Electrical Power Subsystem Test Facility

Purpose:

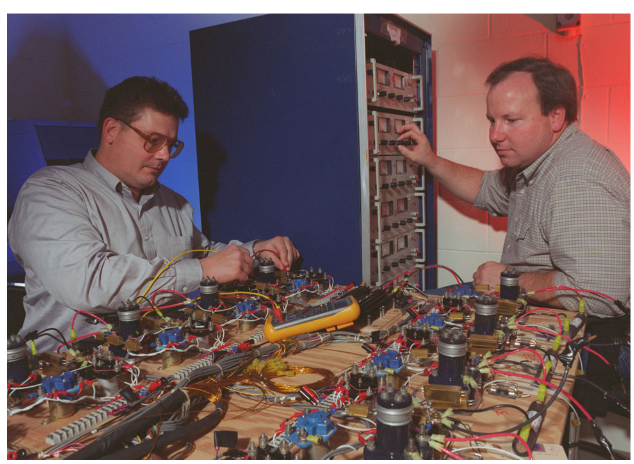
To test and evaluate flight electrical power systems such as batteries, solar arrays, fuel cells, super capacitors, relays, and switches.

Electrical Power Subsystem (EPS) Testing

This facility is equipped with all the necessary components to simulate a full-scale flight EPS. Power supplies or solar array simulators are used to simulate the power generated from the solar arrays or other energy source. Programmable loads or resistor banks are used to simulate the spacecraft loads. Batteries (similar, if not identical, to the flight units) are typically used to serve as the energy storage devices in the system. Thermal chambers, with volumes ranging from 6 to 100 cubic feet, are available to house those EPS components (e.g. batteries) requiring non-ambient temperature / humidity control (typically the batteries). The testing is computer-controlled through the use of a Hewlett-Packard Basic software program that interfaces with the control rack (relays, switches, etc.) via data acquisition and control system. The number of instrumentation channels available is limited only by the scanning frequency desired for a given testbed. The flexibility and power of the programming language allows for virtually any testing scenario to be implemented. The range of testing scenarios is constrained only by the limits of the test equipment being used. EPS nominal operation characterization, flight anomaly investigation, and induced failure / response studies are just a few of the ways this facility has supported some of MSFC's major programs over the last 30 years, including the Chandra X-ray Observatory (CXO) and the Hubble Space Telescope (HST).

Battery and Cell Testing

Using much of the same equipment as for EPS Testing, a full array of battery / cell tests can be performed. This includes conducting electrical qualification and acceptance tests on flight cells or batteries, as well as parametric and life-cycle testing of flight-like or engineering cells or batteries. Another aspect of battery / cell testing that can be performed (similar to the EPS testing capabilities) is that of flight anomaly investigation or induced failure / response studies. Additionally, silver-zinc cell activation can be performed in the facility. The cell chemistries that have been tested in this facility include nickel-hydrogen, nickel-cadmium, silver-zinc, lithium-ion, lithium-thionyl chloride, and nickel-metal hydride. Programs that have benefited from testing in this facility include CXO, HST, Shuttle / Solid Rocket Booster, Propulsive Small Expendable Deployer System, Orbital Maneuvering Vehicle, and Combined Release and Radiation Effects Satellite.

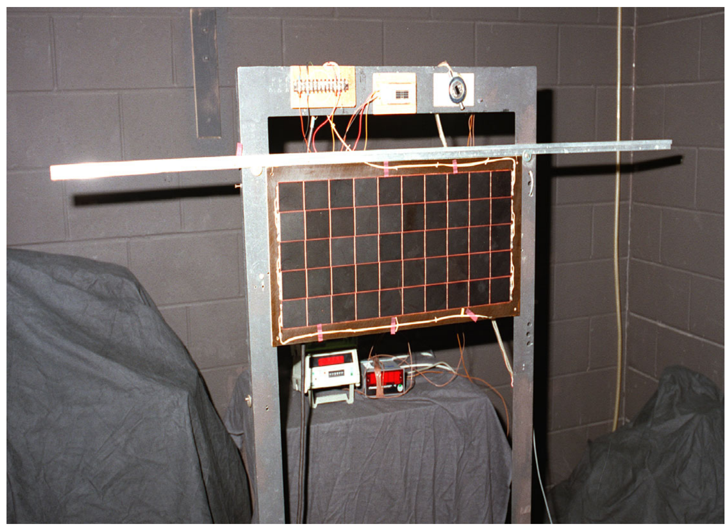


ELECTRICAL POWER SUBSYSTEM TEST FACILITY

Solar Cell and Panel Testing

The solar cell and panel test section of this facility provides the capability to support design, development, testing, and inspection activities required by various solar array user programs. This facility is equipped with a Spectrolab, large-area pulsed solar simulator (LAPSS) that contains its own data acquisition and control system (DACS). The LAPSS is capable of illuminating a circular target area of 210 square feet to the air-mass-zero intensity level of 140 milliwatts per square centimeter, or 1 sun, with an overall uniformity within 2 percent. The facility has recently been upgraded with a multi-junction LAPSS lamphouse (MJL) designed to provide additional control of spectral distribution needed for testing the state-of-the-art space qualified multi-junction solar cells currently in production. The MJL filtering system has adjustments to vary the total power in each of three wavelength bands representing the spectral response of the junctions of a triple-junction solar cell. It works in conjunction with the LAPSS pulse forming network and DACS of the LAPSS system. The integral DACS is capable of gathering up to 150 simultaneous current-voltage data points from a test article. The required performance curve, current-voltage (I-V), is then plotted from these data points. Test articles with output of up to 100 volts and 10 amperes can be tested. The facility also contains a vertical x-y infrared solar panel inspection station with video output. The inspection station is capable of performing cell-by-cell inspections for cell cracks on panels up to 212 x 212 centimeters in size. Additionally, the facility contains the equipment necessary to perform temperature-coefficient-characterization testing of single solar cells from ambient temperature up to 110 °C.

Nearly 8,000 square feet is dedicated to power systems testing. The facility is protected from inadvertent power outages by a 20 kilowatt (KW) uninterruptible power supply system consisting of a bank of lead-acid batteries continuously in parallel with the facility's primary power bus and a 20 KW diesel generator capable of providing power indefinitely to the facility within 30 seconds of power loss. The facility also receives gaseous



nitrogen service for the purpose of purging the thermal chambers in which hydrogen can potentially be emitted. This facility is located in Building 4475.

