystem design, and laboratory testing for missile electrical ground support equipment, aircraft armament, and fire control for free rockets. All phases are performed from determining concepts of electrical systems and subsystems through hardware development and testing to reviewing of changes received from the fielded units. Systems and subsystems have included missile checkout equipment, nuclear and conventional power plants, maintenance test equipment, helicopter rocket fire control systems, missile launcher electrical controls for azimuth and elevation, fixed wing aircraft armament electrical system engineering, missile system ground networks, and training equipment.

Besides the in-house laboratory work, technical supervision is performed on work contracted to universities and aerospace industries for research and development of missile electrical support and test equipment.

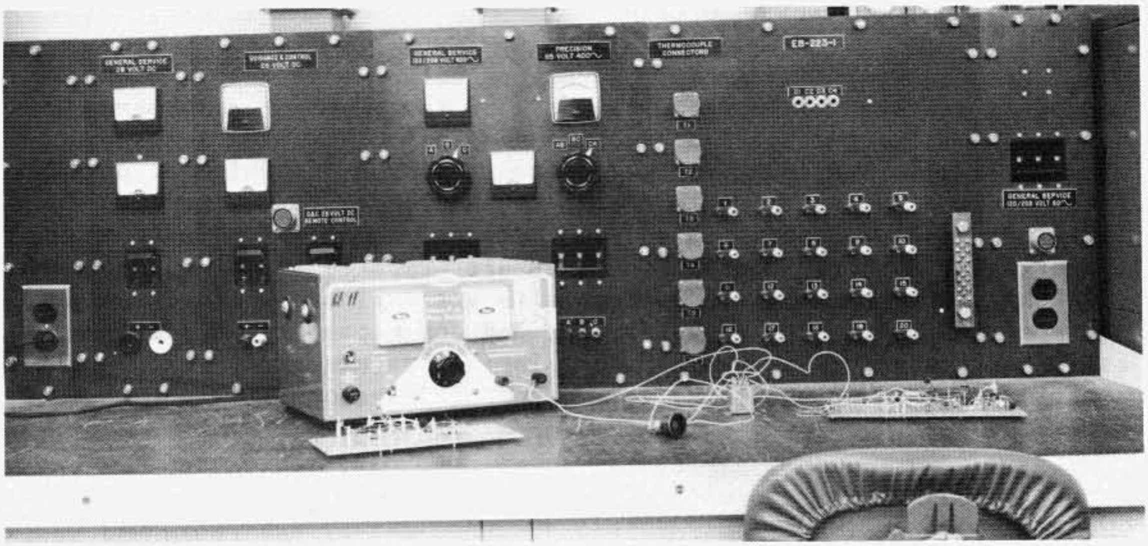
*Facilities:*

The branch has been arranged within five rooms, each 25 by 19.5 feet. The rooms are provided with work benches, interconnecting panels, and necessary office equipment.

The Electrical Laboratory is equipped for testing and using transistor and microelectronic devices; such as, switching circuits, static power supplies, amplifiers, and oscillators. Breadboard and prototype development testing is done. The equipment includes precision power supplies, signal generators, recorders, high speed counters, oscilloscopes, strobotacs, a servomechanism laboratory, and various meters and instruments. Various temperature controls and an environmental chamber permit a wide variety of operating conditions to be simulated. Large systems can be tested in the Crane Bay with interconnection to subsystems on the laboratory bench. Also available is a pneumatic system which can be used in testing combination pneumatic-electrical control systems.



Servo Synthesis Equipment Designed for the Rapid Assembly and Testing of Control Systems by Simulation with Standardized Components



Typical Laboratory Workbench with Power Supply Instrumentation and Signal Patching System

LAUNCH AND HANDLING EQUIPMENT DESIGN BRANCH

The Launch and Handling Equipment Design Branch provides design and development support to missile and free-flight rocket weapon systems in the area of mechanical launch and handling equipment for R&E firings, qualification and feasibility testing, system compatibility testing, and prototypes of tactical items. The work includes: research for new missile launching methods and techniques; studies of camouflage, deployment time, rocket motor blast, and effects of rocket blast on launchers and surrounding equipment, including forces, temperatures, and overpressures; design and development of missile launchers and erectors for guided and free-flight missiles and rockets; devising methods of erecting the missiles on the launcher; design and development of blast shields and deflectors for missile systems ground support equipment.

