VIII.1

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

TECHNICAL FACILITIES & EQUIPMENT DIGEST

January 1967

National Aeronautics and Space Administration

NASA

MSFC - Form 454-1 (Revised September 1961)

FOREWORD

This document portrays the capability of technical facilities and equipment at the George C. Marshall Space Flight Center (MSFC), one of three basic field centers under the NASA Office of Manned Space Flight*. It is located adjacent to Huntsville, Alabama, on 1800 acres within the confines of the United States Army's Redstone Arsenal. Although MSFC has acquired various facilities throughout the country, notably the Michoud Assembly Facility at New Orleans, Louisiana, and the Mississippi Test Facility, forty miles northeast of that city, the capability of those sites is not treated in this report.

It is intended in this document to give the reader a physical concept of the technical facilities of MSFC at Huntsville and to acquaint him with their general capability and potential. Therefore, the text is a digest of the technical facilities and equipment only. Data on support facilities such as office buildings, warehouses and utilities are not included.

Technical operations are the responsibility of eight basic laboratories and the data herein are grouped in accordance with this operational division of responsibility. A reference index is included as an aid in referring to specific categories of equipment. The eight laboratories are

1. Aero-Astrodynamics
2. Research Projects
3. Computation
4. Astrionics
5. Propulsion and Vehicle Engineering
6. Manufacturing Engineering
7. Quality and Reliability Assurance
8. Test

* The other two are the Manned Spacecraft Center at Houston, Texas, and the John F. Kennedy Space Center at Cape Kennedy, Florida.

Facilities and Design Office, F&D-P

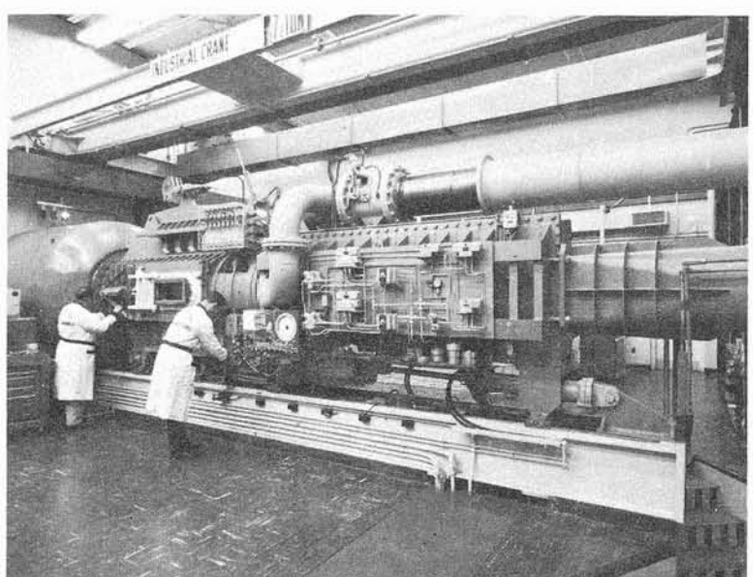
TABLE OF CONTENTS

AERO·ASTRODYNAMICS

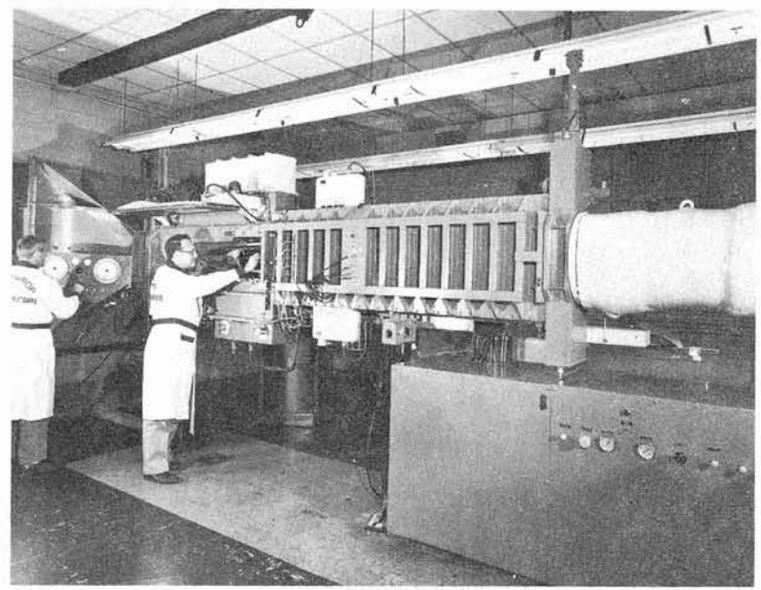
The facilities of Aero-Astrodynamics Laboratory, with the exception of some meteorological equipment, are devoted to fluid mechanics. Although these facilities are labeled "backyard," the quality of performance is not compromised and great versatility is a primary asset. Obtainable flow conditions range from free molecule to continuum flow, with the latter emphasized.

The laboratory has the potential for nonaerodynamic experiments. Precise measurements of static and dynamic force, pressure, temperature and other physical characteristics can be made under adverse conditions. This capability provides an excellent environment for the performance of scale model or other experiments of a nonaerodynamic nature, such as docking, landing dynamics, kinematics, motion studies, etc.

Long Duration Aerodynamic Testing. Long duration experiments in the continuum flow regime are conducted in a trisonic tunnel, a supersonic tunnel and jet flow facilities. The 14 x 14-inch trisonic wind tunnel is of the blowdown pressure type and is used for subsonic, transonic and supersonic testing up to Mach 5. The tunnel has interchangeable test sections for a wide range of requirements.



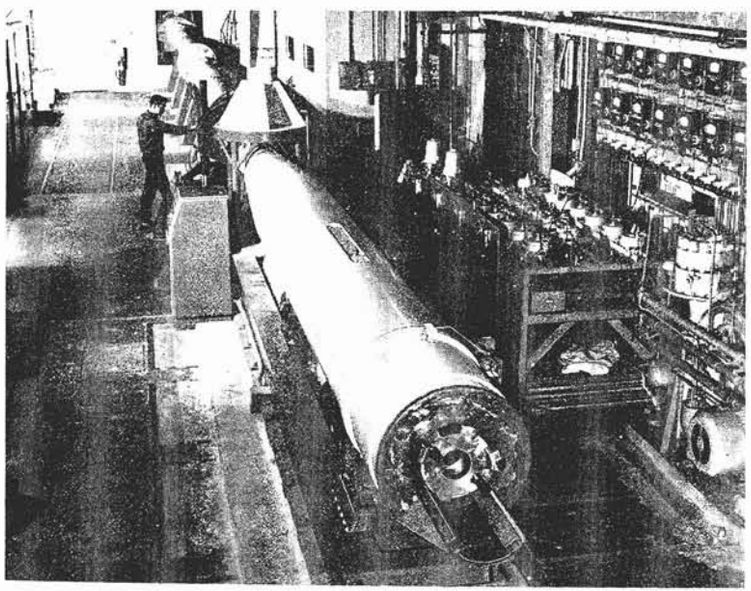
14 x 14 TRISONIC WIND TUNNEL



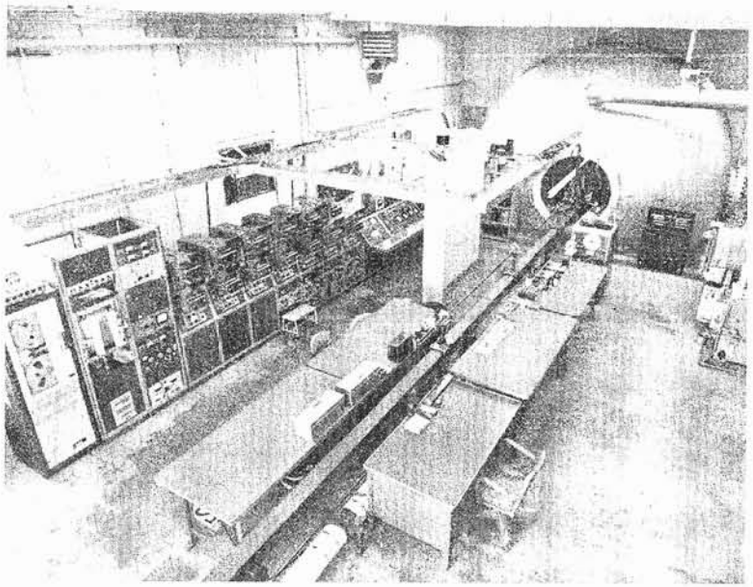
7 x 7 BISONIC WIND TUNNEL

The 7 x 7-inch supersonic wind tunnel operates on the atmospheric supply blowdown principle. Low subsonic and supersonic flow testing from Mach 1.5 to Mach 5 are possible.

Hypersonic Short Duration Testing. A hypersonic shock tunnel provides for experiments in fluid mechanics and heat transfer in the continuum flow regime using short duration techniques. The tunnel is of the reflected shock type and is helium driven with high stagnation pressure. The test nozzle exit is 24 inches in diameter. Capability range is Mach 6 to Mach 15. A high speed, on-line, 32-channel digital data system with a sampling rate of 160 kilocycles per second is provided.



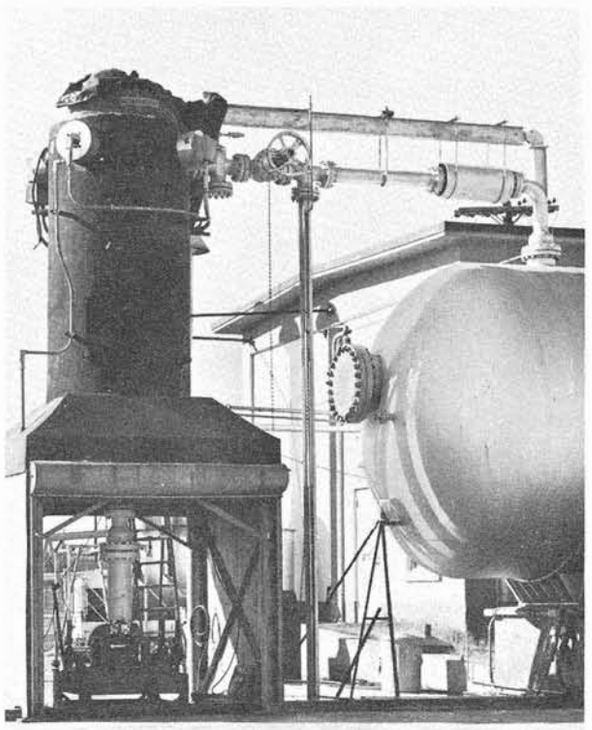
HYPERSONIC SHOCK TUNNEL



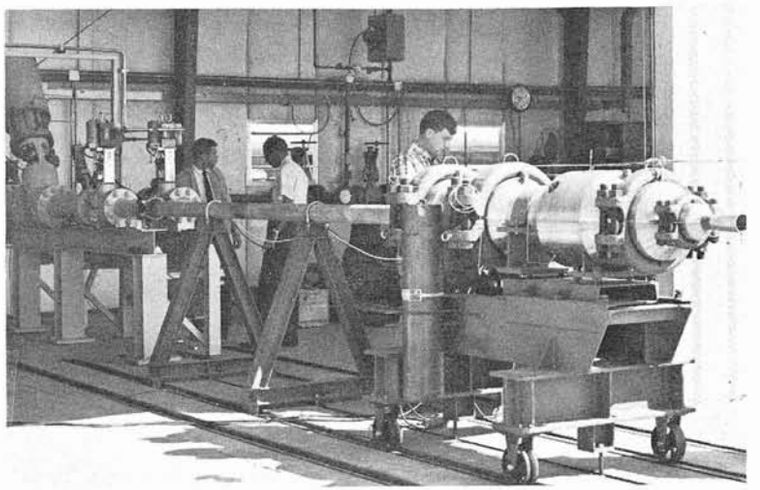
IMPULSE BASE HEATING FACILITY

Basic Flow Investigations. The impulse base flow facility is used to study hot jet pluming and resulting heat transfer and pressure distributions about the base of multi-engine rockets. Combustion weight flows of 60 lbs/sec at 6000° R and 2000 psia can be produced. The altitude chamber is 18 feet in diameter and 26 feet in length. Altitude simulation can be carried to 10^{-4} torr. There is no external flow. Twenty-four oscilloscope and twenty-four magnetic tape data channels are available.

The Hot Flow Test Facility operates from a 500 psi supply, cold or hot (600°F), and discharges to the atmosphere. The facility is used for impingement and nozzle studies, jet mixing investigations, and noise and turbulence experiments.



HOT FLOW TEST FACILITY



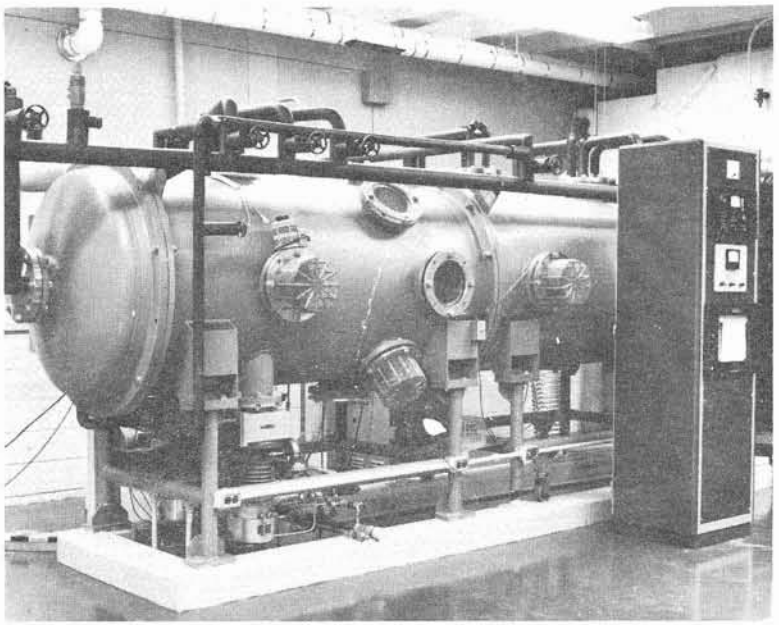
THERMAL-ACOUSTIC JET FACILITY

The Thermal-Acoustic Jet Facility is capable of simulating various rocket engine flows with helium or high pressure (3000 psi) air at temperatures to 1500°F. Designed for advance studies in the mixing region of a high speed jet, the facility is adaptable for other nozzle studies within the operable range.

Rarefied Gas Dynamics. A low density nozzle providing a Mach 4 rarefied gas flow is installed in the Low Density Chamber. This provides a continuous run wind tunnel for investigation of aerodynamic problems created by flight at extreme altitudes, such as determination of various coefficients of aerodynamic interest in various flow regimes, determination of orbital decay in free molecular and transitional flow regimes, study of jet impingement on lunar surface and study of gas-surface interactions.

Vacuum Technology. To provide for studies of outgassing, instrumentation calibration and research in vacuum technology, the laboratory is equipped with a low density chamber, vacuum gage calibration system, auxiliary vacuum systems, molecular beam system and peripheral equipment such as a residual gas analyzer and leak detector.

The Low Density Chamber is a horizontal cylinder $3\frac{1}{2}$ feet in diameter by 14 feet long fabricated with stainless steel with mirror finish interior surfaces. The chamber is capable of operating at pressure from 760 torr to the 10^{-7} torr range when being pumped by two 6-inch oil diffusion pumps and liquid nitrogen cooled cryopanels.

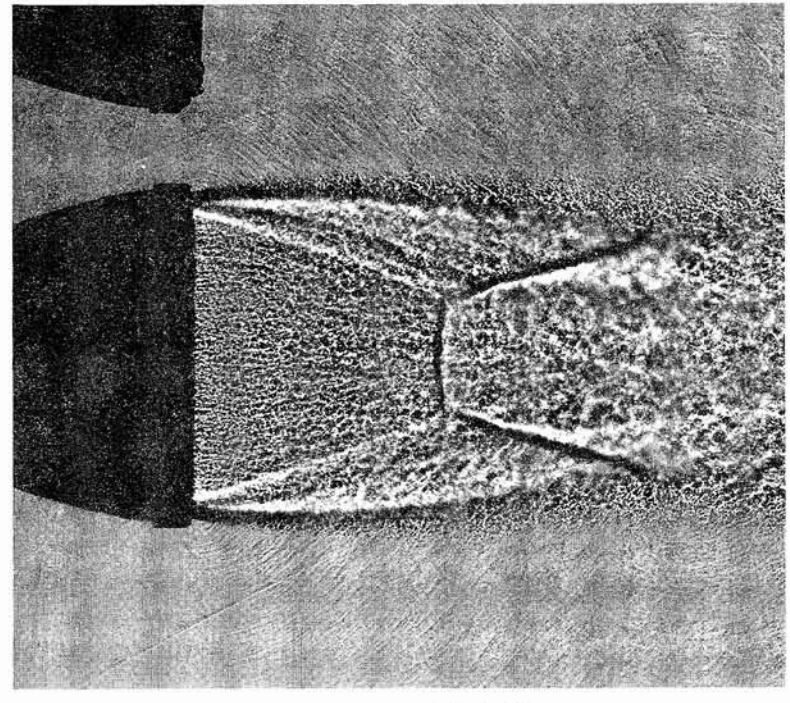


LOW DENSITY CHAMBER

Thermal Radiation Experiments. A radiation furnace treats experimental specimens in thermal radiation tests and provides sensor calibration capability. The exposure angle is 5° to 180°. The specimens are exposed to diffuse, black body radiation from ambient temperatures to 3000° F at pressures from 5 mm Hg to ambient and may be remotely manipulated.

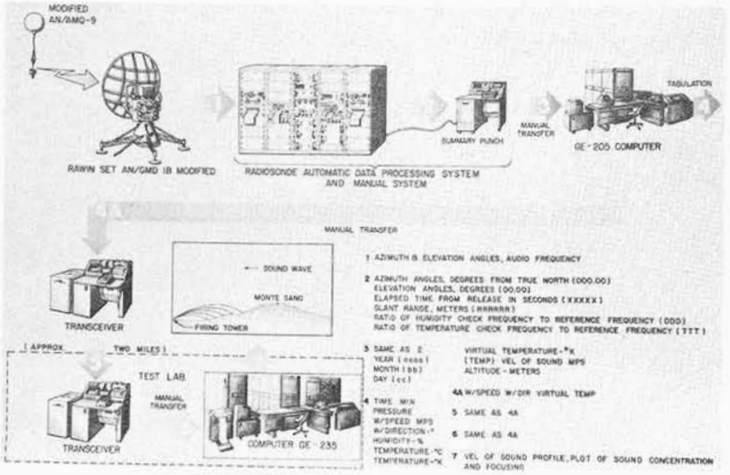
Scale Model Experiments. Diverse laboratory space and equipment provide potential for scale model experiments in landing stability, docking, impact and shock, and motion studies of tethered objects, control compliance, etc. Included is a wide range of transducers and calibration gear for mechanical, electronic, optical and hydraulic-pneumatic devices.

Support. A full complement of auxiliary equipment associated with the fluid flow and space environmental testing facilities described above is provided. These support items include large air storage and vacuum vessels, compressors and exhausters, numerical and analog high speed data acquisition and reduction systems, a medium scale digital computer, high speed photography, schlieren and shadowgraph systems, control rooms, flow conditioning equipment, etc. Of special interest may be the variety of instrumentation and analysis equipment for acoustic and unsteady or fluctuating pressure studies.

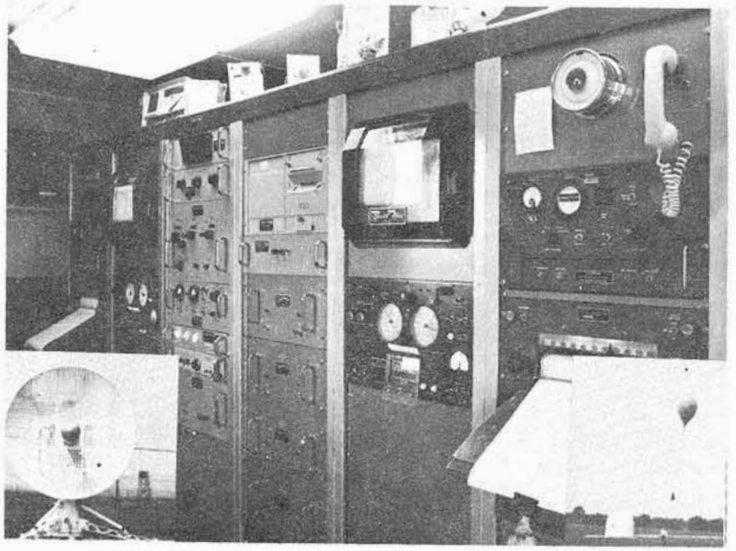


SUPERSONIC JET FLOW

Rawinsonde Automatic Data Processing System (ADP). The ADP System provides information of local atmospheric conditions from surface up to 30 kilometers. The system consists of a Rawin Set AN/GMD IB, a Balloon-Borne Transponder (Radiosonde) and the Automatic Print-Punch Recording System. The ADP System will automatically track a Balloon-Borne Transponder, measure and record slant range, and decommutate, digitize, and store Radiosonde Telemetry, (temperature, humidity, and reference signal), azimuth angles, elevation angles, and elapsed time data. The store data is punched on cards from computer processing.

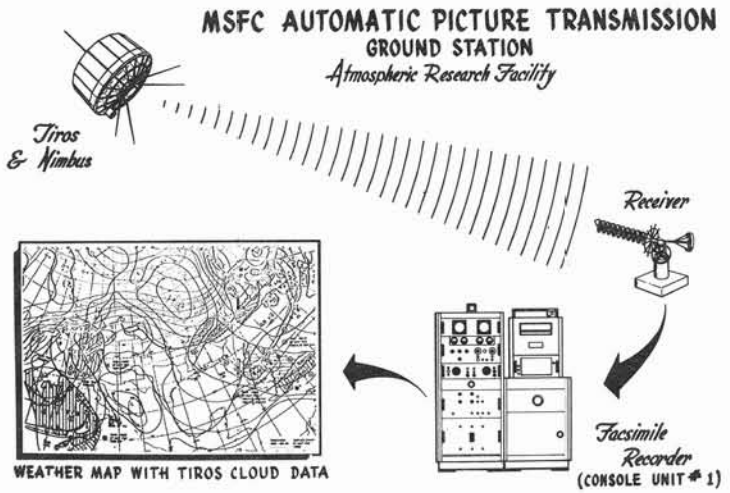


AUTOMATIC DATA PROCESSING DIAGRAM



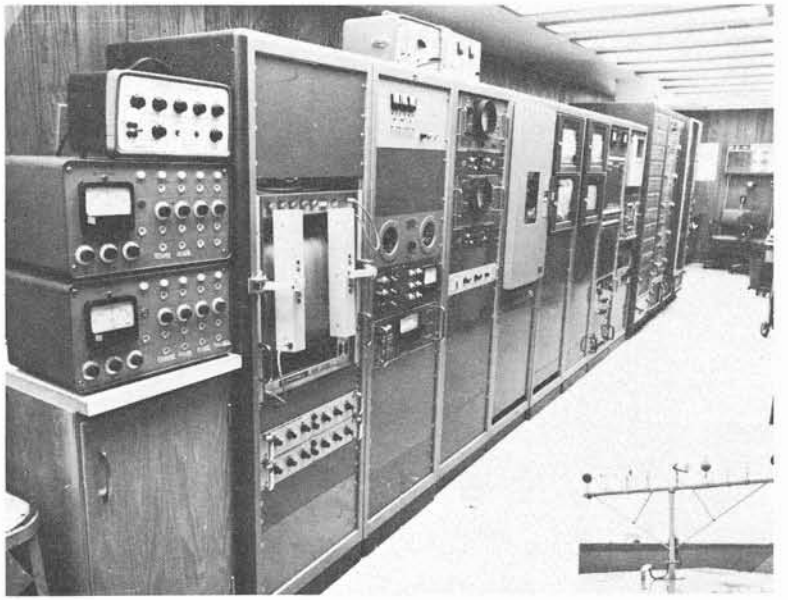
RAWINSONDE MEASURING SYSTEM

Automatic Picture Transmission Ground Station. This tracking station is used to record weather pictures being transmitted by Tiros and Nimbus Satellites. The station uses an automatic receiver tracking system. A magnetic tape is incorporated to provide reproduction of picture received on a single pass.



AUTOMATIC PICTURE TRANSMISSION

Dynamic Wind Measuring Facility. The Dynamic Wind Facility is used for anemometer studies and comparison tests. The system has capabilities of testing up to 7 anemometers simultaneously recording wind speed and direction. The recording system provides instant visual records and a magnetic tape system for recording data for computerized data reduction.



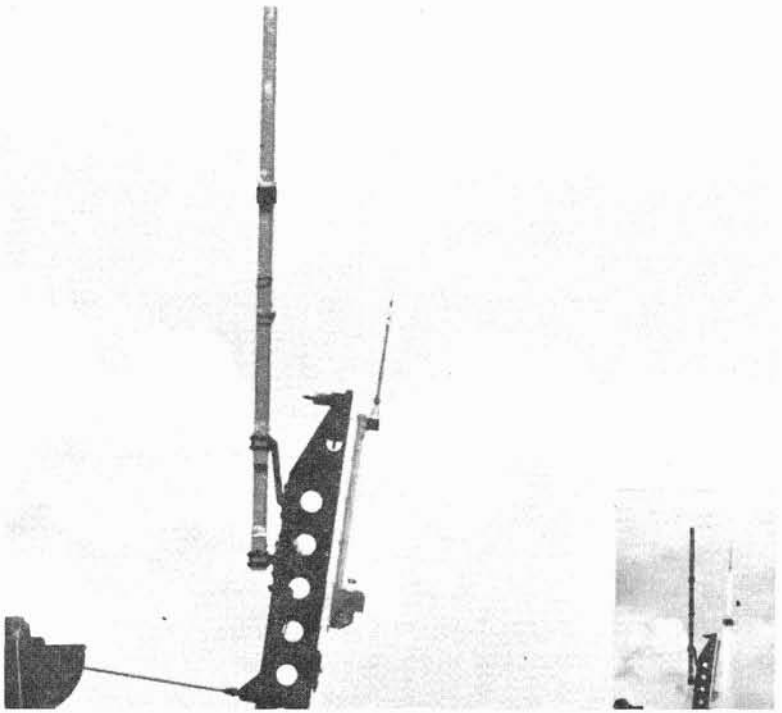
DYNAMIC WIND MEASURING FACILITY

High Altitude Wind Measuring System. A Rocketsonde provides data for studies of atmospheric conditions from 30 to 300 kilometers. Several systems are now operational, such as the Arcas, Cajun-Dart, Hopi-Dart, and the Nike-Tomahawk with the appropriate payloads. These systems provide capabilities of recording wind profiles, temperature, density, and pressure at altitudes exceeding the range of the Balloon-Borne Radiosondes.

The Cajun-Dart and Hopi-Dart measure wind flow at altitudes from 70-90 kilometers. These systems employ the technique of ejecting a metallic material "Chaff" and its drift is tracked by radar to determine wind speeds and direction.

The Arcas measures winds and temperature from 30-60 kilometers employing a parachute-borne telemetry package similar to the Radiosonde unit.

The Nike-Tomahawk with the thermosphere payload measures ion temperature, density, temperature, pressure and winds in the altitude region 120-300 kilometers, employing a telemetry package.



HIGH ALTITUDE WIND MEASURING SYSTEM

NASA's 150-Meter Meteorological Tower Located At Cape Kennedy, Florida. The 150-meter tower provides information for studies in (1) The characteristics of the lower atmospheric wind and temperature profiles as a function of height and time, (2) Gust shape phenomena, (3) Spectra of turbulence, (4) Correlation properties of steady-state and turbulent flow, (5) Calculations of Diffusion Parameters for defining atmospheric dispersion and diffusion, (6) Wind criteria on severe weather, etc. Instruments are located on the northeast and southwest sides of the tower. An automatic switching device is employed to select data for recording from the upwind side of the tower thus reducing tower shedding effects. Sensors are located at the 3, 18, 30, 60, 90, 120, and 150 meter levels.

METEOROLOGICAL TOWER

RESEARCH PROJECTS

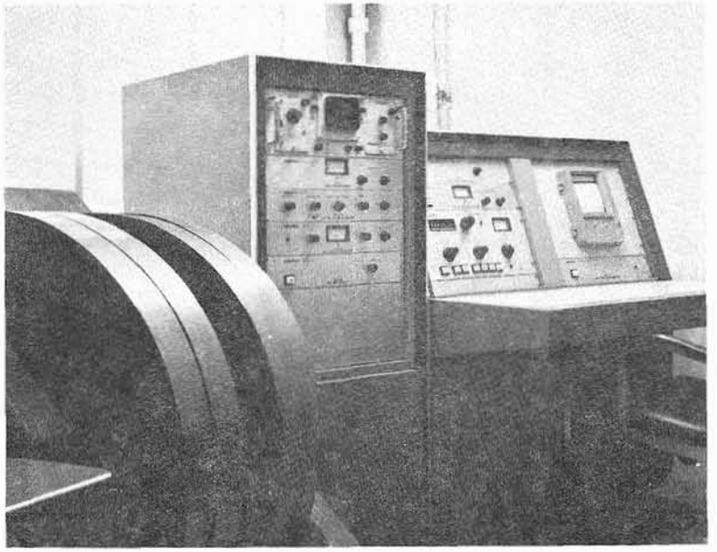
The facilities and equipment in the Research Projects Laboratory provide a capability for applied research in the fields of physics and astrophysics, space environment, nuclear and plasma physics, space thermodynamics, meteoroid measurements and advanced systems and instrumentation.

The laboratory is characterized by the flexible multi-use combinations of space and sensitive equipment. The majority of equipment is of a "plug in" nature, portable and semi-portable, requiring minimum special utilities. The experimental set-ups are not permanent and are modified and replaced as required.

Electromagnetic Radiation Physics. Activity in this field is housed in a 900 square-foot area containing

- ultra high vacuum system with 18-inch diameter by 24-inch chamber
- 4-inch oil diffusion vacuum system
- thermal conductivity calorimeter
- line heat source thermal conductivity apparatus
- thermal conductivity probe
- SG-4 grating spectrophotometer
- infrared radiometer

Thermal conductivity of solid particulate and foamy or frothy materials can be measured over a temperature range from 4°K to 400°K and pressure range from atmospheric to 10^{-13} Torr. In addition, laboratory facilities can measure both total radiation from samples at temperatures near or below 100°K and spectral radiation from heated samples over the wave-length range from 5 to 25 microns.



ELECTRON PARAMAGNETIC RESONANCE EQUIPMENT AND MAGNET

Meteoroid Physics. Contained in 900 square feet of floor space are

- 250 kilojoule - 1 megajoule fast capacitor bank and associated equipment
- discrete particle accelerator
- large vacuum containment tank
- diagnostic equipment
  - framing camera
  - image converter cameras
  - spectrograph
  - timing devices, etc.

Within the scope of its capabilities for meteoroid physics research the laboratory produces high velocity, high density plasmas for particle acceleration and develops and calibrates meteoroid detectors. Meteoroid simulation can be conducted with projectiles ranging in diameter from 50 to 1000 microns at velocities exceeding 10 kilometers per second. Penetration and cratering mechanics, electromagnetic radiation and charge liberation of particles during impact are studied as well as the behavior of material in a state of high internal density subjected to extremely high pressure.

RESEARCH PROJECTS

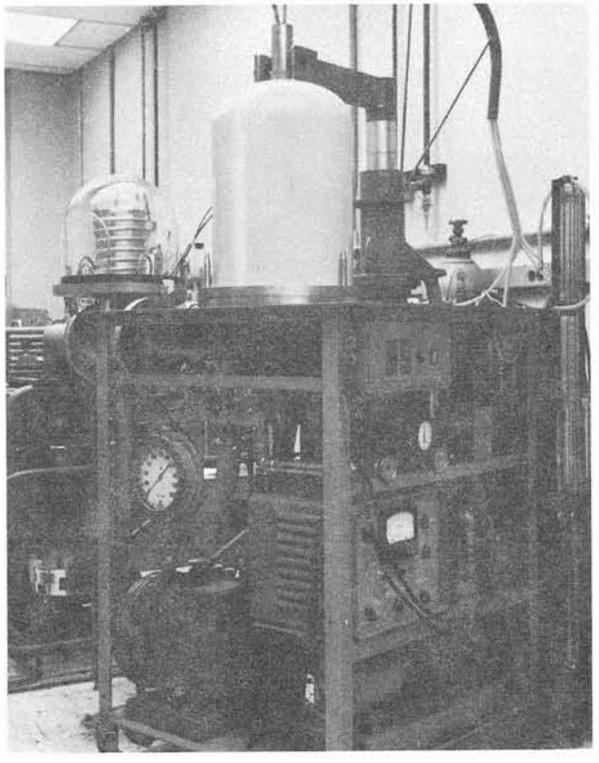
Optics. For the calibration, testing and checkout of optical instrumentation the Optics Laboratory utilizes a 3-meter optical bench with auxiliary accessories such as carriers, a telescope, etc. A 24-inch by 18-inch film viewer for 16, 35 and 70 mm film permits examination and engineering measurements of photographed phenomena. The laboratory can also establish methods and equipment requirements for remote optical observation of hazardous tests.

Geology and Geophysics. Equipment located in the 1800 square feet devoted to this study area include an ultra-high vacuum system (10^{-12} Torr), a high vacuum system (10^{-7} Torr) and a particle accelerator for investigations in a range up to lunar escape velocity. Facilities of the laboratory provide for studies of secondary impacts on non-metallic "rock" materials and effects of vacuum on mechanical properties of these materials.

Field Measurement Physics. This laboratory segment includes

- small vacuum chamber
- magnetometer
- electrometers
- electronic test instruments
- shop and laboratory equipment

Facilities provide for measurements of electrical and magnetic field strengths, exploration of new electric and magnetic field measuring techniques applicable to the development of field measuring instruments, and performance evaluations of electric and magnetic field meters. The laboratory has a space simulation capability of 10^{-8} Torr.



THERMAL CONDUCTIVITY CALORIMETER

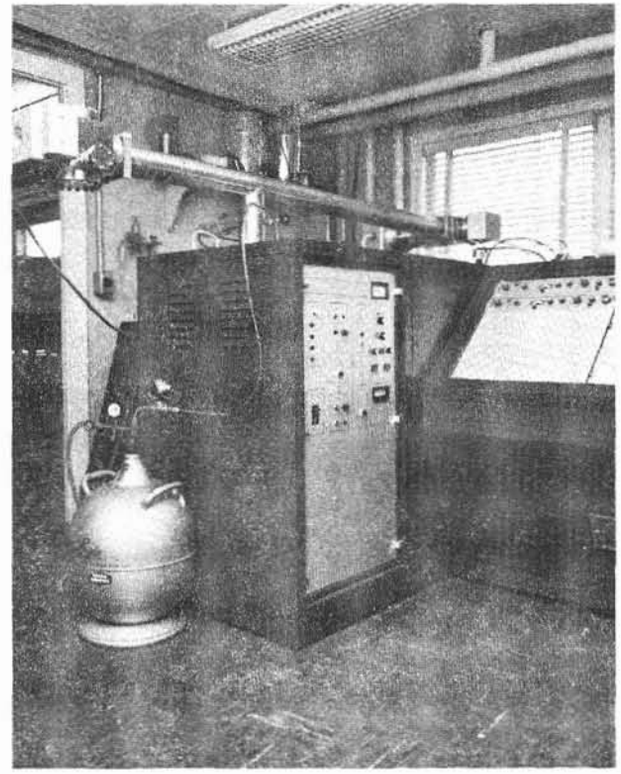
Radiation Physics. This function occupies a working area of 500 square feet and houses

- multi-channel radiation analyzer
- ultra-fast coincidence system
- solid state and scintillation detectors
- ultra-high vacuum system
- radioactive sources

The laboratory has provisions for studies of space vehicle radiation shielding, basic radioactive decay schemes, cosmic ray telescope advanced detection systems and space radiation environments.

Scientific Data Analysis. In 2000 square feet of floor space are contained a Burroughs 5000 therminal with card reader/punch line printer; 4 AMTRAN terminals with Tektronix cathode ray storage scopes, keyboards, scientific flexwriters, stylus input and paper tape reader punches; a Calcomp on-line incremental plotter; an optical character recognition device; electronics logic-module breadboard equipment; oscilloscopes; and one IBM 1130 computer.