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Instrumentation and Control Facility

Purpose:

To research, design, plan, coordinate, and direct the application of components and subsystems for Flight Instrumentation Systems.

Inertial Navigation Sensors Development and Test Laboratories

The Inertial Navigation Sensors Development and Test Laboratories provide the capability to analyze and evaluate inertial sensors and strapdown inertial navigation systems. These facilities consist of three precision rate tables, recording instrumentation, and supporting test equipment. The rate tables are mounted on massive concrete pads designed to decouple the facility from building vibrations and to minimize ambient seismic noise. The rate tables provide precise information about rotation axes that can be tilted parallel to the earth's spin axis to remove the effects of the earth's spin. These tables are used to evaluate rate sensors for bias, scale factor, scale factor linearity, bias stability, and other performance characteristics. These rate tables have been used to support many programs in the past including Solid Rocket Boosters (SRB), Transfer Orbit Stage (TOS), Astro, Avionics Flight Experiment (AFE), etc. Current plans are to use the tables in support of NASA-led activities in the Flight Mechanics area of the Second Generation Reusable Launch Vehicle (RLV) program. The tables are located in Building 4487.

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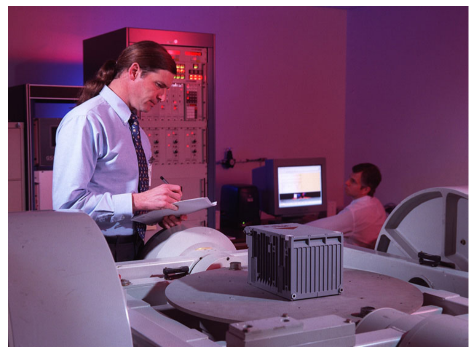
Navigation Components Development Laboratory

This laboratory provides the capability to develop and evaluate navigation components for launch vehicles. The facility consists of a three-axis rate simulator, a high-fidelity Global Positioning System (GPS) simulator, a rooftop GPS antenna, a GPS base station, a 6-processor simulation computer, workstations, and a data display computer. The facility allows the development of Kalman filters that blend the outputs of inertial measurements systems and GPS receivers for the precise navigation of launch vehicles. This lab will provide a unique capability to rapidly prototype and test blending filters using a variety of inertial measurement units and GPS receivers with various trajectories. The laboratory is presently used in a NASA-led Gen II study called Robust Integrated Technology and Testbed for Navigation of RLVs. It will also support the Low-Cost Avionics for RLVs study which is a joint MSFC AMCOM venture. The facility is located in Building 4487.



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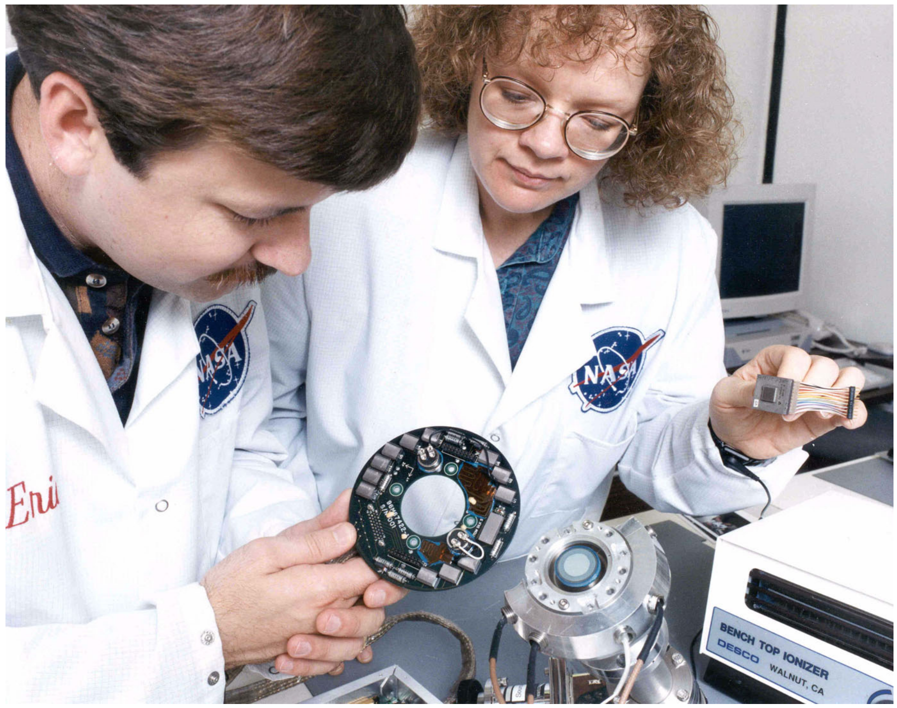
IMAGING RESEARCH FACILITY

Purpose:

To accommodate the design, fabrication, and testing of a wide variety of imaging systems.



The Imaging Research Facilities involve three different laboratories for the design, fabrication, and testing of imaging systems. The imaging test and measurement laboratory is available for the development and test of analog or digital imaging systems and components such as cameras, optics, recorders, or frame grabbers. Concepts, as well as systems, may be tested by using specialized electronic, recording, and spectral monitoring equipment. Some of the projects supported by the test and measurement laboratory include: Spacelab, Microgravity Glovebox (MGBX), Solid Rocket Booster (SRB), Delta-L, Automatic Rendezvous & Capture (AR&C), Space Flight Holography in a Virtual Apparatus (SHIVA), Lightening Mapper Sensor (LMS), and Evolution of Local Microstructures (ELMS).

The electronics imaging laboratory is used to design, breadboard, and test electronic circuits to build complete imaging systems. Project components developed and/or tested in the electronics laboratory include: Solar X-ray Imager (SXI) camera, MGBX video recording unit, Equiaxed and Transient Dendritic Growth Experiment (EDSE/TDSE) lighting system, Space Coherent Lidar Experiment (SPARCLE) test bed, and Delta-L thermal control system.

The imaging research laboratory was developed as a testbed for imaging system research and development. ESD-resistive workstations, optical benches, and video acquisition equipment accommodate the testing of conventional components or systems as well as innovative designs. Imaging systems requiring precise optical alignment, image processing, and strick lighting control can also be accommodated. Center Director's Discretionary Funds (CDDF) research, Misible Drop in Microgravity (MDMG), and Microgravity Science Glovebox (MSG) are some of the projects supported by this laboratory. These facilities are located in Building 4487.