The branch also performs load, stress, weight, and balance analyses for launchers, loaders, erectors, and special purpose vehicles; and conducts computer simulation programs investigating the sensitivity of design parameters of launchers, trailers, and vehicle suspensions and hydraulic systems. The branch is responsible for performing or directing the design, development, testing, and installation of mechanical equipment for handling and servicing missiles and free-flight rockets, and electromechanical firing accessories (disconnect systems for ground-to-missile cables). Acceptance criteria are established for assigned equipment, and functional tests are performed to determine adequacy.

## REQUIREMENTS AND ANALYSIS BRANCH

The Requirements and Analysis Branch establishes design requirements for missile system ground support equipment major components based on Qualitative Materiel Requirements and other user requirements documents. The branch makes theoretical analyses of equipment performance to use as a basis for the establishment of test requirements and to aid in test analyses. Objectives and requirements for environmental, operational, dynamic, and static tests are prepared to establish proof of feasibility and design. Test results are evaluated, performance is compared against design requirements, and any necessary corrective actions are recommended. Aiming and laying systems are developed for missile systems not utilizing active inertial sensors within the missile for these functions.

## CONTAINER AND AUXILIARY EQUIPMENT DESIGN BRANCH

The Container and Auxiliary Equipment Design Branch designs and develops containers for all types of missiles and rockets (less the warhead section). This effort includes selection of materials and the complete structural design and qualification of units containing shock and vibration isolation systems or environmental control systems. It conducts feasibility studies, evaluates test results to qualify design, and prepares the specifications and engineering drawings. It assists in preparing detailed technical and test requirements. Significant among the responsibilities of this branch are those of providing and implementing for worldwide use special preservation, packaging, packing, transportation, and storage methods; selecting or designing, developing and evaluating methods and equipment for the transporting, storing, transfer, and cleaning of compressed gases, missile fuels, and oxidizers; designing and developing ground hydraulic equipment, pneumatic equipment, and missile shelters; and determining missile systems requirements for heating and air-conditioning equipment.

## TEST AND CHECKOUT EQUIPMENT DESIGN BRANCH

The Test and Checkout Equipment Design Branch plans, conducts, and evaluates studies to define test requirements and establish test equipment capabilities for maintenance of missile systems. The branch coordinates test and checkout equipment requirements, capabilities, and programs within MICOM and provides a technical focal point for coordination with outside activities. Additionally, the branch conducts technical trade-off analyses between various proposed maintenance concepts and equipment. Supporting research and component tasks for advancing the state-of-the-art for missile system test and checkout equipment and test techniques are planned and conducted or directed.

# REDSTONE SCIENTIFIC INFORMATION CENTER

The Redstone Scientific Information Center operates in support of the technical activities and facilities of the U. S. Army organizations located in the Huntsville area and the NASA George C. Marshall Space Flight Center. Organizationally it is one of the elements of the Research and Engineering Directorate of the Missile Command. Use of the Center's services extends the capabilities of the laboratories and other technical facilities by providing library services, information research, and translations.

The Center serves as the principal source of classified and unclassified information on basic and applied research, in all areas of interest in missile and space vehicle development, not only for the Army organizations and MSFC, but also for their contractors. Holdings presently number about a million documents and over 140,000 catalogued books and volumes of periodicals; monthly acquisitions average over 10,000 new documents and 2,000 books. Standing orders placed with publishing houses call for advance copies of technical and scientific books in the fields of chemistry, physics, engineering, mathematics, and astronautics. Reports are received from many sources immediately upon issuance. More than 2,800 different scientific, technical, and professional journals from more than 30 countries are received regularly.