RESEARCH PROJECTS



TIMES OF FLIGHT MASS SPECTROMETER

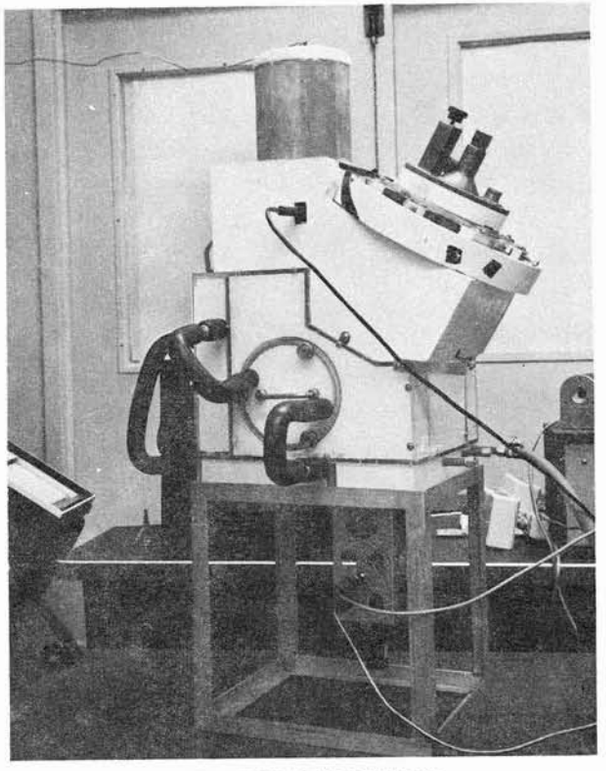
The equipment in this laboratory is applied to the development and execution of advanced methods of data analysis and translation. Typical efforts are the development of greatly increased speeds in scientific computations and design drafting; the solution of problems in vector and tensor calculus symbolically; improvements in the manipulation of algebraic expressions; and a reduction in the time required to type and edit scientific papers.

RESEARCH PROJECTS

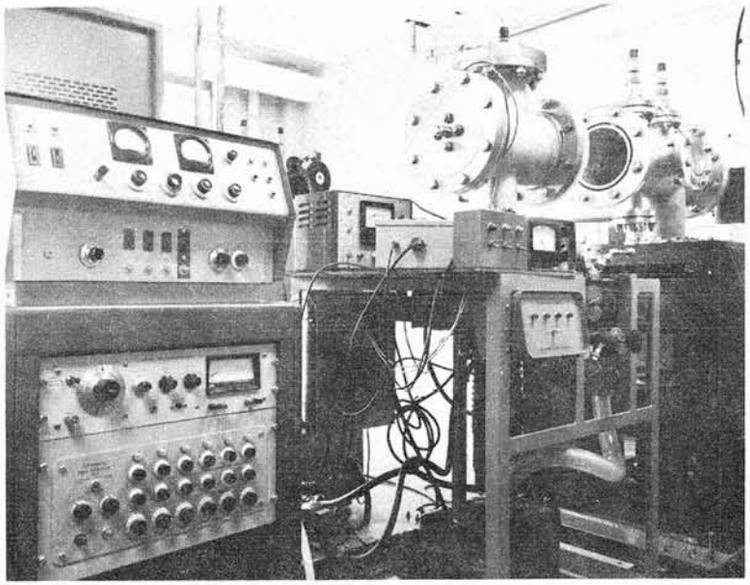
Atmospheric Physics. A 1600 square-foot area houses a horizontal vacuum chamber 30 inches by 48 inches long with quartz window, bakeout heaters, and LN_2 shroud. Pressure level attainable is lower than 10^{-10} Torr. Associated laboratory and field instrumentation include

- leak detector
- 4-channel instrumentation magnetic tape recorder
- portable scanning spectrophotometer
- 35-mm cine-pulsed boresight data camera
- 2 modified MK 51 gun director mounts
- 2 cine-spectral polarization recorders
- Questar telescope with 35-mm camera
- oscilloscopes

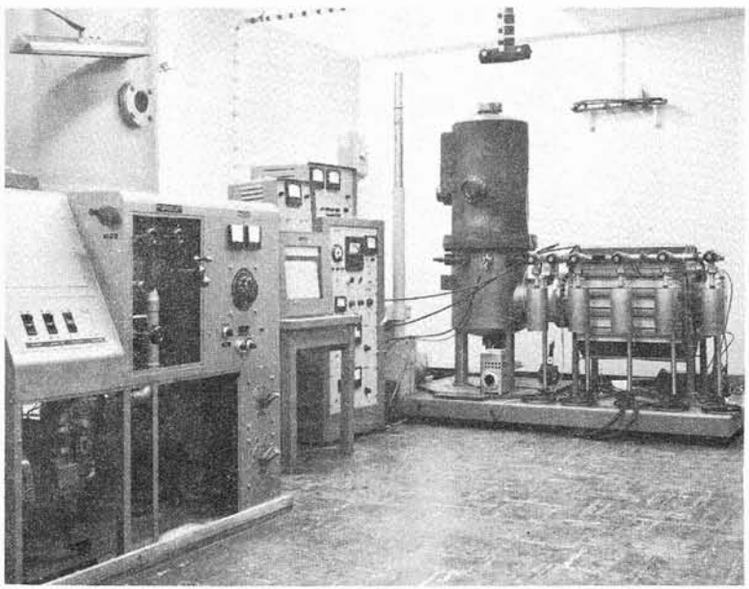
This laboratory carries out experimental research in simulated tenuous earth and planetary atmospheres. Emissions from combustion products simulating rocket exhausts and the interaction with these atmospheres are investigated. Optical properties of simulated lunar and planetary materials under high vacuum, from ultraviolet through infrared wavelengths, can be studied.



INFRARED RADIOMETER



KINETICS REACTION LABORATORY WITH RESIDUAL GAS ANALYZER AND REACTION CHAMBER



LUNAR GEOLOGICAL AND GEOPHYSICAL VACUUM LABORATORY

RESEARCH PROJECTS

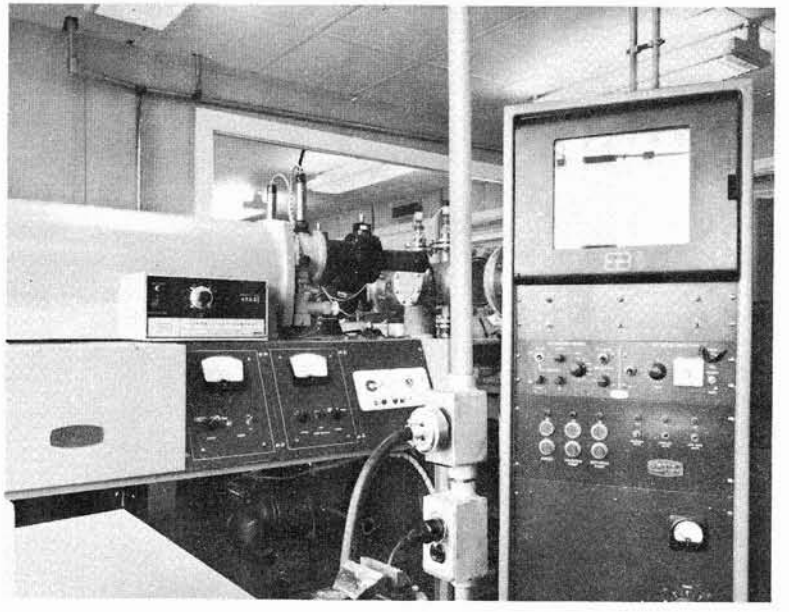
Thermal Environment Physics. This laboratory, comprising a 2000 square-foot area, houses a small space simulation chamber, 3 feet in diameter by 4 feet long, with a solar simulator, vacuum chambers and

- high precision laboratory radiometric equipment
- portable radiometric equipment for in-sites measurements
- ultraviolet irradiation lamps
- electron paramagnetic resonance equipment
- magnetic susceptibility equipment
- calorimeters

The laboratory is equipped to measure directional spectral reflectance and emittance from 0.25 to 50.0 microns and to calibrate radiometric equipment. Research projects can be conducted in simulated space or lunar environments to 10^{-8} Torr to study space environmental effects on the radiometric characteristics of surfaces, performance of active and semi-active thermal control devices and in support of developing thermophysical flight experiments.

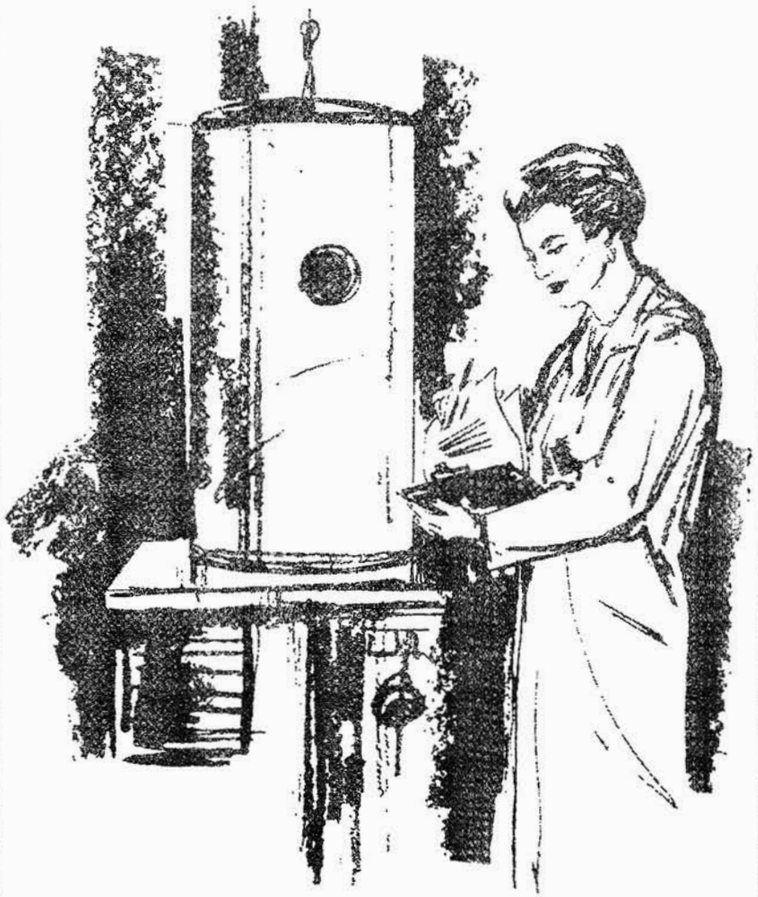
Reaction Kinetics. The facilities and major equipment of the Reaction Kinetics Laboratory, incorporated in a 1600 square-foot area, have the following capability:

- Times of Flight Mass Spectrometer Bendix Model 3015 is used for analysis of gases and vapors, partial pressures and free radicals and for studies of reaction kinetics.
- Residual gas analyzer CVC model 31-C13 performs analyses of gaseous mixtures leak detection.
- Vacuum ultraviolet scanning monochrometer Jarrell-Ash model 78-751 makes spectroscopic measurements in vacuum UV to 500 Å source of monochrometer radiation in vacuum UV.
- Spectrum line measuring comparator (Grant Instruments) measures intensities and compares line spectra obtained from spectrometers and spectrographs.



VACUUM ULTRAVIOLET SCANNING MONOCHROMETER

RESEARCH PROJECTS



- A reaction chamber, constructed of stainless steel with 6- and 9-inch diffusion pumps, LN_2 baffles, gages, viewing ports and feedthroughs, simulates high altitudes. UV radiation molecular beam techniques are used for flash photolysis and spectral absorption studies.

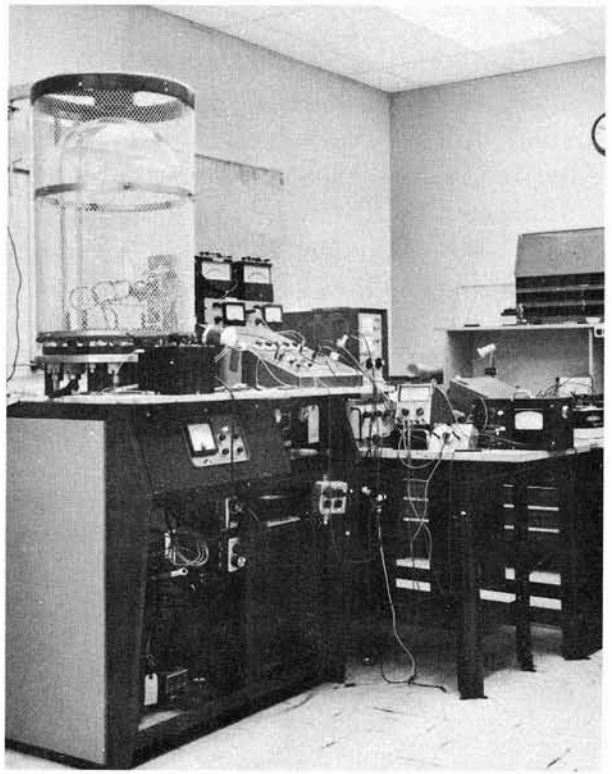
- A capacitor bank power supply of 10-20KV, 18,000 joule, with rectifier, controls and meter, supplies high energy pulse to flash tubes, lasers, etc.

- UV radiation sources - Kemlite helical flash tubes, helium discharge sources, Jarrell-Ash Wilkensen high intensity sources - in the range of 500 Å to visible provide for photolysis and spectral absorption studies.

- An STL trigger delay generator is used for optical pickup in coordinating electronic measurements with flash photolysis.

- An Abtronics signal delay generator delays signals in flash photolysis studies.

In addition the laboratory contains electronic measuring and recording equipment, oscilloscopes and plug-in oscillographs, trace recording cameras, vacuum gages and Cooke recording gages.



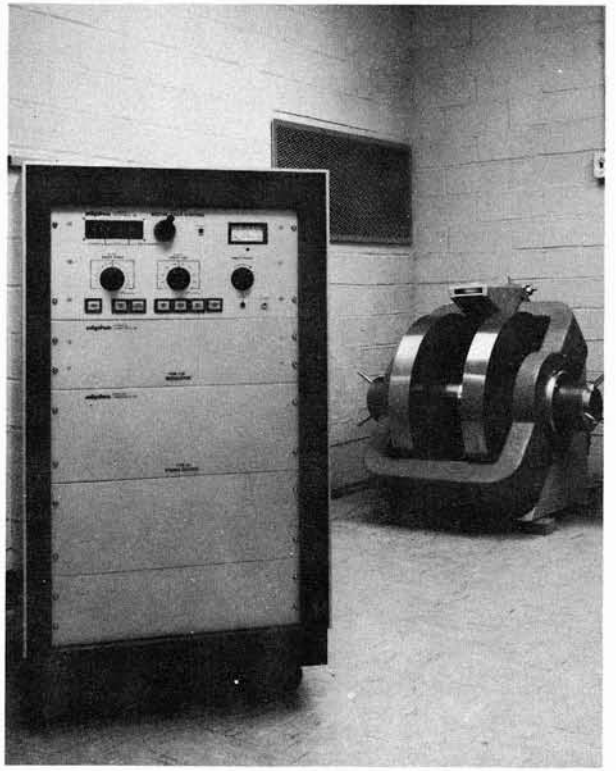
ELECTRONIC FIELD MEASUREMENT LABORATORY

Plasma Physics. A partial listing of equipment for this laboratory includes

- small vacuum chamber
- plasma probes
- oscilloscopes
- dewar for LN_2 and He

and an on-line computer arrangement for real-time reduction and interpretation of data.

Space plasmas can be simulated to measure plasma probe voltage, potentials on satellites and other space plasma phenomena. Theoretical calculations of space plasma phenomena can be evaluated with an AMTRAN computer system at vastly increased speeds.



MAGNETIC SUSCEPTIBILITY APPARATUS

COMPUTATION

During 1967 the Computation Laboratory will acquire analog, hybrid and high speed digital computers, providing MSFC with the computation potential necessary in research and development of space vehicles and in efficient administrative management of the Center.

In late 1966 the Computation Laboratory will acquire a large scale, centralized, third-generation computer. The new computer will permit the phase out of most presently installed digital computer equipment and will provide greatly increased computation capacity at lower cost. It will, furthermore, add a new dimension to the scope of MSFC operations by providing effective real time capacity and furnishing management with direct access to information through visual display devices. The modularity of the computer will permit the expansion of its capacity to meet any increased computation requirements in the future.

Analog and Hybrid Simulation. This functional subdivision of the laboratory is equipped for studies concerning flight simulation, lunar traverses, rendezvous, orbital docking, a reusable booster, a mobile lunar laboratory, engine start-up and cut-off, including fuel flow, sloshing, heat transfer, etc., and other operations using physical and mathematical models. Floor space is 7881 square feet. Computers for these simulation projects include

- PB 440 + Trice II (1)
- PB 250 + Trice I (1)
- ASI 2100 + EAI 1231 RV (1)
- EAI 231 RV (3)
- High speed statistical computers (2)

1401 COMPUTERS FOR PREPARATION OF INPUT DATA FOR 7094 COMPUTER AND CONVERSION OF MAGNETIC TAPE DATA TO HARD COPY OR CARD FORM

Scientific Problem Solving (Digital). This functional subdivision of the laboratory, comprising 16,723 square feet of floor area, is equipped for digital computations in the areas of aerodynamic analysis, flight mechanics, flight performance (pre and post), dynamics, thermodynamics, static and flight test data reduction, general support of automatic checkout, PERT, APT, management system models, real time data acquisition and computation, vibration and acoustical studies, weather, wind tunnel and miscellaneous data evaluation, and operations and numerical analysis research. Computers performing these computations include

- IBM 7094 II (2)
- medium size computers (13)
- small computers (20)

7094 COMPUTERS, USED FOR SCIENTIFIC PROBLEMS, TRAJECTORY SIMULATION AND REDUCTION OF FLIGHT DATA

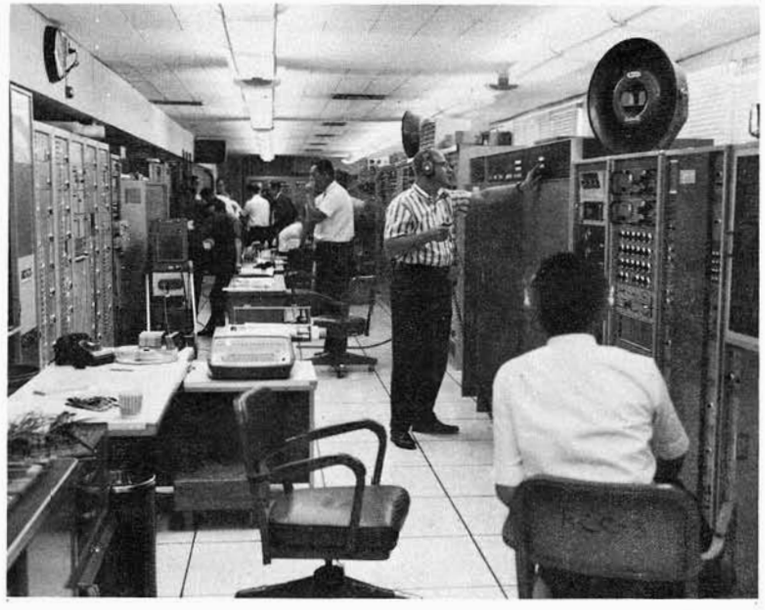
Data Reduction. This functional subdivision of the laboratory, utilizing approximately 10,000 square feet of working area, is equipped for data acquisition, data processing, data reduction and ancillary functions. Equipment used in the various functions include:

- B5500 digital computer provides data reduction of realtime, post-flight and supporting research.
- SC-4020 microfilm printer/plotter shows the graphic display generation from digital computers.
- RCC-3 cycle counter converts cyclic data to input form for digital computation.
- Analog to digital converter system converts analog signals to sampled digital computer input form.
- Analog ground station produces oscillograms for analog input signals.
- PCM ground station produces oscillograms and digital computer input from analog PCM signals and serves as the interface between the data transmission line and the B5500.
- UNIVAC 1004 III computer serves as a data communication terminal. It is a general purpose computer for data reduction.

COMPUTATION

- Time generation and transmission station generates and transmits frequency and time standards for use throughout the Marshall area.
- Receiving and recording station receives and records TM and video signals via radio, and microwave links from satellites, launch vehicles and captive tests.

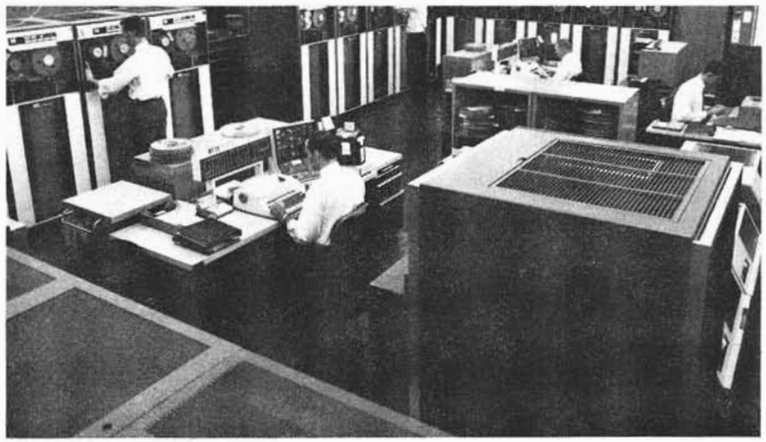
DATA REDUCTION COMPLEX (ANALOG TO DIGITAL STATION IN FOREGROUND)



Engineering and Industrial Systems. This functional division of the laboratory called the MSFC Data Center is equipped to furnish automatic data processing support for engineering, industrial, and management applications. Approximately 8820 square feet of floor space are utilized for computer requirements. This area will be expanded by 4300 square feet in mid-1966. Equipment used in the various functions include:

- IBM 7010 Central Processors (2)
- IBM 7740 Communications System
- IBM 1030 and 1050 Remote Stations (38)
- IBM 1401 Computer
- IBM 7702 Data Transceiver
- UNIVAC 1004 Card Processors (3)

MSFC DATA CENTER 1401 COMPUTER



7010 COMPUTERS IN MSFC DATA CENTER

Typical applications are in engineering documentation, vehicle parts breakdown, quality control, parts reliability, automatic checkout data support, calibration functional testing, configuration management, contract reporting, documentation control, budget, managerial data display, and in general management areas, such as travel, personnel, security, supply, and finance. Application systems use remote-inquiry, teleprocessing, time-sharing, etc., techniques and equipment.

MSFC DATA CENTER 1004 PROCESSORS

MSFC DATA CENTER 7740 COMMUNICATION SYSTEM

7010 WITH 1050 TELEPROCESSING STATION

ASTRIONICS

The facilities and equipment in Astrionics Laboratory provide a broad capability for developing and evaluating components and systems involved in aerospace communications, guidance and control, air-borne and ground instrumentation, vehicle and ground power, and electrical integration systems.

In addition to the substantial investment in standard bench equipment, such as oscilloscopes, meters, power supplies, etc., the laboratory has a very large inventory of special equipment. The combination of these facilities and equipment together with the specialized manpower skills into a total complex produces a unique over-all capability.

Inertial Sensor and Stabilizer Development. The laboratory development and test programs use 18,000 square feet of working space.

Electronic research and development is accomplished utilizing general test equipment, oscilloscopes, meters, power supplies, etc. Comprehensive electromechanical research and development of internal sensors utilizes centrifuges, vibration tables and temperature cabinets.

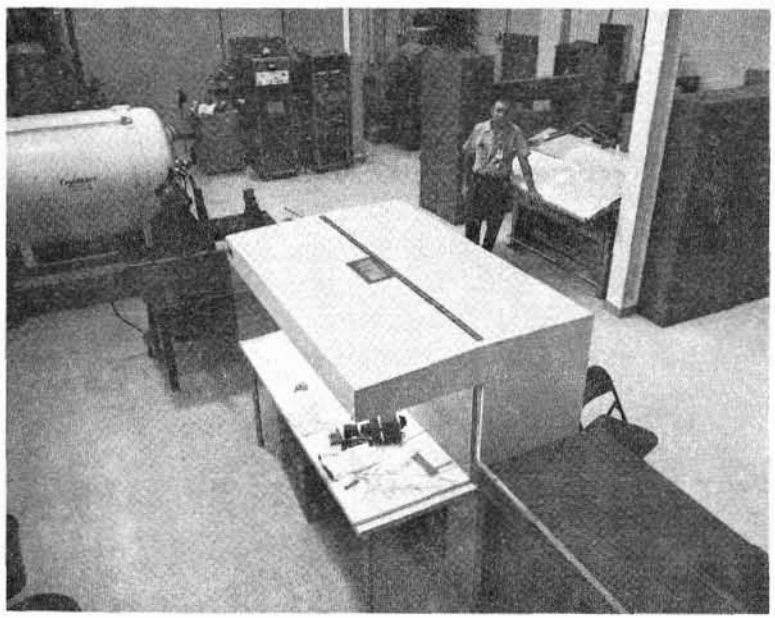
Inertial platform prototype equipment, including complete systems, sensitive gyroscopes and accelerometers, can be tested utilizing special test fixtures, temperature controlled enclosures and rooms, vibration isolation pads and versatile power supplies. Flight components and systems are tested in a semi-clean production test area and celestial seeking systems are tested in a dark room, 250 square feet in area, containing power supplies, sun sources, star sources and an isolation pad.

High quality clean rooms, totaling 1500 square feet, provide the correct environment for disassembly, assembly, evaluation and testing of gyroscopes and accelerometers, platform systems and components. Equipment for these functions includes dynamic balancing machines, special assembly tools and precision ball bearing evaluation fixtures.

A full complement of data collecting and recording equipment, design and drafting space, etc., supports engineering design and evaluation. Inspection and repair functions, including inspection and minor repair of inertial platform systems, test equipment and components, are carried out with special fixtures and tools.

PROTOTYPE SHOPS

Prototype Development and Supporting Fabrication Activities. Total area of this functional subdivision of the laboratory is 25,000 square feet. Included in the complex are a complete machine shop, comprising an area of 14, 000 square feet, for mechanical fabrication and assembly; an electrical shop, 7000 square feet in area; and a full complement of necessary equipment in support of fabrication activities.



THERMAL AND VACUUM TESTING

The Machine Shop has a balanced variety of both conventional and high precision equipment. Heat treating equipment also is provided. Machining and fabrication of small and medium size components is carried out with emphasis on high precision accuracy requirements: machining operations are within .00005-inch accuracy; lapping is within .000015-inch roundness; surfaces can be finished to two micro-inches and flatness to one light band. Advanced methods are employed in the mechanical fabrication of special materials and metals, such as beryllium.

Specialized machine tools include an electrical discharge grinding machine, ultrasonic machining equipment and chemical milling equipment. Conventional equipment includes machine tools, lathes, grinders, shapers, jig borers, gear cutting machines, drill presses, pantographs and engravers, honing machines, band and power hacksaws and vertical, horizontal and universal milling machines. Numerical control machines include a continuous path type 3-axis super precision milling machine, a step-to-step type milling machine, a vertical jig borer and drilling machines.

For processing sheet metal, the shop is equipped with punch presses, power shears, press brakes, metal forming and bending machines, a vapor blast machine and a sheet metal fabricator. Resistance, spot, arc sigma, heliarc and electron beam welding can be carried out. Precision lapping machines and finishing lathes provide an assembly capability for any fabrication.

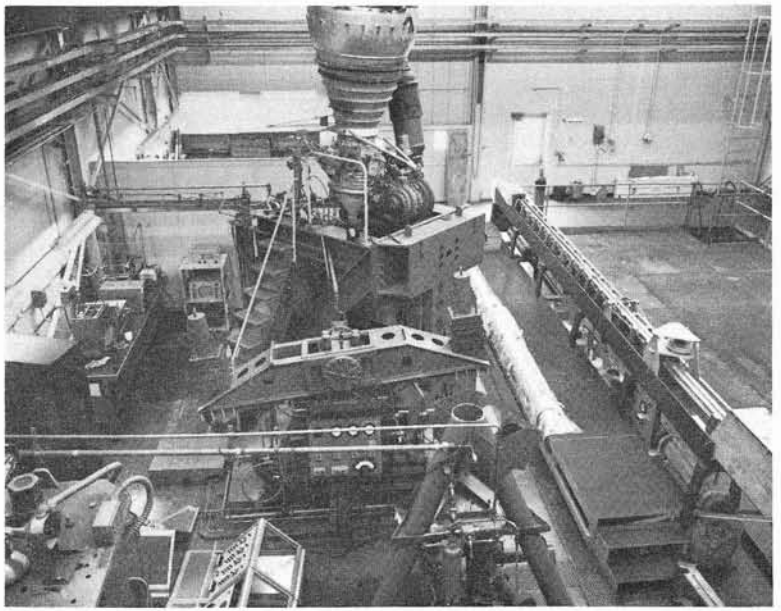
Mechanical, electrical and electromechanical measuring and testing equipment include surface analyzers, auto-collimators, balancing machines, optical gaging equipment, comparators, theodolites, microscopes, interferometers, a differential gaging system and a conventional and coordinate measuring machine.

The Electrical Shop has a wide range of capabilities for accomplishing electrical fabrication, component and unit assembly wiring, coil winding, printed circuit board processing and manufacture, module assembly, electronic and electrical component potting and encapsulation and general laboratory support.

In addition to these shops' facilities, the laboratory has a calibration unit completely equipped for electrical and electronic instrument calibration. Power distribution equipment supplies special power requirements, special voltages, frequencies and measuring circuits for space vehicle development.

This subdivision of the laboratory also carries out development projects in micro-electronics. Included in this field are studies in thin film deposition, vacuum technology investigations, micro-electronic circuitry and interconnection improvement, and an extended development of welding of micro-circuitry. Some of the equipment used in these projects include injection and compression molding machines, a micro-circuitry assembly machine, mass flowmeters, etc.

Other developmental capabilities include chemical research of special purpose plastics and conformal coatings of electrical and electronic circuit components and sub-units; metal plating process improvement, precision plating, anodizing and etching; design and development of special tooling fixtures and equipment; and flat conductor cable development in circuitry and interconnection.



SATURN ELECTRO-MECHANICAL THRUST VECTOR CONTROL SIMULATION LABORATORY

Applied Research and Environmental Testing. This facility is divided into the following individual functional subdivisions and areas:

- Optical Laboratory, 1080 square feet in area, is equipped with optical benches, lasers, optical and laser components, etc., for experiments and construction of lasers, optical systems and their components, etc.

- Spectrographic Laboratory, 600 square feet in area, is used for spectrographic experimentation. It contains high quality spectrographic and spectrophotometric equipment.

- Optical Tunnel is 100 meters long and evacuable with 20-foot by 20-foot access rooms at either end. Laser and optical systems can be evaluated.

- Two astro-domes are used for field testing of electro-optical and laser systems and testing of advanced laser and optical launch tracking systems. The domes are 12 feet and 14 feet respectively in diameter, are air conditioned and have isolation pads in their bases.

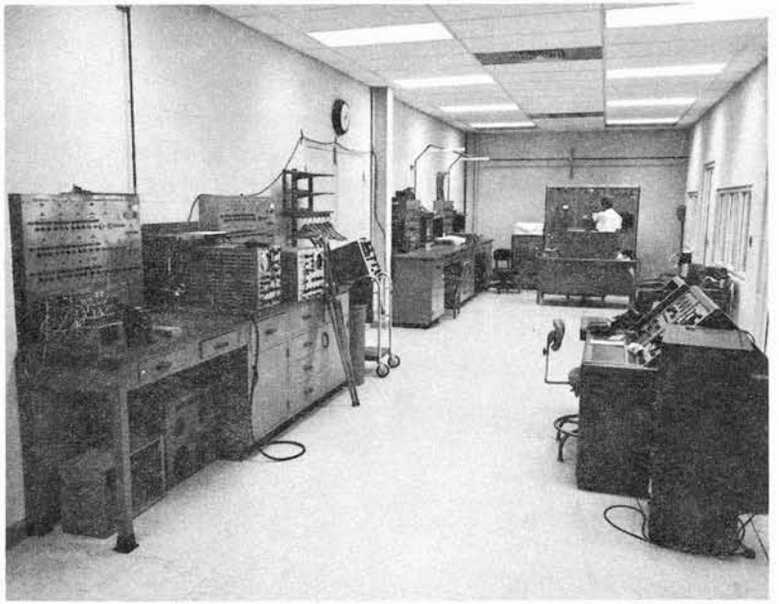
- Environmental Test Area, comprising 14,000 square feet, contains vibration and acceleration tables, vacuum equipment, a linear accelerator and acoustic equipment. Developmental and environmental testing is conducted.

- High-Quality Clean Room (Class I-III) incorporates diffusion furnaces, photo-engraving equipment, evaporators, etc., in a 1000 square-foot area. Complete fabrication and evaluation of integrated circuit devices can be carried out.

- Non-Linear Magnetic Laboratory is 500 square feet in size. It includes evaporators, Kerr magneto-optic equipment, etc., for the fabrication and evaluation of thin film memories.

- Diagnostic Laboratory uses 500 square feet to accommodate thermal plotters, X-ray equipment, a scanning electronic microscope, etc., for analysis of failure mechanics in integrated circuits and transistors.

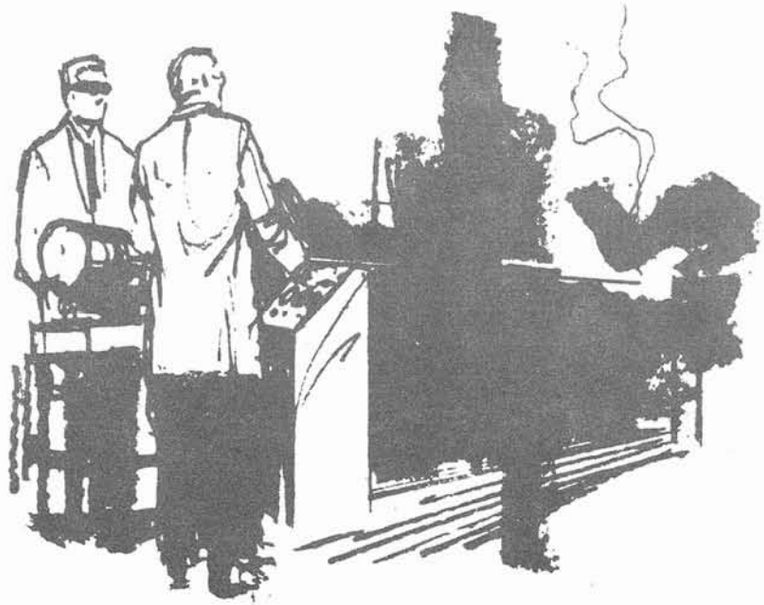
ENVIRONMENTAL TEST AND RELIABILITY UNIT CLEAN ROOM



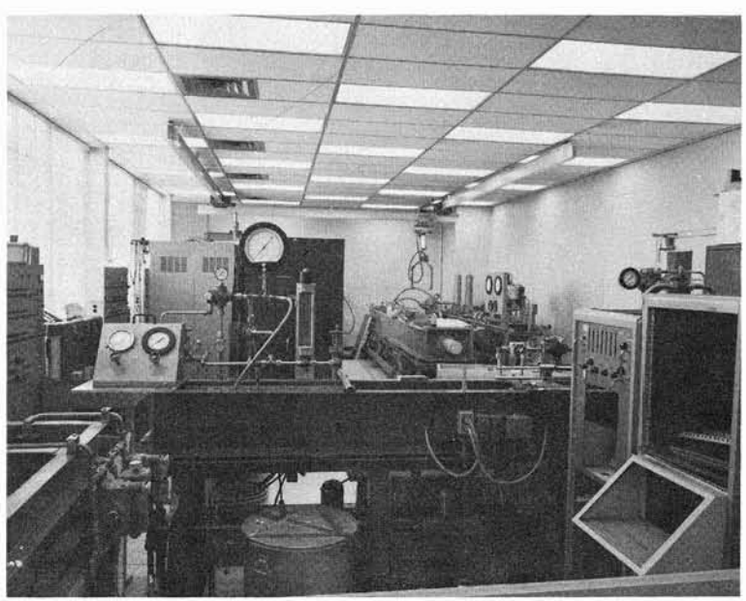
VIBRATION CONTROL CONSOLE

Guidance and Control Systems and Components Development. This facility is divided into the following functional subdivisions and areas:

- The Checkout Laboratory, 800 square feet in area, utilizes an aerospace test and evaluation console for checkout of the launch data adapter and digital computer.
- A 1250 square-foot laboratory contains an RCA-110A computer with Saturn V display for computing program and ground systems tests.
- The Control Sensor Laboratory is 500 square feet in area and contains specialized equipment for checkout of rate gyros and control accelerometers, and for acceptance testing and qualification checks of control sensors for flight equipment.
- The Applied Dynamics Laboratory provides analog computers for solution of guidance and control problems.
- The General Laboratory and support area comprises 1500 square feet. Circuits and subassemblies can be built and an area is provided for their testing; breadboard circuits are also constructed.

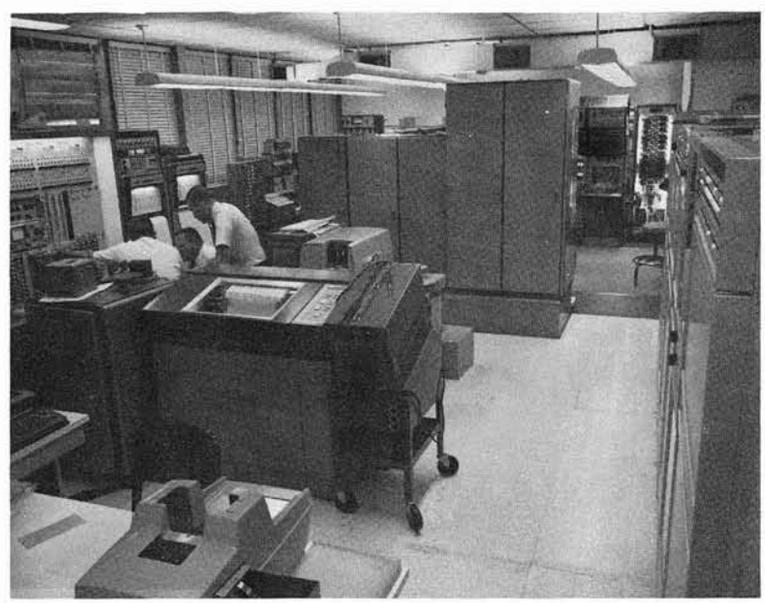


- The Hydraulic Development Area of 3700 square feet contains actuator test and checkout equipment, load simulator fixtures for actuators (engine simulators), large pumping equipment with a pressure force up to 3000 psi and accessary equipment. Actuation and gimballing systems of space vehicles can be developed, loading conditions of actuators simulated, and actuators and hydraulic equipment tested.