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Microgravity Accelerometer Test Facility

Purpose:

To provide the capability to test various types of accelerometers used for inertial navigation or low-gravity experiments.

A granite surface plate mounted on an air-isolated table attenuates vibrations from the ground or the building. This table is mounted on a very thick concrete seismic pad for further isolation. A precision, motorized dividing head and laser interferometer are used to position accelerometers in the local gravity field to obtain scale factor and bias calibration values. An optional tiltmeter may be mounted on the table to obtain sub-arc second accuracies. A computer compiles the calibration data and can display the results in graphic and tabular form. Other pieces of equipment are available to measure other aspects of accelerometer performance, such as power spectral density and random drift.

Presently, the facility is being used to calibrate the accelerometers for the g-LIMIT Program. The facility is located in Building 4487.

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Attitude Control Components Test Facility

Purpose:

To provide the capability to perform functional, life, and acceptance testing of control moment gyros and reaction wheel assemblies.

Included in the facility are explosion-proof test vaults, one of which is mounted on a seismic isolation pad. These vaults are a unique capability, which allows safe testing of high-energy rotating devices such as gyros and reaction wheel assemblies. The larger of the two vaults has a video system capable of safely observing the device as it undergoes torque sequences. Automatic test equipment is available to monitor the attitude control component's performance, record data and provide automatic shutdown of the test in case of a malfunction. Presently, the facility is supporting the life testing of attitude control components for the Chandra X-Ray Observatory and the International Space Station. The facility is located in Building 4487.

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Computer and Data Systems Facilities

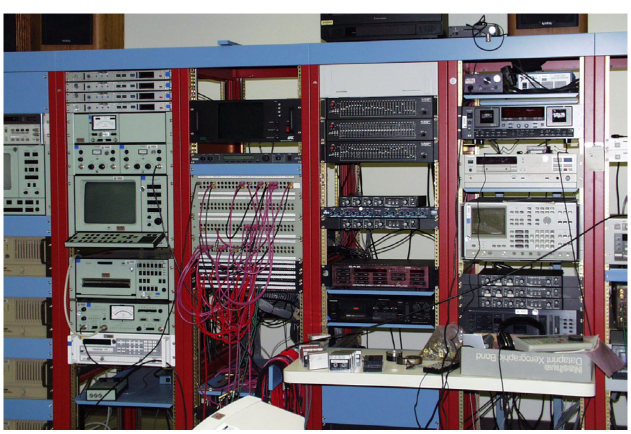
Purpose:

To design and develop computer controlled subsystems, such as engine controllers and data systems, for space flight and ground support avionics systems.

The objectives of these facilities are to:

1) plan and perform the analysis, design, development, and test of flight computers and data systems for space vehicles, experiments, and payloads;
2) design, fabricate, and test automated ground computer systems; and
3) plan and direct the analysis, design, development, and test of flight data systems including flight computers, data acquisition systems, data storage devices, and audio communication.

In support of these activities, the Avionics Department contains five different categories of laboratory facilities. The Audio Laboratory and the Design Simulation Laboratory provide state-of-the-art capabilities that are unique within MSFC. The other three are bench labs equipped with measurement, test, and instrumentation equipment used to support the development, assembly, integration, and testing of computers and data systems, supporting a wide variety of flight and non-flight projects.



Audio Laboratory

The Audio Laboratory is a facility for development and testing of flight audio subsystem designs. Thisfacility consists of two main areas; an acoustically isolated test chamber and a control room. The test chamber provides a high degree of sound isolation from the outside area for subjective evaluation of audio sound quality in the presence of controlled amounts of noise. The control room supports testing in the audio chamber and is a general-purpose audio laboratory for bench testing of audio hardware, computer simulation of audio design concepts, and support for testing in the audio chamber.

The laboratory is located in Building 4477. The Control Room occupies 800 square feet of space and the Audio Chamber is 22’ x 27’ x 17’ high.

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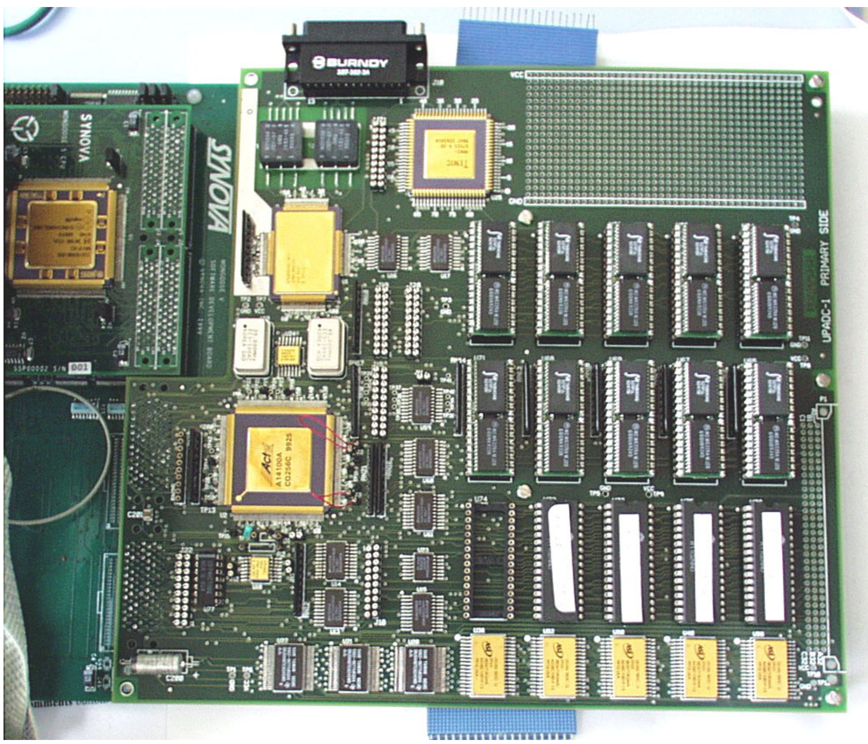
<u>Design Simulation Laboratory</u>

The Design Simulation Laboratory is the heart of MSFC's state-of-the-art electronic design capability. The hardware models located in this laboratory, are combined with the Very High-speed Description Language (VHDL) and Verilog CAD programs available at each designers desktop computer via network connectivity and floating licenses. Together, these tools support board-level system simulation as well as the development of custom designs for Field Programmable Gate Arrays (FPGAs) and Application Specific Integrated Circuits (ASIC.) This allows for full logic simulation of hardware before prototype units are built.