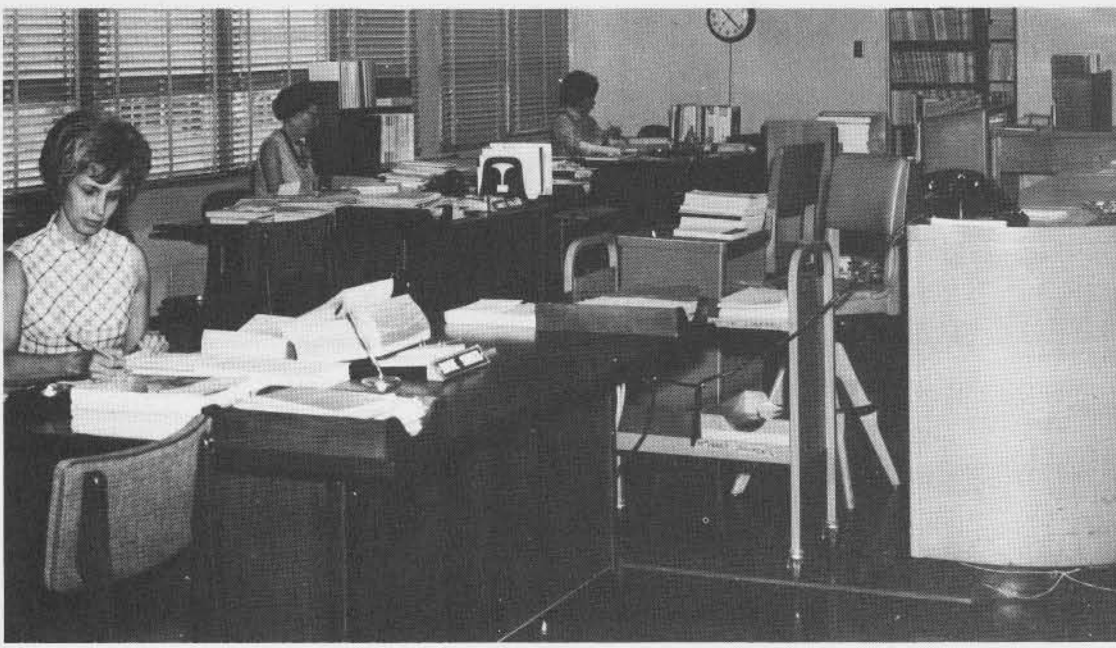
Book Circulation Desk

All of the traditional services of a major scientific library are available with respect to both unclassified and classified data. An extensive collection is maintained for reference use within the Center at all times by means of noncirculating copies. Copies of items are loaned, reproduction facilities are furnished for patron use, and a reference staff is available to assist patrons with their information problems. Items unavailable in the local collections are obtained from other organizations by interlibrary loans.


Corner of Main Reading Room

A number of special services are available from the library and from the other branches of the Center:

- Copies of reports and articles from other sources are provided to patrons on request.
- Current periodicals are regularly routed to Army and NASA patrons who must stay abreast of advances in their technical fields.



Reference Librarians in Documents Section
(circulation desk at right)

- Literature research resulting in evaluation surveys and summaries is available on a cost reimbursable basis.
- Translation service is available on both an in-house and contract basis. In-house capabilities emphasize German and Russian, but limited help can be furnished in a number of other languages. Immediate informal assistance is available for those who need only facts; more formal translations are prepared when required.
- Weekly lists of recent classified and unclassified acquisitions, translations completed, and literature surveys underway are published and distributed to patrons.

Mechanized Microfiche Files

The Center uses many modern information handling techniques; most apparent to the patron are those involving microforms and computer searches. In the case of the latter, bibliographies on many topics are produced by mechanical means.

# ROHM AND HAAS COMPANY

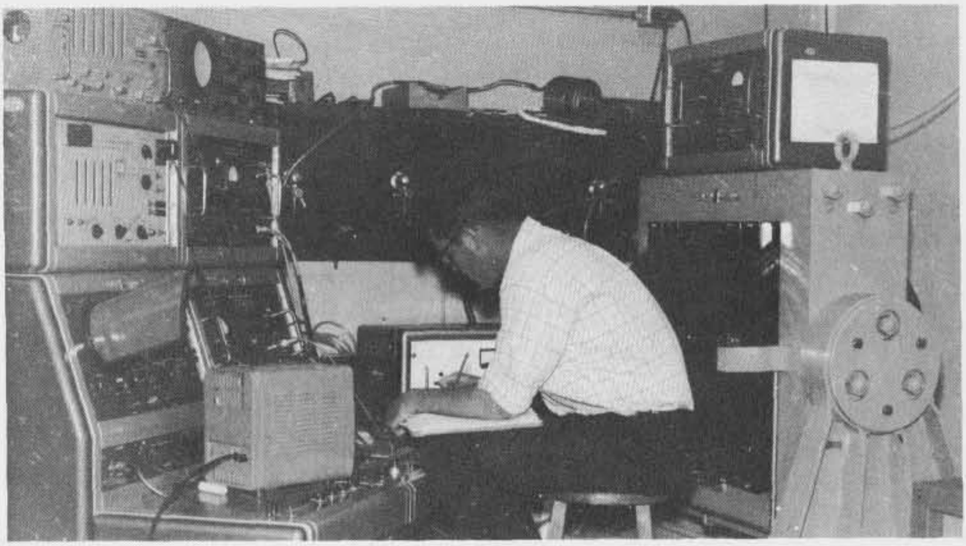
## Redstone Research Laboratories

The Redstone Research Laboratories of Rohm and Haas Company, under contract with the Department of the Army, operate a Government-owned facility conducting research and development on chemical propulsion for Army missile systems. The programs include basic and applied research on solid propellants, research and development on solid propulsion systems, and a variety of services in the area of chemical propulsion to meet Department of Army needs. These three areas of effort -- propellant research, propulsion research and development, and services -- involve a broad-base study of propellant properties, ballistic measurements, and the development of standardized testing procedures.