HYDRAULIC TEST FACILITY

HYBRID FLIGHT SIMULATOR FACILITY



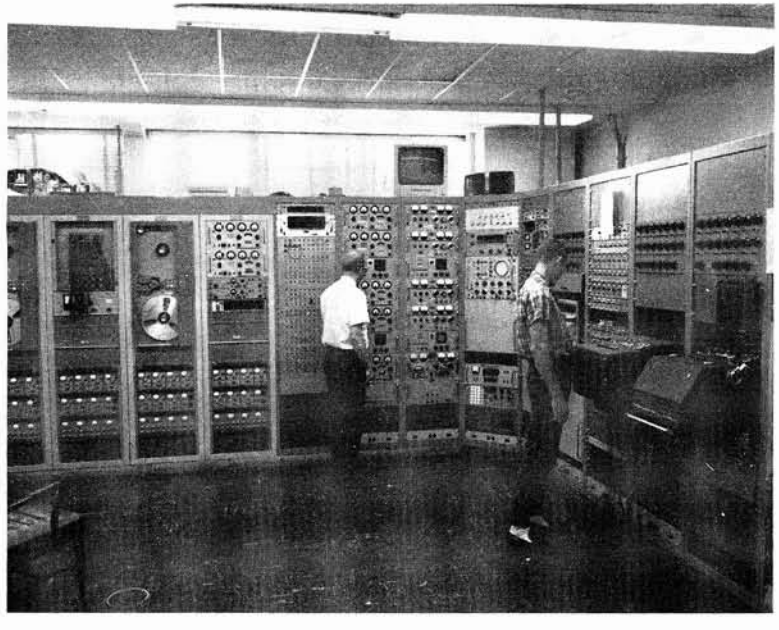
An altitude motion simulator with a three-axis system simulates motions of satellites and payloads in orbit; the equipment is housed in an area of 1000 square feet. Simulators for G and C systems used in conjunction with test equipment provide simulated flight conditions for systems testing of flight components; operations are observed through remote TV. This equipment also is contained in an area of 1000 square feet.

Instrumentation and Communications Development. Laboratory functions involving telemetry are conducted in a 7000 square-foot area. Advanced telemetry laboratory equipment includes a telemetry analyzer, checkout consoles for evaluation of subcarrier oscillators and mixer amplifiers and a checkout console for evaluation of testing of time division multiplexers. This equipment provides capability for complete telemetry systems analysis, for performing experiments and measurements, for performing data reduction of telemetry laboratory and flight experiments, and for hardware development in the field of advanced telemetry techniques. The laboratory also is equipped to perform studies, experiments and design of FM/FM (proportional and constant bandwidth), SS/FM, PCM/FM, PAM/FM, VHF and UHF techniques, airborne recording systems and data compression systems.

The Mobile Telemetry Ground Station, 800 square feet in area, is used for studies of flight systems to determine optimum data acquisition and selection of transmission techniques.

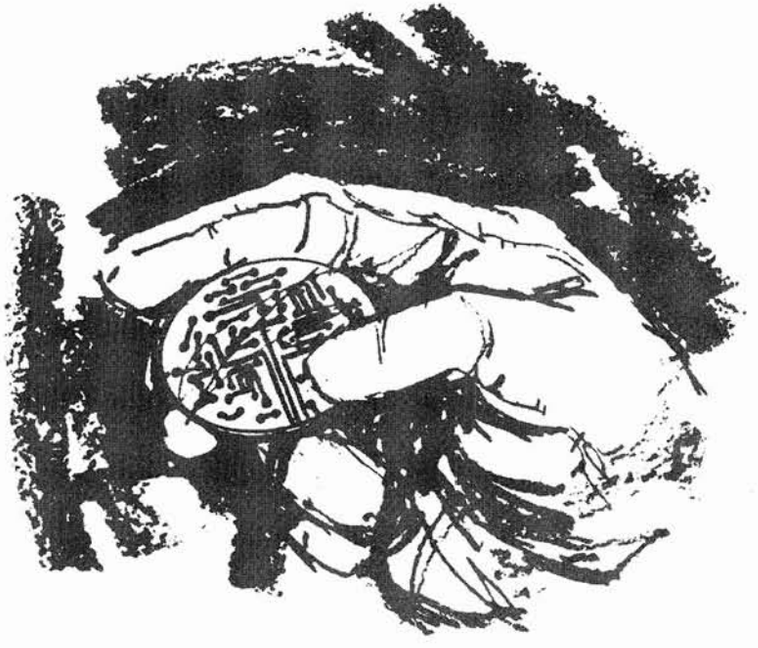
The Radio Frequency Laboratory of 8000 square feet provides facilities for conducting studies, experimentation and hardware development in the fields of radio frequency communications, techniques, tracking devices and systems; in TV technology, especially as applicable to space flight vehicles; and for digital data systems. A mobile RF laboratory (300 square feet) and a mobile TV laboratory (300 square feet) provide additional communications capability.

TELEMETRY GROUND STATION



The Radio Frequency Test Area is a 2400 square-foot laboratory located in a remote area of low radio frequency interference. The laboratory includes an anechoic chamber (33 feet by 33 feet by 120 feet), three outdoor pattern ranges and impedance measuring facilities. A non-reflecting RF environment can be used year round in conducting measurements and experiments on the properties of antenna systems. Capability further provides for recording pattern and polarization data from full and reduced scale space vehicle antenna systems and measuring the radiation characteristics of these systems.

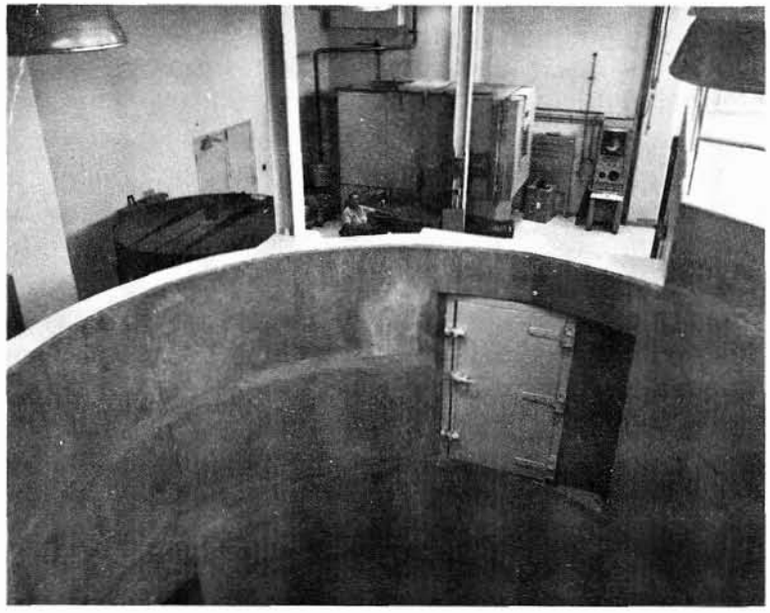
The Radio Frequency Propagation Facility (1600 square feet) atop Green Mountain, approximately 10 miles from the Laboratory facilities on Redstone Arsenal, is a specially located remote receiving station in a minimum RF noise interference area. It is equipped with a selection of antennas, control equipment, readout consoles and displays, etc., providing capability for both ground propagation and flight experiments and measurements. It is particularly equipped to track and receive transmission from vehicles traveling in space. Together with laboratory facilities located on Redstone Arsenal, it is used for long baseline RF experiments and measurements.



ASTRIONICS

The Airborne Instrumentation Laboratory, 8740 square feet in area, comprises a variety of special equipment oriented toward instrumentation development on vehicles or payloads. Included in this special equipment are a low frequency linear acceleration table, an oscillating rate table, a rate of turn table, a precision rotary tilt table, a sinusoidal pressure generator, vacuum systems, an amplifier checkout console, a microphone calibrator, a photographic instrumentation laboratory, a signal conditioning test console, a frequency analysis ground station, a vibration calibration system and an interferometer calibration system (to 20 kHz).

Capabilities for experimentation and development of instrumentation include those involved with radiation monitoring, temperature, fluid behavior, upper atmosphere density and composition, pressure, vacuum, angle of attack, voltage, current, error signals, strain, acceleration, vibration, acoustics, signal conditioning, automatic checkout, optics and photographic instrumentation. Also under development are advanced instrumentation concepts, hazardous evaluation sensors, fiber optics, vibration measurement, mosaic photodetectors, TV on film airborne recording and playback, and solid state laser illumination.



CENTRIFUGE ROOM

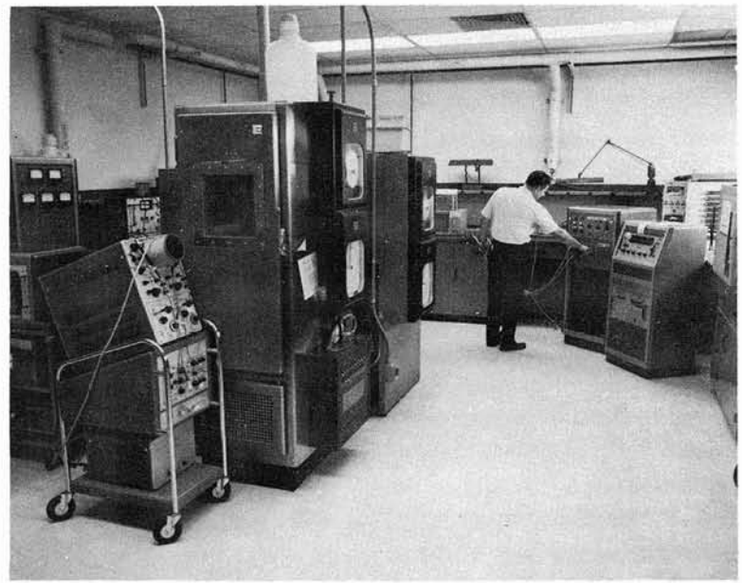
The Hazardous Operations Laboratory is a specially constructed 6600 square-foot facility equipped for handling materials of a hazardous nature. The radiation cells have 5-foot thick walls, plug doors, a manipulator, etc. For handling LN_2, LOX and cryogenic materials the test cells have special safety instrumentation, explosion proof electrical wiring, etc. A reinforced concrete cell has bullet proof windows for high pressure testing.

The laboratory facilities include a high pressure source up to 30,000 psi, LOX flow test equipment, temperature chambers, temperature standards, cryostats, a neutron generator, an X-ray generator and radiation sources. Experimentation and development projects dealing with instrumentation for space vehicles pertain to radiation, cryogenics, high pressure, LN_2, LOX and LOX flow characteristics. Detection instrumentation under development is for leak and fire detection and explosion and for detecting hazardous conditions.

The Fluid Test Facility is a 4500 square-foot laboratory containing flow calibration equipment and a tower for a 40-foot high V-tube. The facility is used to develop slosh sensor instrumentation and flow calibrations of instrument unit flowmeters. Fluid behavior studies relate to flow, level, slosh, mass, density and leakage characteristics.

ASTRIONICS

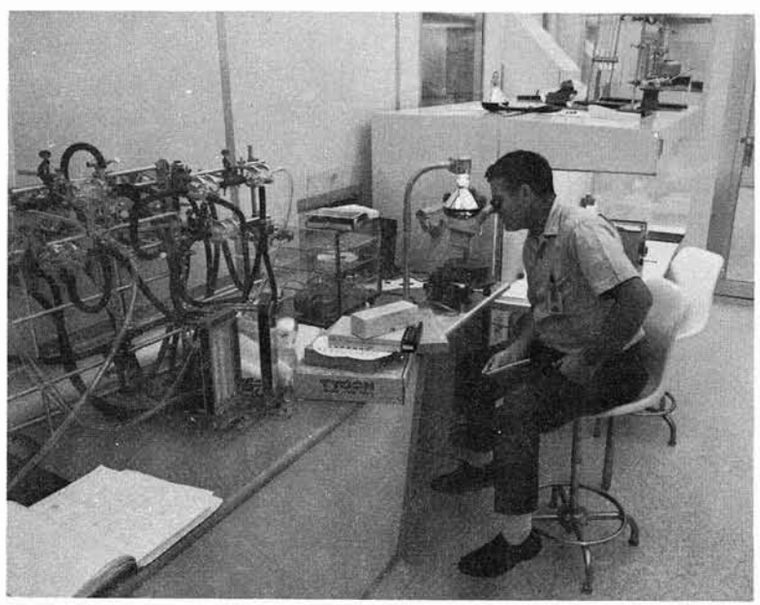
The Airborne Motion Picture Support area is 500 square feet; it is used for airborne photography and recording.



TRANSISTOR BETA AND ICBO MEASUREMENTS

Electrical Systems Integration. Four major areas are incorporated in this laboratory:

The General Design Area is responsible for the design concept and reliability criteria of integral electrical subsystems for multistage launch and space vehicles. Coverage includes all electrical assemblies and subsystems as well as the complete electrical ground support equipment required for test checkout and launch. These electrical systems and equipment are designed, developed, tested and evaluated by the laboratory. Total working area is 24,000 square feet.



DIFFUSION AND PHOTO MASKING OF A MICROCIRCUIT

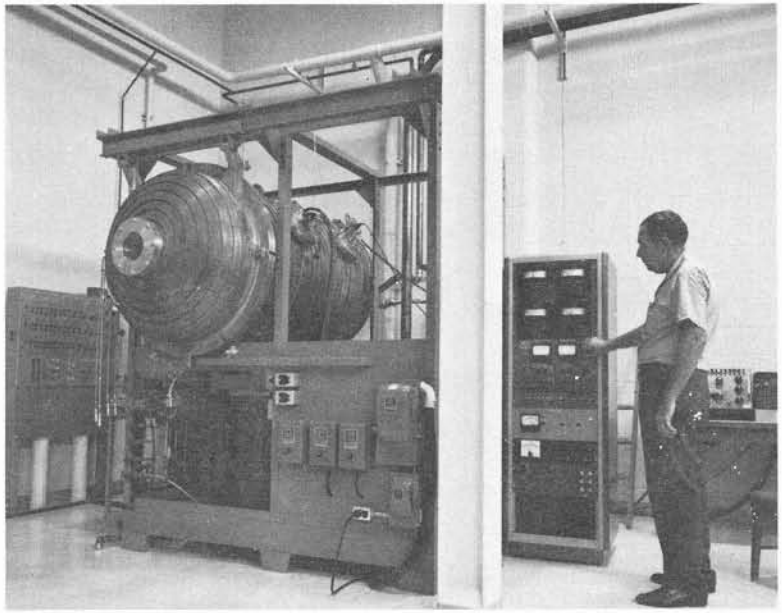
ASTRIONICS

The Saturn IB Systems Development Facility is 6500 square feet in dimension with computers and simulation equipment. Facilities enable simulation of the complete vehicle and ground support equipment for Saturn IB vehicles. Launch programs can be developed and automatic checkout is provided for design or design changes in the system.

The Saturn V Systems Development Facility, also comprising 6500 square feet of area, has equipment similar to that of the Saturn IB facility, but applicable to the Saturn V vehicles.

Electrical Support Equipment Checkout Facilities, incorporating a total of 35,000 square feet, contain a full complement of computers and checkout equipment including a digital events evaluator, an automatic panel checkout machine, automatic circuit testers, simulation equipment, etc. The facilities are used for checkout and acceptance of Saturn IB and Saturn V electrical support equipment.

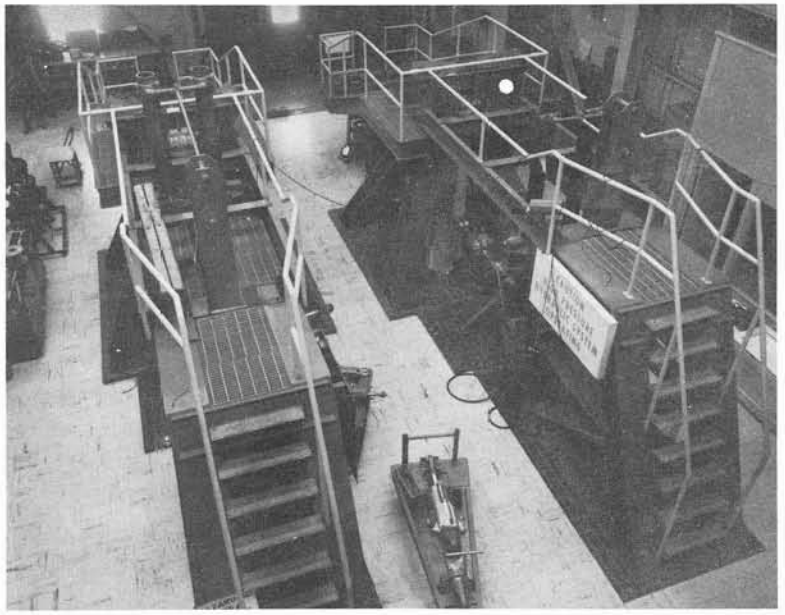
Electro-Mechanical Engineering. The General Design Area encompasses 11,000 square feet and provides the capability for research, development and design engineering of mechanical and electro-mechanical components, sub-systems, systems, simulators and environmental test facilities. Design engineering is performed in electronic packaging, test devices and special assignments in space technology. Detailed documentation for items assigned can be prepared, including test procedures associated with test fixtures, devices and details.



VACUUM CHAMBER

ASTRIONICS

Flight Dynamics Simulation. Both analog and digital computer systems as well as simulation equipment are contained in the 12,000 square-foot facility. The laboratory is utilized for the design and verification of guidance and control systems and is capable of hybrid, analog and digital simulation. Interfaces are provided for incorporation of flight and flight type guidance and control hardware.



S-IVB AND S-II INERTIA SIMULATOR

PROPULSION AND VEHICLE ENGINEERING

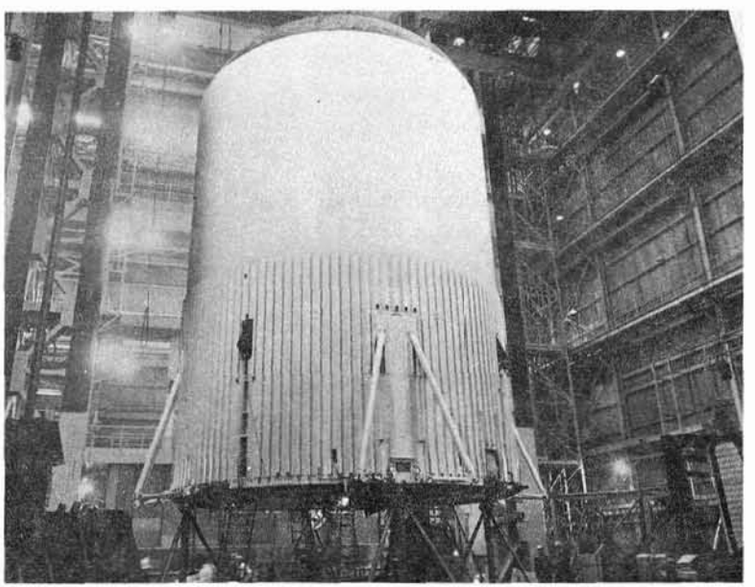
The facilities and equipment of the Propulsion and Vehicle Engineering Laboratory provide capability for research, development, and test in the fields of structures, mechanics, propulsion and materials as applied to launch and space vehicles and their payloads. The complex includes equipment for providing a variety of test environments, chemical and photographic analysis, heat transfer study, structural testing, flow testing, dynamic testing, radiation exposure and analysis, 3 million pound Universal Hydraulic Testing Machine, etc.

Static Load Testing. The Static Test Tower in Building 4619 has a test floor area 86.5 feet by 48.5 feet with anchor plates. The tower can accommodate specimens 35 feet high and 21.5 feet in diameter. Small tensile test machines have capability up to 400,000 pounds. Two 10-ton cranes are 42 feet high; one 20-ton crane is 80 feet high.

The Load Test Annex (LTA) 15,000 square feet in area, accommodates a static test tower with crosshead height of 115 feet and 30 million pound capacity. The tower can accept a preassembled article of 54-foot diameter or an article 65 feet in diameter if it is assembled in the tower. Two 30-ton bridge cranes have a hook clearance up to 106 feet.

The LTA Extension building comprises a total area of 37,587 square feet. Included in this addition is a high bay section of 19,900 square feet with anchor plates and two 20-ton cranes with 80-foot hook height. A universal test machine has a 3 million-pound capability. There are 2 test pads external to the building: One is 42 feet by 42 feet; the other is 52 feet by 52 feet and has dead man anchors.

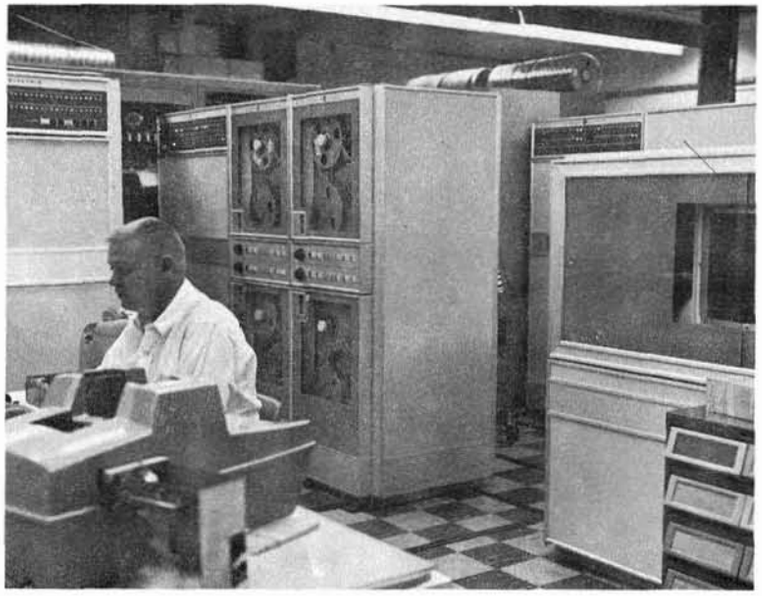
The Data Acquisition/Processing System consists of 2 GE 235 computers together with a Master Control Program. The computer system, serving Building 4619, LTA and its extension, and outside test pads, is comprised of four 1KC subsystems capable of sampling a maximum of 3072 transducers in a single scan; total capacity is 8000. The multiplex Master Control Program permits concurrent testing.



INTERIOR OF LOAD TEST ANNEX

Vibration Testing. Over 20 vibration exciters of various types and capabilities exist within the laboratory. This number consists of small shakers for system calibration; long-stroke electrodynamic, long-stroke hydraulic, 8000 force-pound shakers; and one large 28,000 force pound shaker for component testing. The electronic control equipment is available to perform sine and random tests. Tests requiring single or multiple shakers can be performed as well as combined elevated temperature-vibration testing. The necessary electronic analysis equipment is available to perform almost any type of vibration analysis desired.

A dynamic test trailer is used as a test control and data acquisition facility for complete vehicle dynamic tests. The trailer contains consoles which control either a 1500-pound or two 500-pound electrodynamic shakers through a frequency range of 0 to 3000 cps, an oscillator for controlling test frequencies, an oscilloscope for displaying data from any one of 100 accelerometer channels, a 50-channel oscillograph providing direct readout from accelerometers and a digital converter for producing complete data tapes. There is a low frequency amplifier capable of producing 40 KVA with the following combinations, all at 0.1 to 30 cycles per second:



RECORDER ROOM FOR TEST DATA

2 model 350 shakers (± 2-inch displacement) @ 10,000 pounds

or 1 model 350 shaker @ 20,000 pounds

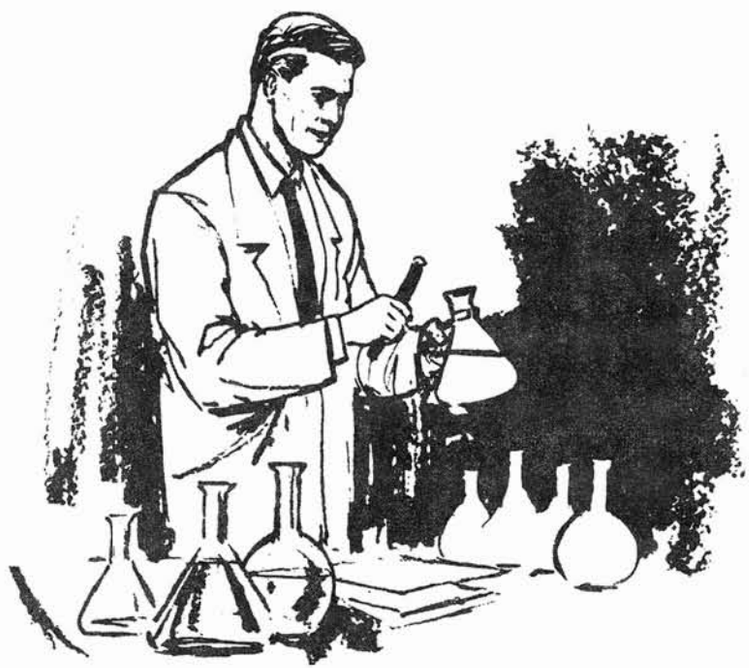
or 2 model 310 shakers (± 0.5-inch displacement) @ 5,000 pounds

or 1 model 310 shaker @ 10,000 pounds.

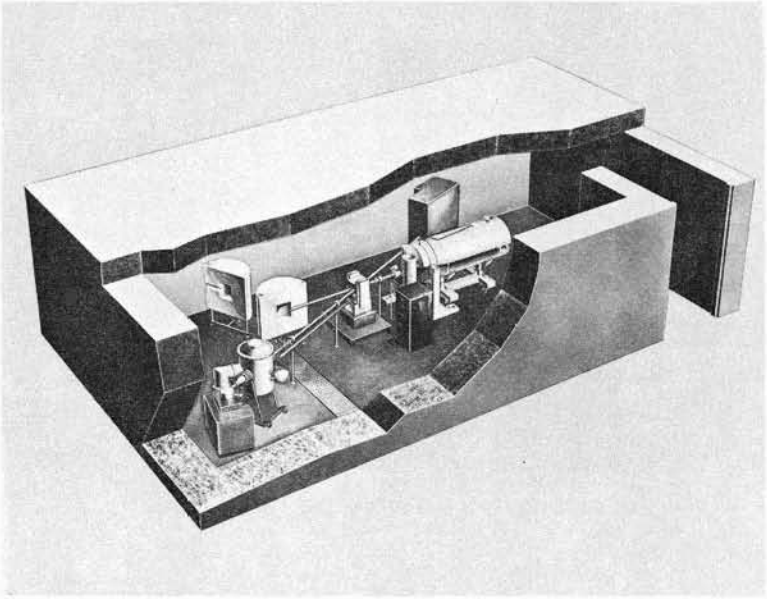
There is a high frequency amplifier capable of producing 20KVA with the same combinations, all at 20 to 2500 cycles per second; it also can handle one model 310 shaker @ 40,000 pounds.

A completely equipped impedance trailer is available for performing impedance tests on full scale and scale model vehicle structure. Graphic displays of force, acceleration, impedance, phase angle, transmissibility and power spectral density are quickly obtained. This system has the capability of tape recording test data and immediately processing the data after the test is performed. Up to 60 channels of phase accurate data can be recorded during one test where the desired data is below 4000 Hz.

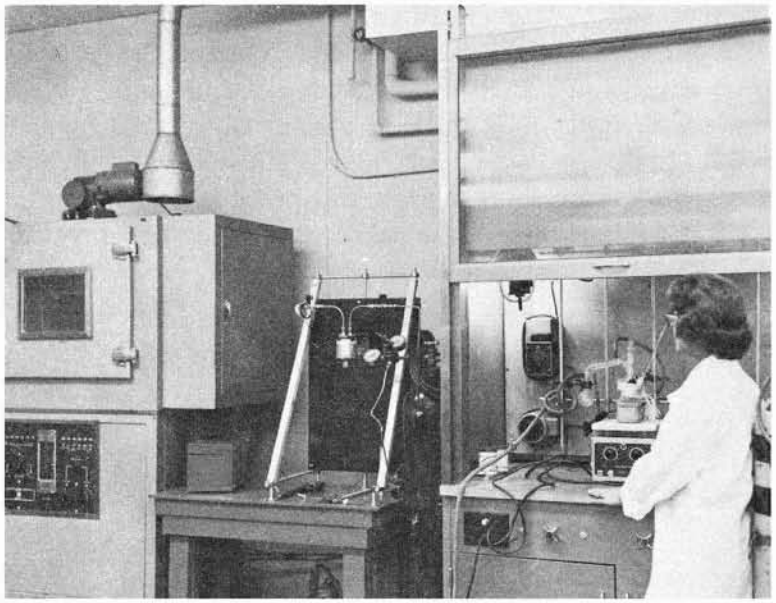
PROPULSION AND VEHICLE ENGINEERING



Shock and Acceleration Testing. Limited shock testing can be performed on certain shakers by use of an available wave form synthesizer. In addition, there is a drop test shock machine, with a 3-foot by 3-foot table of 1000 pound capacity, a pneumatic shock test machine of 100,000 pound capacity and a small pneumatic shock machine capable of testing components up 150 pounds with terminal velocities up to 300 inches per second. A centrifuge of 8-foot radius of gyration can provide accelerations of 100 g maximum on 500 pounds per arm.



CUTAWAY OF ION ACCELERATOR

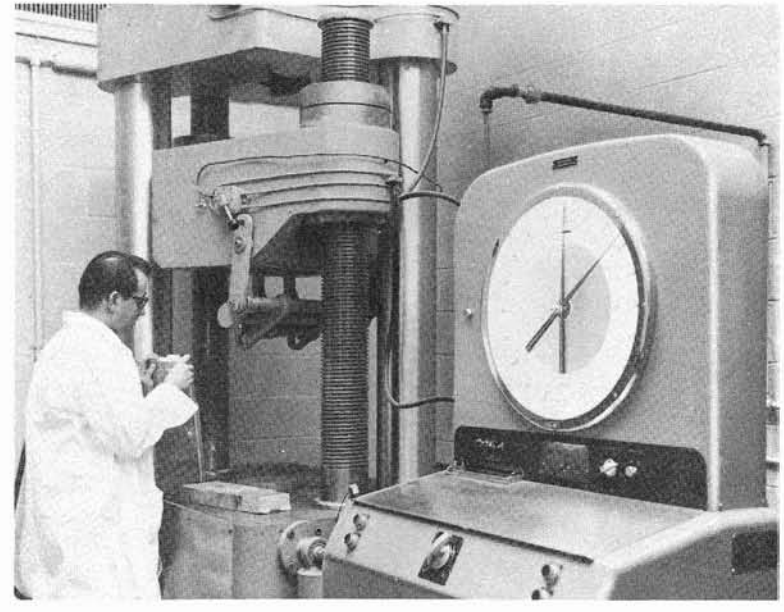


SYNTHESIS OF ORGANIC POLYMERS

Acoustic Testing. There is a 4846 cubic-foot reverberant room and an anechoic room of approximately 1500 cubic feet. A test section between these rooms will accept panels up to 6 feet square for sound transmission studies. Grazing incidence tests on 5-foot by 5-foot panels can be performed in a progressive wave test section. The major random noise source provides 40 000 acoustic watts (166 db pwl Re 10^{-12} dyne/sec cm) to the reverberant room. Maximum continuous test time is 30 minutes at maximum power. At lower power levels the test time is extended. Closed circuit television is available for instrumentation coverage for the acoustic test areas as well as the vibration areas.

Computation. Computations can be performed on an IBM 1620 computer system whose capacity is 60,000 BCD digits and an SDS 930 computer system with 4 mag-pack units (28 million character capacity) and 8000 words (core) of storage. These systems, including their support equipment, provide capability to sort microfilm on test measurement analysis, develop dynamics and loads calculations and make stress or loads analysis of structures. They are also used for various tests and special projects in the vibration and acoustic areas.

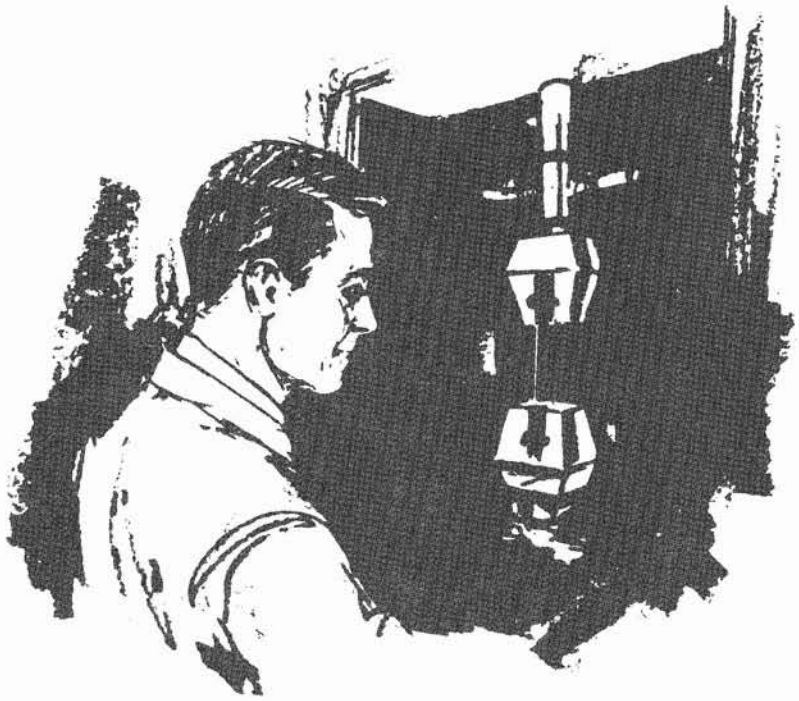
High Temperature Testing. There are two systems for providing power to banks of radiant heating elements which are built into special reflector configurations for each test setup. The upper limits of control in temperature are 1000°C and in heat-flux, 100 Btu/ft^2/sec. One system has 3000 KVA divided into 6 channels for power control with 4 power outlets for each channel. The entire system is analog-controlled and analog-recorded. The other system has 3750 KVA divided into 18 channels for power control with multiple power outlets for each channel. This system includes a highly flexible control and recording scheme whereby the data acquisition and processing system described under "Static Load Testing" can be used to compute and tabulate results.



MECHANICAL PROPERTY TESTING MACHINE

Hydraulic Research, Development and Test. Floor area devoted to this activity is 25,000 square feet. Operations utilize a clean room of Class III quality, 600 square feet in area, for processing of flight test components and systems. Four hydraulic fluid and RP1 flow stands have capacity up to 400 gallons per minute and 5000 psi. A hydraulic impulse of 0 to 400 psig in 15 milliseconds can be provided on an impulse test stand. The pump test stand has a capacity of 100 HP and 30,000 RPM. The engine gimbal test stands can accomodate gimballing equipment up to the size required for F-1.

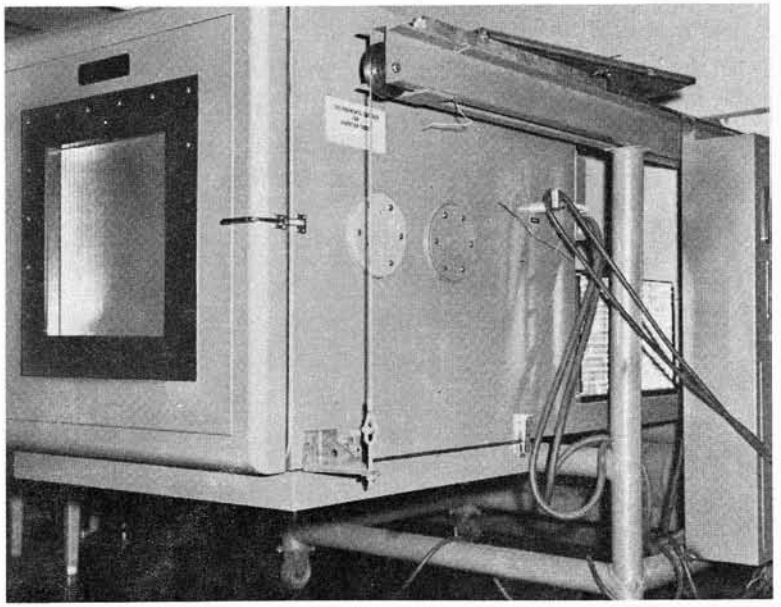
Heat Transfer. Studies performed in test stands employ scaled down models to investigate heat transfer in propellant systems and in two-phase flow systems (liquid-vapor), insulation schemes for cryogenic tanks and calorimeter development for heat radiation measurements. Existing capability allows for investigation of present problems, but models and facilities can easily be modified as required.