Capabilities within the Design Simulation Laboratory come from simulators developed by Synopsis and Model Technology, then combined with Synopsys hardware modelers and software model libraries. Synthesis tools for Synplicity, Synopsys, and Exemplar allow rapid logic design and improved circuit performance. The hardware modeling system allows complex device model development using the actual silicon for devices with up to 640 pins. Currently available models include the PowerPC603, MongooseV, the Summit controller for Mil-Std-1553, and other processes and complex I/O devices.

The Design Simulation Laboratory is located in Building 4487 and occupies 470 square feet of space.

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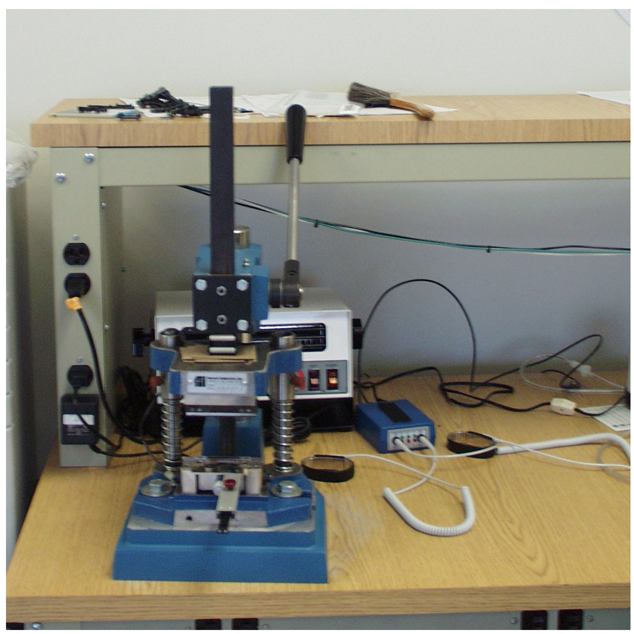
Programming and Forming Laboratory

In many cases, before components can be soldered to a circuit board, it is often necessary to modify the configuration of the parts. This is particularly true for computer and data system designs that rely upon embedded software, or programmable devices. Current designs also make extensive use of flat-pack style surface mounted parts. Ordinarily these parts are delivered to MSFC with the leads unformed, and attached to frames. These devices need to be formed into a footprint that matches the layout of the circuit board. The Programming and Forming Laboratory is used among other organizations within the Avionics Department, to prepare these component EEE parts prior to board assembly. The parts processed in this laboratory include development and prototype units, as well as parts for flight hardware.

The laboratory has the capability to program almost any type of electrically programmable part, including Programmable Random Access Memories (PROMs), Electrically Erasable Programmable Read Only Memories (EEPROMs), Programmable Logic Devices (PLDs) and Field Programmable Gate Arrays (FPGAs.) In addition, rewriteable devices such as UV-PROMs can be erased by exposure to ultraviolet light, then reprogrammed as desired. Current devices in use include Altera family PLDs and Actel FPGAs, as well as a variety of EEPROMs and PROMs. All of these activities take place at verified ESD workstations, which prevent damage to the devices during programming and handling. Normally programming steps must be performed prior to lead-forming of surface-mount components, as the programmers are designed to accommodate the footprint of the device as shipped from the manufacturer in the holding frames.

Lead forming is also performed on an ESD workstation. The laboratory provides the capability to cut away the holding frames and tie-bars, then form and cut the leads to the specified footprint. The former has been manufactured to provide the style of footprint approved by the Avionics Department's Electronic Packaging team, and provides the capability to adjust for the body-height of the part, as well as the configuration of where the leads exit the part body. Since one side of the device is formed with each operation, it is possible to form either dual flatpack or quad flatpack configurations. This provides virtually unlimited flexibility for the types of devices that can be formed.

This laboratory is located in Building 4487 and occupies 985 square feet of space.



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Ground Computers and Unit Test Development Laboratories

The Ground Computers and Unit Tester Development Laboratories are used to develop ground computer systems in support of flight and technology development projects. Examples of ground computer systems developed in these laboratories include engine controllers used to support test fires of engines.

Unit testers are provided for in-house-developed flight computer systems to provide the testing, acceptance, and qualification of flight items. Interface modules are developed to provide the testing of each flight unit interface, and test software ensures the proper operation evaluation of each unit being tested. Both the hardware and software for the unit testers will be developed and integrated together within these laboratories and then certified before use with the flight hardware.

An ongoing effort pursues the enhancement of ground checkout computer system concepts. Evaluation of current commercial off-the-shelf (COTS) products and techniques for the efficient flow of system data provides knowledge for development of future systems. Man/machine interface techniques are investigated to improve human interaction during space vehicle ground testing.

Past projects include the design, development, fabrication, test, and delivery of an automated checkout system for Spacelab level IV activities to the Kennedy Space Center (KSC). Key subsystems of the MSFC-delivered, level IV-related units are kept at MSFC to allow simulation of fault areas when problems are experienced at KSC. Through these activities, personnel can design rapid fixes for incorporation at user sites.

Both laboratories located in Building 4487 and occupy 2815 and 979 square feet respectively.

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Computer and Data Systems Facilities

Computer and Data System Hardware

Computer and data system hardware is tested, integrated, and verified within these laboratories. This includes the use of custom-designs, commercial-off-the-shelf (COTS) hardware or a combination of both.

In addition to supporting projects of the MSFC Product Line Directorates these laboratories also support ongoing research and technology projects such as the Center Director Discretionary Funds. The capabilities of test equipment and personnel in such areas as data acquisition, telemetry systems, optical data buses, and data storage is also maintained.

In order to conduct electronics testing, these laboratories possess a variety of state-of-the-art commercial test equipment such as oscilloscopes, multi-meters, function generators, precision power supplies, etc. More specialized equipment allows the monitoring and testing of Mil-Std-1553 data buses, VME computer communication, and other industry standards. In addition, custom test equipment, such as breakout boxes, unit testers, and other special test fixtures are frequently developed for each project and used in the test process.

The laboratories are located in Building 4487 and comprise six areas of 706, 985, 295, 767, 680 and 685 square feet respectively.