Gorgas Laboratory

### CHEMICAL RESEARCH

Gorgas Laboratory contains 22 individual chemical laboratories, all of which have been specially designed to allow potentially hazardous reactions to be carried out with maximum safety. Most of the laboratories are equipped with vacuum benches for gas phase reactions at low temperatures. Twelve reinforced concrete cells, completely isolated from the laboratory, are available for particularly hazardous or scaled-up reactions.



Characterizations of New Materials Include n.m.r. Spectroscopy.

Equipment available for analysis of new compounds includes: a Consolidated 21-620 mass spectrometer; two nuclear magnetic resonance spectrometers (a Varian A-60 and a Varian HR-40) with associated spin-decoupling and signal-averaging accessories; an electron paramagnetic resonance spectrometer (Varian V4502-11); Perkin-Elmer Model 521 and Model 137 infrared spectrophotometers; a Perkin-Elmer Model 303 atomic absorption spectrometer; a Beckman DK-1 spectrophotometer; two linear temperature programmed gas chromatographs; and the usual microcombustion and other analytical apparatus.

For polymer characterization, equipment includes: differential thermal analysis (D.T.A.) apparatus; thermogravimetric analysis (T.G.A.) system based on the Cahn Electrobalance; Perkin-Elmer DSC-1 differential scanning calorimeter; Mechrolab Model 301 vapor-pressure osmometer; Hallikainen automatic membrane osmometer; Mechrolab Model 502 high-speed membrane osmometer; and Waters Model 300 gel-permeation chromatograph.

Gel Permeation Chromatograph for Polymer Characterization

Equipment for fundamental thermodynamic studies includes a precision rotating bomb calorimeter, two shock tubes, and equipment for flash photolysis. Complete equipment is available for the processing of small quantities of experimental propellants and the determination of preliminary physical and ballistic characteristics.

## CHEMICAL PROCESSING

The chemical processing facilities are located in several buildings which were converted from old propellant lines and one building which was constructed in 1954 specifically for the manufacture of explosives on a pilot-plant scale. It was designed to allow remote operation during the processing of detonable materials.

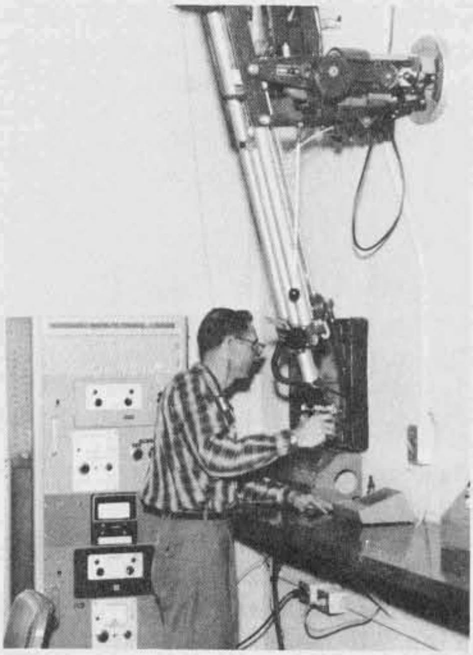
The major building, containing 5500 square feet of floor space, is divided into six explosive operating bays, the largest of which has a ceiling height of 28 feet and a floor area of 560 square feet. Reinforced concrete walls around five of the six bays are designed to provide complete protection to personnel if as much as 70 pounds of explosive detonates high order. As much as 200 pounds of material which has been thoroughly tested and will not detonate high order can be handled. To increase safety, compressed air is used to power equipment and to operate control circuits, and steam is used for heating.

Processing equipment for all chemical engineering unit operations is available and is designed to allow flexible arrangements.