Environmental Chambers. Two space simulation chambers, each of 75 cubic-foot volume can attain a vacuum of 10^{-7} Torr and temperature of ±300° F. A walk-in high-altitude chamber, 560 cubic feet in volume, has a 1 Torr pressure capability and a temperature range from -100° F to + 350° F. The vacuum, temperature, humidity chamber is 8 cubic feet in volume and can maintain a 1 Torr vacuum at -300° F to + 600° F temperature with a 0 to 100 relative humidity. The temperature chamber, 27 cubic feet in volume, has capability of -300° F to +600° F. A 112 cubic-inch vacuum furnace provides temperatures up to 2760° C at pressures down to 10^{-6} Torr. The 75 cubic-foot explosion chamber provides selected initial pressures of from 1 Torr to 60 psi.

Cryogenics. For cryogenic studies a LOX-LH_2 high pressure test stand has a working pressure up to 1000 psi and a capacity of 150 pounds of LOX or LH_2. LN_2 test stands have a dewar capacity up to 40 tons.

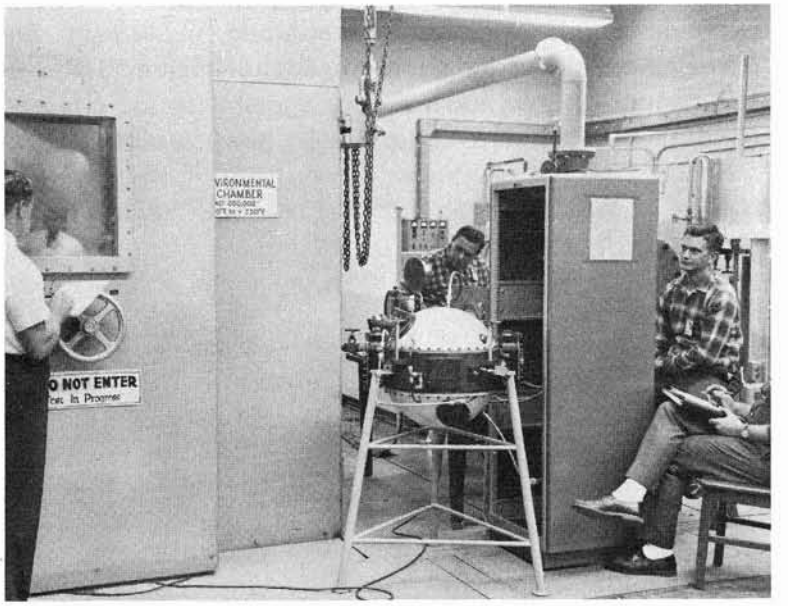
Fluid Mechanics. Flow test stands provide for studies of vortex, terminal drainage, surge pressure, stratification, bubble dynamics and geysering in turbulent fluid flow. Metal and plexiglass tanks can be prerotated, pressurized, drained and vibrated. Model studies are conducted as well as similarity and two-phase flow investigations.



ENVIRONMENTAL CHAMBER FOR VIBRATION TABLE

Data Acquisition and Calibration. In addition to the data acquisition and calibration equipment already mentioned there is a 2200 square-foot Recorder and Evaluation room containing 80 strip chart recorders, 3 visicorders, 6 oscillographs, 3 digital recording systems (25 channels each), 1 digital recording system (100 channels), 2 tape recorders, 2 oscillograph trace readers, 2 X-Y data plotters, as well as oscilloscopes, cameras, power supplies, calibration equipment and electrical support equipment.

Pneumatic and General Test. Facilities consist of high pressure test cells, zero leakage testing equipment occupying 400 square feet and miscellaneous facilities for testing of valves, regulators, pressure switches, ejection systems, etc. There are a total of 8 pressure test cells comprising 640 square feet of floor area. All are connected to an air pressure source of 3000 psi and GN_2 source of 5000 psi.



ALTITUDE CHAMBER FOR ENVIRONMENTAL TEST

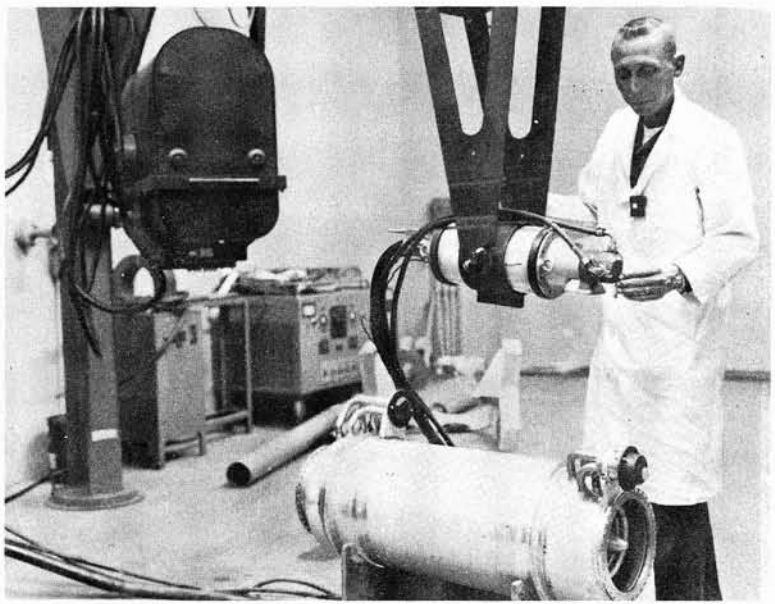
Materials Development, Evaluation, and Fabrication. Floor area devoted to laboratory activity in the materials research and development field is approximately 23,000 square feet. An additional 4000 square feet contains a completely equipped machine shop to produce small detailed parts when necessary and otherwise support the development activities. Laboratory support also exists in a capability for filament winding components up to 12 inches diameter by 20 inches long and for vapor deposition of coatings (including refractory materials) to both metallic and non-metallic substrates up to 25 square inches in size.

Twelve vacuum systems and associated small chambers are used to determine compatibility of materials with combined vacuum and temperature environments of 1 atmosphere to 10^{-10} Torr and -200° C to + 500° C.

Radiation effects on the useful properties (mechanical strength, physical properties, and chemical properties) of materials, especially when combined with other environmental parameters such as temperature and vacuum, are investigated in a 2400 square-foot area. A 2 MEV Van de Graaff accelerator and radioisotopic, ultraviolet and X-ray sources are employed.

PROPULSION AND VEHICLE ENGINEERING

A complete spectrum of non-destructive testing equipment is contained in a laboratory area of 4000 square feet. The facility carries out feasibility studies and development programs of techniques for nondestructive determination of properties and structural integrity of materials and components. These methods utilize X-rays, isotopes, ultrasonic techniques, infrared radiation, eddy current and magnetic particles.



X-RAY EXAMINATION OF A HEAT EXCHANGER

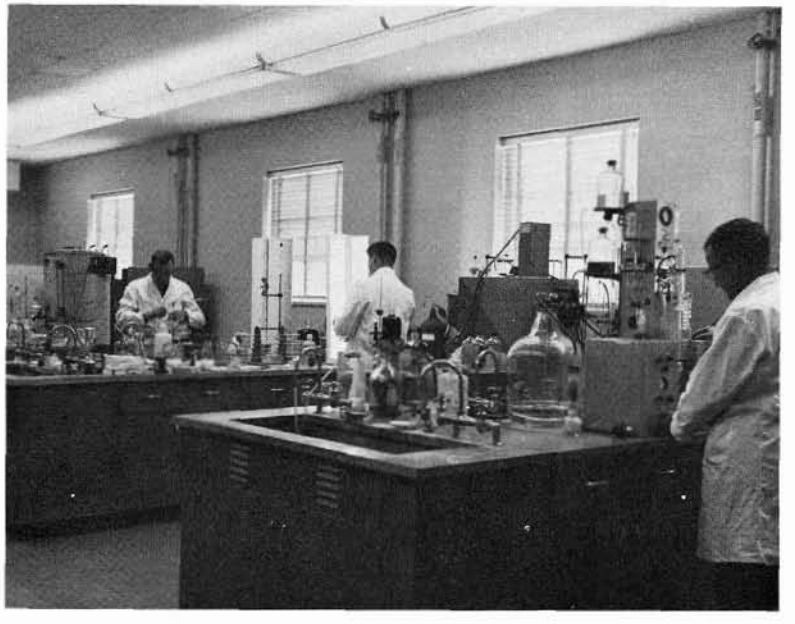
PROPULSION AND VEHICLE ENGINEERING

An 800 square-foot area is equipped to determine the effects of hypervelocity impact on materials. The velocity range is 20,000 to 100,000 feet per second for particles with mass between 0.0005 and 0.5 gram. Methods are determined for minimizing the detrimental effects of hypervelocity impact.

Equipment for complete evaluation of electrical materials is located within a 1200 square-foot area. These evaluations involve determination of such properties as dielectric strength, dielectric constant, dissipation factor and conductivity. Temperature and pressure environments that can be provided range from -253°C to +300°C and 10^{-10} Torr to 1 atmosphere.

There is capability for evaluation and/or development of lubricants for both low and very high bearing loads under a variety of operating conditions including space environments.

Mechanical and physical testing occupies 2500 square feet of floor space. Equipment exists for measuring all important mechanical and physical properties of materials from -269°C to temperatures in excess of 1000°C.



WET ANALYSIS LAB

PROPULSION AND VEHICLE ENGINEERING

RUBBER AND PLASTICS TECHNOLOGY.

Fully equipped laboratories are available to develop and evaluate manufacturing processes required to obtain specified materials properties and to adapt materials for use under extreme environments and performance requirements. Rubber, plastic, metal, ceramic and composite materials are involved.

MANUFACTURING ENGINEERING

Manufacturing Engineering Laboratory has large fabrication and assembly high bay areas and associated cranes, large access doors, machine shops, clean rooms, and specialized equipment necessary for producing and refurbishing prototypes of large aerospace hardware systems. It includes equipment for research and development in advanced manufacturing techniques, methods and tooling for structural, surface finish, and pressure vessel applications.

MANUFACTURING ENGINEERING

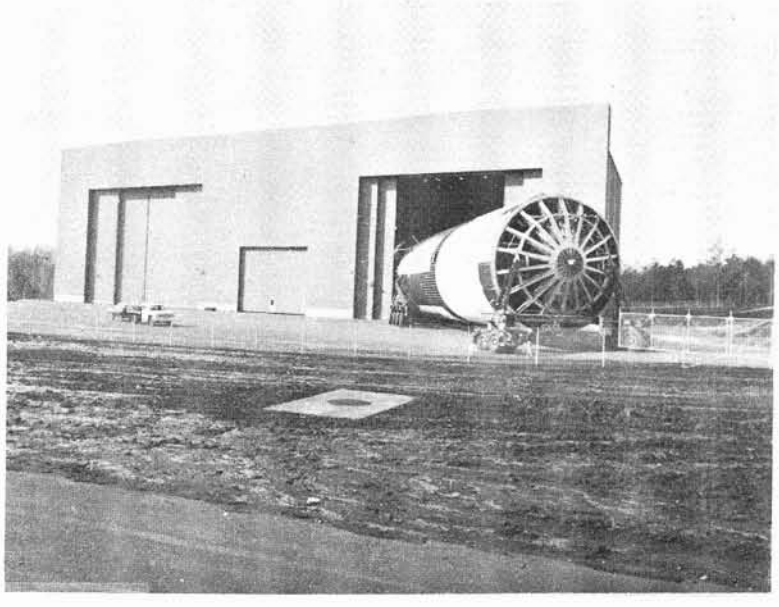
High Bay Fabrication and Assembly Space. The following chart summarizes the space in Manufacturing Engineering Laboratory with 30' or greater truss clearance for accommodation of large hardware items.

	Truss Clearance	Cranes No. & Tons	Hook Ht.	Sq. Ft.
Building 4705				
Component Development Facility	43'9"	2-10	35'3"	45,200*
	30'	1-5	22'11"	5,400**
	30'	1-5	22'11"	8,500*
Building S-4755				
Multipurpose Technology Facility	86'	2-90	70'	45,000**
Building 4707				
Composite Structure Development Facility	34'0"	2-20	25'	38,000
Vertical Assembly/ Cleaning	151'	1-60	140'	6,400

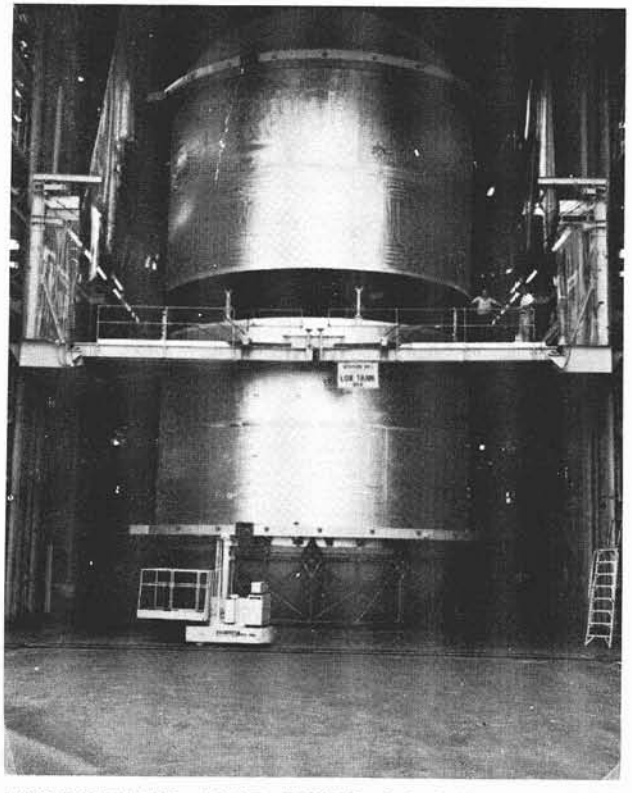
* Capability of temporary environmental control of specific portions by use of curtains and portable A/C.

** Environmental control.

MANUFACTURING ENGINEERING



MUTLI PURPOSE TECHNOLOGY FACILITY



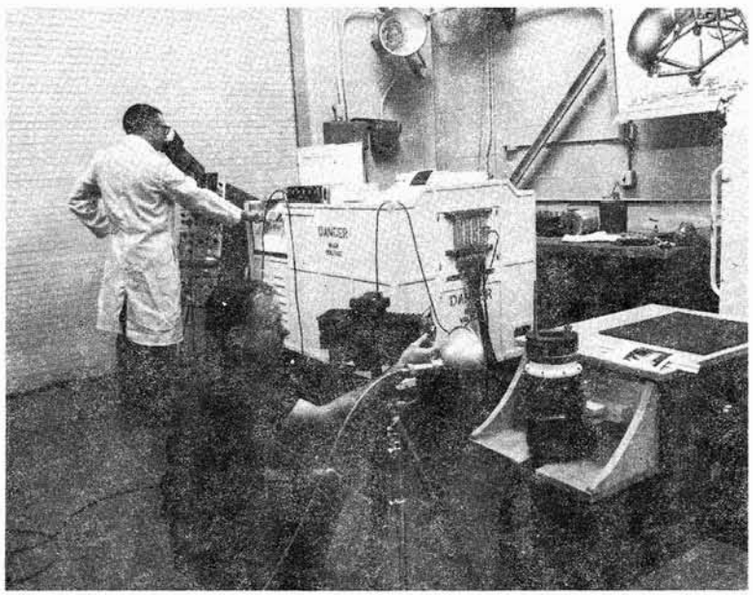
HYDROSTATIC TEST TOWER IN BUILDING 4707

Machine Shop and Precision Machine Shop. The Machine Shop, located in Building 4705, encompassing a 33,800 square-foot area, is capable of both general machine shop functions as well as special operations. A Class I environmental room, 5700 square feet, contains a Precision Machining Shop with a capability of working to tolerances of .0001 inches. The Machine Shop is supported by two 20-ton cranes with a hook height of 25 feet. In addition to the standard lathes, milling machines, planers, radial drills, grinders, etc., the shop contains the following equipment:

- numerically controlled machines
- six-position turret drill
- vertical die mill (16 inches by 24 inches)
- horizontal die mill (48 inches by 120 inches)
- machine lathe (14 inches by 96 inches)
- skin mill (with table 12 feet 3 inches by 36 feet)
- vertical boring mill (12 feet)
- radial drill (8 feet)
- engine lathe (34 1/2 inches by 132 inches)
- planer (6 feet by 14 feet)

MACHINE SHOP IN BUILDING 4705

MANUFACTURING ENGINEERING

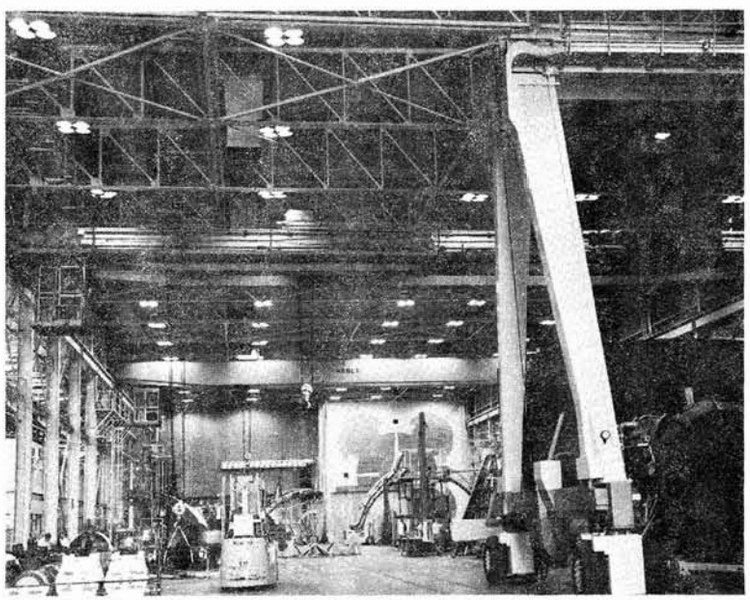


18,000-JOULE PORTABLE POWER SUPPLY

Tube Cleaning. The facility has a Class II clean room equipped with solution tanks of 30-gallon capacity. Automatic process control consoles are employed as well as equipment for ultrasonic cleaning, vapor degreasing, vacuum drying and packaging. Aluminum, stainless steel and Hastelloy tubes up to 3 inches in diameter and 60 feet in length can be cleaned. Cleanliness is evaluated by particle count. The cleaning area is 3600 square feet.

Valve Clinic. A Class III clean room includes a receiving disassembly room, assembly room and packaging area, all equipped with Whitfield benches of Class IV clean room specifications. An evaluation laboratory, change room and air locks are part of the clinic; 3000 psi clean air, nitrogen and helium are supplied.

The clinic is capable of disassembly, inspection, repair, modification, cleaning, cold check pressure and flow testing to 50 scfm., evaluation of valves and similar subassemblies and packaging these to 40 cubic-inch envelope size.



ASSEMBLY AREA OF BUILDING 4705

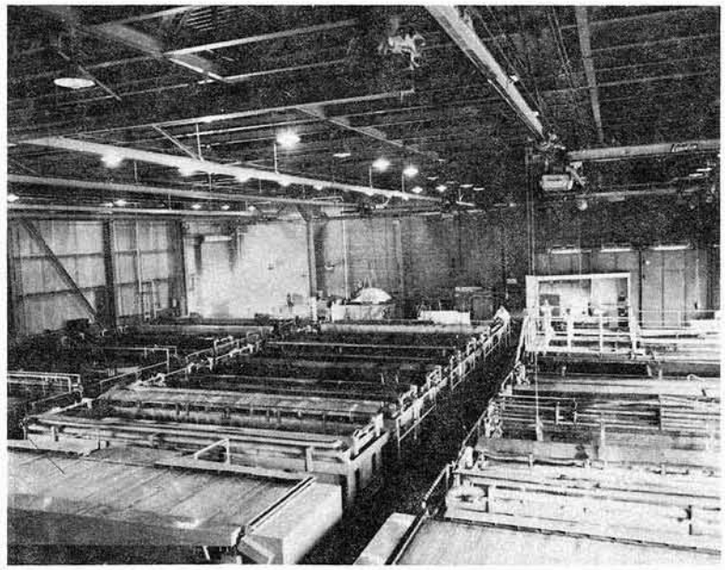
Surface Treatment. The area involved is 23, 500 square feet and includes

- 23 cleaning tanks (5 feet by 24 feet by 10 feet)
- 2 trichlorethylene vapor cleaners (5 feet by 24 feet by 10 feet)
- 2 drying ovens (5 feet by 24 feet by 10 feet)
- paint booth (20 feet by 60 feet)
- 80 cleaning and electroplating tanks (3 1/2 feet by 3 1/2 feet by 3 1/2 feet)

which enable high standard chemical and mechanical cleaning, electro-polishing, painting, anodizing, chemical milling, pickling, passivating and metal plating.

An instrument surface finish room with 18 plating units has a capability for developing processes in nickel, copper, silver, rhodium, chrome, anodized, black oxide and electro-polished finishes.

Metal Forming and Fabrication. The equipment in this 15,000 square foot area has complete capability for forming and joining large pieces of sheet metal. Stainless steel high alloy plates up to 120 inch widths and 3/8 inch thickness are processed. Equipment includes a 10-ton crane with 35-foot hook height as well as roll forming machines, brakes, automatic and manual welding equipment, flame cutting equipment and radiographic inspection equipment.

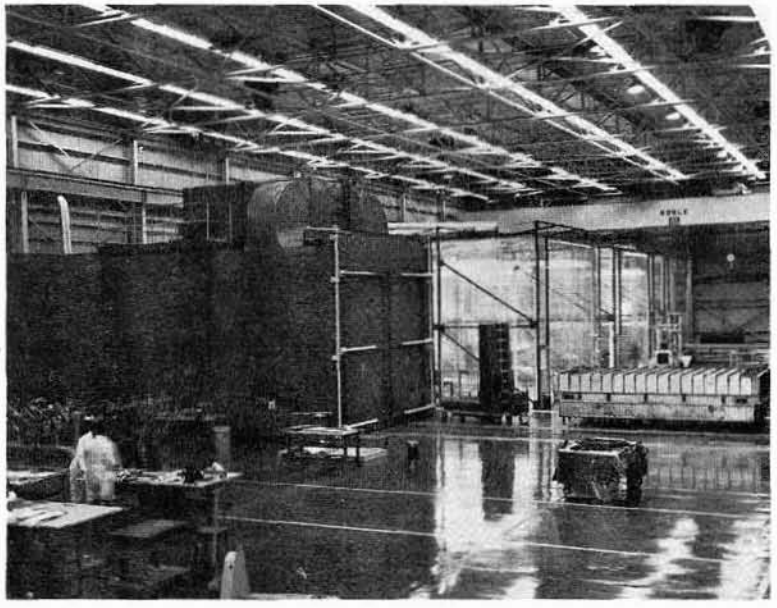


LARGE TANK AREA IN SURFACE TREATING FACILITY

Composite Structure Development Facility. The composite Structure Fabrication Facility in Building 4707 occupies an area of 44,900 square feet, consists of three environmentally controlled lay up rooms, cleaning tanks, spray booth, pre-fit lay up tables, drills and saws. The 20-ton crane service has a hook height of 25 feet. The drying oven heats to 250°F.

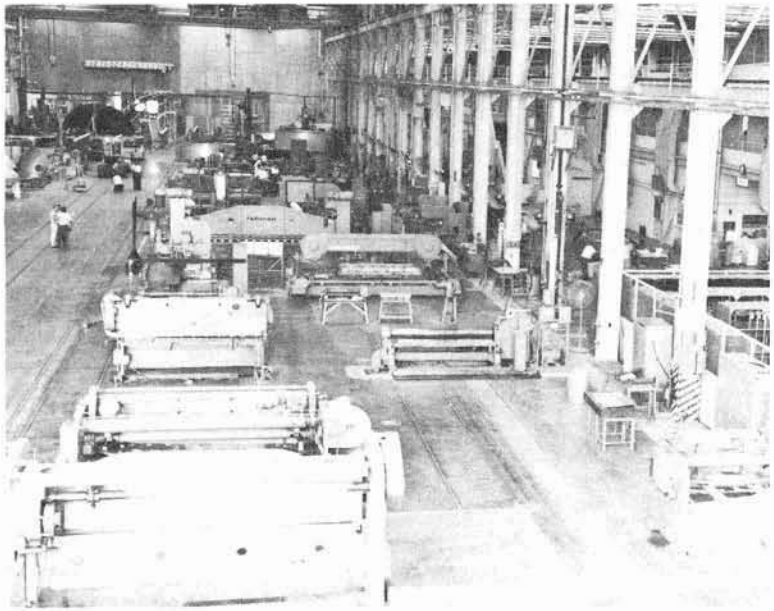
There are two autoclaves: The larger (16-foot diameter by 32 feet) has a maximum temperature of 750°F, maximum pressure of 110 psi and minimum pressure of 25 Torr. The smaller (10-foot diameter by 14 feet) has 250°F maximum temperature; pressure range is from 30 Torr to 150 psi.

Composite structure panels can be fabricated in steel, steel alloys, or aluminum either in flat plates or curved shapes up to 16 feet wide, 30 feet long and any practical thickness.



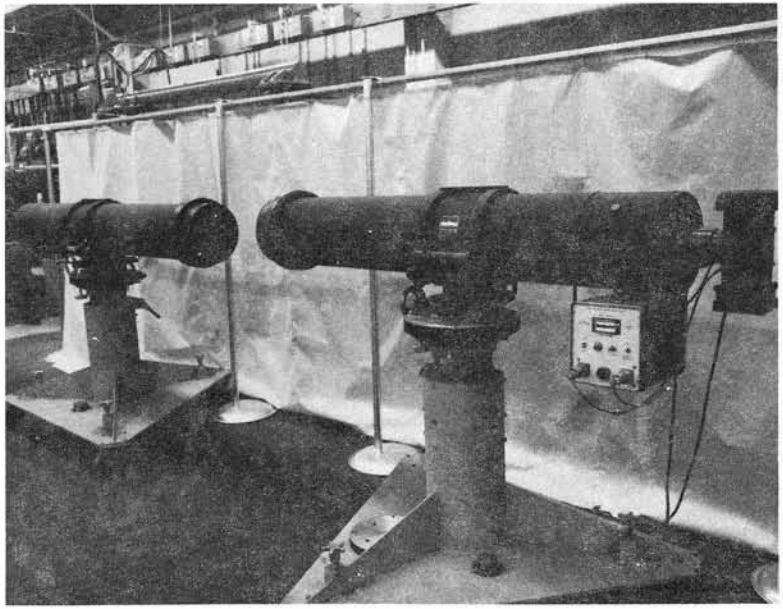
FABRICATION AREA IN THE COMPOSITE STRUCTURE DEVELOPMENT FACILITY

Welding Development. The laboratory has provisions for conventional and electron beam welding in addition to its plasma arc and induction brazing equipment. The area, including high vacuum welding chambers, is 12,800 square feet. Basic and applied research and development is conducted as related to the fabrication of stainless steel alloys, aluminum, "exotic" alloys and refractory metals.



METAL FORMING AND FABRICATION SHOP

Material Evaluation. Scope of capability includes metallurgical analysis and testing and evaluation of material specimens including composite structures. Operations utilize tensile, compression, fatigue, hardness and creep test equipment; film processing and X-ray equipment; a micro-electron probe spectrograph; and a metallograph. Floor area is 4270 square feet.



SCHLIEREN APPLICATION SYSTEM

MANUFACTURING ENGINEERING

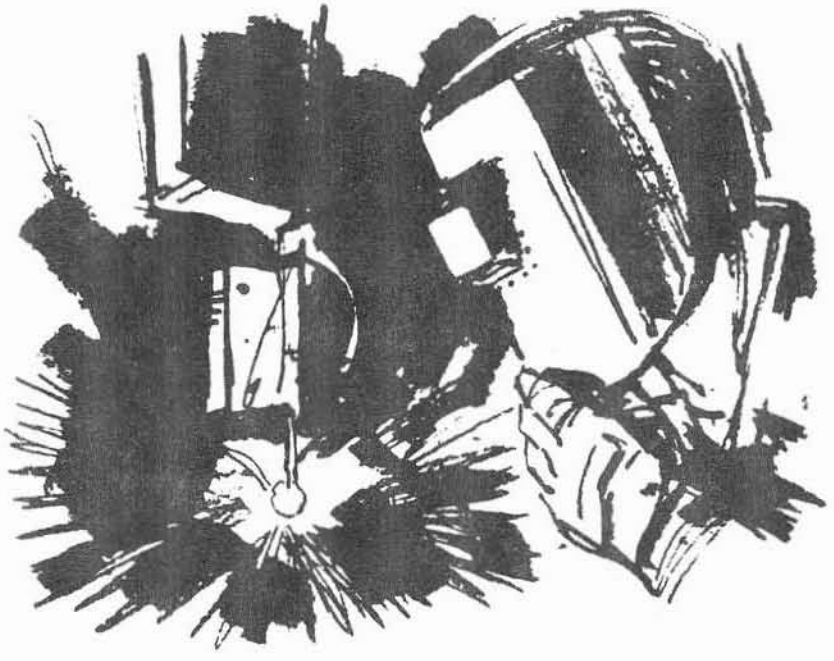
Processes and Methods Development. Floor area is 12,000 square feet. The laboratory is designed for development and testing of new processes, techniques, mechanical manufacturing devices and materials as related to fabrication and assembly.

Examples of specific work areas are

- explosive forming
- corrosion control
- composite structure fabrication
- plastics and adhesives
- heat treating
- mechanical connections
- new materials application

Equipment for these functions include temperature-controlled forming presses; a tempering induction furnace with temperature variance from 2500°F to 3000°F; beryllium machining equipment; precision measuring instruments such as a Talyrond, profilometer, INDI-RON and shadowgraph; a Royco particle nephelometer; a spectrophotometer; gas chromatograph; and a sterilization facility.

ULTRA HIGH VACUUM RESIDUAL GAS ANALYZER



MANUFACTURING ENGINEERING

Electronics Development. Research and development is conducted in the application of electronics, electro-mechanics and physics to the following areas as they relate to fabrication and assembly processes:

- physical and thermal measurement
- magnetic and electro-hydraulic forming
- infrared photography
- laser technology
- instrument development

The laboratory encompasses in a 12,000 square-foot work area, high intensity magnetic forming coils, computers, electronic monitors, X-ray "Vidicon," fiber optics, closed circuit TV, equipment for vacuum measurements and calibrations, ultra-high speed Laser, cameras and a 240,000 Joule capacitor bank.

QUALITY AND RELIABILITY ASSURANCE

The Quality and Reliability Assurance Laboratory has the equipment and facilities to perform the following functions.

- To establish, supervise and maintain a comprehensive quality and reliability assurance program for launch vehicle systems and material during the developmental, manufacturing and assembly phases and to assure that material accepted meets established quality and reliability levels.

- To perform analysis, tests and checkout of launch vehicle systems, their subsystems, components and related support equipment to assure satisfactory performance under the conditions and purposes for which designed.

- To develop and apply techniques in quality and reliability engineering necessary to ensure the quality and reliability of space vehicle parts, components and systems.

- To provide a composite quality and reliability assurance technical capability in depth, which will ensure the technical adequacy and performance of industry in the manufacture, delivery, test and launch of space vehicles.

QUALITY AND RELIABILITY ASSURANCE

High Bay Space. The following chart summarizes the space in Quality and Reliability Assurance Laboratory with truss and crane clearance greater than 30 feet for accommodation of large hardware items.

Building	Truss Clearance	Cranes No. & Tons	Cranes Hook Ht.	Sq. Ft.
4708*	43' 9"	2 - 10	33' 9"	51,700
4708* * (Pressure Cell)	35'	None		7,800
4752* * *	65'	1 - 20	53'	21,700
4705* * * *	35'	None		7,722

* High Bay Doors 92' 11" wide and 43' 9" high. Floor capacity 2000 lb/ft^2.
* * Door 32' wide and 36' high at east end.
* * * Doors 60' wide and 65' high at each end. Floor capacity 2000 lb/ft^2.
* * * * Door 32' 5" wide and 34' 11.5" high at west end of area.

INTERIOR OF COMPONENTS AND SUB ASSEMBLY ACCEPTANCE BUILDING

CONTROL ROOM, PERFORMANCE TEST CONTROL

QUALITY AND RELIABILITY ASSURANCE

Dimensional Laboratory. Calibration tests are performed for length, threads, optics, angles, roundness, hardness and flatness. Dimensions are traceable to specifications of the Bureau of Standards through gage blocks certified to a few millionths of an inch. The area involved is 1000 square feet and a temperature of 68° F ± 1° is maintained.

- Standard measuring machine has a range of 0 to 80 inches with a ±.000030-inch accuracy.
- Internal comparator has an internal range from 1.25 to 10 inches; external range is 9 inches.
- Auto-collimator has an accuracy of ± 1 second within a range up to 100 seconds for surface plates.
- Clinometer range is 0 to 360° and accuracy is 1 second of an arc.
- Contour projectors for calibration of threads, straight and tapered, are accurate to 2 minutes in a range up to 80 to 1.

Physical Laboratory. This laboratory occupies 1600 square feet. Temperature and humidity are maintained at 73° F ± 2° and 50 percent respectively. High pressure gas and vacuum are provided and certification for pressure measurement is based on high accuracy dead weight standards up to 40,000 psi. Facilities include a mobile field calibration unit, mass three mettler balances with 0 to 1000 gm range and 1×10^{-6} gm resolution, torque calibrators with a 0 - 4000 ft/lb range and a force accelerometer calibrator covering a range up to 100 G and 10 kHz frequency with ± .2 percent peak accuracy.

NAVIGATION SYSTEM TEST STATION

Electrical/Electronics Laboratory. Calibrations are conducted in voltage, resistance, current and frequency. A virtually complete secondary calibration is possible from dc to radio frequencies including microwave frequencies to 18 GHz. An RF screen room, 192 square feet in area, provides 60 dB attenuation for RF measurements.

Total laboratory area is 2500 square feet. A voltage standard is maintained by two banks of saturated standard cells in constant temperature air baths. Resistance standards are kept immersed in a thermally regulated oil bath. Standards for current are derived from the resistance and voltage standards. A thermocouple element, certified against a dc reference voltage, provides traceability in ac voltage and current.

The Environmental Test Laboratory. This laboratory occupies 11,590 square feet with 7722 square feet of high bay space and contains both force application and environmental equipment to perform qualification tests on flight components. Specific capabilities of the primary equipment are listed below.

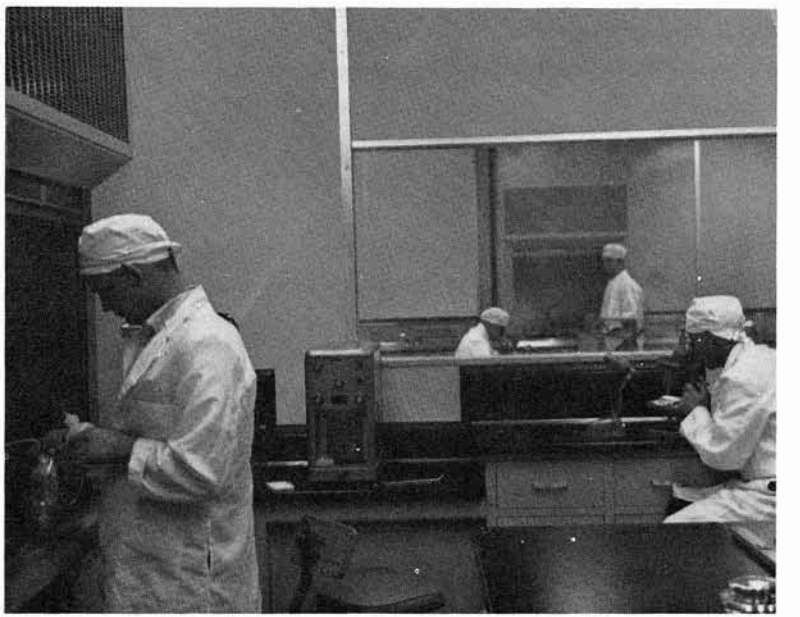
- Vibration testing - the installation has a force table rated at 5000 pounds and driven by a 50 kw amplifier. The table permits 0.5 inch double displacement at 5 Hz and can accelerate 25-pound specimens to 50 G at 200 Hz. Maximum rating is 30 G.

- Centrifugal acceleration - of the three centrifuges, the largest has a gyration radius of 18 feet and can accelerate a 300-pound mass to 100 G; the c-159 centrifuge is rated at 75 G/load rating of 2000 pounds; the smallest is capable of accelerations up to 800 G and is rated at 1000 pounds.

- Mechanical shock - a 3-inch Consolidated Electrodynamics Hyge Shock test machine can produce a shock of variable magnitude up to 8000 pounds force; the wave can be altered.

- Support equipment - a full complement of support equipment is provided to achieve flexibility and develop the full potential of the basic fixed equipment. This includes measurement and data recording devices, power supplies, special camera, etc.

- Environmental Chambers - Twelve chambers ranging in size up to 35 cubic-foot test volume can expose specimens to a variety of extreme environments. These include pressure to 20,000 psi, vacuum to 5×10^{-9} Torr, temperature from -300°F to +535°F, humidity, salt spray and explosion. Combined environments that can be produced in a controlled manner are altitude-temperature-humidity, altitude-explosion, salt spray-temperature and vibration-temperature.