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Failure Analysis and Test Facility

Purpose:

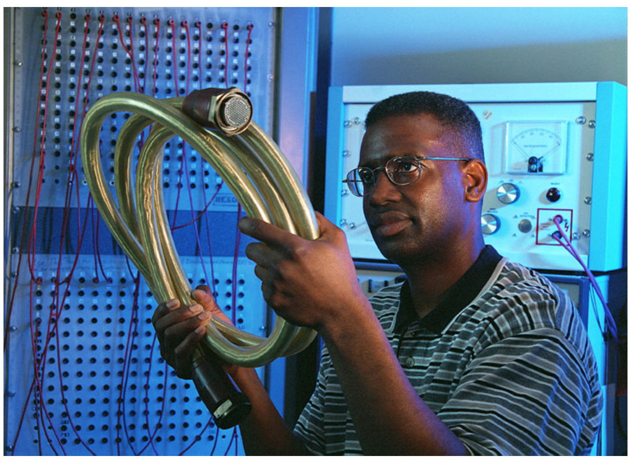
To provide Electrical, Electronic, Electromagnetic (EEE) parts screening and analytical services for MSFC in house projects, including the screening and failure analysis of EEE parts and electrical testing of EEE parts, cable assemblies and wiring harnesses, and prototype electrical black boxes.

EEE Parts Screening and Failure Analysis

Screening and failure analysis of EEE parts and electrical testing of EEE parts, cable assemblies and wiring harnesses, and prototype electrical black boxes are major categories of this MSFC facility. The team uses and maintains the following facilities in Building 4487 for screening and failure analysis: the Light Optics Laboratory (visual inspection, optical microscopy, film and real time radiography), the Scanning Electron Microscopy (SEM) Laboratory (SEM imaging and elemental analysis), the Fourier Transform Infrared Spectroscopy (FTIR) Laboratory (chemical identification) and the Electrical & Environmental Test Facility particle impact noise detection (PIND) testing, curve tracing, parametric testing, leak testing and other environmental factor testing). Screening services include up-screening of flight parts (microcircuits, hybrids, and various semiconductor devices) usually consisting of PIND testing and radiography inspection in accordance with military specifications, and construction analysis or destructive physical analysis of parts being evaluated for use. Construction and destructive physical construction quality of parts being considered for use. Components analysis includes visual inspection, radiography testing, PIND testing, bond strength testing, microsectioning, electrical and environmental testing, FTIR analysis, and microscopic examination and recording using light and scanning electron microscopy. Failure analyses are performed on suspected failures and in order to identify both the immediate cause of the failure symptoms and the root causes leading to the failure. Analyses are typically conducted on resistors, capacitors, microcircuits, semiconductors, relays, printed circuit boards, cables and connectors.

Failure Analysis and Test Facility

Visual inspection tools range from simple magnifying lenses to high quality stereomicroscopes and photomicroscopes. A number of fine optical microscopes and metallographs are available with bright-field, dark-field, polarized light and differential interference contrast modes of observation. An SEM is capable of resolving features smaller than 100 angstroms, providing great depth-of-field for three-dimensional like images of component surfaces. The SEM has several modes of operation that provide unique information about integrated circuits and semiconductors. Voltage contrast and induced current modes of operation provide continuity maps and subsurface diffusion profiles without physically probing the surface. The SEM with energy dispersive x-ray spectroscopy can be used to determine the chemical elements present at micrometer sized and larger damaged sites.



Precision cutting and grinding tools are used to open and precisely section components for analysis.

FTIR microscopy provides the capability of nondestructively identifying minute quantities of chemical compounds present at damage sites on EEE components. FTIR can identify organic compounds which consist largely of carbon and hydrogen which are generally not detectable by the SEM.

Electrical Parts Test Laboratory

Various functions are performed here including acceptance testing of electrical piece parts and components (microcircuits, semiconductor devices, resistors, relays, etc.), electrical parametric testing in the failure analysis of electrical piece parts, electrical integrity acceptance testing of cable assemblies and wiring harnesses, and the fabrication and electrical testing of prototype electrical black boxes and related cable assemblies. Acceptance tests are performed on incoming electrical piece parts to insure functionality prior to board population. Automated test systems are necessary tools in testing today's state-of-the-art electrical piece parts. The HP 82000 Digital Test System, GenRad 1731 Linear Test System, and Testronics 201C Discrete Test Systems are used in these efforts. High voltage potential testers, digital multimeters, meggers, mating test cables, break-out boxes, and switching megger boxes are used in electrical integrity tests on incoming cable assemblies. Fabrication skills, soldering and crimping certificates, adequate laboratory workstations and proper materials and tools enable the facility team to build black box prototypes, circuit cards, and interconnecting cable assemblies. The Electrical Parts Test Laboratory is located in Building 4705.

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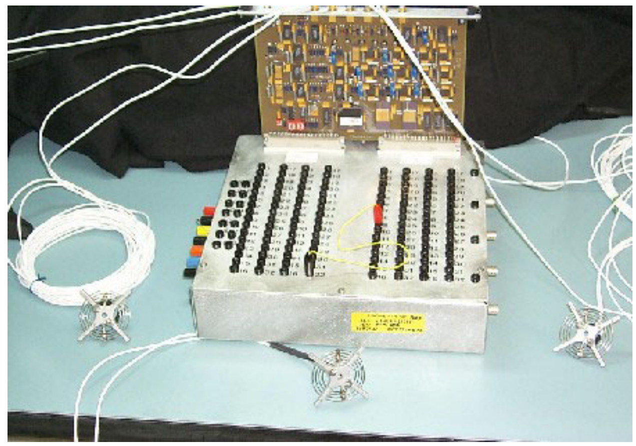
Control Electronics Facilities

Purpose:

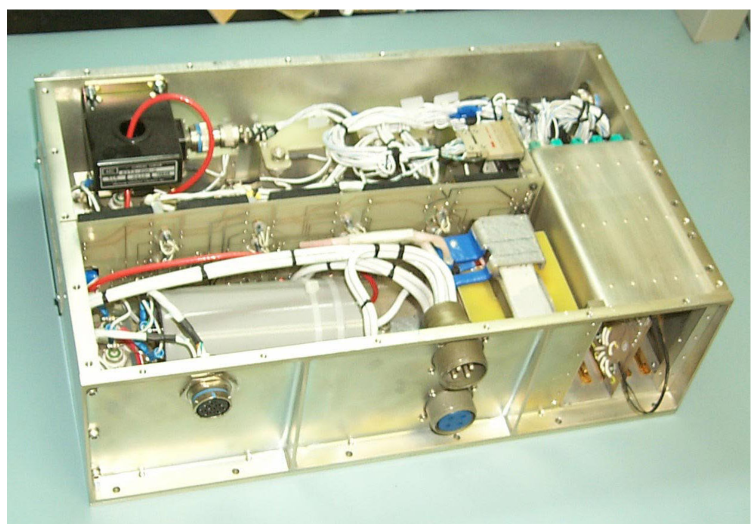
To perform the research, design, test, develop, and implement electronic control systems, digital electronic systems, and motors for space and ground-based applications and experiments.