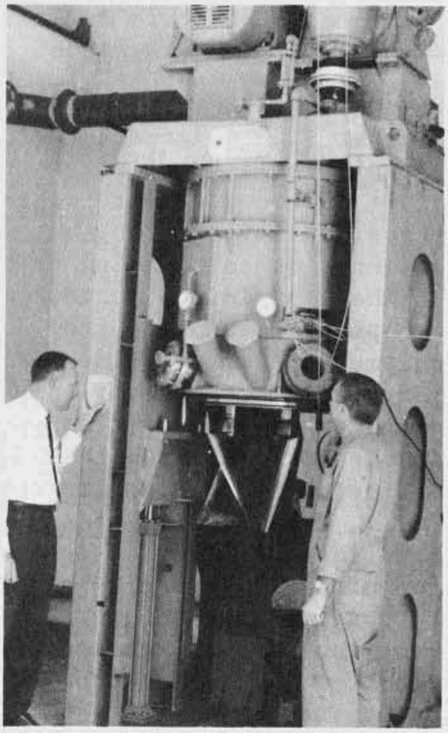
## PROPELLANT PROCESSING

Several buildings with reinforced concrete walls between bays and with blowout side walls and roofs are available for propellant processing on a pilot-plant scale. Three of the buildings, containing a total area of 11,000 square feet, were originally constructed as a solventless propellant pilot line, but have been modified to various degrees for the experimental loading of motors with castable composite propellants. These buildings contain mixing and casting facilities, with mixing capacities ranging from 15 to 1000 pounds. The versatility of the equipment permits a wide variety of propellant types to be processed. Auxiliary equipment is available for finishing the motors. Since the mixing and casting facilities were designed for the processing of new high-impulse propellants, they include a number of safety features. Most of the operations are remotely controlled.

A building containing a total floor area of 1850 square feet is used for mixing and casting of experimental composite propellants. There are six explosive operating bays and an operating corridor. Equipment includes a 1-gallon mixer in which mixing and casting are conducted remotely, and a completely remote 2-pound mixing, casting, and curing facility. Using this facility and the static ranges, 1-pound motors can be made and fired without exposure of the operators at any stage of the operation.



Most Propellant Operations are Remotely Controlled.



Five-Gallon and Fifty-Gallon Vertical Mixers

A 3900-square-foot building is used for the crushing, grinding, and sizing of crystalline materials such as oxidizers; for x-ray inspection of loaded motors; and for analysis of propellant raw materials. There are five explosive operating bays, a laboratory, a lead-lined x-ray room, and a darkroom, all completely air-conditioned. Equipment available includes micro-pulverizers, ball mills, a blender, a 250-kV x-ray unit, and instruments such as a micromerograph, Alpine screener, and Sorptometer for measuring oxidizer particle sizes. Routine quality control chemical analyses are also performed in the laboratory.

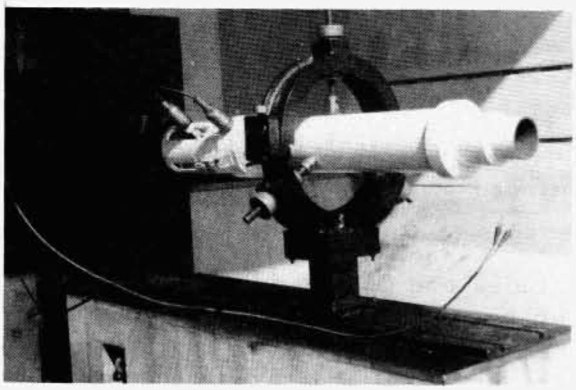
A building with 2600 square feet of floor area is used for ultra-fine grinding and blending of oxidizers. There are four explosive operating bays, two work rooms, an equipment room, and connecting corridors. Equipment includes a 4-inch Micronizer fluid-energy mill for dry grinding to a nominal 3-micron mean diameter, a 2.6-gallon vibro-energy ball mill for wet grinding to a nominal 0.5-micron mean diameter, and a twin shell blender having a 50-pound capacity. All hazardous operations are remotely controlled.

## BALLISTIC TESTING

The solid propellant evaluation facilities include a case preparation area, propellant handling area, conditioning facilities, static test range, dynamic test range, and data reduction facilities.

The case preparation area consists of tanks for solvent-soaking the fired cases; two grit blasters, one hydroblast machine, and a dry sand blast unit; a large vapor degreaser; and equipment for insulating and lining of motor cases. The propellant-handling area occupies 14 bays separated by reinforced concrete walls, with facilities for grain preparation, igniter fabrication, and motor loading. Equipment is available for temperature-conditioning motors containing up to 100 pounds of propellant over a range of $-80^{o}$ to $150^{o}F$.