COMPONENT CLEANING FACILITY

Other capabilities for component evaluation, methods developments, servicing and support of the Quality and Reliability Assurance function are as follows:

For pneumatic and hydraulic engine component investigations a Class II clean room of 1540 square feet with a 5606 hydraulic oil stand is employed. Component failure can be investigated, hydraulic flow meters calibrated and contamination control evaluated. The stand can accommodate up to 400 gallons of oil and operating pressures up to 4000 psi.

A Class III-IV clean room of 560 square feet has provisions for complete evaluation of filters with ability for cleaning and checking contamination of parts. A Class III clean room, 680 square feet in area, has a 3000-psi air and nitrogen supply for complete analysis and detection of hydro-carbon material.

The facility for evaluation and development of advanced test and checkout methods contains 2000 square feet, has a 3000-psi air and nitrogen supply, and is equipped with a vacuum chamber 12 feet in diameter and 16 feet long. The chamber can be evacuated to 10^{-5} Torr.

The Chemical Laboratory performs surface treatment operations, bonding processes and platings and tests gases. Air, gas, vacuum and nitrogen are supplied to work benches. Equipment includes an electric muffler furnace, pyrometer, infrared equipment and fume hoods.

The pressure test cell is used for hydraulic and pneumatic checkout of the F-1 engine. The area has 7800 square feet of high bay. Panels and consoles are used in engine checkout; walls can withstand 3000 pound nitrogen and air blast. R-J1 console capability is up to 300 gallons flow and 3000 psi.

HIGH BAY AREA IN VEHICLE INSPECTION HANGAR

The Hydraulic Pumping Station occupies 660 square feet, including the pump room motor control center and fuel storage. Specially designed stainless steel tubing and fittings convey oil up to 3000 psi pressure to the pressure test cell and to the stage under checkout. Capacity is 300 gallons.

The S-1C Checkout Station is composed of 24,000 square feet of high bay area and a two-story structure housing mechanical and electrical checkout equipment. It provides for the complete checkout of the Saturn V S-IC stage including computer operations. The entire area is enclosed by a blast screen designed for a blast load of 230 pounds per square foot.

The S-V Breadboard Facility, also a two-story structure, contains 3000 square feet on each floor. Both Launch Control Center and Launch Umbilical Tower equipment are housed. An additional 10,000-foot high bay area is allocated for stage simulators and mockups.

The Equipment Handling and Welding Area occupies 7100 square feet of Building 4708 high bay area. Lift-a-lofts, tow motors, loaders and hysters are used to handle equipment such as computers, racks and consoles. Necessary welding for assembling work benches, panels and miscellaneous items is done with electric, oxy-ace and heliarc equipment..

QUALITY AND RELIABILITY ASSURANCE

The area for receiving and inspection of electrical and electromechanical component parts entails 30,000 square feet including a high bay area of 21,700 square feet. Equipment items included are

- Automatic Diode and Rectifier Test Instrument
- Automatic Zener Diode Test Instrument
- Transistor and Component Tester
- Relay Tester

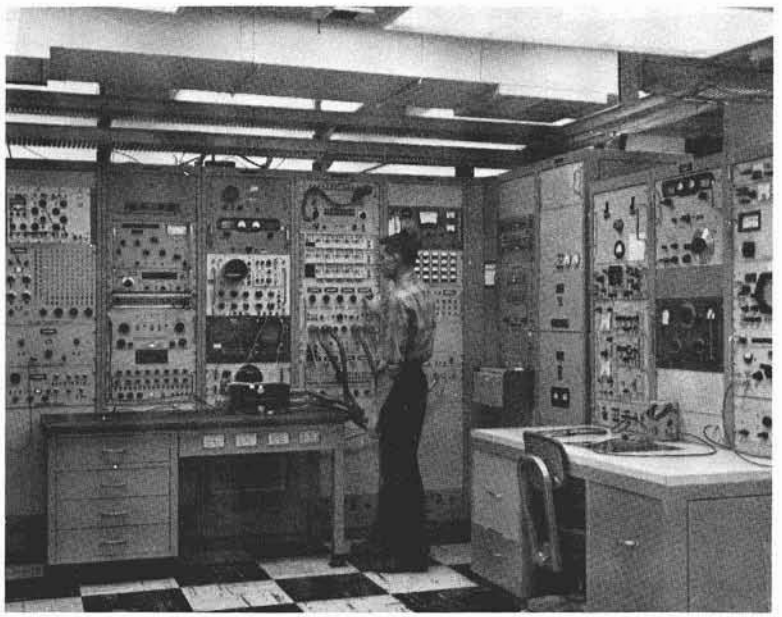
Complete and thorough testing can be conducted for leakage, resistance, polarity, resolution, impedance and voltage drop.

A Mass Spectrometer and Radiflo Activation Unit are used to detect any internal barrier or external wall leakage of hermetically sealed parts. The RA unit uses a radioactive tracer gas unit, is automatic and self-contained.

A 34-foot diameter Century-Detroit Rotary Table is used for inspection alignment and checkout of large components where close tolerance and precision angular measurements must be determined. It has axial eccentricity total indicator reading in inches and .0005 planar wobble of ± one-half second.

The Hydrostatic Line and Valve Testing complex is 5000 square feet in area. The overhead industrial bridge crane has a 5-ton capacity. Valves and piping can be tested under extreme pressures. The pneumatic components test stand has a pressure range of 3200 to 10,000 psi; a fuel test panel operates up to 2800 psi with flow rate of 19 gpm; two LN_2 test towers with a fuel control panel operate at 150 and 250 psia. A vacuum dry oven, 3 feet in diameter by 12 feet, operates at .5 psia and 160°F.

QUALITY AND RELIABILITY ASSURANCE



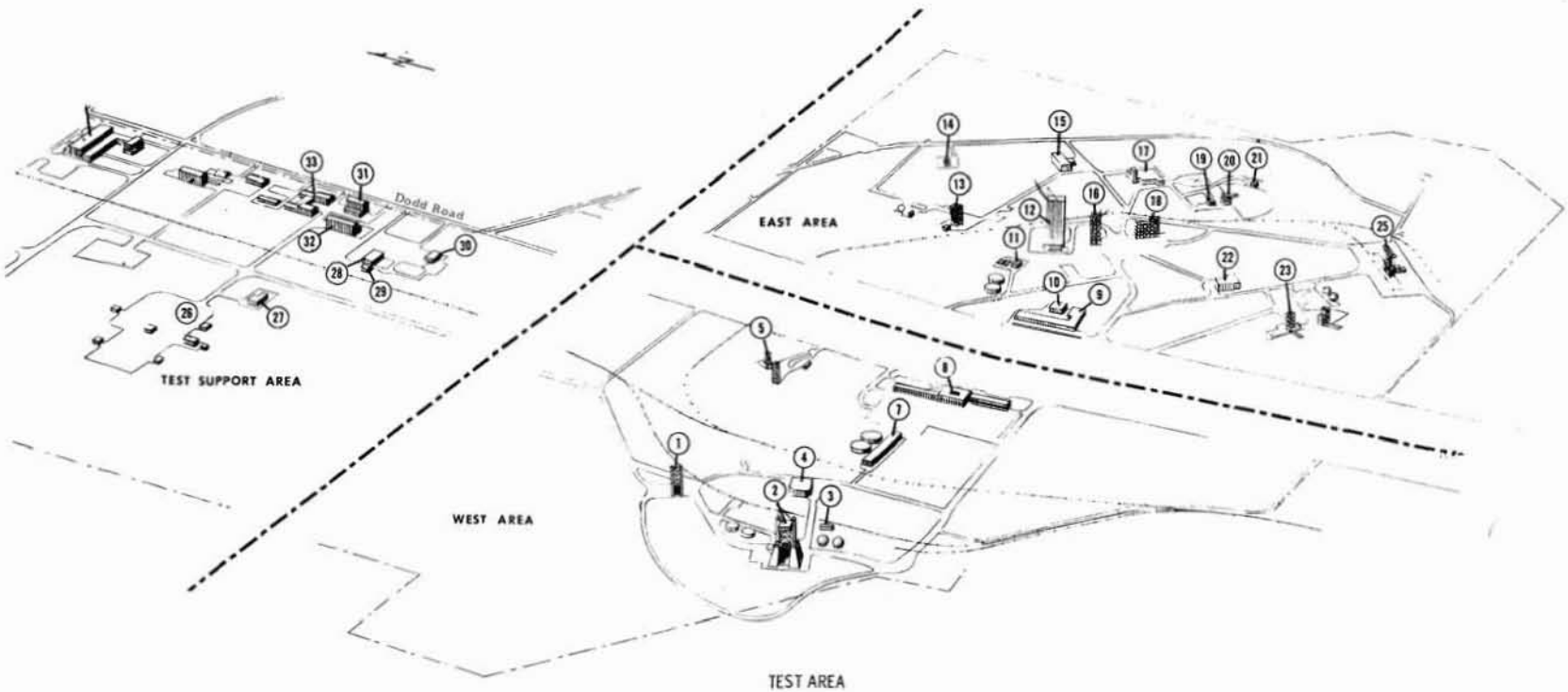
TELEMETRY GROUND STATION

TEST LABORATORY

The Test Laboratory has facilities for performing research, experimental and developmental testing programs of launch vehicle stages, their systems, components, and ground support equipment.

These facilities include a number of vertical stage static firing test stands, several single engine test stands, ground support equipment test and checkout facilities, full scale vehicle dynamic test stands, blockhouse control and measuring centers, model engine and component test stands and cells, industrial water reservoirs and pumping facilities, an instrument development shop, a test support shop, high pressure gas generating plants, high pressure gas storage and distribution systems, cryogenic and propellant storage and distribution systems and large stage land transporters.

The test complex consists of three major geographical test areas: West Test Area, East Test Area, and Test Support Area. Additional test facilities are located northwest of the Test Support Area.



TEST AREA

WEST AREA

1	4696	F-1 Engine Static Test Stand
2	4670	S-IC Stage Static Test Stand
3	4676	Helium Booster Station
4	4674	West Blockhouse
5	4665	Interim Test Stand Area
7	4667	Industrial Water Pump Station
8	4666	Test Division Engineering Building

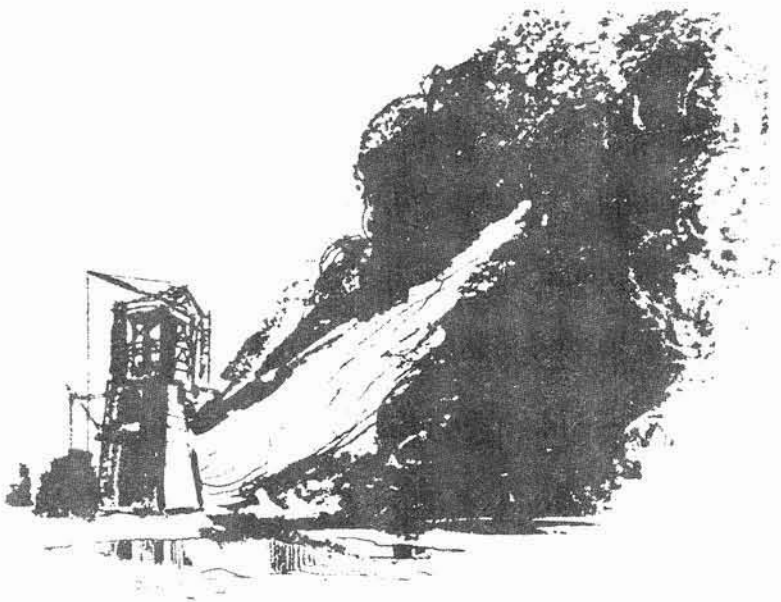
EAST AREA

9	4566	Test Division Engineering Building
10	4567	Industrial Water Pump Station
11	S-4549	Deionized Water Facility
12	4550	Saturn V Dynamic Test Facility
13	4522	Test Stand 500
14	4530	Test Stand 300
15	4561	Control and Service Center
16	4557	Saturn IB Dynamic Test Facility
17	4583	Recording Instrumentation Center
18	4548	F-1 Turbopump Test Facility
19	S-4539	Preparation Building
20	4540	Test Position 116
21	4541	Control Building
22	4570	East Blockhouse
23	4564	H-1 Engine Static Test Stand
25	4572	Uprated Saturn I Stage Static Test Tower

TEST SUPPORT AREA

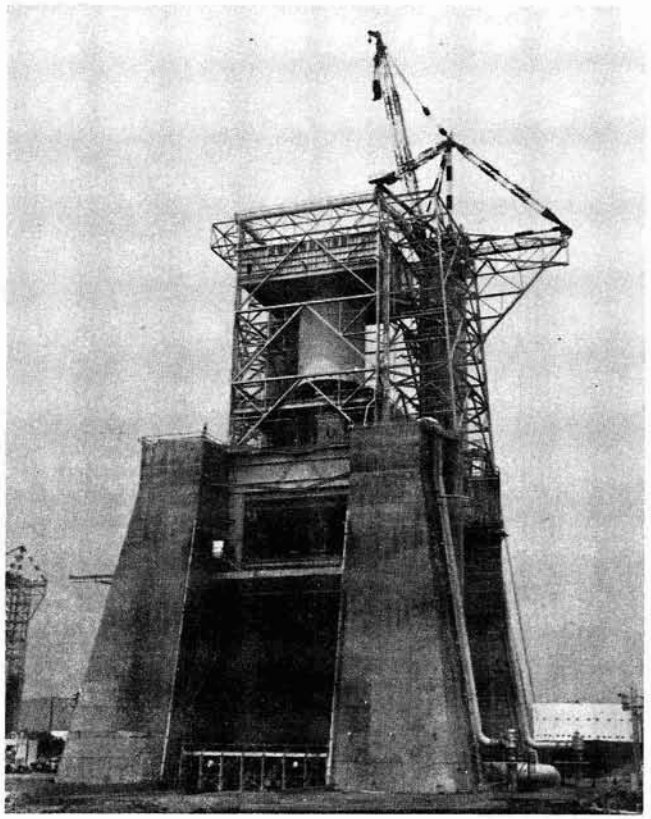
26	4646	GSE Test Facility Area
27	4648	High Pressure Pneumatic Test Facility
28	S-4659	Gaseous Nitrogen Generation Facility
30	S-4647	Air Compressor Facility
31	S-4655	Vehicle Engine Preparation and Turbopump Shop
32	S-4656	Ground Support Equipment Testing
33	S-4653	Components Service Facility
34	4650	Instrumentation Development Laboratory and Test Support Shop Facilities

WEST TEST AREA



The S-IC Stage Static Test Stand (4670) is 405 feet in height, including the derrick boom and superstructure; the superstructure is 267 feet high and 162 square feet at the base. The foundation of the stand is keyed into bedrock approximately 45 feet below grade. Capability is provided for static firing 7.5 million pound thrust stages for 150 seconds duration. With modifications the stand could accommodate stages 170 feet long and 40 feet in diameter with thrust up to 12.0 million pounds.

Incorporated into the test stand complex are the following facilities: a 200-ton overhead derrick and 150-ton lower derrick, a water cooled deflector with 320,000-gpm flow rate, 450,000-gallon LOX storage and 300,000-gallon RP-1 storage, 10,000-gpm LOX flow rate to stand and 2000-gpm RP-1 flow rate to stand, 5000-psi GN_2 (6250 cubic feet), GHe (2500 cubic feet) and 3500 psi air service.



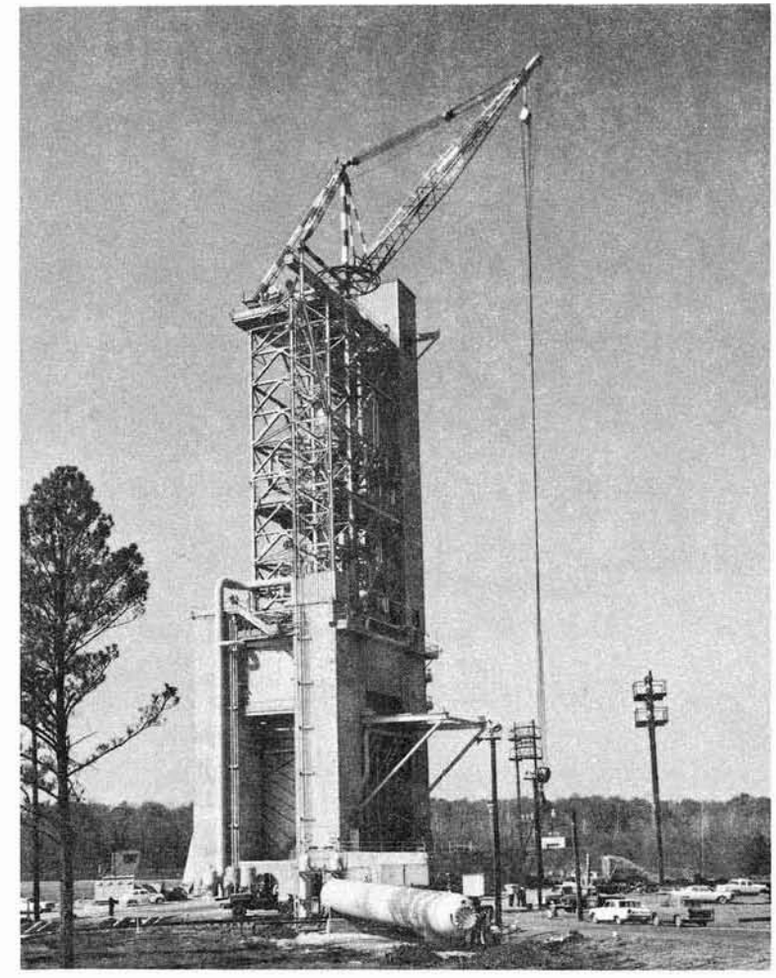
S-IC STAGE STATIC TEST STAND

The F-1 Engine Static Test Stand (4696) is a vertical engine static firing test stand, 239 feet high and 4560 square feet in area at the base. The foundation is keyed into bedrock approximately 40 feet below grade. The shop and terminal room comprise 2652 square feet of area.

At present the stand can static fire 1.5 million pound thrust RP-1 and LOX engines for 150 seconds duration and with modifications could handle engines or stages of 2.5 million pound thrust and diameters up to 33 feet. Equipment includes a water cooled deflector with 135,000-gpm flow rate, 3500-psi air, and 5000-psi GN_2 and He service. LOX and fuel are supplied through lines from the S-IC Test Stand.

The West Blockhouse (4674) serves as the central data acquisition and control center for the S-IC stage and F-1 engine static test stands. The facility is 29,631 square feet in floor area and contains instrumentation which provides 168 strip chart recorder channels, 600 digital channels, 480 oscillograph channels and 130 tape recorder channels. The Event Recorders include 22 Easterline Angus, twin, 40 channel, 28 VDC, inking recorders totaling 880 channels.

Analog Recorders include 6 Easterline Angus, twin, 4 channel (two 0-24/32 VDC and two 0-50 MV DC at 50 microamps) recorders totaling 24 channels.



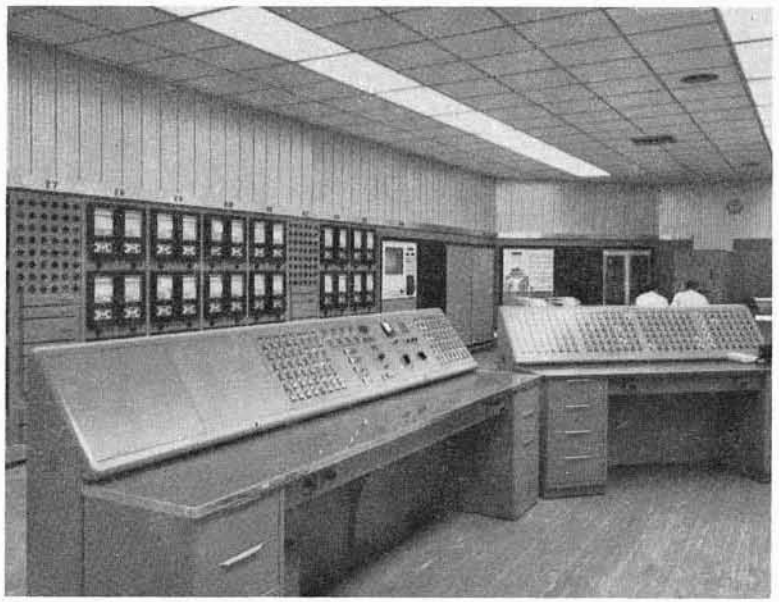
F-1 ENGINE STATIC TEST STAND

The Analog Event Recorders consist of 2 Easterline Angus, twin, 0-150/300/600 VAC (RMS) or 0-50/150/300 VDC and 0-50 MA DC at 50 microamps with 16 event channels providing a total of 4 analog channels and 32 event channels.

Two Digital Events Evaluators, each incorporating a 5 DS 910 computer with programming and modifications are utilized as digital event recorders. Each unit handles 758 channels with a 4 millisecond scan. Each computer has typewriter, magnetic tape, paper tape punch outputs and paper tape reader input.

Two RCA-110 Digital Computers have paper tape input/output, typewriter output, magnetic tape input/output, relay driver output, DA converter output, AD converter input and event input. Capability of each includes 41C high speed memory, 32K drum memory, 1008 each discrete inputs and outputs and 2 each AD and DA converters.

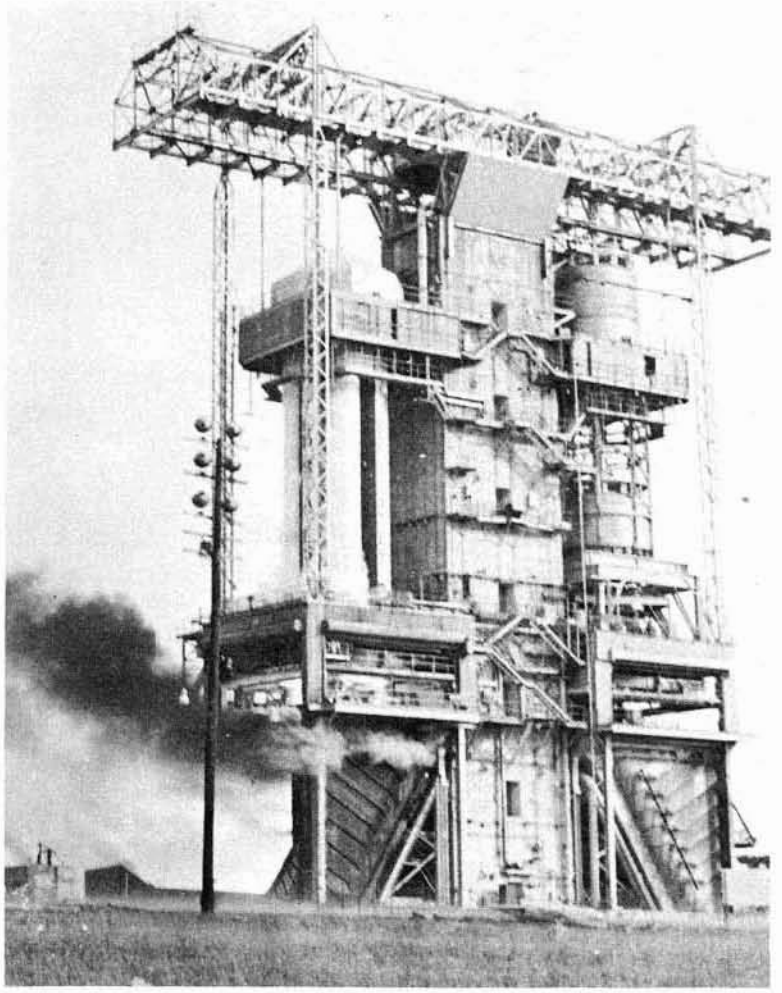
The RCA-110A Digital Computer has card punch output, magnetic tape input/output, card reader input, line printer output, relay driver output, event input, DA converter and AD converter input. Capability of this equipment comprises 32K high speed memory, 32K drum memory, 1008 discrete output, 1512 discrete input, 2 DA converters and 2 AD converters.



WEST BLOCK HOUSE RECORDER ROOM

The Uprated Saturn I Stage Static Test Tower (4572) is a two-position test stand, approximately 175 feet high and 600 square feet at the base. The support shop, office space and terminal room utilize 13,360 square feet of area. Each position of the tower can static fire 1.6 million pound thrust stages or engines utilizing LOX/kerosene propellants and accommodates stages 82 feet long and 22 feet in diameter. A 100-ton overhead crane and a 45-ton gantry crane serve the facility. Each position has

- water cooled deflector - 52 000-gpm flow rate
- 100 000-gallon LOX storage
- 50 000-gallon RP-1 storage
- 5000-psi GN_2 and GHe service
- 3500-psi air
- 1100 data channels wired into blockhouse



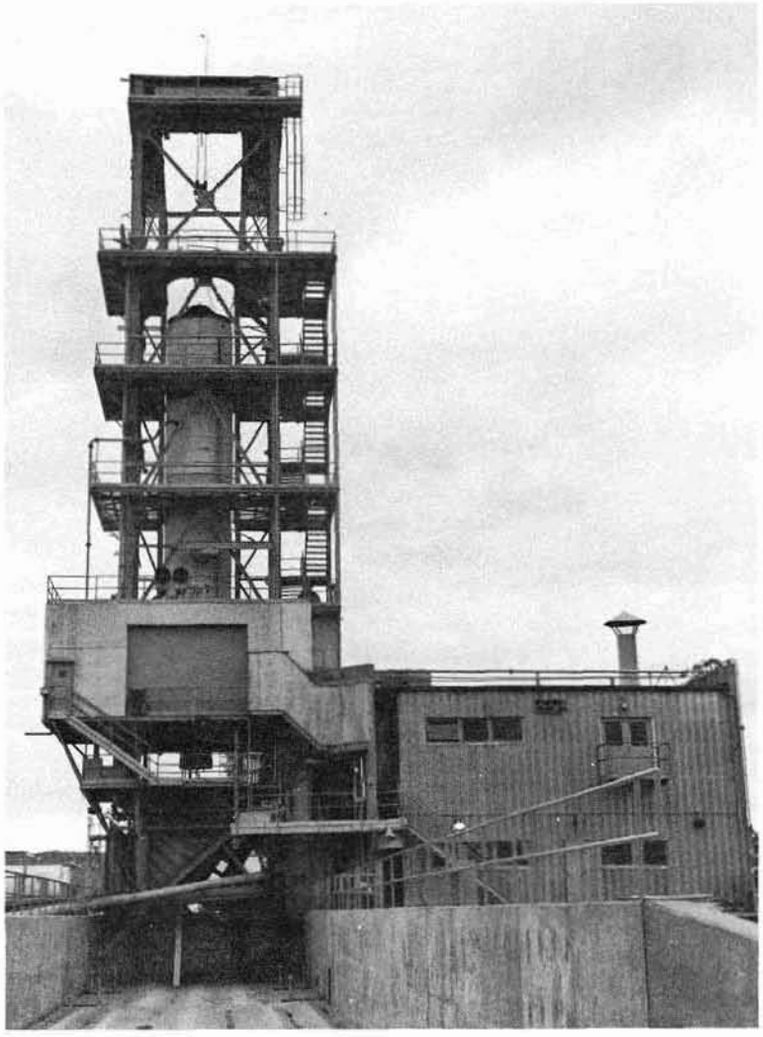
UPRATED SATURN I STATIC TEST TOWER

The H-1 Engine Static Test Stand (4564) has two vertical static firing positions. Each is approximately 110 feet high, with base areas of 480 and 216 square feet. Capability provides for static firing 200 000 pound thrust LOX/RP-1 engines for 150 seconds duration. The stand has a 25-ton overhead bridge crane, 5000-psi GN_2 and GHe service and a water cooled deflector with 12,500-gpm flow rate. LOX is supplied from S-IVB stand storage (56,000 gallons) and RP-1, from underground lines.

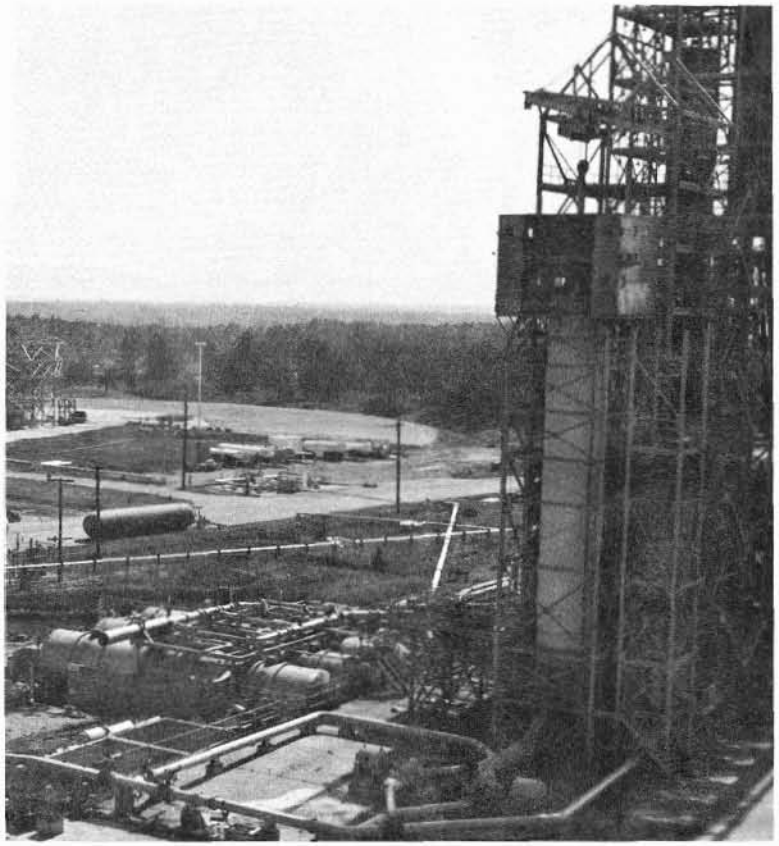
Instrumentation capabilities include 96 channels for pressure, 60 event types for temperature, 60 for vibration, 108 for miscellaneous measurements, and 230 recording and monitoring channels.

The Cold Calibration Test Facility (4588) is 24 feet by 68 feet at the base with a height of 84 feet. The three distinct test sections of the facility are described below.

The H-1 Turbopump Test Facility, located in the south side, utilizes a gas generator driven S-IB 200K H-1 turbopump to provide capability for performing checkout, calibration, qualification, research and development tests on the S-IB/H-1 turbopump and propellant feed systems.



H-1 ENGINE STATIC TEST STAND



COLD CALIBRATION TEST FACILITY

The gas generator is fed LOX from a 500-gallon capacity, 3000-psig pressure rated tank; fuel is pumped from the F-1 turbopump GG fuel run tank (reference F-1 Turbopump Test Facility). The H-1 turbopump is mounted on the H-1 bobtail engine with S-IB suction lines from simulated S-IB tank sumps. The main LOX and fuel run tanks are each rated at 10,000 gallons and 150 psig. The facility utilizes a 12,500-gallon, 50-psig fuel storage tank. The F-1 turbopump LOX storage tanks provide LOX storage for the H-1 turbopump facility also. There are approximately 180 instrumentation channels.

The 40,000-gpm Flow Bench, located at the north side, enables calibrations of large flowmeters in water. The tank holds 30,000 gallons of water and has 45-psig pressure rating. The two water pumps are each rated at 20,000 gpm and are driven by two 800-HP, 4160-volt, three-phase motors.

The Tank Mounted Prevalve Test Facility, also located at the north side, provides for tests of S-IC LOX tank mounted prevalves under water flow conditions. The tank has a 10,000-gallon capacity of 150 psig.

TEST LABORATORY

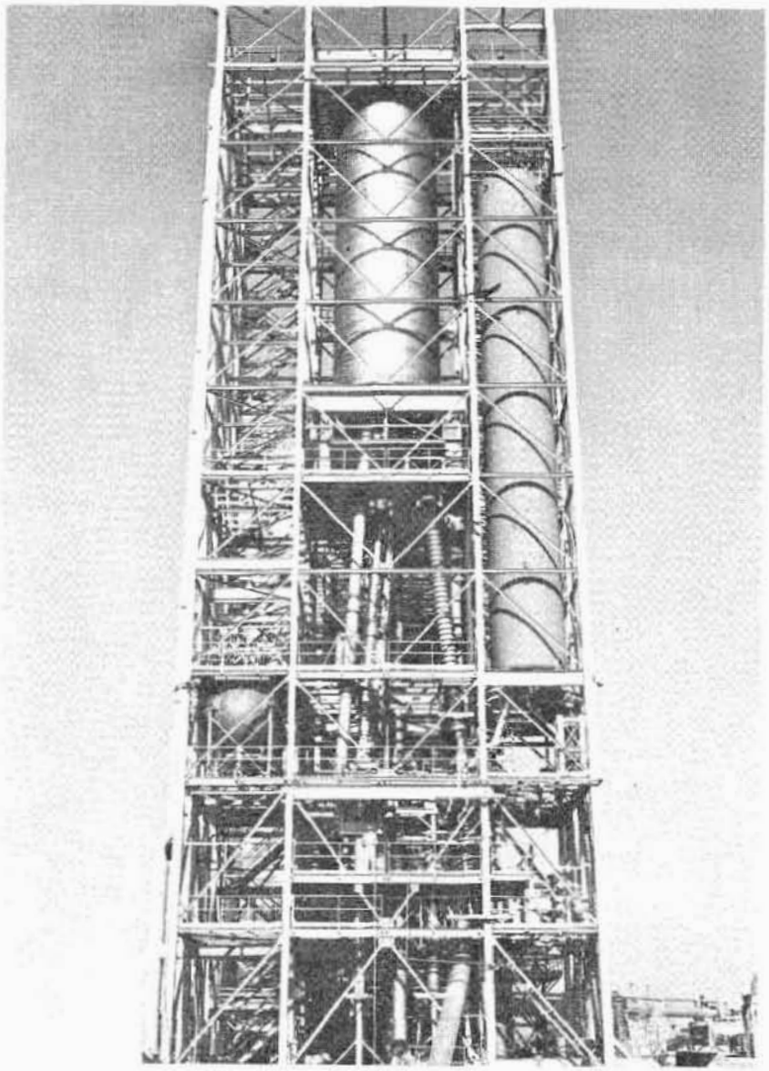
F-1 Turbopump Test Facility (4548) provides the capability to perform checkout, calibration, qualification, research and development tests on the S-IC/F-1 turbopump and propellant feed systems. The structure base is 36 feet by 51 feet and is 156 feet high.

The gas generator driver F-1 turbopump (Block II) used by the facility is attached to an F-1 bobtail engine and can be bootstrapped or operated with propellants supplied from auxiliary run tanks. S-IC flight suction lines are installed. S-IC fuel and LOX suction lines, separate from those supplying the F-1 turbopump, may be utilized to conduct prevalve and suction line qualification, checkout and calibration tests.

Tanks installed in the structure include

- 46,000-gallon main fuel run (100 psig)
- 46,000-gallon main LOX run (150 psig)
- 3000-gallon GG fuel (2200 psig)
- 3000-gallon GG LOX (1800 psig)

There are three LOX storage tanks, each of 28,000-gallon capacity and 50-psig pressure rating, attached by LOX ducting. Approximately 220 instrumentation channels are available.



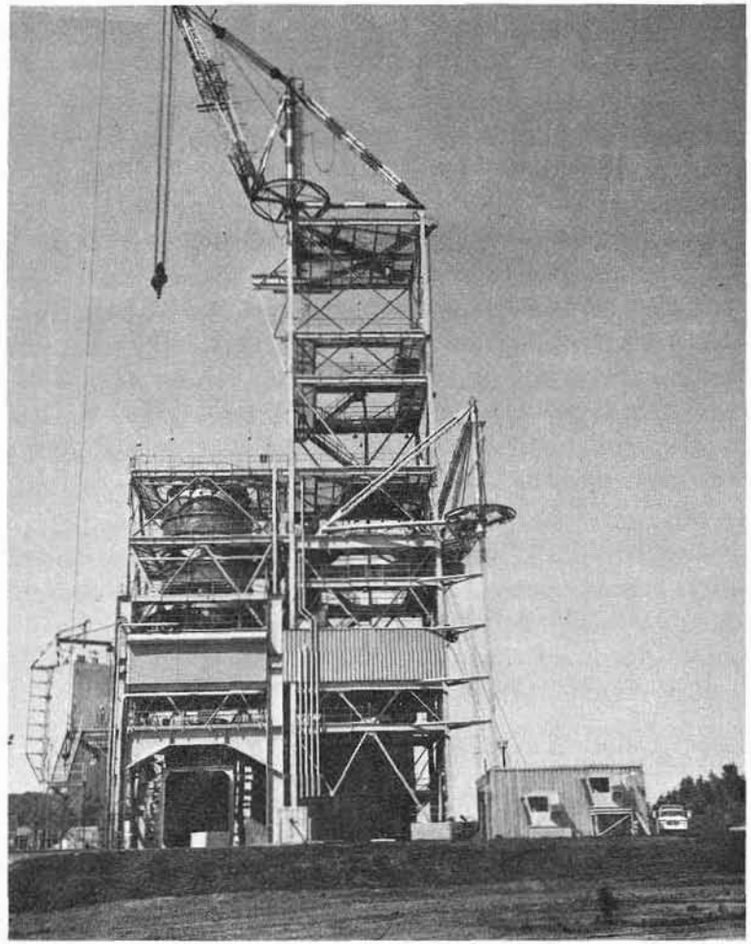
F-1 TURBOPUMP TEST FACILITY

TEST LABORATORY

The S-IVB Static Test Stand (4514) is a two-position LOX/hydrogen vertical static firing test stand. The superstructure of one position is 156 feet high and the other is 88 feet; the area of the two stands at the base is 2448 square feet. The shop and terminal room adjacent to the stand have an area of 3200 square feet. The stand can accept stages 60 feet long by 22 feet in diameter and can static fire 300,000 pound thrust stages or engines for 500 seconds duration. The superstructure is designed to withstand 300,000 pounds thrust.