Control Electronics Development Laboratory

This laboratory provides MSFC with the capability to perform research, design, development and implementation of both microprocessor and discrete component-based electronic control systems for space flight vehicles and experiments. In-house programs include a wide variety of circuit designs, ranging from linear low-power amplifiers for precision control systems, to multi-kilowatt (kW) switch-mode amplifiers for propellant flow and thrust vector control of ascent vehicles. Circuit designs range from linear low power amplifiers for precision control systems, to multi-kilowatt (kW) switch mode amplifiers for propellant flow and thrust vector control of ascent vehicles.



Modern control techniques utilizing neural networks, fuzzy logic, and adaptive controls are developed in this laboratory. Typical equipment comprising the laboratory includes dynamometers; an environmental chamber; a laminar flow bench; oscilloscopes; servo and logic analyzers; resistive, capacitive, and inductive meters; transistor curve tracers; precision voltage and current references computers; and logic programmers.



Programs supported in this lab include ISS/Environmental Control and Life Support System (ECLSS) Urine Processor Assembly (UPA) Power Module and Data Module, g_LIMIT, Equiaxed Dendritic Solidification Experiment (EDSE), Self-Diffusion in Liquid Experiment (SDLE), Quench Module Insert (QMI), Bridgman Unidirectional Dendrite in a Liquid Experiment (BUNDLE) and Magnetic Levitation (MagLev).

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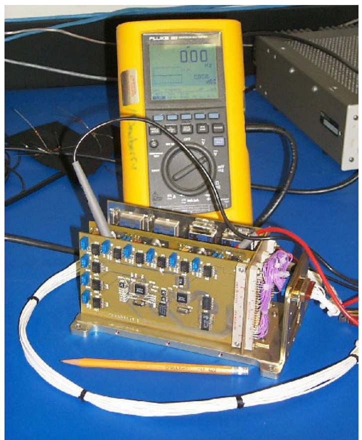
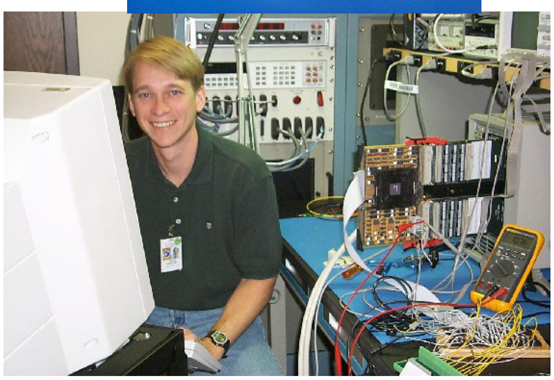
Control Electronics Facilities

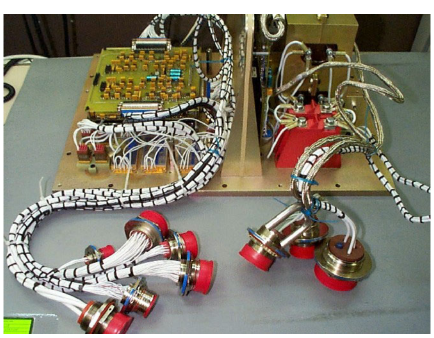
Digital Signal Processor (DSP) Systems Development Laboratory

To provide MSFC with the capability to perform research, design, development and implementation of digital electronic systems for space-and Earthbound science experiments, signal conditioning, thermal control, instrumentation, and control systems.



In-house programs include the Differential Ion Flux Probe with Mass measurement (DIFP-M) for ProSEDS, ISS/ Environmental Control and Life Support System (ECLSS) UPA, Advanced Health Management System (AHMS) for SSME, Equiaxed Dendritic Solidification Experiment (EDSE), Fast Trac Engine (MC-1). Typical equipment includes power supplies, oscilloscopes; digital multimeters; logic analyzers; resistance, capacitance, and inductance meters; transistor curve tracers; micro-controllers; computers; logic device programmers; and embedded control software and firmware development tools.





Supporting verification of contractor-developed flight and ground hardware, this laboratory provides real-time support for anomaly investigation of MSFC flight systems. This laboratory supports the development of embedded control systems based on surface mount technology from concept to prototype hardware, and provides design, fabrication and test of Thin Quad FlatPak (TQFP) chip based DSP systems.

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Motor Development Laboratory

This Laboratory provides MSFC with the capability to perform test and characterization of vendor supplied electric motors of different technologies such as DC Brush, Permanent Magnet Brushless DC (BLDC), Stepper , and Induction, for both flight and ground applications. Typical equipment includes dynamometers; power, current, voltage, and phase meters, motor controllers and power sources.

Programs supported in this lab include ISS/ Environmental Control and Life Support System (ECLSS) UPA, Quench Module Insert (QMI), Self-Diffusion in Liquid Experiment (SDLE).

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Antenna Test Range Facility

Purpose:

To provide the capability of performing accurate measurements of impedance, insertion loss, isolation, frequency, power, and antenna radiation distribution patterns.

Antenna Test Range

This facility utilizes both a 400-foot and a 2,640 foot range to measure far-field antenna radiation distribution patterns on scale models of spacecraft and/or payloads. Antenna pattern data on all ranges can be recorded in analog or digital form and presented in polar or rectangular form. The facility also has a 120 x 30 x 30 foot tapered anechoic chamber.

The 2,640-foot antenna test range consists of two 90-foot test towers used to elevate the test article and the transmit antenna to simulate free-space conditions. Positioning control and data recording instrumentation are located in a trailer adjacent to the receive site. The transmit site is equipped with an eight foot parabolic dish and a small building for placement of signal generators and power. This range is suitable for antenna pattern measurements from 2 to 60 GHz.

A small, onsight machine shop is used for construction of items needed in tests, such as small model antennas, ground planes, and mounting brackets. The shop and offices for test engineers are located in Building 4194 which also serves as a primary control/monitor center for antenna measurements. There is also a building with a roof-top radome, which provides a free-space environment for some antenna measurements and protects personnel and equipment from the weather.