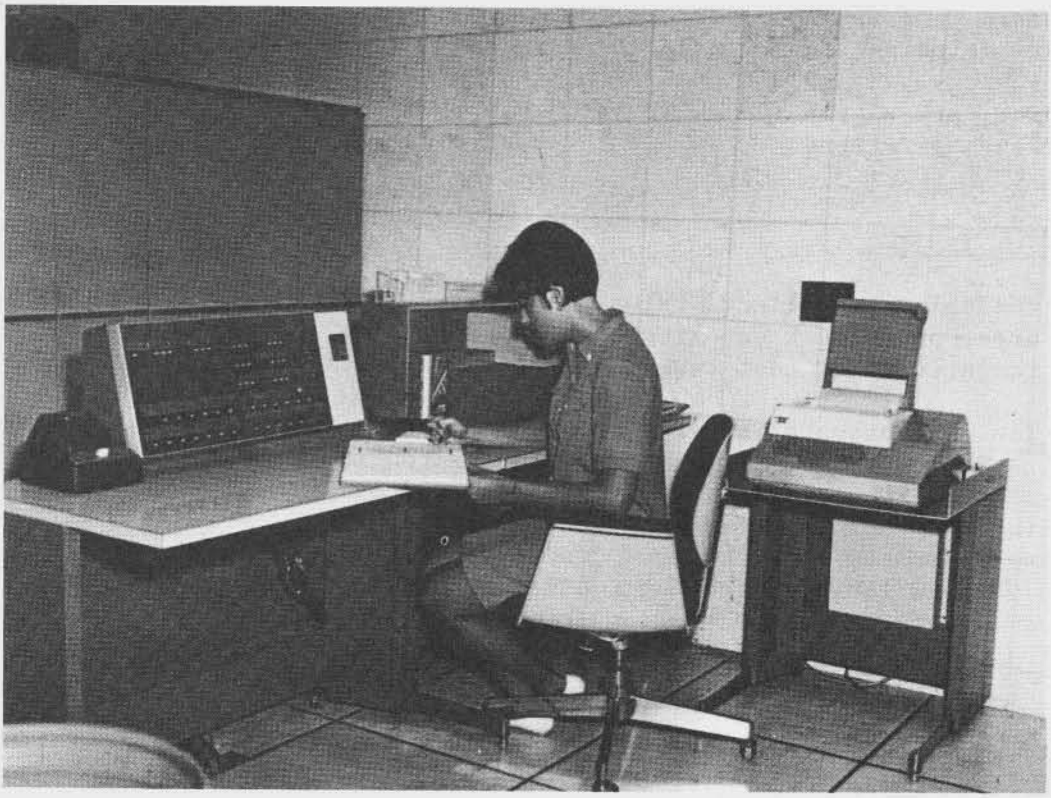
An open-air test stand is available for evaluating hybrid and liquid rockets. The stand is a 10-by-20-ft sloping concrete pad, with a small thrust block at one end. Reinforced concrete walls on each side protect the tankage and pressurization equipment. The facility is covered with a roof to provide all-weather operation. Instrumentation and operating cables are protected by conduit and are tied into the data acquisition system. The pad is surrounded by gutters connected to a sump so that spills may be easily washed down and removed.



Experimental Rocket Motor Ready for Static Testing

Two reinforced concrete test bays and an instrument room make up the static test range facility for solid propellant rocket motors. One bay contains a facility for the remote firing of 10-gram and 0.3-pound static test motors. Rounds may be assembled using a manipulator so that personnel are not exposed to hazardous propellants.

The dynamic test range is located adjacent to one of the static test bays. Small rounds are launched through a suitable tube into a 30-inch-diameter tunnel. Three light sensors in the tunnel provide time signals for calculating the round's velocity. This is suitable only for in-tube-burning motors, since the tunnel is only 30 feet long.



Digital Computer for Recording Data from Rocket Motor Firings and for Use in Engineering Problems

The data acquisition system includes one CEC oscillograph; a Honeywell 7700 analog tape recorder to record and play back high-frequency, transient data; two channels of Dymec-digital instrumentation to provide integral values of the pressure and thrust channels; and a digital computer data system. The computer data system consists of a Raytheon Model M-2 analog-to-digital converter, a Raytheon Model

EM-3 multiplexer, an EMR-6020 computer, and the control and interface equipment. Up to 24 pressure, thrust, temperature, and flow rate channels are sampled, recorded on a disc file, and later reduced and printed out in tabular form.

This instrumentation gives a precision of measurement of 0.1% and is used to fire motors containing from 10 grams to 100 pounds of propellant. The EMR-6020 computer is also available for the solution of engineering problems.

Microwave equipment is available for measurement of radar attenuation of rocket exhausts, and high-speed motion picture cameras are available for photographing test firings, providing for visual analysis of motor operation.