The complex includes a 75-ton overhead derrick, 50-ton lower derrick, 56,000-gallon LOX storage and 150 000-gallon hydrogen storage, 3500-psi air, 5000-psi GN_2, GHe and GH_2 service, 1400 cubic-foot H_20 volume, 5000-psi GH_2 storage and a water cooled deflector (25,000-gpm flow rate).

The run tanks now on the stand hold 77,000 gallons of LH_2 and 20,000 gallons of LOX. Instrumentation includes 132 pressure channels, 72 temperature channels, 72 vibration channels and 120 event recorder channels.



S-IVB STATIC TEST STAND

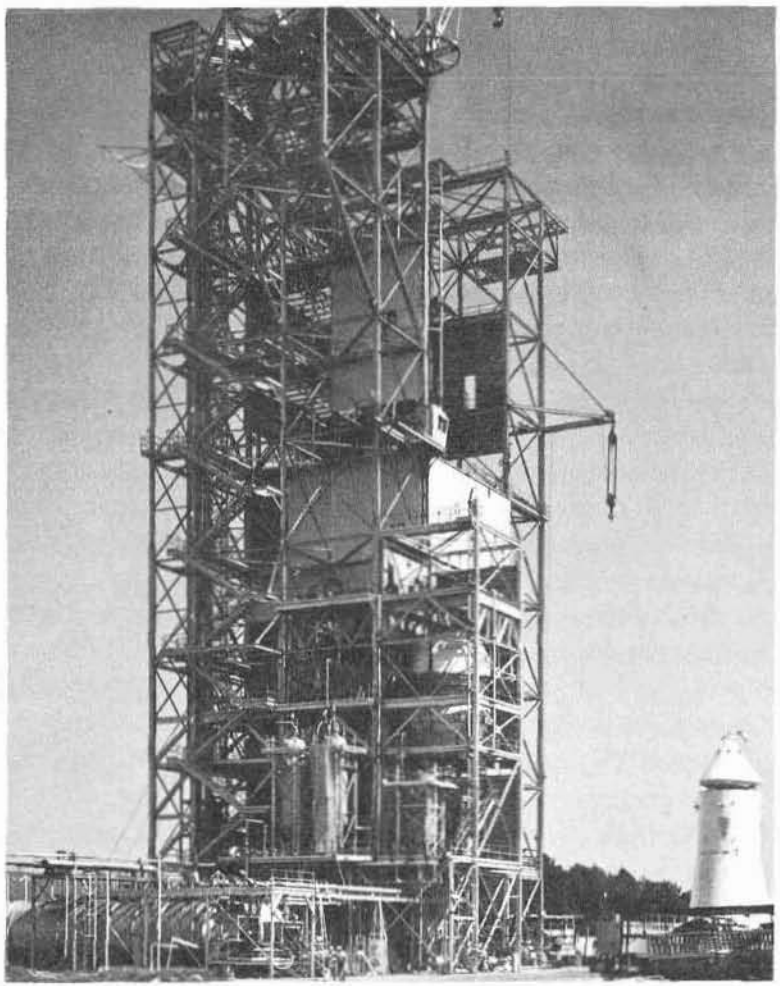
TEST LABORATORY

The Saturn IB Dynamic Test Facility (4557) has a base 100 feet by 60 feet and is 204 feet in height, not including a 50-foot stiff leg derrick. The major facility is comprised of four areas.

- Dynamic Testing
- LOX Slosh Test Facility
- LH_2 Slosh Test Facility
- Hydraulic Unit

The Dynamic Test Facility provides the capability to dynamically test the entire Saturn IB vehicle and separate flight configurations. Vibration loads can be induced in the pitch, yaw, roll or longitudinal axis to obtain resonance frequencies and bending modes. The main derrick has 75-ton hook with 50-foot radius and a 10-ton auxiliary hook of 60-foot radius. The jib hoist can accommodate up to 60 tons.

The LOX Slosh Test Facility is located in a bay of the Saturn IB Dynamic Test Stand. The facility provides the capability to perform studies in support of the S-IC stage in the areas of tank pressurization, propellant geysering, LOX stratification, sloshing and tanking phenomena.



SATURN IB DYNAMIC TEST FACILITY

The installation consists of a one-third scale battleship model of the S-IC LOX tank and five LOX suction lines. It is pressurized with gaseous oxygen from an gas generator-heat generator system. The gas generator is operated with propellants supplied from two pressure vessels, each having a 2800-gallon capacity and 1500-psig rating.

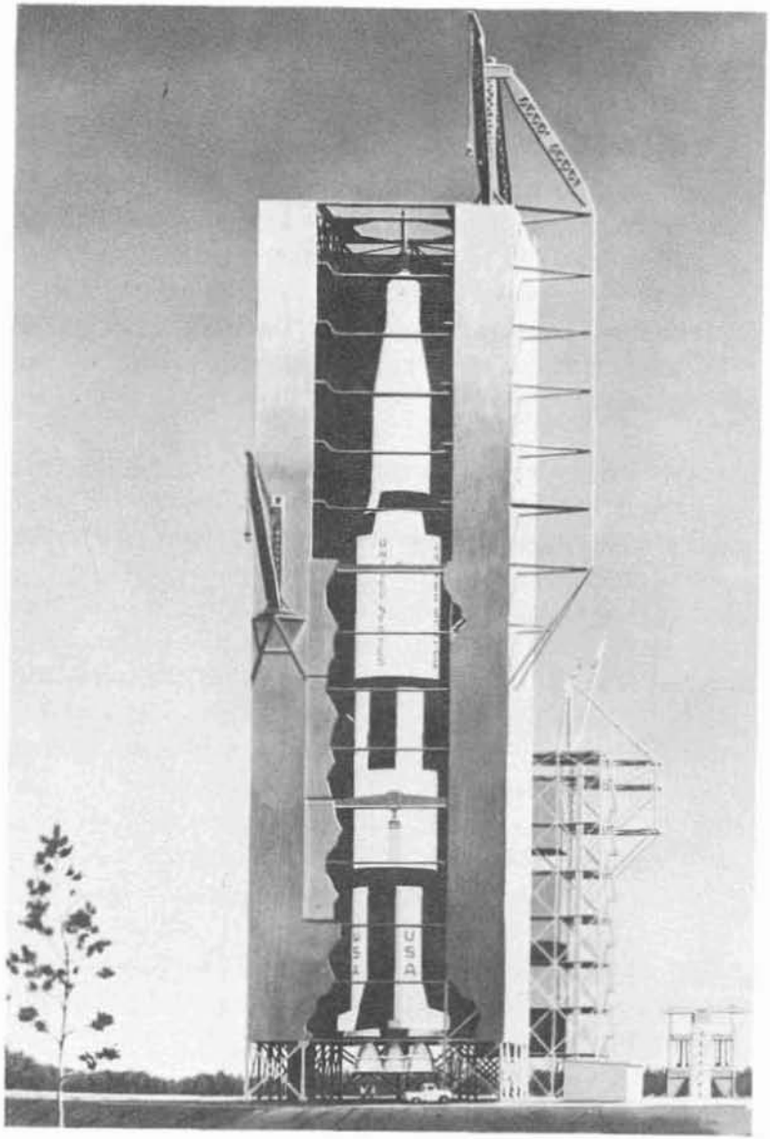
Two H-1 engine heat exchangers in series provide pressurant gases. The Slosh Tank has a 23 000-gallon capacity and 60-psig rating and can be oscillated by a hydraulic drive mechanism at a frequency range from 0.0 to 0.7 cps; maximum displacement is 8 inches (peak to peak). The LOX storage tank can hold 28,000 gallons and has a 50-psig rating. Approximately 250 instrumentation channels are utilized. The LH_2 Slosh Test Facility is located in a 24-foot by 24-foot base and 96-foot high extension of the Saturn IB Dynamic Test Stand. The facility provides for LH_2 research and development tests in the areas of tank pressurization, stratification, sloshing, tank phenomena and recirculation in line LH_2 pumps and in tank mounted LH_2 pumps. Instrumentation is approximately 250 channels.

The facility utilizes the same drive mechanism and gas generator - heat exchanger system used by the LOX Slosh Facility. LH_2 is supplied from a 2000-gallon, 100-psig tank to the heat exchanger for conversion to gaseous hydrogen to pressurize the LH_2 Slosh Tank.

The LH_2 Tank consists of an S-IV battleship with a 32,000-gallon capacity, 35-psig LH_2 tank and a 9500-gallon capacity, 45-psig LOX compartment, separated by a common bulkhead. The LOX compartment enables testing in an elipsoidal tank in the studies of tank pressurization, stratification, sloshing, recirculation and tank phenomena.

The Hydraulic Unit is capable of supplying hydraulic fluids for operation of F-1 engine servoactuators to evaluate their performance, capabilities, gimbal properties and endurance. The unit is utilized for the calibration of the servovalve and operation of servoactuators on the Saturn V Dynamic vehicle. Four hydraulic pumps are employed, each with a rating of 110 gpm at 3500 psig. The pumps are driven by two 350-HP, 4160-volt, 3-phase electric motors. The unit can utilize 5606 hydraulic oil, JP1 or RP1 fluid.

TEST LABORATORY



SATURN V DYNAMIC TEST FACILITY

The Saturn V Dynamic Test Facility (4550) consists of a Dynamic Testing Facility with a base area 98 feet by 98 feet and a tower height of 360 feet. A 64-foot stiff leg derrick gives a total height of 424 feet. Dynamic tests on the entire Saturn V vehicles as well as on separate flight configurations are conducted in this facility. Vibration loads are induced in the pitch, yaw, roll and longitudinal axis to obtain resonance frequencies and bending modes. The main derrick has a 200-ton hook with 70-foot radius and an auxiliary 40-ton hook with radius of 100 feet; the secondary derrick has a 175-ton hook with 50-foot radius.

The Low Gravity Test Facility, located in a bay of the Dynamic Test Facility, provides a free fall height of 296 feet with maximum drop weight of 4000 pounds at a 25 g deceleration. The test package envelopes used are 3 feet in diameter by 4 feet long and weigh 400 pounds. The package is capable of a deceleration range of 15 to 25 g's. The test environment can achieve a maximum of 2.5×10^{-2} g down to a minimum of 10^{-5} g. Studies of low gravity fluid mechanics and thermodynamics phenomena are performed, calibrations of accelerometers are made and flight instrumentation can be subjected to low gravity conditions.

LOW GRAVITY FACILITY

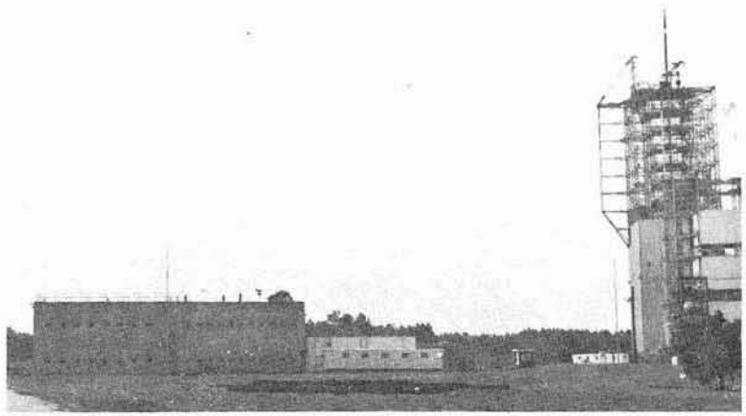
The East Blockhouse (4570) serves as the central data acquisition and control center for the East Test Area. The floor area of 30 790 square feet and included 180 stripchart recorders, 600 digital channels, 660 oscillograph channels and 179 tape recorder channels. Thirty-five Easterline-Angus, twin, 40 channel, 28 VDC, inking recorders provide 1400 channels for event recording.

Analog Recorders include 6 Easterline Angus, twin, 4 channel (two 0-24/32 VDC and two 0-50 VDC at 50 micro amps) recorders which provide a total of 24 analog channels.

The Analog Events Recorders include 2 Easterline Angus, twin, 0-150/300/600 VAC (RMS) or 0-50/150/300 VDC and 0-50 MA DC at 50 micro amps with 16 event channels, providing a total of 4 analog channels and 32 event channels.

The Digital Events Evaluator is a 5 DS 910 computer with programming and modifications used as a digital event recorder. The computer handles 758 channels; scan is 4 milliseconds. The unit includes a typewriter, magnetic tape, paper tape punch output and paper tape reader input.

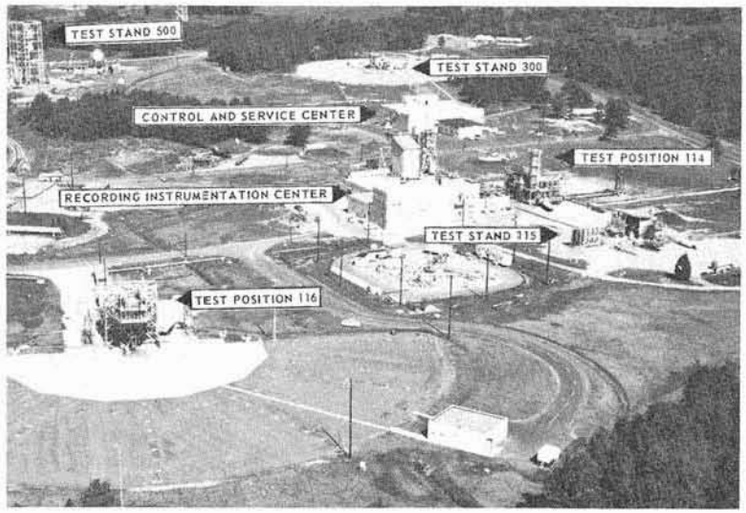
The RCA-110 Digital Computer has paper tape input/output, typewriter output, magnetic tape input/output, relay driver output, DA converter output, AD converter input and event input. The capability of the computer includes 41C high speed memory, 32K drum memory, 1008 each discrete inputs and outputs and 2 each DA and AD converters.



EAST BLOCK HOUSE

COMPONENT TEST FACILITIES

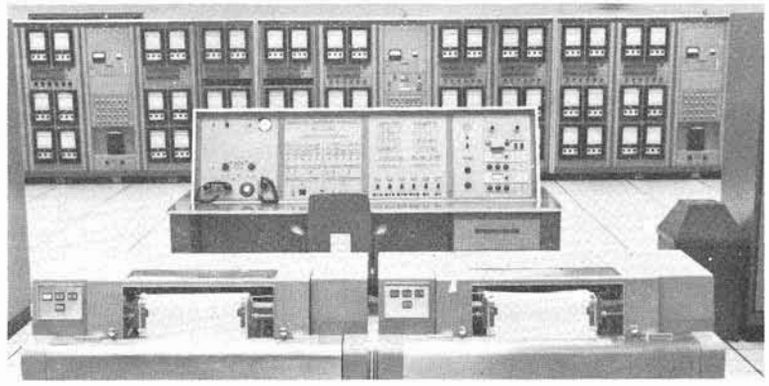
The Component Test Facilities include a Recording Instrumentation Center, a Control and Service Center as well as many Test Cells, Test Positions, and Test Stands for development and test of launch vehicle components.



COMPONENT TEST FACILITIES (EAST AREA)

The Recording Instrumentation Center (4583) is a blast-resistant structure. Control consoles within the building provide remote control for associated test positions. The instrumentation center, comprising the major part of the building's interior, houses the data acquisition systems including terminations, patch panels, switching devices, signal conditioning equipment and associated instrumentation. Capability includes the following channels:

- 192 strip chart
- 287 oscillograph
- 56 tape
- 546 digital



RECORDING INSTRUMENTATION CENTER

Shop space is available for associated preparations and maintenance of control devices and instrumentation. Office space houses 15 engineers and facilities exist for approximately 34 technicians. A concrete tunnel connects Buildings 4583 and 4561, and has cable trays lining both walls to service both instrumentation and electrical control; sufficient space remains for working on the cables and for a passageway.

The Control and Service Center (4561), a reinforced concrete building which is blast resistant and air conditioned, houses the control consoles and instrumentation connections (for recorders in Building 4583) for test operations at stands 300 and 500.

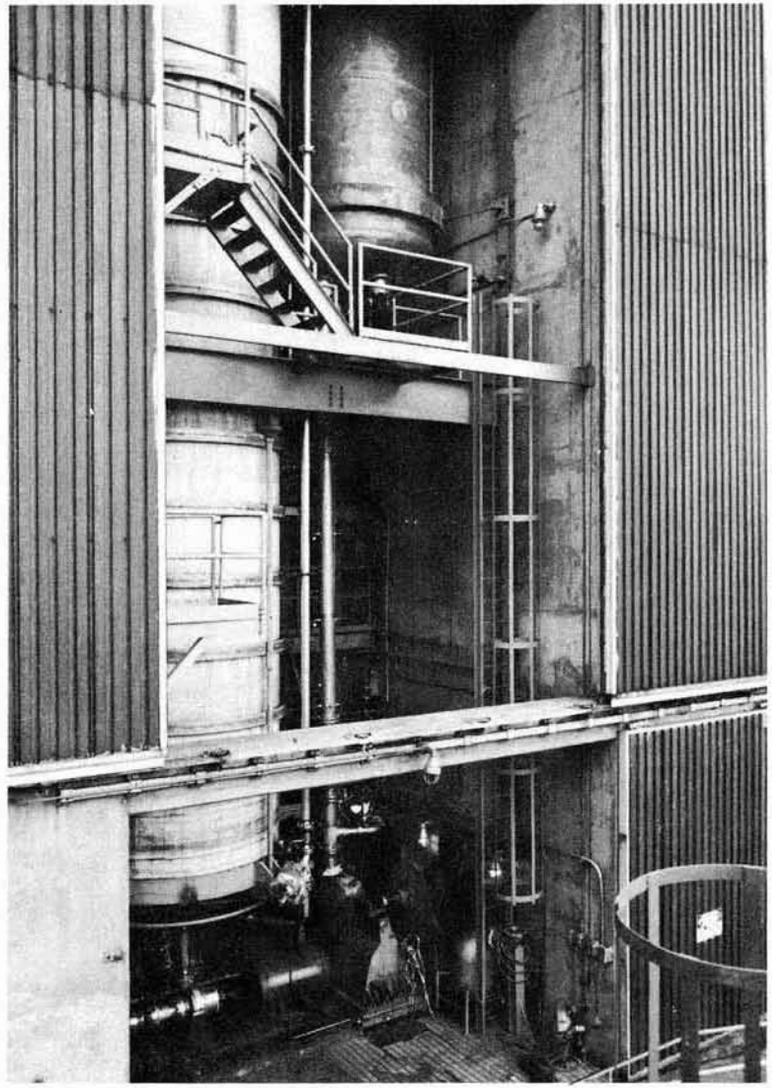
A mechanical preparation shop, approximately 5500 square feet in area is contained within a high bay and is served by a 10-ton bridge crane with a hook height of 17 feet. Metal working machine tools include a power feed band saw, power hack saw, drill press, Doall band saw, two lathes and a radial drill.

In addition there is a support shop for electrical control activities and a small room constituting a third floor to the building providing space and equipment for an area coordinator who handles switching of road lights and other warning lights and announcements.

TEST LABORATORY

Test Position 100. This outdoor test cell, of explosion proof construction, is most suited to hazardous testing of cryogenic centrifugal pumps or other rotating equipment. The cell is 26 feet by 26 feet by approximately 60 feet high and has a steel bed plate, 6 feet by 16 feet, in the floor for mounting test items. A shaft of 0- to 15,000-rpm range extends into the cell for driving rotary test items. The shaft is turned through gear boxes by a variable DC motor of 1200-horsepower rating which can also develop 2400 horsepower for a few seconds. The upper part of the cell contains two LOX storage tanks -- one has an 1800-gallon capacity, the other, a 5000-gallon capacity with 50-psi rating; there is a direct connection to an adjacent 28,000-gallon catch and storage LOX tank. The cell has a supply of 5000-psi GN_2/LH_2, 3500-psi air service and 150-psi industrial water.

Data acquisition instrumentation is provided by a recording instrumentation center and remote electrical control consoles provide facility and test item control.

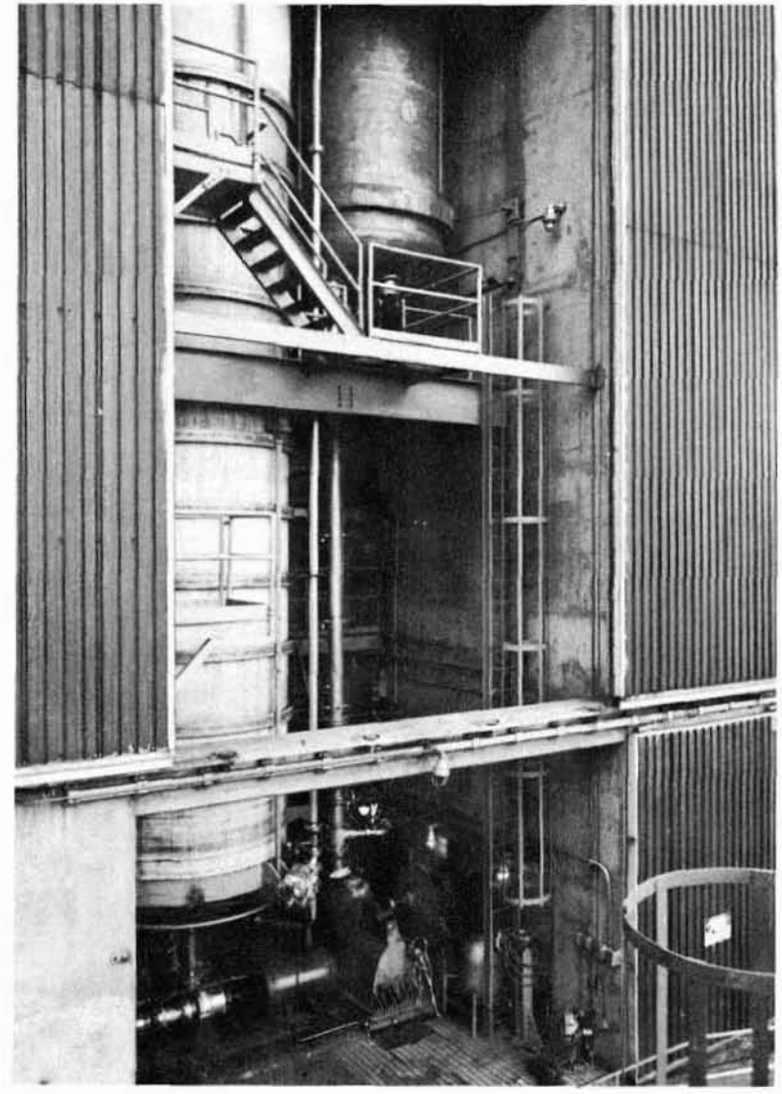


TEST POSITION 100

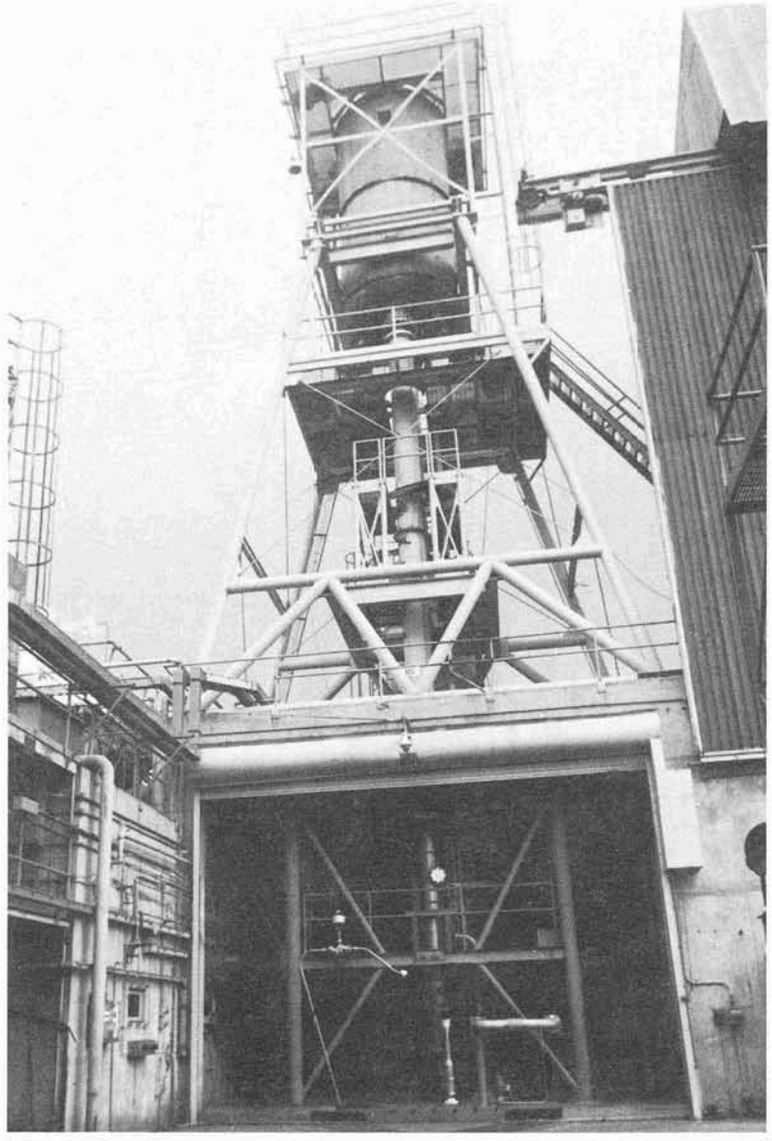
TEST LABORATORY

Test Position 100. This outdoor test cell, of explosion proof construction, is most suited to hazardous testing of cryogenic centrifugal pumps or other rotating equipment. The cell is 26 feet by 26 feet by approximately 60 feet high and has a steel bed plate, 6 feet by 16 feet, in the floor for mounting test items. A shaft of 0- to 15,000-rpm range extends into the cell for driving rotary test items. The shaft is turned through gear boxes by a variable DC motor of 1200-horsepower rating which can also develop 2400 horsepower for a few seconds. The upper part of the cell contains two LOX storage tanks -- one has an 1800-gallon capacity, the other, a 5000-gallon capacity with 50-psi rating; there is a direct connection to an adjacent 28,000-gallon catch and storage LOX tank. The cell has a supply of 5000-psi GN_2/LH_2, 3500-psi air service and 150-psi industrial water.

Data acquisition instrumentation is provided by a recording instrumentation center and remote electrical control consoles provide facility and test item control.



TEST POSITION 100

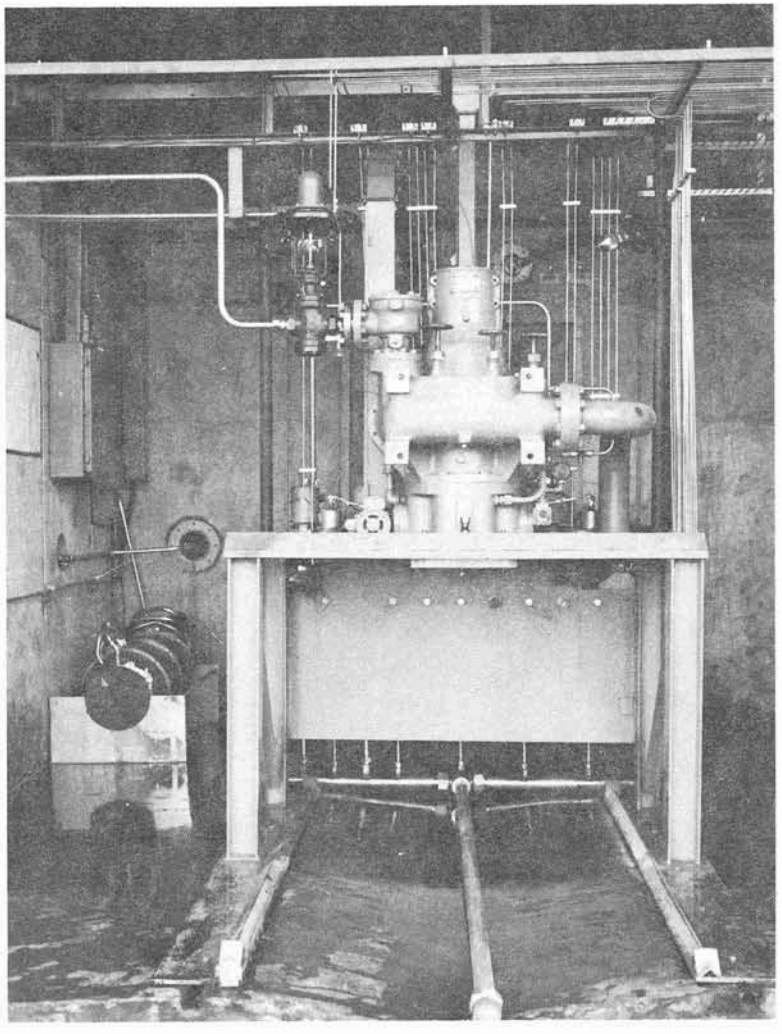


TEST POSITION 101

Test Position 101. This outdoor test cell, of explosion proof concrete construction, is suited to research and development performance tests on hardware items such as cryogenic thermal pumping systems, pumps and valves, environmental altitude tests of components and evaluation tests of cryogenic materials.

The cell is 26 feet by 26 feet by 20 feet high; at one end there are viewing windows and the opposite end is open. Fuel is supplied from a 10,000-gallon 50-psi LOX tank, and a 500-gallon 3000-psi LOX tank. In addition there is a 5000-psi GN_2 supply, a 5000-psi service air supply and a 150-psi industrial water system. The recording instrumentation center and electrical control console in Building 4583 serve the cell.

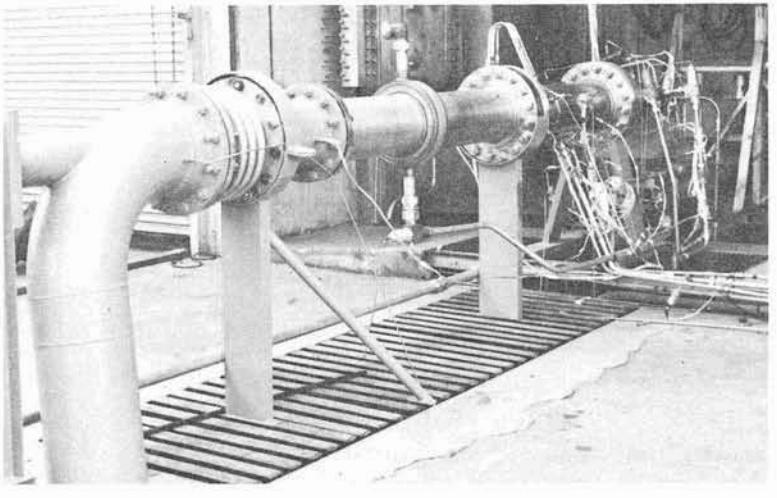
Test Positions 102, 103, and 104. These outdoor test cells, 12 feet wide by 15 feet deep by 12 feet high, are of explosion proof concrete construction and open at one end with viewing windows at the opposite end. The positions are suitable for research and development performance tests on hardware items, such as scale model combustors, cryogenic valves, pneumatic equipment, hydraulic equipment and water flow studies. The test cells are connected to 500-gallon 3000-psi LOX, LN_2 and RP-1 tanks; a 200-gallon 1000-psi water tank; a 500-gallon 3000-psi water tank; a 5000-psi gaseous nitrogen supply; a 3500-psi air supply; and a 150-psi industrial water supply. The facility is served by the recording instrumentation center and electrical control consoles in Building 4583.



TEST POSITION 102

Test Positions 105, 106, 107, and 108. These outdoor test cells are 16 feet wide by 15 feet deep by 12 feet high, of explosion proof concrete construction, and open at one end with viewing windows at the opposite end. Each cell is connected to 500-gallon 3000-psi LOX, RP-1, LH_2 and water tanks; a 5000-psi gaseous nitrogen supply, 3500-psi air supply and 150-psi industrial water system. The cells are served by the recording instrumentation center and electrical control consoles in Building 4583.

Capability is suited to research and development performance tests on hardware items such as scale model combustors, gas generators, heat exchangers, exhaust ducting, cryogenic valves and pneumatic-hydraulic equipment.



TEST POSITION 106

Test Position 109. Testing is suited to non-combustion objects requiring rough temperature and humidity controls. The cell, 15 feet wide by 21.5 feet deep by 10.5 feet high, is thermally insulated for maximum temperatures in the order of 165° F with humidity control. The facility is served by a recording instrumentation center and by remote electrical control consoles and can be provided with connections to LOX, LH_2, RP-1, gaseous nitrogen, compressed air and industrial water.

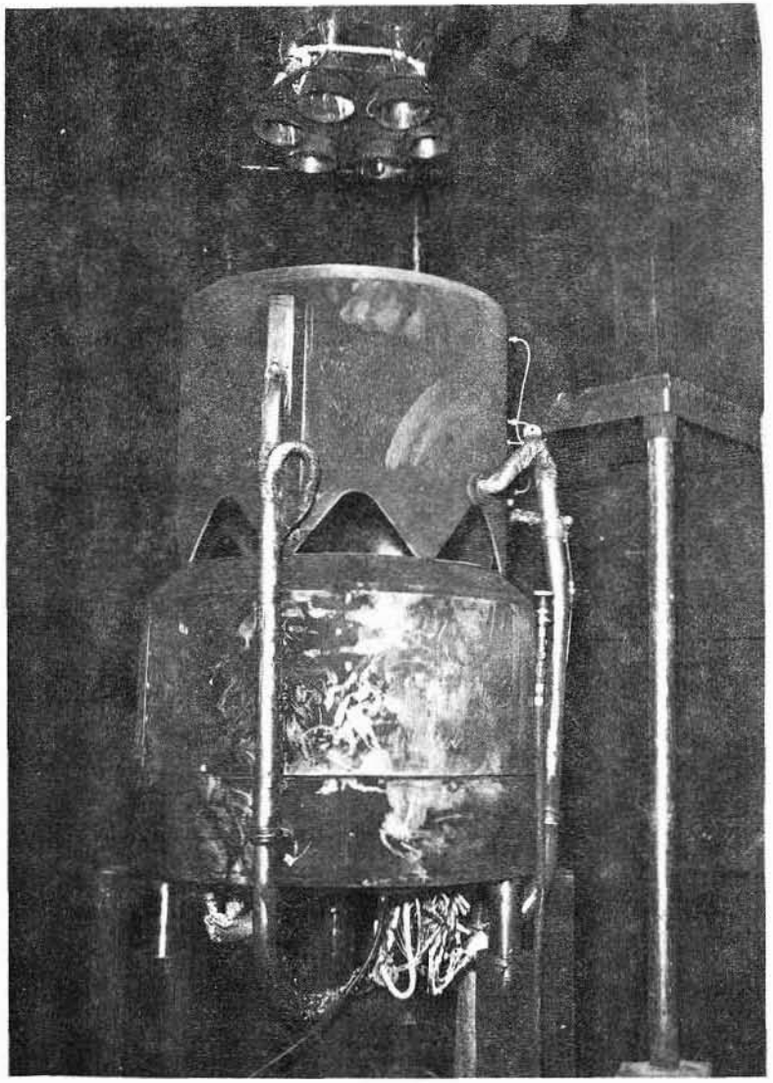
Test Position 105B. This open structural steel structure is 3.3 feet wide by 6 feet deep by 8.5 feet high, located 30 feet from observation windows. It is suited to research and development performance tests on hardware items, such as scale model combustors using LOX/GH_2 or LOX/RP-1, cryogenic valves, pneumatic equipment and water flow.

The facility is connected to 500-gallon 3000-psi LOX, LN_2 and RP-1 tanks; a 500-gallon 3000-psi water tank; a 200-gallon 1000-psi water tank; a 5000-psi gaseous hydrogen supply; a 5000-psi gaseous nitrogen supply, a 3500-psi air supply; and a 150-psi industrial water supply. The test position is served by the recording instrumentation center and electrical control consoles in Building 4583.

Test Position 110. Also thermally insulated, this cell has the same dimensions as Test Position 109 but is designed for temperatures down to the order of -65° F for testing non-combustion items requiring low ambient temperatures. A mechanical refrigeration system is built in and can be supplemented by discharging LN_2 into the cell. Connections are provided to LOX, LN_2, RP-1, gaseous nitrogen and compressed air. A recording instrumentation center and remote electrical control consoles serve the position.

Test Position 112. This test facility is used for altitude studies such as materials tests, ignition problems, scaled-vehicle studies (for example, separation of upper stages), lunar surface studies, attitude control motors and jet plume behavior.