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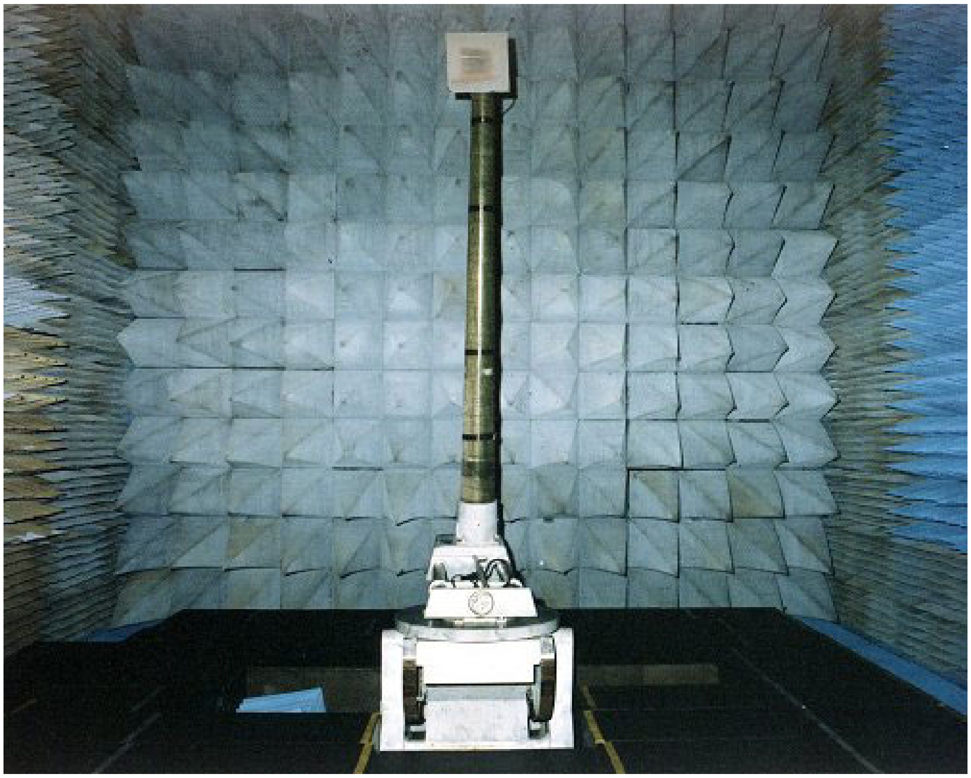
Antenna Test Range Facility

Microwave Anechoic Chamber



The MSFC antenna test range also has a 120 X 30 X 30 foot tapered anechoic chamber. The chamber is shielded to prevent interference from external electromagnetic sources, and is equipped with shielded doors which allow test devices to be moved into the chamber. Models or test devices up to 12-feet in diameter may be supported on the 15-foot tower in the chamber. The control room, located underneath the tapered end of the chamber, is equipped with a complete antenna pattern measurement system. The chamber is most often used for antenna pattern measurements to support antenna design work, to verify scale model antenna patterns, and to measure free-space patterns of prototype or flight antennas. It is also used to measure antenna impedance and field strength. The chamber operates from 200 MHz to 40 GHz and has a shielding of > 80 dB at S-band.

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Marshall Avionics System Testbed Facility

Purpose:

To evaluate candidate avionics architecture and components to support the early concept definition, demonstration, and software verification and validation (V&V).

The focus of the Marshall Avionics System Testbed (MAST) is on providing a facility to demonstrate, test, and evaluate advanced earth-to-orbit avionics systems and components such as:

- Avionics architectures and components,
- Guidance, navigation, and control algorithms,
- Health management algorithms
- Software development methodologies.

The primary objective of the MAST is to provide a facility which programs can use to bridge the gap between technology development and technology implementation. The goal is to make this capability available during early program development and also to allow multiple programs to use the lab simultaneously. Some of the benefits the use of the MAST provides a program include the following:

- Early establishment of realistic design requirements and performance specifications,
- Early resolution of technical risk areas,
- Evaluation of competitive designs through test and demonstration in a neutral setting.

The MAST has recently evolved into an integrated set of simulation laboratories. The labs that comprise the MAST are the Vehicle Simulation Laboratory (VSL) , Engine Simulation Laboratory (ESL), and the Actuator Test Lab (ATL). This integrated set of labs provide the capability to integrate, in a closed-loop environment, an end-to-end avionics system required for earth-to-orbit launch vehicles. The capabilities include detailed simulations of launch vehicles, engine systems, environments, and ground systems plus the ability to stimulate various sensors and actuation systems. The labs are designed in modular fashion so that simulations of missing avionics components can be "plugged-in" to the environment. The three labs are interconnected by VMIC fiber-optic VMIVME-5576 Reflective Memory Boards located in each facility. Each

board represents a node on the network and is linked by two fiber-optic cables for passing address, data, and interrupt information. Data written to the on-board RAM of any node will appear or be reflected in the RAM of all other nodes. Running at full speed, the link can support a 6.2 Mbyte/second transfer rate. A redundant transmission mode of operation is supported to ensure that critical data is received error free. The amount of time to transmit data from one node to another can be calculated based on the distance between each node and assuming a typical latency of 1.5 microseconds per node.

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Engine Simulation Laboratory

The Engine Simulation Laboratory (ESL) consists of high fidelity real-time simulations of rocket engine systems with models of high frequency pumps, combustion devices, propellant lines, actuators, valves and sensors. The lab contains both an Electronics Associates, Incorporated (EAI) SimStar and an Applied Dynamics International (ADI) Real-Time Substation (RTS) for the execution of engine models. The SimStar is a hybrid computer that contains both a digital and an analog processor. For execution on the SimStar, a model is partitioned such that the more demanding high frequency portions are executed on the analog processor and the slower portions are executed on the digital processor. The SimStar also includes a real-time display station for the graphical display of simulation data. The ADI RTS is a Power PC based platform used in simulation of real-time models. In addition to its simulation capability, the RTS is equipped with hardware to electrically simulate typical sensor interfaces such as pressure transducers, thermocouples, flow/speed sensors, and RTD sensors.

The lab also includes a load fixture to which engine propellant valve actuators can be mounted. The load fixture is used to simulate the loads an actuator would see while operating propellant valves. The load fixture, which is hydraulically actuated, generates loads based on outputs from valve flow models or commanded static loads.