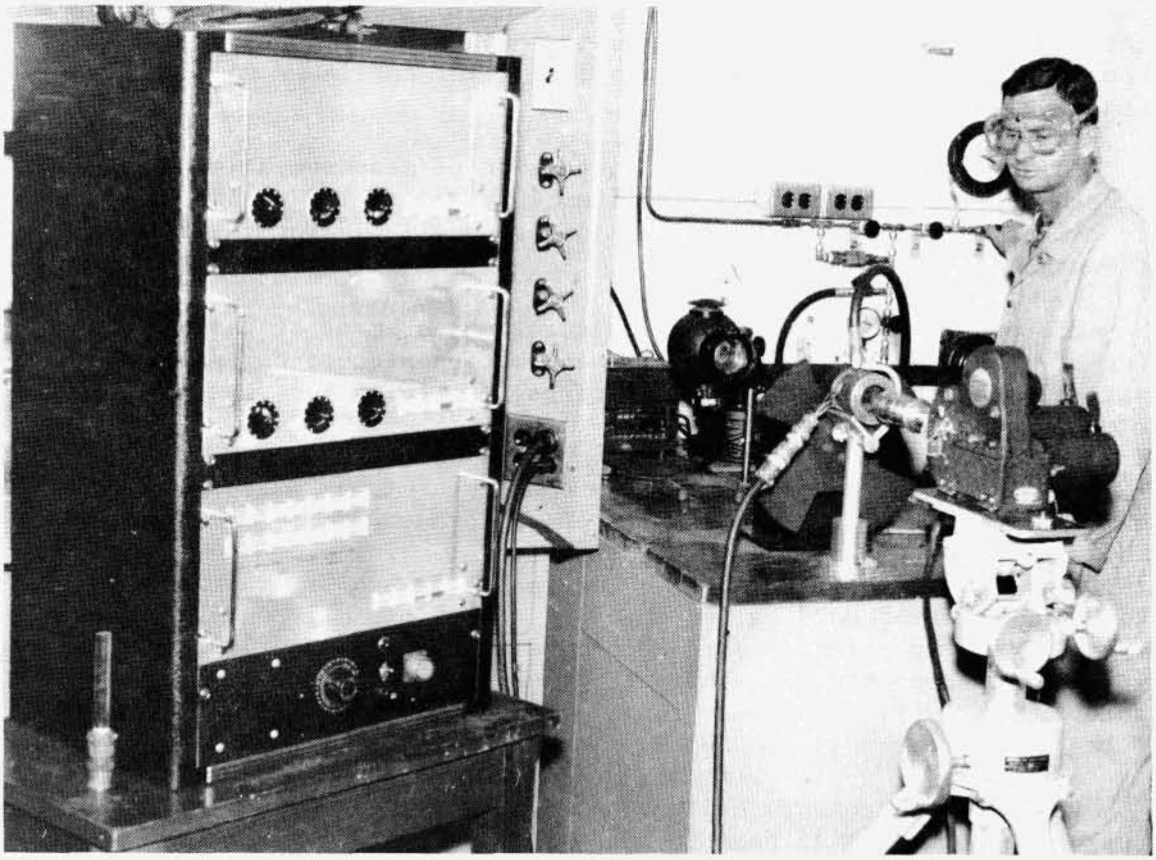
The laboratories also operate a smoke measurement research facility. Small test rockets are fired in the 40-cubic-meter chamber under controlled temperature and humidity conditions ranging from -40° to 120°F at 10% to 90% relative humidity. The rocket exhaust is mixed with air and then subjected to detailed analyses. Some of these analytical capabilities are particle size determination, aerosol optical density, visible and near infrared absorption, and the time dependence of these factors. In 1969, capability for continuous mass spectrometric analysis of the vapor phase will be added.

Dead-weight pressure calibration facilities for the calibration of pressure gauges from 15 psia to 20,000 psig are available. Load cells can be calibrated to 5000 pounds with dead weights, and to 50,000 pounds with Morehouse proving rings.

A special building is available for conducting long-term, high-temperature surveillance of solid propellant samples and small rocket motors. Twelve separate oven compartments are heated by circulating oil, with a temperature range of 120° to 170°F available in each unit. The oven temperature is monitored by chart recorders. Each oven can hold up to 100 pounds of propellant, and is designed to vent a fire or explosion without damage to the other units.

A window bomb facility is available for studying propellant combustion processes. High-speed motion pictures provide microscopic views of the burning surface and approximate burning rate values. More accurate (3%) burning rate measurements are obtained in two strand burners giving a combined pressure-range capability from 14 to 20,000 psia.

Combustion instability tests are run using both end- and center-vented motor configurations. Equipment available includes high-frequency pressure transucers, an 80-kHz tape recorder, a variable bandpass filter, a Panoramic sonic analyzer, and auxiliary instrumentation for computer reduction of data.



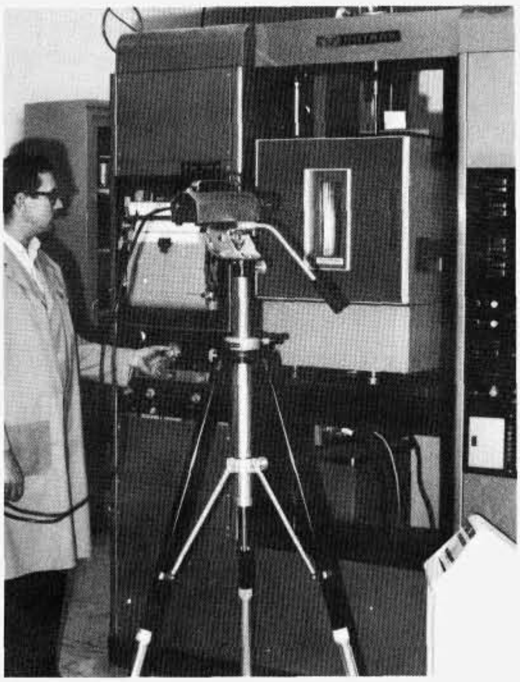
Propellant Burning is Studied Using High-Speed Photography.

Detonation shock sensitivity and DDT (deflagration-to-detonation transition) tests are conducted at an all-weather facility with a capacity of 5 pounds of high explosive confined. This facility is set up for card-gap tests, fracture mechanics, and small-scale hazards evaluation of both liquids and solids. Equipment available includes streak and ultrahigh-speed framing cameras. Temperature-conditioning facilities are located close by.

For larger charges, up to 300 pounds, an outdoor range is used for determining TNT equivalents of condensed explosives and propellants. Instrumentation at the outdoor range includes capability for measurement of peak side-on pressure and pressure profiles of air-blast waves in the 1-to-25-psi range; detonation velocities of condensed-phase systems can be measured by means of ion- or pressure-sensitive probes in conjunction with 8-, 10-, and 100-MHz counter-chronographs.

MECHANICAL PROPERTY TESTING

The mechanical testing laboratory consists of about 800 square feet of laboratory space, and two large reinforced concrete test cells for conducting hazardous operations remotely. The laboratory is used primarily to evaluate the mechanical properties of solid propellant.



Instrumented Instron Tensile Tester

A floor- and a table-model Instron tensile testing machine are used routinely. A Physitech Model 441 optical tracker is available for use as a remote strain extensiometer for research studies, and an automatic data acquisition system is being installed.

Special attachments for the Instron machines include a ball indentation test device for obtaining viscoelastic properties from small samples, a device for conducting uniaxial compression tests, and a quick-loading device for investigating very high tensile strain rates.

The low-temperature failure limits of propellants are determined in a facility devoted solely to this work. Eight low-temperature conditioning cabinets have a useful range of -80° to 50°F for 500 pounds of propellant. Propellant strain data are also obtained in an ambient temperature surveillance building and several high-temperature conditioning boxes.

A separate laboratory, consisting of about 400 square feet of laboratory space and a large reinforced concrete test cell, is used in conducting special stress analysis experiments. Equipment available for this work includes polariscope, a pulse generator for ultrasonic studies, and a precision device for determining stress as a function of temperature at constant strain.

## THERMAL STABILITY TESTING

A laboratory consisting of 1000 square feet of laboratory space and four reinforced concrete test cells is available for propellant thermal stability and thermal property testing. Hazardous experiments are conducted remotely in the test cells. The laboratory equipment includes two adiabatic calorimeters, a specific-heat calorimeter, a small vacuum line, a guarded meter apparatus for measuring thermal conductivity, and several laboratory ovens, temperature control devices, and overheat alarms. Other equipment useful in thermal stability testing -- a differential thermal analysis apparatus, a differential scanning calorimeter, and an apparatus for measuring evolved gas -- is available in other areas.

In addition, the same building houses a 400-square-foot chemical laboratory which is used for studies relating to thermal stability and for investigations of plasticizer migration in propellants, liners, and nonmetallic motor case materials.

A high-temperature surveillance facility is also available for thermal stability testing, and a heated pipe field is available for long-term studies of propellant shelf life. The heated pipe field consists of three sets of nine large heated pipes which are buried deep in the ground and which can be maintained at specific temperatures. This facility is designed to contain any fire or explosion without endangering nearby facilities or personnel.