The test cell is 8 feet in diameter by 37 feet high, connected by a large diameter manifold to four 55-foot high tanks. The total internal volume is 19,900 cubic feet. Vacuum is drawn by mechanical pumps and the maximum vacuum available is 29.29 inches of mercury or the equivalent of 135,200 feet altitude.



TEST POSITION 112

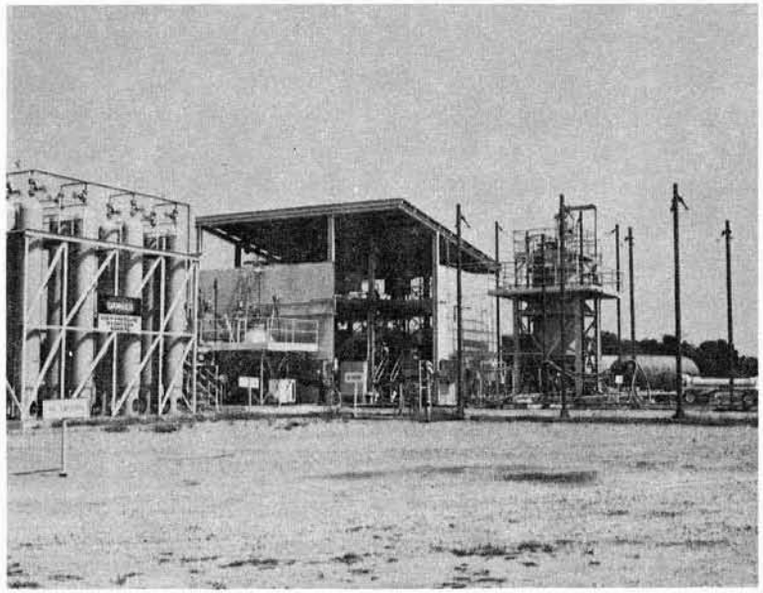
Test Positions 113, 114, and 117. These open structural steel structures, located 30 feet from the Control and Service Center Building 4583, are connected to 2800-gallon 1500-psi LOX, RP-1 and water tanks; a 10,000-gallon 50-psi LOX tank; 500-gallon 500-psi RP-1 tank, 5000-psi gaseous nitrogen supply, 3500-psi air supply and 150-psi industrial water system. It is serviced by the recording instrumentation center and electrical control consoles in Building 4583.

The test position is rated at 50,000 pounds thrust and is suited for research and development performance tests on hardware, including clusters of scale model combustors, flame deflectors, gas generator combustors, heat exchangers, exhaust ducting, cryogenic valves, gas pressurization systems, water flow and pneumatic-hydraulic equipment.

Test Stand 115. This outdoor test position is of open steel construction and is roofed. There are two grating-covered working levels, each 25 square feet in area, with strengths for thrusts up to 50,000 pounds. The facility tanks have the following capacity:

- 2200 gallons, 1500-psi liquid hydrogen
- 500 gallons, 5000-psi liquid oxygen
- 500 gallons, 1000-psi water tank
- 5000-psi gaseous nitrogen
- 250 cubic feet, 5000-psi gaseous hydrogen
- 3500-psi air service
- 150-psi industrial water

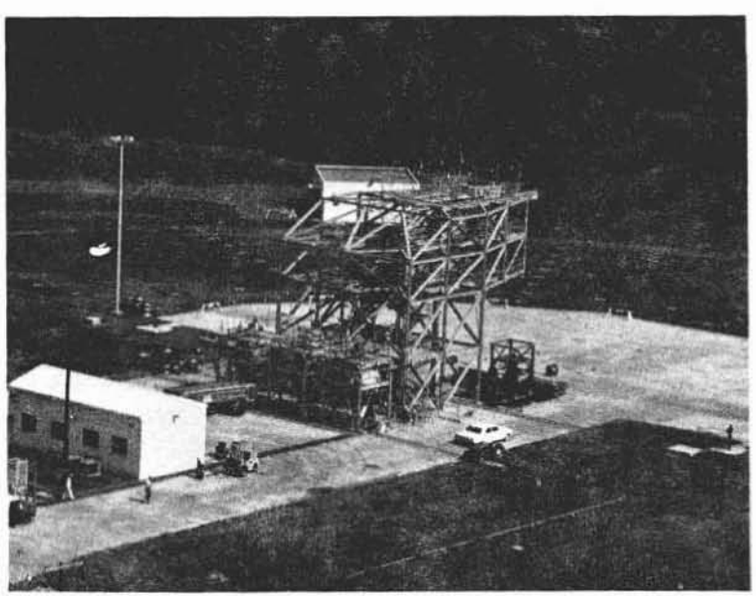
Burn stacks are provided for hydrogen disposal. A recording instrumentation center and remote electrical control consoles serve the area and an observation bunker accommodates four persons to conduct tests. The stand has two positions, 115A and 115B. Test Position 115A provides for research and development of high response, instrumented combustors for combustion stability studies of LOX/GH_2 with chamber pressures up to 3000 psi. LOX/LH_2 tests simulate LOX-rich preburner conditions; other hot gas LOX/H_2 studies are readily adaptable to the facility.



TEST STAND 115

Test Position 115B has a LOX/LH_2 hot gas setup with a separate burn stack for disposal of gas generator products. The facility is readily adaptable to such items as gas generators, heat exchangers, liquid hydrogen valves and other special liquid hydrogen hardware.

Test Position 116 (4540). This structure is of open steel construction and incorporates a cantilevered section for mounting test items. An acoustically clean environment and instrumentation are provided for studies of dynamic pressures generated by noise sources and the facility can readily be adapted for checkout tests of rocket engines, cryogenic valves, etc. The isolated location as well as direction of firing could accommodate exotic propellant tests.



TEST POSITION 116

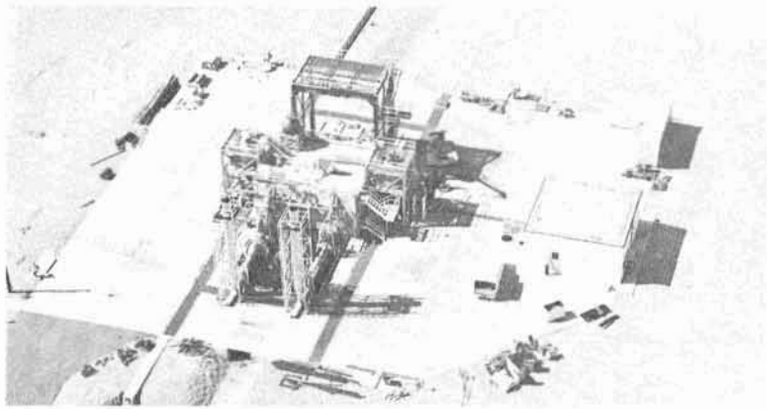
The cantilevered section is designed for 70 K vertical thrust at the centerline; there is no support structure within 22 feet from the centerline of the cantilevered tower framework. A 5-ton bridge crane is located on the top level at 50 feet. A heavily reinforced concrete pad, 20 feet by 20 feet by 3 feet deep, with an embedded anchorage system is symmetrically aligned below the cantilevered centerline. The pad is designed for a 70 K horizontal thrust 10 feet above the pit floor.

Test stand instrumentation and control circuits are ducted to a 12-foot by 45-foot underground terminal room. From here instrumentation goes underground to the instrumentation center in Building 4583; electrical control circuits are ducted underground to Building 4541. There are 148 acoustic measuring stations strategically spaced at 10° intervals over a radius of 180° to cover 250 feet of hardstand area around the cantilevered center. Acoustic instrumentation circuits are ducted to the Control Building 4541.

The structure is of explosion proof concrete with observation windows and houses electrical test control and acoustical instrumentation.

The test stand has a 14,000-gallon 50-psi LOX storage tank, a 3000-gallon 2000-psi LOX tank, a 3000-gallon 2000-psi RP-1 tank and a 3000-gallon 1000-psi water tank; it is connected to supplies of gaseous hydrogen of 5000 psi, gaseous nitrogen of 5000 psi, gaseous helium of 5000 psi, and industrial water of 150 psi.

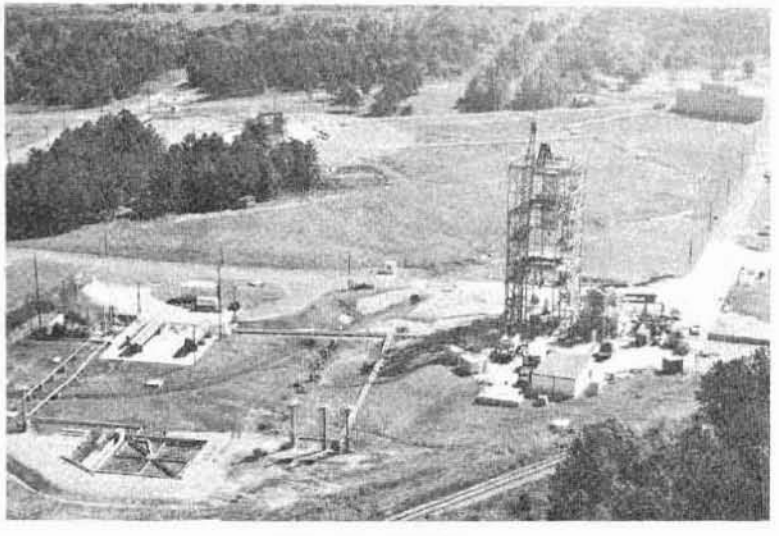
Test Stand 300. This dual position test stand (301 and 302) comprises two open concrete pads, 32 feet by 32 feet with I-beams embedded, separated by a reinforced concrete building serving as a termination center for instrumentation and control cables. The position is connected to 3000-gallon 5000-psi LOX and RP-1 tanks, a 10,000-gallon 50-psi LOX tank; 28,000-gallon LOX supply tank, 20,000-gallon RP-1 storage tank, 5000-psi gaseous nitrogen supply, 3500-psi air supply and 150-psi industrial water system. The recording instrumentation center and electrical control console service the site.



TEST STAND 300

The facility has a 200,000 pound thrust rating horizontally or vertically and is suited to research and development performance tests on hardware such as full scale combustors, gas generator combustors, heat exchangers, exhaust ducts, gas pressurization systems, water flow, cryogenic valves and pumps, cryogenic materials and pneumatic-hydraulic equipment.

Test Stand 500. This test stand has dual positions also. Side 501 has a steel superstructure which will contain a 65-psi LH_2 tank of approximately 65,000 gallons and an 18,000-gallon 65-psi LOX tank. This side is capable of tests on LOX/hydrogen turbopumps where pump discharge fluids are returned to storage, or tests on items with similar requirements. The 502 side is arranged with I-beams embedded in a 31.5 foot square concrete pad and has no superstructure. This side will handle nearly any LOX/hydrogen component or vehicle subsystem test.



TEST STAND 500

Additional facility tanks situated at the stand are a 5000-gallon 2000-psi LH_2 tank and a 3000-gallon 2000-psi LOX tank. Adjacent to the stand is a 110,000-gallon LH_2 storage sphere, a 13,000-gallon LN_2 storage tank, a 28,000-gallon LOX storage tank, two 5000-psi, 700 cubic-foot gaseous hydrogen tanks, a 350 cubic-foot 5000-psi helium tank and a hydrogen converter for recharging the 5000-psi containers. 5000-psi GN_2 and 3500-psi air are available at the stand.

Piping systems have been provided to facilitate transferring LH_2 and LOX from storage to the stand and back. Burn stacks and burn pond handle hydrogen disposal. The stand is served by the recording instrumentation center in Building 4583 and by electrical remote control consoles in Building 4561.

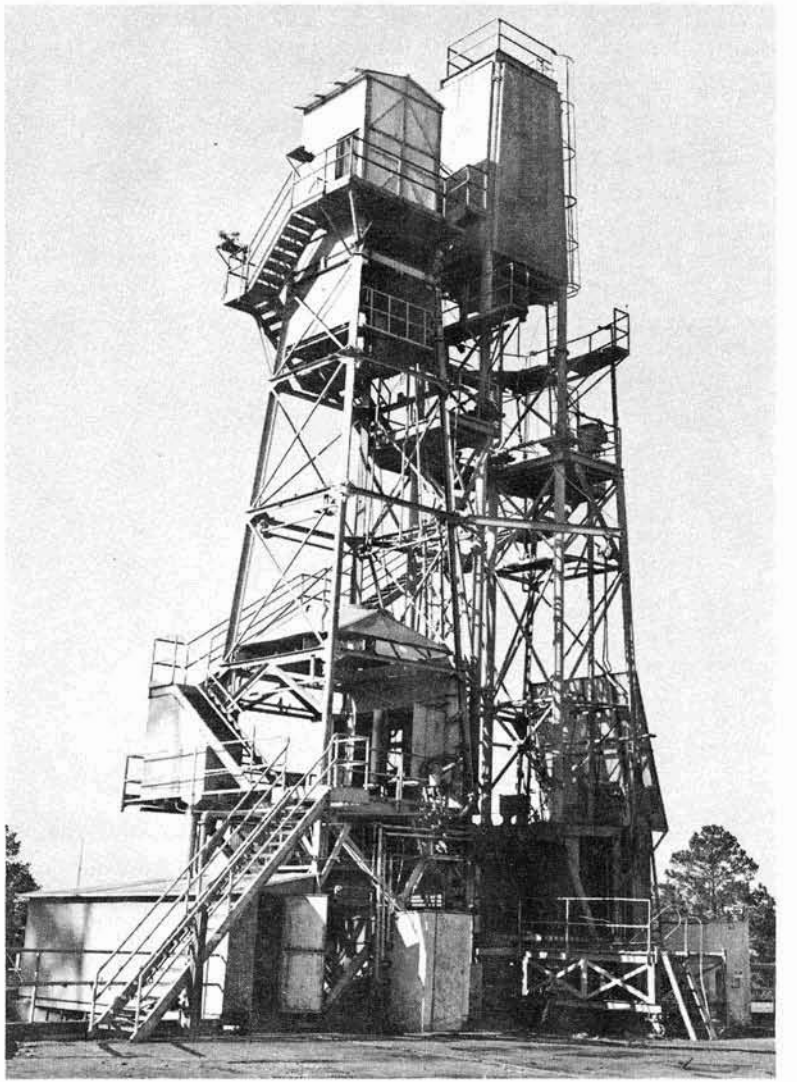
TEST LABORATORY

SPECIAL PROJECT FACILITIES

Special Project Facilities other than the interim test stand are located northwest of the Test Support Area. Special Project Facilities include the interim test stand, LH_2 familiarization facility, ultra high vacuum facility, environmental testing, and storable propellant facility.

The Interim Test Stand (Area 4665) can static fire stages with 100,000 pounds of thrust and is used to conduct R&D cold flow and static test firings on scale model stages and low thrust flight stages.

The facility has its own control and instrumentation center, housed in earth-covered bunkers and trailers. Available are 66 strip chart recorders, 90 oscillograph channels, and 7 analog tape channels. Fifty-five transmission cables with a total of 934 conductors connect the center with the test position.



INTERIM TEST STAND

The Liquid Hydrogen Familiarization Facility (4710) comprises a horizontal LOX/hydrogen engine static firing test stand with propellant tankage and flow measuring equipment. The engine test position has a supersonic diffuser, a steam accumulator and a steam eductor. The stand can static fire 15,000 pound thrust LOX/hydrogen engines for 180 seconds duration at a simulated altitude.

LIQUID HYDROGEN FAMILIARIZATION FACILITY

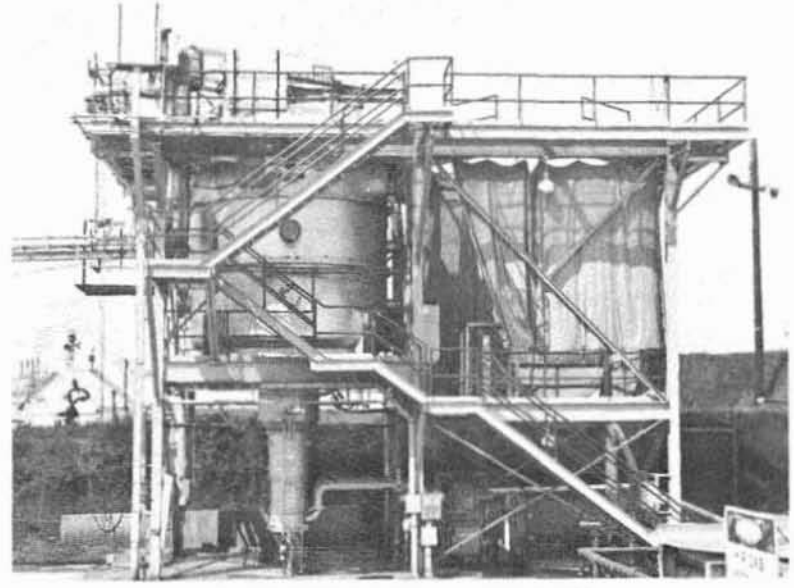
The facility has a 7500-gpm water supply for cooling and firing. The fuel tank holds 2000 gallons; the LOX tank contains 600 gallons and is supplemented with 1000 gallons from the LOX trailer for a total of 1600 gallons.

The instrumentation center contains 110 strip chart recorders, 60 oscillograph channels and 19 analog tape channels. The stand has 5000-psi GN_2 and 3500-psi air service; He and GH_2 are furnished by trailers.

The Ultra-High Vacuum Facility (4748) is designed to test, under simulated altitude conditions, super insulated tanks containing LH_2. The vacuum chamber is 15 feet in diameter by 20 feet high and is constructed entirely of stainless steel. The chamber utilizes two 50,000-liter-per-second diffusion pumps, cold shroud, and a cryo-pumping array.

Capability enables conducting hazardous tests at a simulated pressure altitude of 1×10^{-9} Torr.

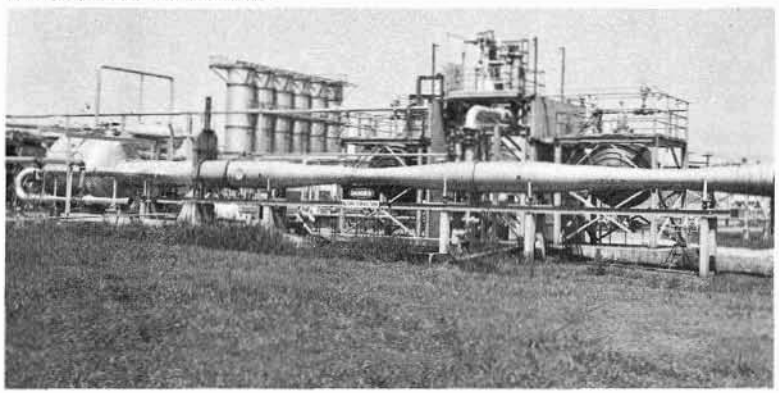
The heat sink of space can be simulated to 110° K. The instrumentation capability at this facility is approximately 150 channels of information.



ULTRA-HIGH VACUUM FACILITY

The Environmental Test "B" Cell (4748) basically consists of an open air building and concrete pad. A 1200-gallon dewar stores LH_2. The facility is utilized to test Mylar honeycomb insulations at LH_2 temperatures and ambient conditions. Small LH_2 calorimeters and 70-inch diameter insulated tanks are tested utilizing LH_2 to determine the thermal conductivity of the insulation. Approximately 110 channels of instrumentation are available.

The Storable Propellant Test Facility (4750) has two positions capable of static firing storable propellant engines under simulated altitude conditions. Each consists of a steam ejector and altitude cell. The small cell (3 feet diameter by 4 feet) has the capability of firing single engines up to 150 pounds thrust. The large chamber (12 feet diameter by 15 feet) will accommodate the S-IVB Auxiliary Propulsion System Module. Each chamber will operate at an altitude of 120,000 feet. There are approximately 150 channels of instrumentation.



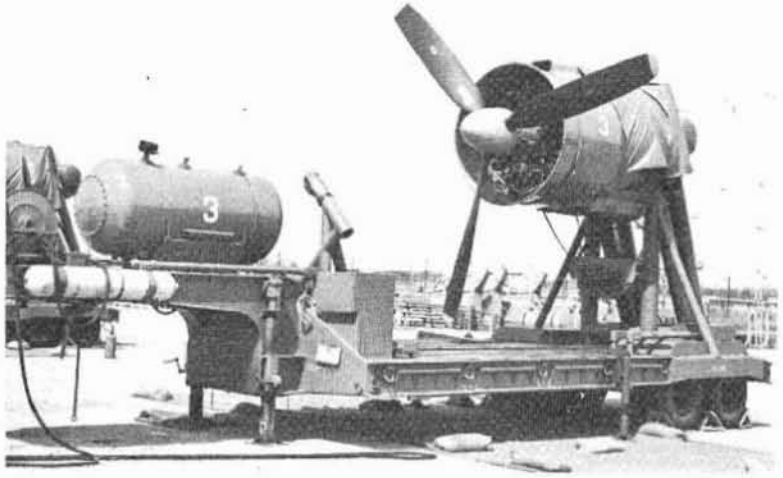
STORABLE PROPELLANT TEST FACILITY

GROUND SUPPORT EQUIPMENT TEST FACILITY

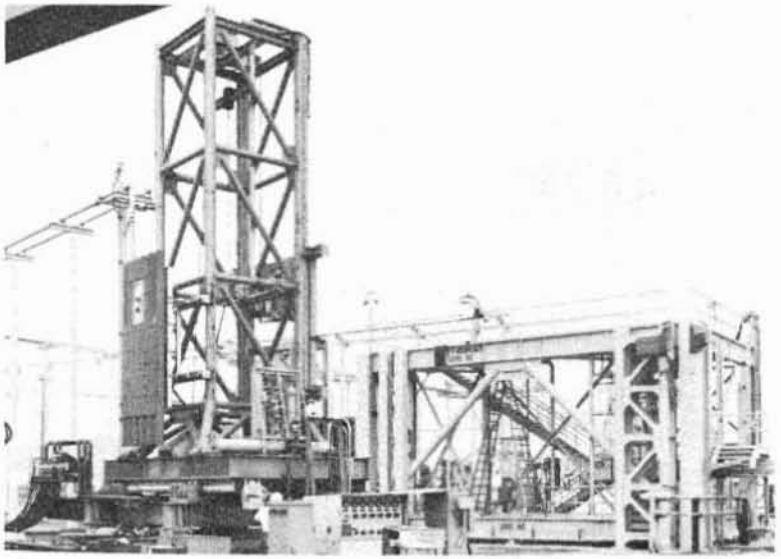
Ground Support Equipment Testing (S4656) devotes 10,000 square feet of assembly area and 1600 square feet of sub-assembly area to general laboratory use; an additional 1200 square feet of space is for general office use. Handling equipment includes two 30-ton cranes with hook heights of 30 feet. The high pressure GN_2 gas system provides 5000 psi pressure for general purpose testing.

The GSE Test Facility is a complex of 10 paved acres comprising diverse equipment and structures. Four aircraft engines mounted on trailers serve as wind machines and produce 65 knot winds. The 8 vehicle simulators duplicate Saturn V lift-off acceleration; they have a random motion to ± 20 inches and contain Saturn V skin panels and umbilical connectors. There are 10 umbilical tower simulators similar to the portions of the LC-39 mobile launcher umbilical tower where the service arms are mounted.

A cryogenic distribution system provides LH_2 and LN_2 at 150 psi to the test facility; the system has no tankage or pumps. In the compressed gas distribution system, the GN_2 supply connected to the main distribution system feeds GN_2 at 5000 psi to each tower and the vehicle simulator; the helium source is self-contained and has two 35 cubic-foot storage bottles to supply helium at 5000 psi to the cryogenic area.

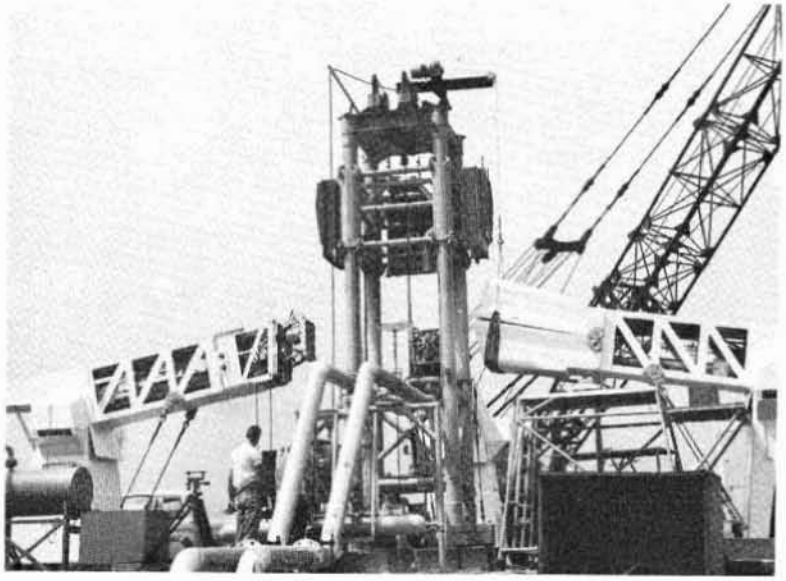


WIND MACHINE NUMBER 3



VEHICLE SIMULATORS

Five support buildings provide a total working area of 1280 square feet for instrumentation, control and personnel. The pumphouse also is 1280 square feet in area and has a hydraulic power pack with a capacity of 400 gpm against a 4300-psi head. The load test structure has a capability of 3000 kips down, 3000 kips up and 500 kips sideload and is applied hydraulically to accommodate Saturn V holddown arms.



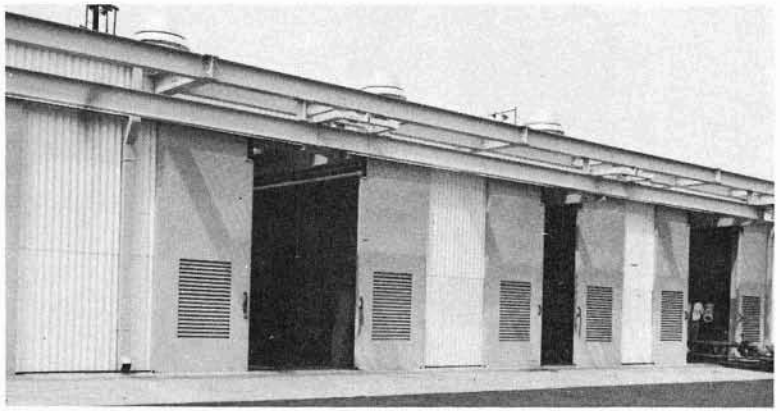
SATURN V HOLDDOWN ARMS

The blockhouse, a two-story reinforced concrete structure containing 2200 square feet of floor area, has the following instrumentation:

- analog-to-digital data system - 200 channels (5000 channels-per-second scan rate.)
- strip chart recorders (24)
- oscillographs - 72 channels
- computer - 250,000 characters-per-second storage
- binary to digital readout converter
- visual display
- printer - 300 lines-per-minute
- X-Y plotter

Control equipment located in the blockhouse permits control of the warning system, the cryogenic system, 10 remote control fire nozzles, 4 wind machines, 8 vehicle random motion simulators, 5 vehicle lift-off devices and event recorders.

Building 4648 has 7200 square feet of floor area with 4 high pressure test cells and accommodates a wide range of equipment, machines, and systems. The facility capability encompasses flowtest to 15,000-psi GN_2 at flow rates up to 540,000 scfm and flowtest at 10,000-psi helium with flow rates up to 200,000 scfm as well as leak, burst, and proof tests at gas pressures up to 25,000 psi and hydrostatic pressures up to 100,000 psi. Storage systems include two 2600-gallon LN_2 tanks, eight 12 cu. ft. and six 8 cu. ft. 10,000-psi helium bottles and six 100 cu. ft. 15,000-nitrogen bottles.



HIGH PRESSURE TEST FACILITY

GENERAL SUPPORTING FACILITIES

The general supporting facilities complement the major test areas and facilities.

Closed Circuit Television System. The system utilizes 81 chains of equipment providing test monitoring from remote locations. The facility has four video tape recorders providing a capability for pictorially recording as many as four tests simultaneously. The system serves the East Test Area, the West Test Area and the Test Support Area.

Photographic Equipment. This facility provides photographic coverage for all tests within the Test Laboratory. Cameras include

- 32 low speed (8-128 frames/sec)
- 99 low to medium speed (16-500 frames/sec)
- 25 high speed (250-8000 frames/sec)
- 4 sequence

Portable Instrumentation Vans. There are 4 portable instrumentation vans, all of which provide measurements of temperature, flow, pressure loads, strain, etc. Each can be located at various locations within the Test area. The equipment of each is listed below:

- Instrumentation Van #1, MSFC 2925
  16 strip chart recorders
  two 50-channel oscillographs

- Instrumentation Van #2, MSFC 2926
  100-channel digital data system with
  6 channel-per-second scan rate
  two 50-channel oscillographs
  6 strip chart recorders

- Instrumentation Van #3, MSFC 2817
  100-channel digital data system with 10
  channel-per-second scan rate
  4 strip chart recorders

- Instrumentation Van #4, MSFC 2940
  100-channel digital data system with 10
  channel-per-second scan rate
  one 50-channel oscillograph
  4 strip chart recorders

Saturn Stage Transportation Instrumentation. There are three 36-channel units located in mobile trailers and four 8-channel portable units for measuring and recording such parameters as vibration, temperature, humidity and strain on the Saturn stage boosters during movement of the boosters.

Far-Field Noise Propagation and Measurement System (4565). A far-field monitoring system, consisting of 48 land line field units and 1 base station, 1 telemetry unit and 10 portable tape recorder units, is used for acquiring Saturn booster noise level information within a 36 kilometer radius of the Test Laboratory complex. The data handling system, a GE 235 computer and associated equipment, acquires data from the far-field monitoring system and performs mathematical analyses of acoustic and meteorological data. The base station and computer are located in the Acoustical Control and communication center (4566). For mid-field acquisition two trailers have 28 channels of data acquisition equipment and one trailer, a 14-channel system; data can be acquired within 5000 feet of the booster test stands.

ACOUSTICAL HORN

The acoustic data reduction system includes an octave band and 1/3 octave band system for data reduction in the frequency range of 1 to 200,000 cps, and a narrow band system for reduction from 1 to 20,000 cps. High frequency acoustic data is acquired from small rocket tests by 28 channels of data acquisition equipment in the frequency range of 30 to 80,000 cps. An acoustic horn produces 150,000 acoustic watts in a 360° azimuth for predicting acoustic levels in the surrounding areas.

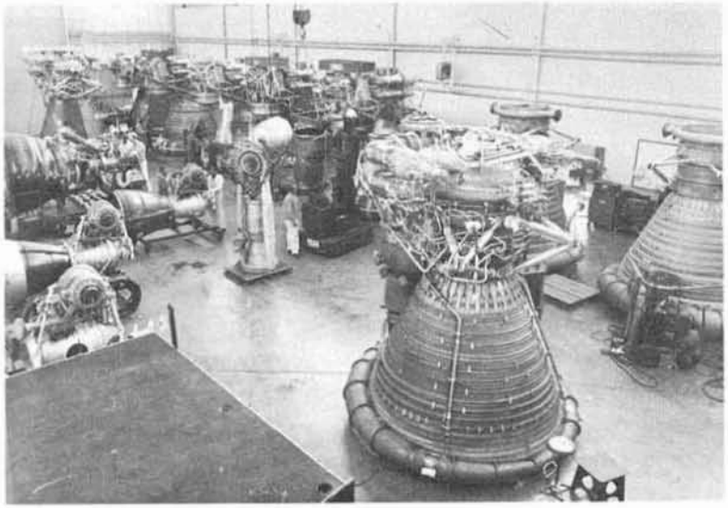
Test Support Shop Facilities (4650). This complex includes the Machine Shop, Shop Fabrication and Erection, and Field Fabrication and Erection, each 22,200 square feet in area. The Machine Shop is air conditioned and includes boring mills of 3- and 40-inch capacity (including one dial-a-matic 4 inch), small precision drilling machines up to 8-inch radial, surface grinders of the balanchard and pedestal type, shapers up to 14-inches and saws up to 13- by 16-inch capacity. A 20-ton overhead crane provides lifting and handling capability.

Shop Fabrication and Erection is devoted to operations of all types of welding, metal forming and pipefitting. Equipment includes 300- and 400-amp gasoline welding machines; sigma, submerged arc, short arc, plasma arc and portable 400-amp heliarc cutting machines; metal rolling and shearing machines; press brakes; beveling and nibbling machines; power saws, etc. A 3-ton overhead crane serves the area.

TEST SUPPORT SHOP

Field Fabrication and Erection has a 40-foot by 60-foot door and 40-foot high bay. A 25-ton overhead crane and two 10-ton cranes serve the facility. The area reserved for large fabrication and assembly is 40 feet with embedded members to tie down fixtures, etc. for welding. Equipment includes power punching and abrasive cut-off machines, a 24-inch power hack saw, oxygen and acetylene cutting equipment, electric welding, portable air compressors and pneumatic tools. Mobile equipment includes heavy duty tractors and trailers of 100-ton capacity and mobile cranes from 10- to 130-ton capacity.

Vehicle Engine Preparation and Turbopump Shop (4655). The building is of sheet metal construction with an area of 11,200 square feet by 50 feet high. The bridge crane has 2 trollies, 25 and 10 tons respectively, and a hook height of 41 feet; a 1-ton crane has a 12-foot hook height. Capability enables buildup and preparation of liquid rocket engines for static firing and buildup and repair of turbines, LOX and fuel pumps for these engines.



VEHICLE ENGINE PREPARATION SHOP

Components Service Facility (4652). The insulated, double wall, sheet metal building has a shop area of 16,000 square feet plus 6400 square feet for offices and utilities. The high bay height is 20 feet: high bay East has a 3-ton crane with 15-foot hook height; high bay West has a 5-ton crane of identical hook height. In addition, there is a low bay area 9 feet in height. The components support shop is responsible for the repair and maintenance of stage and engine GSE, test facility components, valves, regulators, filters, relief valves, stage and engine components, gas generators, main valves, prevalves LOX loading and transfer pumps, hydraulic pumps, etc. The shop also fabricates flexhoses (AN type fittings) up to 2 inches.

COMPONENTS SERVICE FACILITY

Gaseous Nitrogen Generation Facility (4659). This facility generates and supplies gaseous nitrogen at 5000 psi to all major MSFC facilities through a high pressure storage and distribution system. The maximum generating capability of the facility is 1,080,000 standard cubic feet per hour. Liquid nitrogen is stored in six-13,000 gallon and two-28,000 gallon vessels. Four-4000 gallon transport tankers are used for delivery to various test sites.

GASEOUS NITROGEN GENERATION FACILITY

Helium Booster Station (4676). The facility has a maximum capacity of 1650 scfm helium at 5000 psig per MSFC specification 364A. Equipment includes

- 1 Chicago pneumatic, 450 scfm @ 5000 psig
- 1 Aminco Diaphragm type compressor, 300 scfm @ 5000 psig
- 1 Chicago Pneumatic compressor, 300 scfm @ 5000 psig
- 1 cryogenic purification system
- 2 purification systems consisting of scrubbing towers, dryers, felt filters and metallic filters

HELIUM BOOSTER STATION

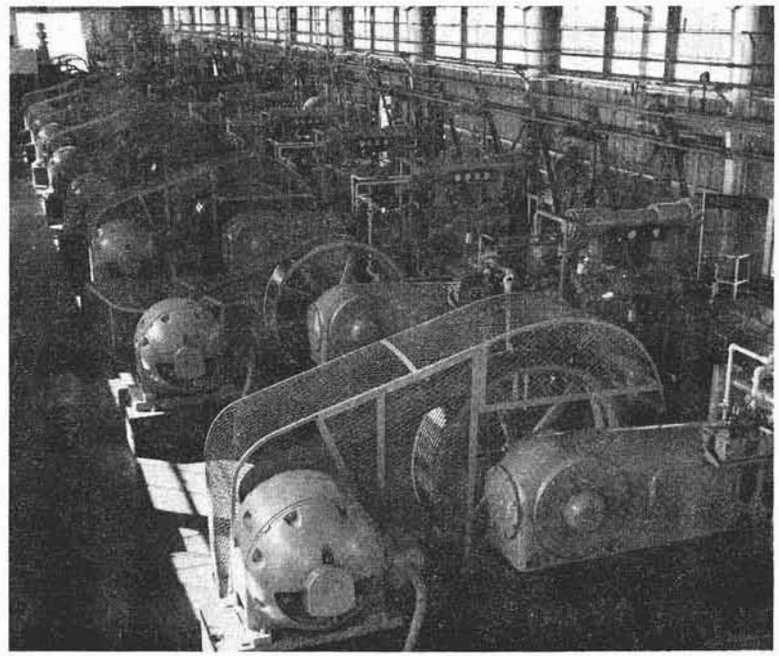
Air Compressor Facility (4647 & 4747). Capability of the complex provides 4450 scfm of missile grade air at 3500 psig and 230 scfm of missile grade air at 5000 psig. The facility is equipped with

Building 4647

- 4 Norwalk Compressors, 550 scfm at 3500 psig
- 2 purification systems consisting of scrubbing towers, dryers, felt filters and metallic element filters.
- two-1250 cu. ft., 3500-psi storage bottles.