The Laboratory Command and Data Simulator (LCDS) functions as a simulated vehicle interface to an engine controller through an avionics bus. The LCDS also acts as a node on the reflective memory network for the transfer of simulation data between the Vehicle Simulation Laboratory (VSL) and ESL.

The capabilities of the ESL allow for the development, test, and demonstration of the following:

- Engine avionics systems (e.g. engine controllers, valve actuators, and sensors),
- Engine control and monitoring algorithms,
- Software verification,
- Hardware and software integration.

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Actuator Test Laboratory

The Actuator Test Laboratory (ATL) is operated by the MSFC Propulsion Laboratory and is used in the design, development, and test of actuation systems. The ATL contains several load stands that are suitable for actuators ranging from small solenoids to large thrust vector control actuators. The lab supports active research in the areas of electro-mechanical actuators and power generation and delivery methods. Within the ATL, an interface computer is used to act as the interface between the VSL and ATL. This computer also interfaces with the actuator controller to send actuator position commands and receive position feedback.

Vehicle Simulation Laboratory

The Vehicle Simulation Laboratory (VSL) is designed to provide a tool for the demonstration of advanced vehicle avionics technologies such as the following:

- Flight computers,
- Navigation systems (e.g. Inertial Measuring Units (IMU), GPS receivers, etc.)
- Fault tolerant components and architectures,
- Autonomous Guidance Navigation and Control (GN&C) algorithms,
- Automated software generation and verification and validation products.

The major components of the VSL are:

- Three Encore 91 computers hosting real-time execution of detailed vehicle mathematical models,
- Contraves/Geortz three axis rate table driven by outputs from the vehicle model,
- Display console for real-time display of simulation data and ground station emulation,
- Cabling to support fiber-optic and copper redundant avionics busses,
- Workstations with toolsets (e.g. MATRIXx, Dataviews, G2, TAE+, etc.) to support flight software development, mathematical model development, and data visualization.

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Flight Robotics Laboratory

Purpose:

To provide a full scale, integrated simulation capability for the support of the design, development, integration, validation, and operation of orbital space vehicle systems.

The Flight Robotics Laboratory (FRL) is built on developed technologies such as air bearing floors, servo drive overhead robotic simulators, precision targets, gimbals, 6-Degrees of Freedom (DOF) mobility units, and manipulator and visual system evaluation facilities. The facility is centered around a 44 foot by 86 foot precision air bearing floor, the largest of its kind. A mobility base called the Air Bearing Spacecraft Simulator (ABSS) is used on the air bearing floor and is capable of 6 DOF motion. The ABSS will hold a 400 pound payload. An 8 DOF overhead gantry, called the Dynamic Overhead Target Simulator (DOTS) provides a 1000 pound payload capability for simulating relative motion with respect to a fixed target on the facility floor. A computer system provides inverse kinematics and allows the gantry to act as a target or as the 6 DOF rendezvous vehicle. The target reaction dynamics are simulated through force / torque feedback from sensors mounted at the payload interface. A raised floor area houses the Manipulator Systems Facility (MSF). For the evaluation and development of robotic manipulators including end effectors.

The FRL also provides a dual RF output, Global Positioning System (GPS) Satellite Radio Frequency (RF) simulator that operates in real time, in closed loop fashion with GPS receiver hardware in the loop. When connected to this simulator, two GPS receivers will provide navigation data as if they were on separate, moving vehicles in Earth orbit, viewing a real GPS constellation.

The FRL is a versatile test facility in that both open and closed loop system testing can be accomplished in either a digital or hardware-in-the-loop mode. It is presently being used to simulate the docking conditions of an automated rendezvous and capture system (AR&C) for the AR&C program. In this application, iterative computer interactions provide guidance and control data allowing the proper positioning of the docking sensor relative to a target pattern for closed loop control. Simulation control commands also drive a solar simulation for proper orbital lighting conditions. The dynamic model also drives graphic representation of the simulation and displays dynamic data in real time on Silicon Graphics terminals.

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Contact-Dynamics Simulation Laboratory

Purpose:

To provide a simulation testbed for the study of the contact-dynamics of full-scale docking and berthing mechanisms.

As different space vehicles were developed, interfaces between the vehicles were also developed, creating a need to verify the operation of the interfaces. The Marshall Space Flight Center's Contact-Dynamics Simulation Laboratory (CDSL) was developed in response to the need to evaluate the Earth-orbit dynamic response of the interfacing mechanisms. This facility allows engineers to simulate how a docking or berthing mechanism would behave in earth orbit under a variety of conditions. This simulation can be used to determine the capture envelope of docking and berthing devices. It can also reveal the stresses a device will experience once in space through the use of force and torque data recorded during a simulation. Past simulations have resulted in the re-design of some mechanisms, improving their performance, and ensuring that they could perform the task for which they were designed.

In the CDSL, one component is attached to a motion-base, while the other component is mounted to a force and torque sensor fixed in the support structure above the motion-base. The motion-base is a hydraulically driven CAE-LINK Stewart Platform which is used to simulate the relative motion of the berthing and docking mechanisms in six degrees of freedom. The motion-base is commanded by an Alliant FX-80 parallel super computer, which runs a simulation program modeling two vehicles in earth orbit. When the two components of the mechanism touch, the force and torque sensor sends the contact forces and torques to the Alliant computer, which then uses the information to calculate the resulting motion of the simulated vehicles. The computer calculates the relative motion of the simulated vehicles and commands the motion-base to move appropriately. As the motion-base moves, several safety sensors are checked to ensure the test article is not damaged by the motion-base.

The computer drives several control panels allowing engineers to monitor the simulation. The computer also sends data to Silicon Graphics workstations to drive graphics displays of the simulated vehicles. Further, the CDSL has the ability to simulate the manual control of a vehicle.

The simulation can be used to dock or berth two distinct vehicles, or the simulation can be used to berth two objects together using the Shuttle Remote Manipulator System (SRMS). The two-body simulation has the capability of modeling flexible body vehicles and of modeling different control systems for the vehicles. The SRMS simulation is a complete flexible body simulation capable of simulating the flexible booms and joints of the SRMS, the joint servos, the SRMS control system, as well as flexible payloads and base vehicles.

The CDSL is currently testing the Boeing Common Berthing Mechanism, which will be used to attach International Space Station (ISS) modules together.

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