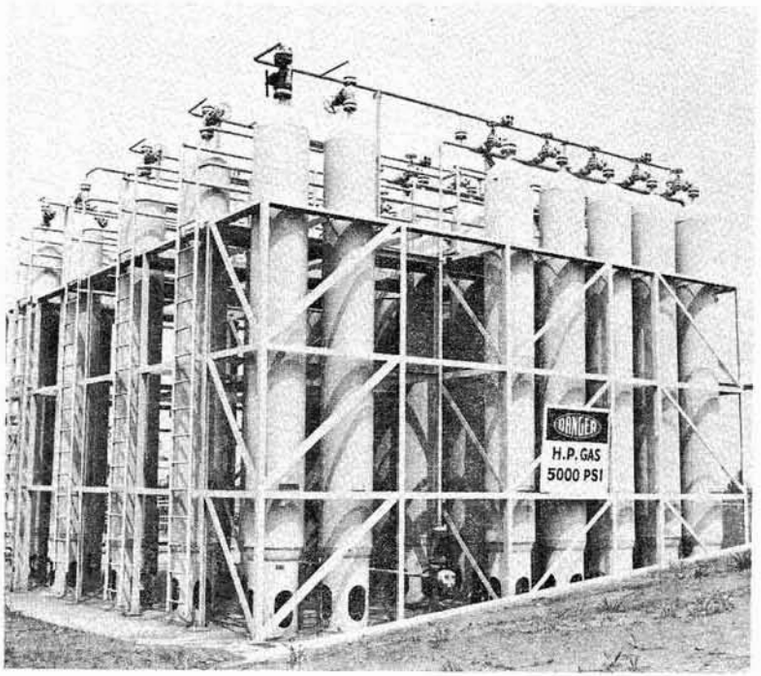
Building 4747

- 10 Chicago Pneumatic compressors, 225 scfm at 3500 psig
- 1 Chicago Pneumatic compressor, 230 scfm at 5000 psig
- 2 purification systems consisting of scrubbing towers, dryers, felt filters and metallic element filters.



AIR COMPRESSOR FACILITY

High Pressure Gas Storage and Distribution Systems. Ten air storage batteries consist of various sizes of bottles manifolded together and tied into a main transmission system. The working pressure of the system is 3500 psig; total storage capacity of the batteries is 14,164,114 scf; line capacity is 119,500 scf and transporter capacity 8200 scf.



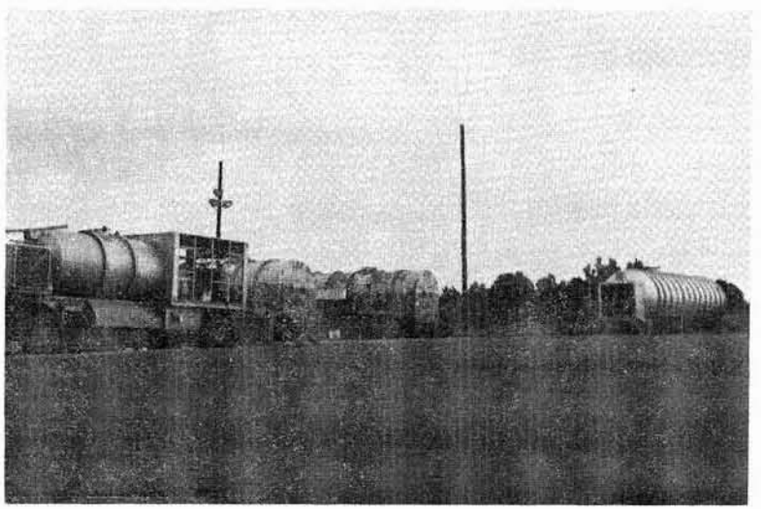
HIGH PRESSURE GAS STORAGE SYSTEM

The gaseous nitrogen storage battery system is identical to that for storing air except that working pressure is 5000 psig and storage capacity is 3,669,000 scf. Seven trailer transporters have 5000-psig rating and 2 are rated at 3500 psig; their combined capacity is 103,600 scf.

Gaseous helium has 1 storage battery consisting of 3-1250 cubic-foot, 5000-psig bottles manifolded and tied into a main transmission system. Working pressure is 5000 psig and storage capacity is 1,251,000 scf. Seven trailer transporters, rated at 5000 psig, have a 490,000-scf capacity.

Liquid and Gaseous Hydrogen Facilities. The equipment and capability of the facility are as follows:

Total liquid hydrogen storage capacity is 39,000 gallons; 1588 scfm of gaseous hydrogen can be generated at 5000 psig. Two liquid hydrogen transport trailers each have a 7800-gallon capacity; the gaseous hydrogen capacity of 6 transport trailers is 400,000 scf at 5000 psi. A portable recharger handles 20,000 scfh of gaseous hydrogen at 5000 psig with a 1500-gallon LH_2 storage tank. The recharger for the S-IVB stand provides 75,000 scfh of gaseous hydrogen at 5000 psig with a 2500-gallon LH_2 storage tank.



LIQUID AND GASEOUS HYDROGEN FACILITIES

RP-1 Fuel Storage Facilities (East Test Area). The total RP-1 storage capability of the complex is 147,000 gallons and total transporter capacity is 30,000 gallons. The equipment serving storage functions are

- 6 transport trailers, 5000 gallons each
- 3 underground storage tanks, 17,000 gallons each
- 4 underground storage tanks, 19,000 gallons each
- 1 underground storage tank, 20,000 gallons

and associated pipe, pumps and filters to load and unload transporters and fill run tanks on test towers.

RP-1 Servicer. The servicer/transporter has a 3000-gallon storage tank with required pump, filter and piping to furnish clean and waterfree RP-1 fuel. Delivery of 100 gpm of clean RP-1 is made at 150-psig discharge pressure.

Industrial Water Pump Stations (4567 & 4667). The facility has a total storage capacity of 8 million gallons with a pump capacity of 341,750 gpm at 185 psi. Tankage and pumping systems include:

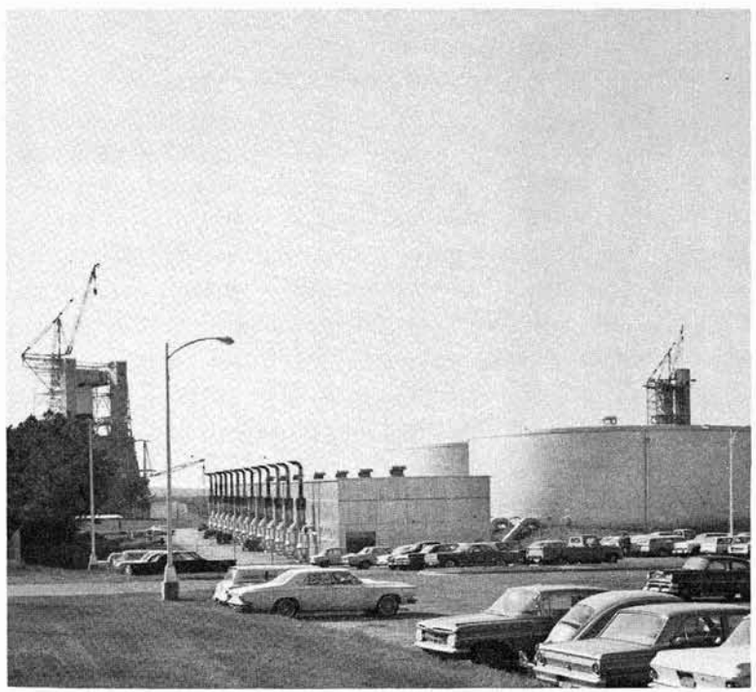
Building 4567

- 7 diesel engine driven pumps, 10,000 gpm each
- 3 electric motor driven pumps, 3250 gpm each
- 1 electric motor driven pump, 1500 gpm
- 1 electric motor driven pump, 500 gpm
- two 1,000,000-gallon water storage tanks

EAST TEST AREA INDUSTRIAL WATER STATION

Building 4667

- 13 diesel engine driven pumps, 20,000 gpm each
- two 3,000,000-gallon water storage tanks



WEST TEST AREA INDUSTRIAL WATER STATION

Deionized Water Facility. Capability produces 90-gpm of deionized water; total deionized water storage is 93,000 gallons and transporter capacity is 21,000 gallons. A breakdown of equipment includes

- 1 deionizer, 100 gpm
- 3 storage tanks, 17,000 gallons each
- 3 storage tanks, 14,000 gallons each
- 1 transporter trailer, 6000 gallons
- 1 transporter trailer, 8500 gallons
- 1 transporter trailer, 4000 gallons
- 1 transporter trailer, 2500 gallons

Hydrazine - UDMH and N_2O_4. Small amounts are supplied with special drums for small engine testing.

Ethylene Glycol Service. The trailer transporter has a 6000-gallon capacity.

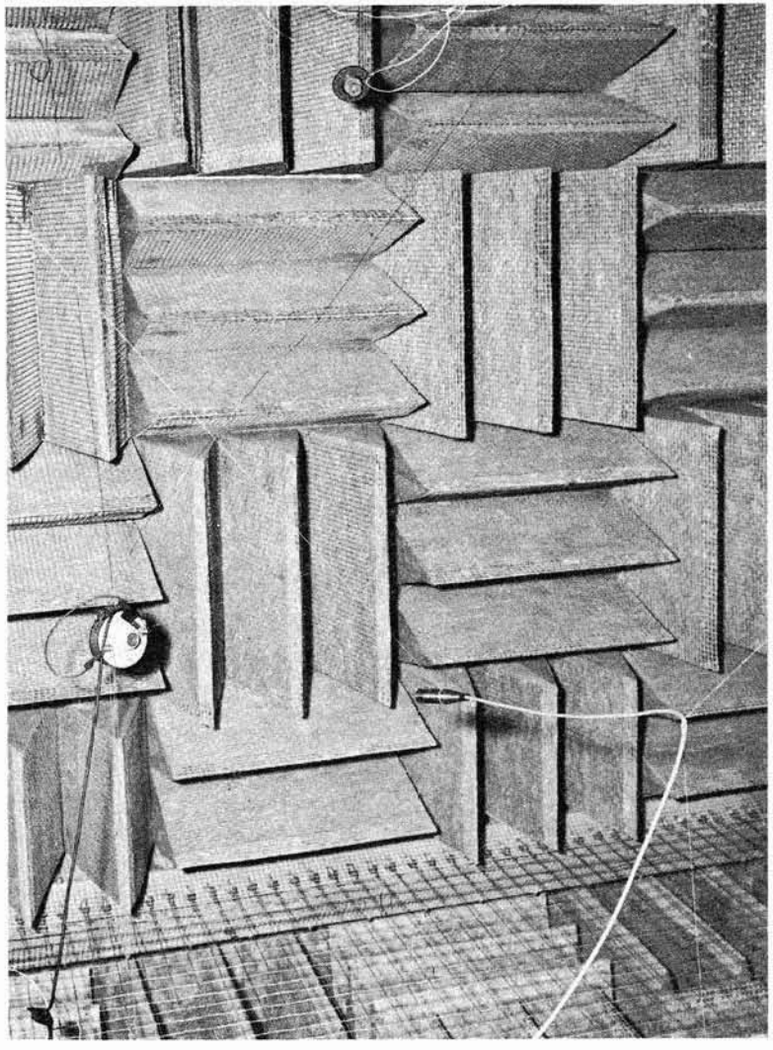
INSTRUMENTATION DEVELOPMENT LABORATORY

The Instrument Development Laboratory (4650) has facilities and equipment for development, modifications, prototype production, test, and calibration of measuring instrumentation, necessary to support the Test Laboratory's mission of static firing and developmental testing of launch vehicle systems, their components and ground equipment. The Instrument Development Laboratory covers five main fields of interest:

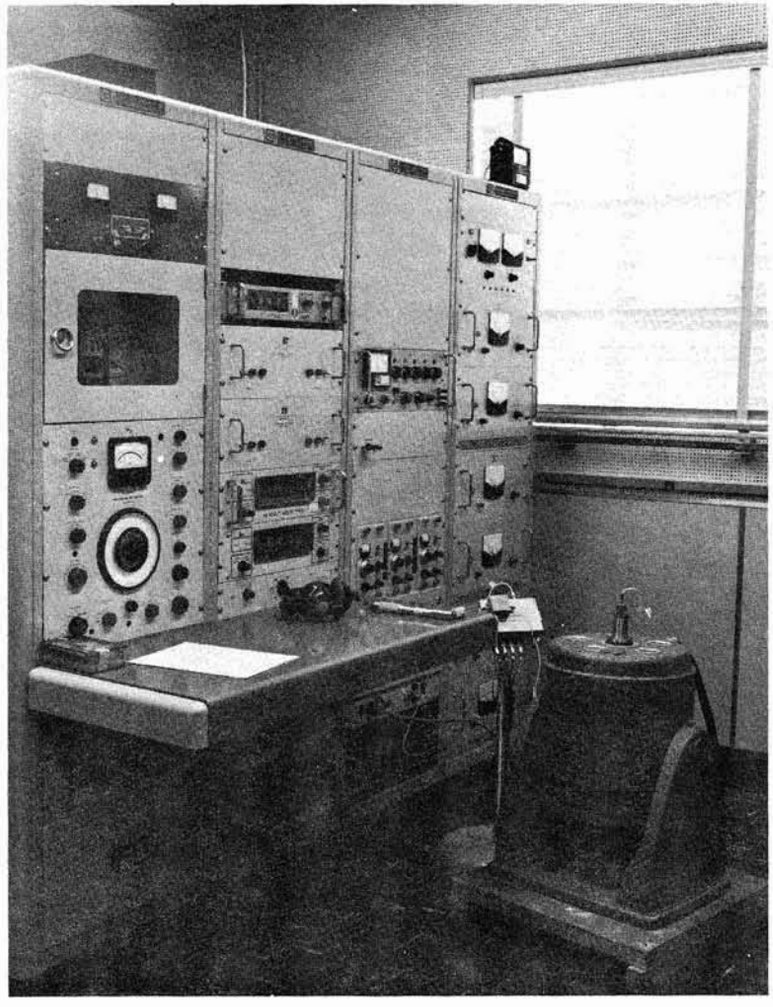
1. Electronics Laboratory
2. Flow and Level Laboratory
3. Instrument Design Laboratory
4. Pressure and Thrust Laboratory
5. Temperature and Physical Laboratory

INSTRUMENT DEVELOPMENT LABORATORY

The Electronics Laboratory develops, tests, and calibrates such electronic instruments as accelerometers, microphones, displacement transducers, attitude indicators, seismic transducers, strip chart recorders, amplifiers, multiplex systems, liquid level readout systems, cathode followers, temperature rise indicators, etc. There is an Acoustics Laboratory for research and calibration of microphones from 1-150 Hz at 110-170 decibel sound level (re: 0.0002 dyne/sec^2). The Anechoic Chamber is an extremely quiet room having no extraneous noises which might degrade the accuracy of microphone calibration. For precision electrical measurements there is a shielded room which is lined with a material that protects against radio frequency and other electrical noise influences. Special shakers and calibration systems provide the capability of calibrating over the range from 5 Hz to 50,000 Hz.



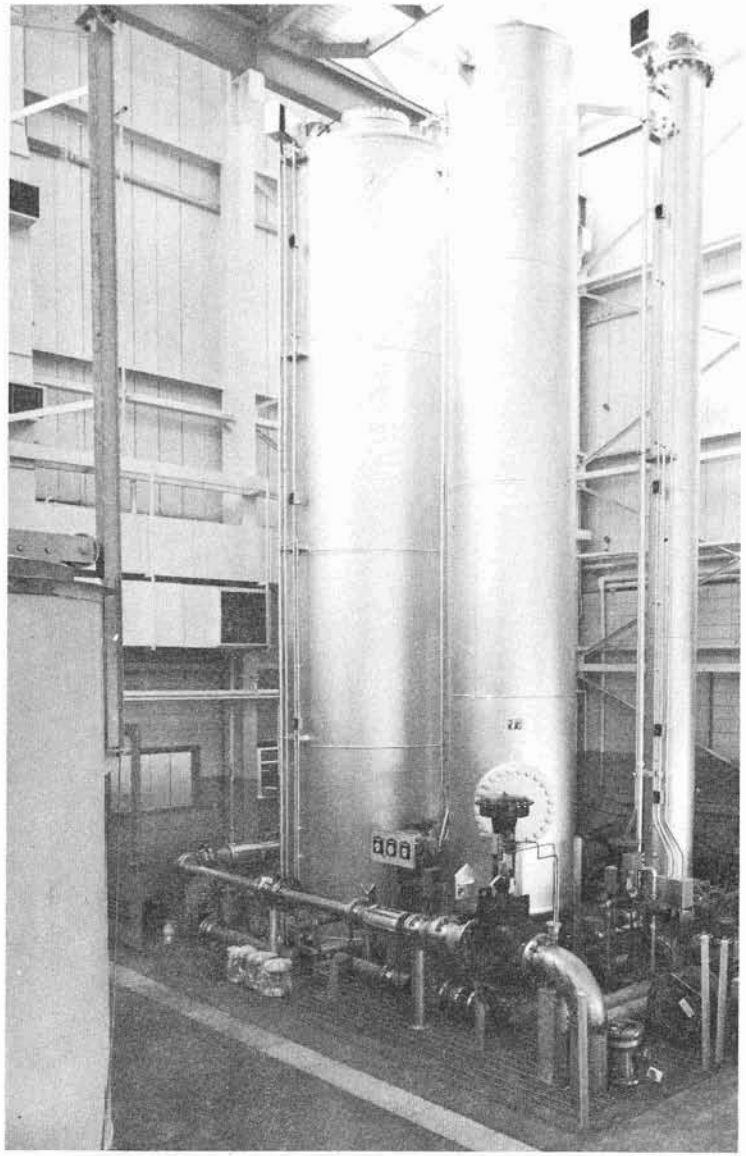
ANECHONIC CHAMBER



ACCELEROMETER CALIBRATOR

Flow and Level Laboratory. The liquid flow calibration facility in the high bay uses as standards some discrete liquid level gages in 27 feet high cylindrical tanks covering three ranges, namely: 125 gpm, 750 gpm, and 3000 gpm. The readout and control console for this facility is in the main flow laboratory. For less precision and more routine calibration, there is a completely self-contained commercial calibration system using the time-weight principle. This calibrator has the capability of calibration at different temperatures, controlling the temperature of the fluid within ± 1° F over a range of 50° F to 150° F. The capacity of this calibrator is 0.6 gpm to 300 gpm and its accuracy is ± 0.1 percent. For gas calibration, the main flow laboratory contains two small Prover Tanks with 0.42 cubic feet (ft^3) and 5 ft^3 volume for flow rates of 0.00035 cubic feet per minute (cfm) to 8.8 cfm. A larger Prover Tank of 200 ft^3 for flow rates up to 350 cfm, is available in the high bay. A special gas calibration system, in a sound and explosion proof room, accommodates calibrations up to 5000 cfm at 3500 psi pressure. This facility uses critical flow nozzles as standards and additional measurements are made by turbine type gas flowmeters, pressure-volume-temperature (PVT) measurement in the supply tanks, and a water displacement method. The accuracy of the Prover Tank systems is about 1/4 percent. The larger gas calibration facility accommodates air, nitrogen, and helium. Its accuracy is approximately 1/4 to 1/2 of 1 percent.

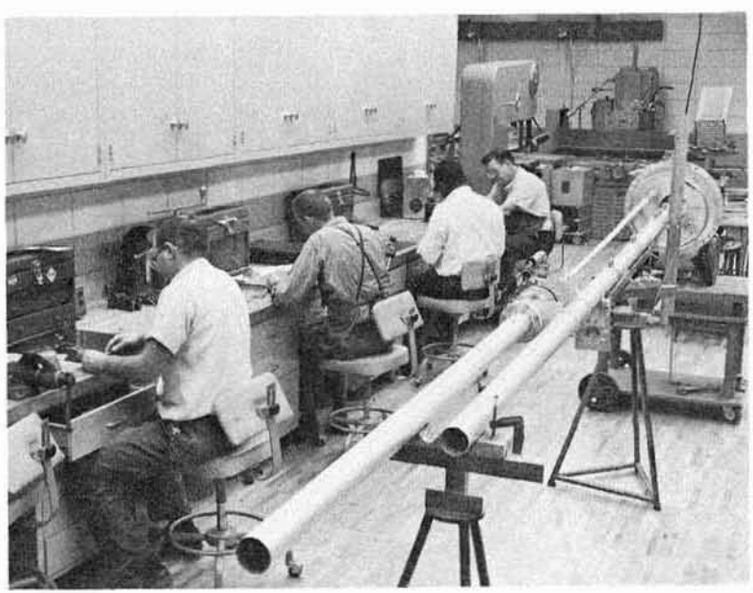
Calibration stands for water and LOX at flow rates up to 40,000 gpm and line sizes of 18 inches and 24 inches are in the test area.



FLOWMETER CALIBRATION SYSTEM

TEST LABORATORY

The Instrument Design Laboratory designs, fabricates, installs and maintains very complex and special instrumentation and devices, e. g. resistance thermometers, thermocouples, calorimeters, and level gages for research and development work.



INSTRUMENT DESIGN LABORATORY

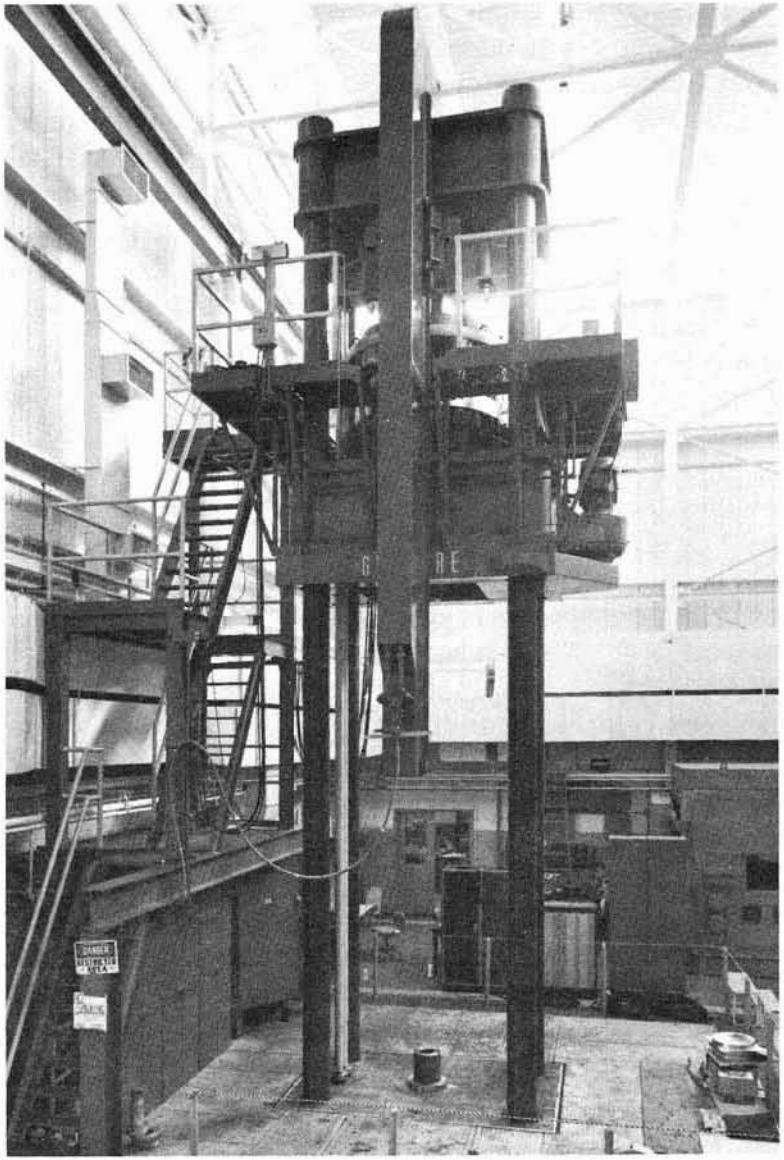
The Pressure and Thrust Laboratory measures pressure, force, weight, mass, stress and strain in support of the various test and development programs. Tests and calibrations are accomplished with automatic, multichannel calibrators and automatic IBM Card Punch Systems combined with high accuracy readout instrumentation and high speed data processing by the Computation Laboratory.

The high bay provides two dead weight machines for the calibration of load cells or other force measuring devices. One unit has a 50,000 lb. capacity while the other has a 500,000 lb. capacity with a possibility to calibrate up to 5,000,000 pounds. The dead weight calibration has an accuracy of 0. 006 percent and the load cell calibrator has an accuracy of 0. 02 percent. Testing and evaluating instrumentation at simulated working conditions is accomplished in the environmental test chamber which has a temperature range of -450° F to +500° F, and a humidity range of 20 to 95 percent relative humidity simulating altitudes up to 150,000 feet. Test Equipment is also available for shock testing to 1000 g's and for linear acceleration testing.

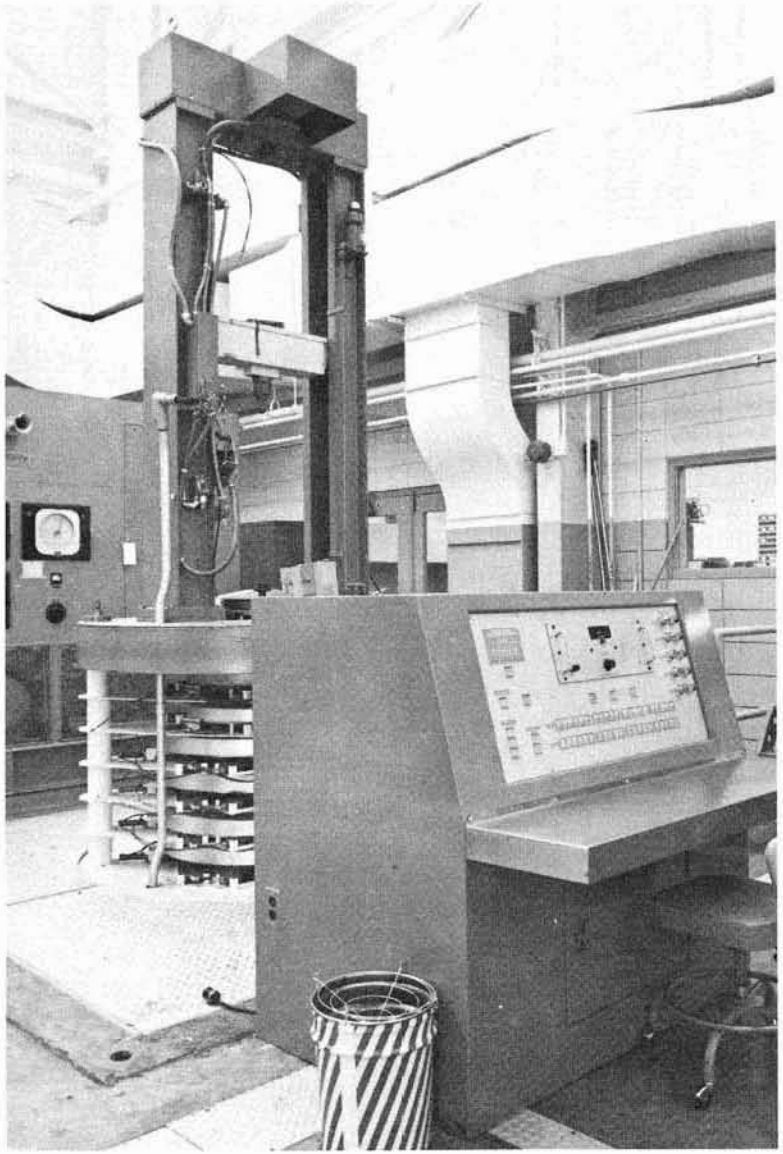
The general laboratory provides: The readout instrumentation for shaker and sinusoidal pressure generator; an automatic pressure calibrator with a small environmental chamber; strain gage application and general pressure calibration facilities.

There is a 12,000 psi Ruska dead weight tester; a 100 lb. equal arm balance; two mercury manometers; two air dead weight pressure testers and a precision differential pressure sensor using a floating piston with air bearings.

TEST LABORATORY

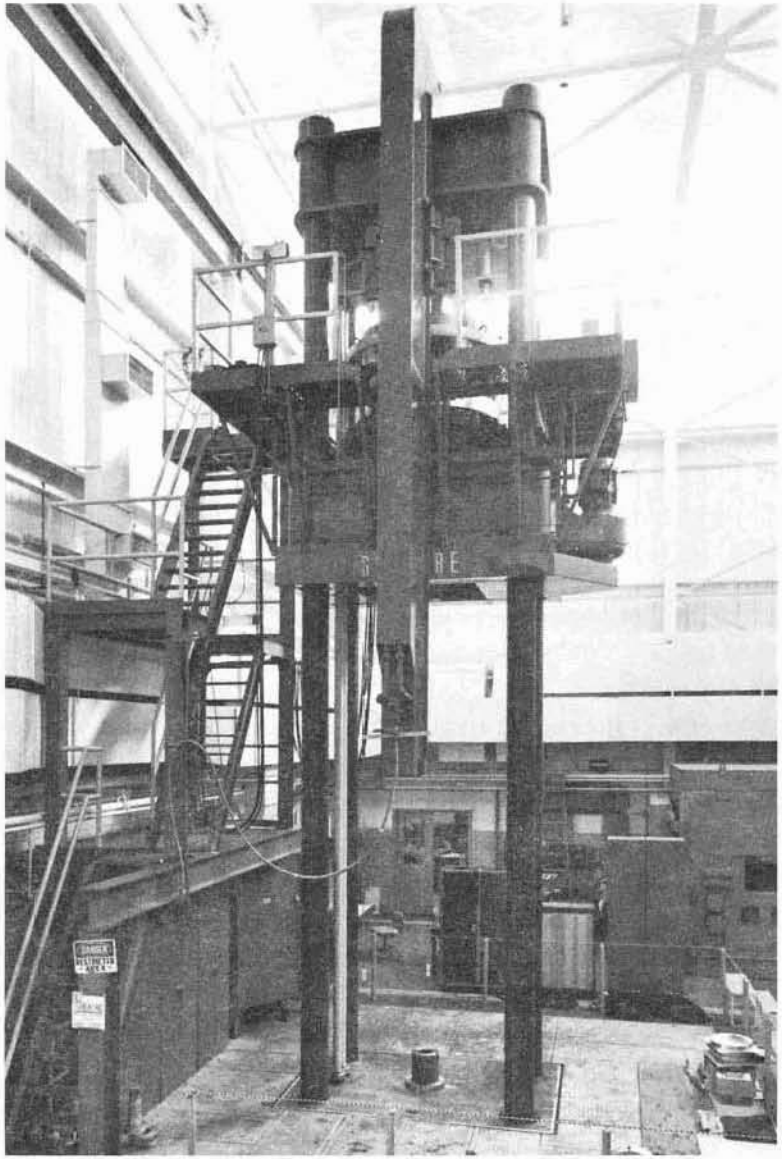


UNIVERSAL FORCE CALIBRATION MACHINE

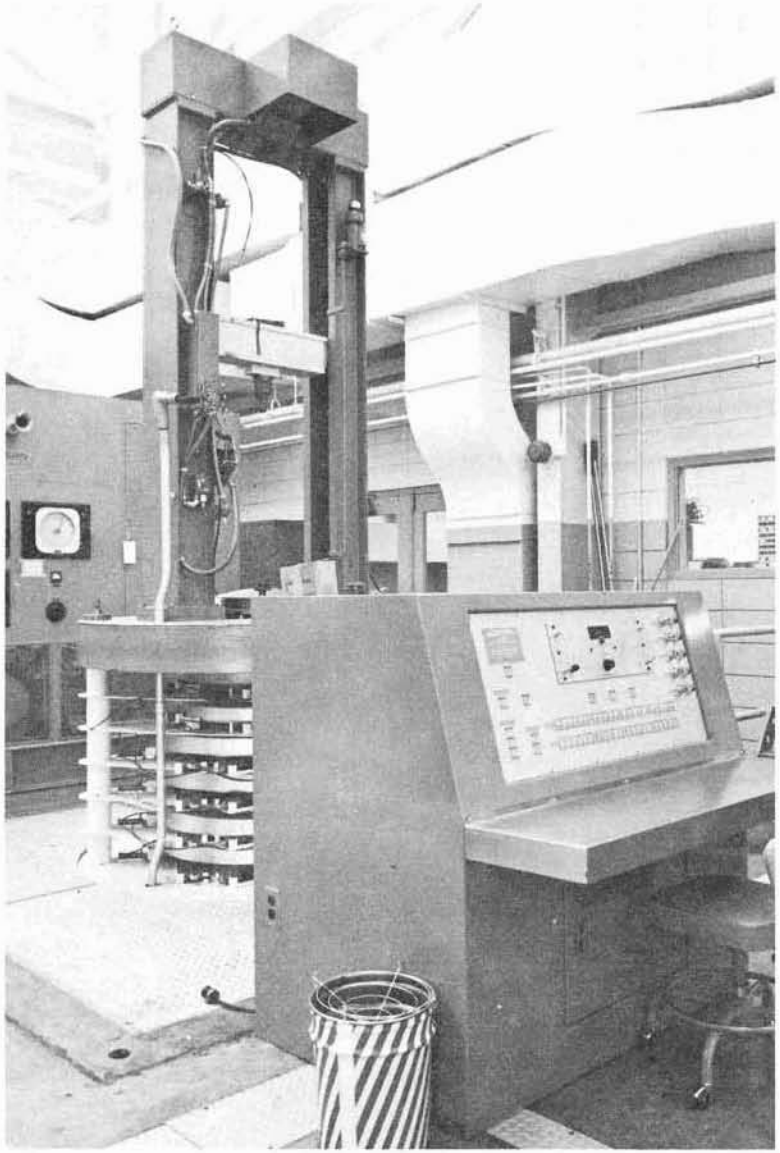


DEAD WEIGHT TESTER

TEST LABORATORY



UNIVERSAL FORCE CALIBRATION MACHINE

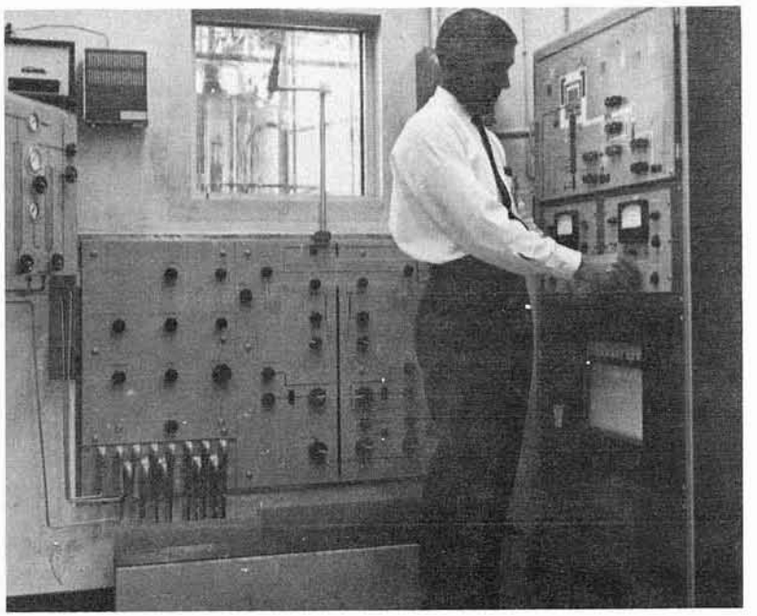


DEAD WEIGHT TESTER

The Temperature and Physical Laboratory develops, selects, modifies, tests, and calibrates instruments to measure temperature, heat flux, humidity, density, acceleration of gravity, composition of gases and other physical phenomena not included in the activities of other labs. It maintains primary and working standards traceable to the National Bureau of Standards and numerous instrumentation and equipment required for research, development, and testing.

In the Temperature and Physical Laboratory are: Freezing point standards with tin, lead, zinc, aluminum, silver, and copper, covering the range of 300° F to 1800° F with an accuracy of ± 0.1° F; automatic thermocouple calibration facilities with printout, covering the range of ambient to 2500° F, using an NBS thermocouple as transfer standard with an accuracy of ± 1° F below 1500°F and increasing to about ± 3° F at high temperatures; and a gravity meter with a repeatability of 0.0001 cm/sec^2. A heat flux calibration facility for calorimeters and radiometers has a blackbody source for primary calibration and grey body for comparison in a range of 0 to 200 BTU/ft^2/sec with a repeatability of ± 3 percent; a humidity generator which facilitates calibration of water vapor monitors over the range of -100° F to 72° F dewpoint temperature; bridges for calibration of Platinum Resistance Thermometers at ice point and liquid nitrogen boiling point; and electronic instruments for nuclear measurements. There is a specially prepared storage for radioactive sources. There is a hooded area for coating humidity measuring electrolytic cells.

There is an LH_2 cryostat providing continuously adjustable temperatures from -440° F to -280° F with an accuracy of ± 0.05° F; boiling point systems for liquid oxygen, liquid nitrogen, and sublimation temperature of carbon dioxide, providing fixed points standards at low temperatures with an accuracy of ± 0.01° F. The LH_2 cell is also used for testing level detectors in liquid hydrogen.



LOW TEMPERATURE TEST FACILITY

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX