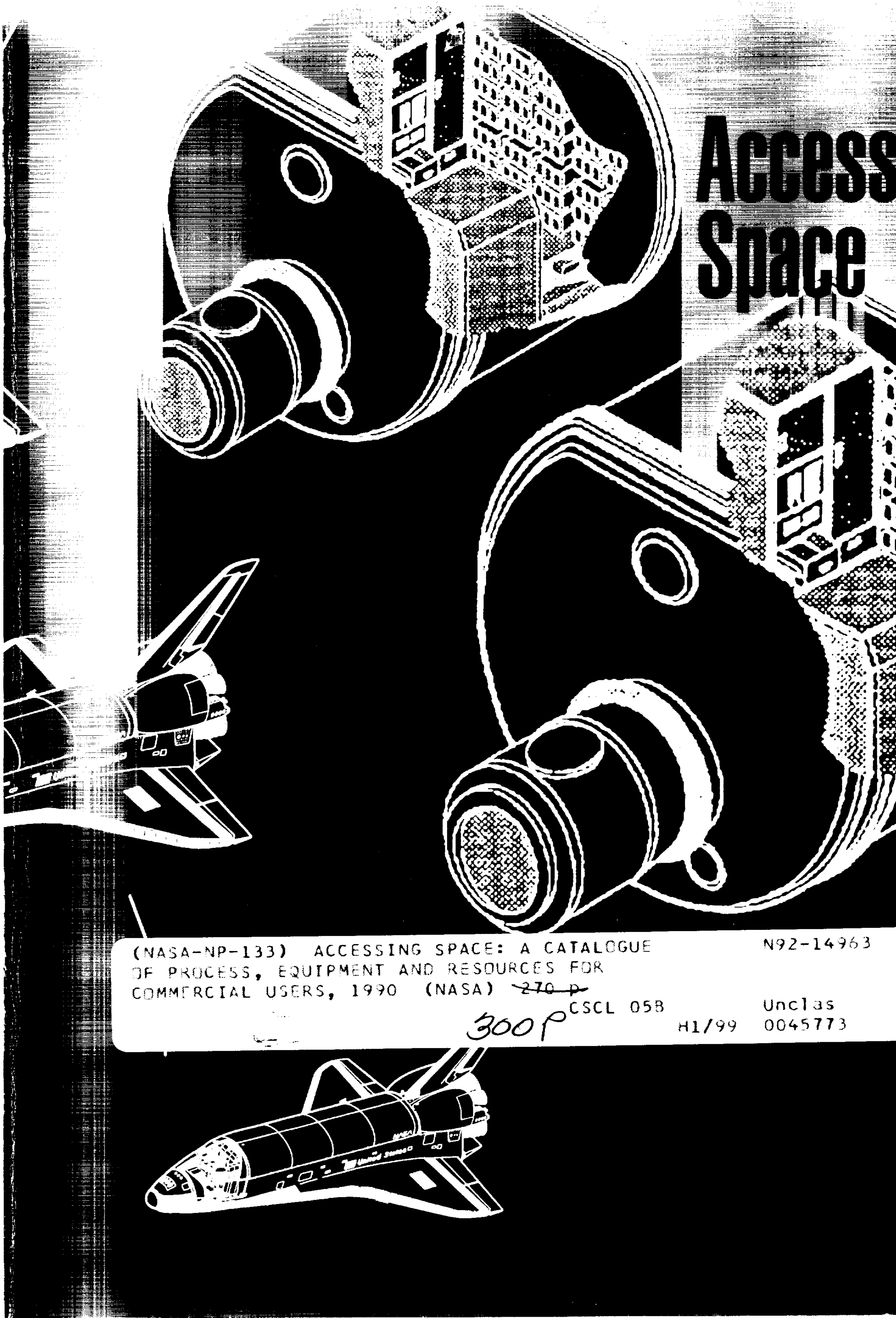
Accessing Space

A Catalogue of Process, Equipment and Resources for Commercial Users

1990



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Accessing Space: A Catalogue of Process, Equipment and Resources for Commercial Users

National Aeronautics and
Space Administration

Office of Commercial Programs
Commercial Development Division

December 1990

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The objective of this catalogue is to provide information to commercial developers of space. Publication herein does not constitute NASA endorsement of the products or services described, nor confirmation of the manufacturers' or providers' performance claims.

This catalogue represents a growing inventory of items and information brought to NASA's attention and is not to be considered all-inclusive or representative of comparative selection. Periodic revisions are planned to include additions or updates. Comments, corrections or submissions should be directed to:

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Foreword

Welcome to the second edition of **Accessing Space**, a publication created to assist U.S. developers of commercial space.

NASA's Office of Commercial Programs is committed to enabling the success of the commercial space ventures of the United States. NASA helps U.S. private firms by stimulating and facilitating the investigation of the unique environment of space, and the investment in and utilization of space activities. Through continuing support to industry, NASA is fostering U.S. leadership in commercial space endeavors and creating new industries that contribute to America's economy and its competitive position in the world market. More importantly, we believe these activities truly accelerate the exploration and utilization of space for the benefit of all mankind. Toward this end, industry teamwork with government is an essential ingredient for success.

This nation, in its government and industry space programs, has made significant investments in space research and development. We have developed an extensive network of centers, installations and ground-based laboratories as well as space-based facilities and unique experiment systems. A major part of these facilities and equipment is now available to the private sector. This catalogue serves an important role in disseminating useful information about such capabilities plus related information.

We are pleased to present the 1990 edition of **Accessing Space** and encourage your review of the broad resources it presents. As you explore the unique characteristics of space and its commercial potential, we welcome you as an entrepreneurial pioneer on the space frontier.

James T. Rose
Assistant Administrator
Office of Commercial Programs
NASA Headquarters
Washington, DC

Introduction to Accessing Space

This catalogue is intended for commercial developers who are considering, or who have in process, a project involving the microgravity environment of space or remote sensing of the Earth. A review of this publication should give the reader both an orientation to commercial space activities and a current inventory of equipment, apparatus, carriers, vehicles, resources and services available from NASA, other government agencies and U.S. industry.

The information presented here describes the array of resources that commercial users should consider when planning ground- or space-based developments. Many items listed in the catalogue have flown in space or been tested in laboratories and aboard aircraft and can be reused, revitalized or adapted to suit specific requirements. Other facilities and equipment are still in the development process.

New commercial ventures are encouraged to exploit existing inventory and expertise to the greatest extent possible. While utilizing commercial space is a complex business, NASA and industry have built a strong foundation for exploration and development. This catalogue is made available to commercial developers to facilitate their entry into space business.

In this second edition, we have responded to our readers' comments, refining our data extensively. We always welcome new thoughts and suggestions. The commercial space community is growing and emerging with the help of industrial and academic laboratories. By providing data on your projects, this document will continue to serve as a valuable means of information interchange within the commercial space community.

Richard H. Ott
Director, Commercial Development Division
Office of Commercial Programs

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Section One: The Process

Space offers special aspects and environments that may be exploited by the entrepreneurial developer in research and technology. Earth orbit offers an advantageous situation for communications, navigational data, or for a synoptic or global view of the Earth or its environment. Space also offers several unique physical environments such as:

- Weightlessness or "free-fall" (microgravity; micro-G);
- Hard vacuum with the equivalent of very high pumping rates;
- Exposure to: high kinetic energy atomic oxygen (in Low Earth Orbit), direct solar radiation or the radiation sink of deep space, and other aspects of the space thermal and radiation environment.

These factors are important to consider in gaining insights as to how the space environment can help to obtain new information or permit new or enhanced processes of commercial interest. Also, the precise ambient environment of space is modulated by the carriers or modes of accommodations utilized, operations and even the presence of the instrumentation of interest itself. In addition, the mode of transportation to space, and recovery as needed, can present other and often severe environments plus other requirements. These factors are important to consider in designing the equipment that will be used in space.

For many investigations the most significant feature of space is micro-G. Acceleration disturbances and gravity gradients may have to be accounted for, but sustained periods of "weightlessness" allow the examination or exploitation of physical processes in ways difficult or impossible to achieve on the ground. There are also possibilities for a range of sustained acceleration levels. If you have questions about the environments of specific carriers or modes of transportation or accommodations, use the contacts provided for those systems. If you have questions about the space environment in general, contact us and we will attempt to respond to you.

The first step towards accessing space is a thorough review of the goals and technical objectives of the investigations in order to help establish the rationale for and viability of space related activities. Exploratory steps may be taken in laboratories that simulate or model the physical environments of space. Drop towers and aircraft flying parabolic trajectories provide limited micro-G environments but may allow significant assessments of hardware or operations. Sounding rockets provide access to longer periods of lower micro-G as well as to other space environments to further assess plans or to directly achieve the desired objectives. Similarly, the Shuttle Middeck provides a relatively simple but constrained capability for exploratory, demonstration or calibration activities, or the capability for obtaining results.

There are a number of paths and options that the commercial researcher should consider in reviewing the means of exploring and exploiting the benefits of space related activities. Experience shows best results typically come from a program that proceeds through careful steps and ground testing plus other intermediate capabilities referred to above. The following section reviews the diverse methods of accessing space for commercial research and development.

The NASA Office of Commercial Programs is sure that the exploration of space will result in discoveries of great social and economic benefit. It is our function to facilitate U.S. industry in this process for the enhancement of our Nation, its economy and, thereby, the well being of each citizen. We welcome you aboard and will do our best to assist you.

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Chapter 1: Accessing Space

By the year 2000, we expect to see a considerable presences and activity in space with the construction and operation of Space Station Freedom and the development of other orbiting craft of the U.S. and other spacefaring nations. We anticipate entrepreneurs will play an active role in establishing a long-term presence in space, identifying the compelling reasons for space activities in addition to providing capabilities such as orbital payload platforms or man-tended laboratories, and other commercially developed space facilities. Recent U.S. administrations have demonstrated consistent support for the development of the commercial space industry, reviewing and strengthening national space policy to stimulate private sector activity. Toward the middle 1990s, the COMmercial Experiment Transporter (COMET) and other commercially developed facilities will offer more opportunities for space-derived products and services.

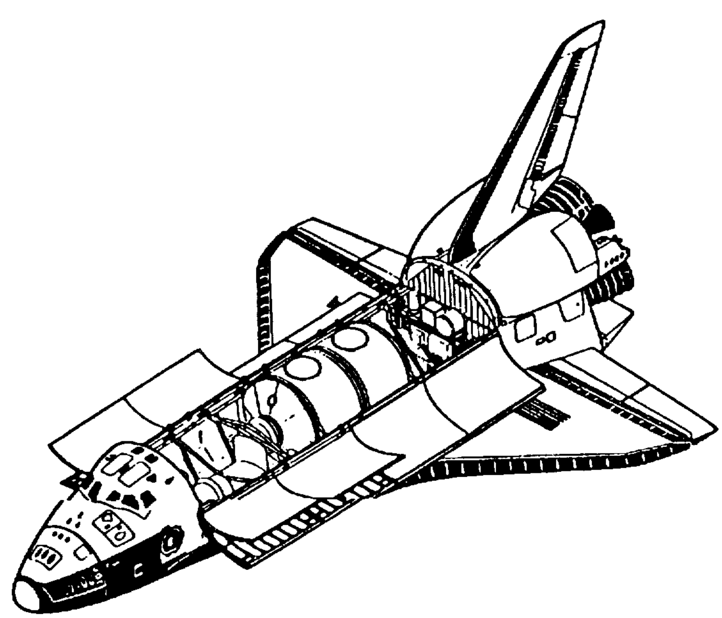
At present, there are several ways for the commercial developer to access space, each of which offers a variety of capabilities to accommodate experimentation. Selection of a vehicle or a facility depends on those capabilities and on the requirements of the project. Accommodation requirements of commercial experiments vary widely. Of prime concern to developers are factors such as experiment control, data handling, electrical power, vibration levels and pointing accuracy, as well as the frequency of flight opportunities.

This chapter offers an overview of these vehicles and facilities and their capabilities for meeting experiment requirements.

Space Shuttle

The most sophisticated vehicle for accessing space and servicing and recovering payloads is the Shuttle (also called the Space Shuttle Program or SSP), where experiments may be conducted for a few hours or as long as several days. Requirements for Earth observation, human intervention, space vacuum and a microgravity environment all are features that characterize the Shuttle as a platform on which to develop research and technology projects.

The Shuttle provides accommodations for a wide variety of experiments in two locations: the cargo bay and the middeck. Advantages and operational restrictions are unique to each area and the choice of carriers and influence experiment design and the means of interfacing experiment hardware.



Space Shuttle (continued)

Middeck and SPACEHAB

The middeck is a confined space located directly below the flight deck and adjacent to the cargo bay. Resources available on the middeck are limited in power, heat-rejection and crew-tending capability. The standard power available is 28 vdc, 115 w. Although space is limited, advantages of experimentation in the middeck include:

- Potential for more frequent flight opportunities
- Reduced payload integration time and cost
- Late access to and early recovery of the experiment package
- Crew interaction with the experiment

The middeck contains mounting space for 42 stowage lockers that normally contain the crew food, clothing and equipment. Unused lockers and/or their mounting spaces are made available for experiment equipment on a mission-by-mission basis. In addition to the locker volumes, the Middeck Accommodations Rack (MAR) is under development to provide additional resources in the middeck (see page 143). At the time of this printing, middeck accommodations were still not available for reimbursable payloads but a pricing policy was in review.

In 1990, NASA's Office of Commercial Programs identified space flight requirements especially in the middeck class that exceed the currently manifested capabilities of the Shuttle, during the period of mid-1992 through 1995.

To help meet these requirements for commercial development flight accommodations and integration services NASA will procure Commercial Middeck Augmentation Modules. NASA has signed a contract with SPACEHAB, Inc., of Washington, DC, for such capabilities, for flights beginning in 1992.

SPACEHAB modules are designed to fly attached in the forward quarter of the Shuttle cargo bay and be accessed by astronauts through a tunnel to the middeck airlock. Each module provides 1,000 cubic feet of additional pressurized volume to the Shuttle and contains accommodations for supporting middeck locker-type payloads and rack-mounted experiments, supplying users with power, data, cooling and crew support resources (see page 148).

Cargo (or Payload) Bay

Larger unpressurized experiments may be accommodated in the cargo bay area, where power and heat-rejection capabilities are available. The cargo bay is 15 feet in diameter and 60 feet in length, occupying the midsection of the Shuttle between the flight deck and crew quarters in the front, and the engine assemblies in the rear. Once in orbit, the cargo bay doors may be opened. In general, cargo bay experiments are fully automated, because crew-tending is not available. Some bay systems do, however, provide a limited data link to the crew cabin for simple control functions.

Carriers

Many carrier systems have been developed for the purpose of conducting science and technology investigations. These carriers involve standard pieces of equipment that serve as a host facility for user instruments and may include one or more mounting structures as well as subsystem interface equipment to tailor such factors as power, communications and environmental controls as required by the particular experiment. Carriers may be pressurized or unpressurized.

Integration time and cost may increase when using large carriers; however, the cargo bay also has provisions for small, self-contained payload carriers that can be integrated rapidly on modest budgets. A number of mounting structures and support systems, known as attached Shuttle payload carriers, make additional space available to researchers at a relatively modest cost; there also are freeflyers that are released in space and later retrieved.

Components and techniques may be tested and qualified for long-duration operations this way, and industrial processes can be evaluated and refined on a small scale before long-range commitments are considered for volume production.

Launch Vehicles

For small experiments, 5-15 minutes of weightlessness can be obtained by using suborbital rockets. Called sounding rockets, these vehicles can launch a small payload up to about 100 miles from Earth; as the payload coasts upward and falls back to Earth, its contents are motionless (weightless) in relation to each other. Although sounding rockets cannot be used for large experiments, the duration of weightlessness produced by the suborbital fall permits commercial developers to explore a wide range of phenomena.

Expendable Launch Vehicles (ELV's) are an alternative to the Shuttle for putting long-term duration experiments in orbit. At present, several launch vehicle companies are developing a new generation of vehicles to accommodate smaller, lighter payloads, such as commercial research experiments, that will be offered at a lower price than larger ELV's. Planning also is underway for a family of small experiment, ELV-based carriers. Demand for these systems is projected to be high, and several developers are designing cost-efficient systems for deploying Low Earth Orbit small payloads.

NASA's Centers for the Commercial Development of Space (CCDS's) are developing a new initiative for launching and recovering commercial payloads on ELV's. The joint project, called COMmercial Experiment Transporter Program (COMET), is scheduled to begin launching in mid-1992. (See page 213 for additional information.)

Opportunities for Commercial Development

Microgravity

Use of ground-based facilities can provide insight into many microgravity processes. For example, very low gravity levels can be achieved in drop towers for short periods of time, allowing scientists to study the interaction of forces in sufficient detail to predict behavior of systems in orbit.

Ground-based facilities present a wide range of options, from R&D laboratories outfitted with sophisticated modeling capabilities, to low-g simulator aircraft, to sounding rockets flying ballistic trajectories. All fit under the rubric of ground-based facilities. The commercial researcher should carefully consider how to exploit these resources since they offer the dual benefits of lower costs and faster integration when compared with orbital operations.

For experiments requiring microgravity conditions, ground-based testing often precedes orbital research. Experiments in these facilities, many of which are located at NASA Field Centers, stimulate ideas for research and serve as the test beds for microgravity research and technology development, such as in the areas of mixing fluids and levitation technology. The Microgravity Materials Science Laboratory (MMSL) at NASA's Lewis Research Center in Ohio is an example of such a facility.

Remote Sensing

Test facilities are available for remote sensing research and technology suited for commercial applications. This field is growing, and equipment such as NASA's large format camera is available for use by the commercial researcher. Remote sensing experiments may be conducted from freeflyers, aboard the Shuttle, on selected aircraft and from specially equipped balloons.

In addition, major achievements have been made in computational research for gathering, integrating, reducing and value-adding data. One of the more advanced programs in this area is based at the Space Remote Sensing Center at the NASA Stennis Space Center in Mississippi, designated as the lead NASA Field Center for remote sensing operations (see pages 29-30).

The Center also manages the Earth Observation Commercial Applications Program (EOCAP), a new approach to leveraging government funds for the purpose of helping the space remote sensing industry establish operational products and services using NASA-developed Earth observations technology. NASA co-funds remote sensing applications research to promote private investments by U.S. industry. Participation includes private sector organizations, educational institutions, other nonprofit organizations and other government agencies. Each participant incorporates an industry partner responsible for commercial implementation of the project. Through this program, businesses are encouraged to invest, over several years, in the development and marketing of high-risk products and services useful to both the private and public sectors. (See also the two Centers for the Commercial Development of Space that are dedicated to remote sensing on pages 38 and 43.)

Opportunities for Commercial Development (continued)

On-Orbit Facilities

On-orbit facilities can provide temporary or long-term exposure to the space environment; as a platform for remote sensing observations, a laboratory for microgravity research, a construction and assembly site or as a docking and resupply site. The Space Station Freedom promises to be one or all of these facilities (depending on the final configuration) at the turn of the century. A strong program is underway to encourage the private sector to develop a consortium relationship with NASA for specific space station-related infrastructure and services.

Before such a station is available however, commercial researchers have several opportunities to investigate the unique qualities of the space environment; its vacuum, radiation, microgravity and global observation perspective. Basic items to consider for experimenting in an on-orbit facility are sufficient volume, power, time on-orbit, data gathering and telecommunications support (as appropriate), sustained microgravity levels (for microgravity research) and pointing capability (as appropriate) and man/robot-attention.

The most immediate opportunity for on-orbit research is on the Shuttle. Missions that fly a 200-mile orbit offer laboratory and observatory time for 5-7 days. An extended duration orbiter (EDO) is under consideration for missions as long as 14 or 28 days. Experiments may be designed to be man-tended or independent; pressurized or unpressurized; and light or heavy, large or small, as required by the research and the accommodations available. Other opportunities for on-orbit research lie in freeflyers, satellites that are launched into orbit by expendable launch vehicles, the Shuttle's expended, refurbished external tank (under development), platforms and Space Station Freedom (under development). These facilities will permit long-term experiment research in space (from several days to several months).

Commercial Payloads on the Shuttle

The first commercial experiment took place on the fourth Shuttle mission in 1982, in the middeck area. Called Electrophoresis Operations in Space (EOS), the project involved a continuous flow electrophoresis system, built to purify biological materials in a microgravity environment. EOS flew on seven missions, 1982-1985. The experiments demonstrated that some 700 times more material can be separated in space than on Earth during the same period, and with better purity levels. The process holds promise for breakthrough drugs and medicines that eventually could save lives and offer new treatments to millions of people suffering from diseases such as diabetes and hemophilia (see page 28).

The first made-in-space product was manufactured on a mission in 1983 and went to market in 1985. Slightly larger than a red blood cell and invisible to the human eye, the product consists of tiny microscopic spheres made of polystyrene, sold in lots of 30 million by the National Institute of Standards and Technology. Microgravity allowed these spheres to grow more uniformly in size and shape than is possible on Earth. Customers use the spheres to help calibrate and focus electron microscopes and to improve microscopic measurements in electronics, medicine, environmental pollution research and other high-technology areas.

Crystal-growth experiments on the Shuttle have demonstrated that the manufacture of crystals in microgravity has tremendous industrial potential. Crystals grown in orbit have fewer imperfections and therefore improved electronic characteristics. Researchers believe such crystals may lead to a new generation of higher-speed microelectronic components for computers, radar and communications systems. During the Spacelab-I mission in 1983, one type of protein crystal grew 1,000 times larger than the same type did on Earth. Such large protein crystals allow bioengineers to study the atomic structures of protein molecules, knowledge essential for designing new drugs. The molecular models derived from such space-grown crystals may well be the foundation for new miracle drugs of the 21st century.

In 1990, NASA's Office of Commercial Programs began a study into the underlying nature of crystal formation, made possible as a result of a payload flown under the 3M Corp.'s first Joint Endeavor Agreement (JEA). After the flight of 3M's Physical Vapor Transport of Organic Solids (PVTOS) payload in 1985, 3M scientists noticed unexpected differences between some of the crystalline thin films grown during the flight and those grown as ground control samples. The implied effects of convection on the resulting film growth may hold clues about crystal formation that can benefit Earth-based crystal growth operations for materials development. Investigators now are interested in studying these samples using fractal analysis which may help determine information about self-ordering mechanisms in the formation of the crystalline microstructure. Several NASA Field Centers, universities and companies are involved in this exciting project.

Opportunities for Commercial Development (continued)

Products and Services

Commercial space businesses are those companies that offer space-related products and services to both government and industry. One of the most well-developed commercial activities is satellite communications, which has flourished since the mid-1960s. Emerging space business activities include products such as:

- Space-processed materials
- Extra-terrestrial materials
- Space-processed finished goods (for space use)

Emerging activities in space services include:

- Advanced transportation systems for launch, inter-orbit and return
- Construction of small- and large-scale structures
- Maintenance and repair of satellites, platforms, stations, transportation vehicles
- Logistics – personnel, food, fuel and supplies
- Laboratory services and manufacturing such as advanced materials
- Communications, audio, video and data position determination systems
- Earth and ocean observation – land, ocean and weather
- Power – solar photovoltaic, solar dynamic, nuclear
- Lodging – room, board and amenities
- Recreation – entertainment, exercise and leisure

Commercial development in the 21st century is likely to fall into two general categories: follow-on phases to current activities in Low Earth Orbit or in Geosynchronous Orbit, such as communications, remote sensing, materials research and materials processing; and new businesses made possible by new infrastructure and routine access to new locations in the Earth-Moon system and, perhaps, on Mars. Examples of new businesses include mining of power resources on the Moon and transportation to and from the Moon. The future holds great promise for private sector initiatives for vehicles, facilities and other products and services. The horizons are limitless.

Other Opportunities

The following are suggested roles and activities, for the commercial developer to consider, that may open up new opportunities:

- Participate as an industrial affiliate in a NASA Center for the Commercial Development of Space. (See page 33.)
- Enter into an agreement with NASA for the development evaluation of specific commercialization projects. Agreements meeting certain objectives of NASA may postpone or reduce transportation costs.
- Participate in an industry council or committee that advises the National Space Council, NASA or another government agency as part of the national space planning process.
- Undertake applications research using results of space-based research or space-produced materials to determine their potential for product use in comparison with their Earth-produced counterparts.
- Participate in multidisciplinary industrial consortia to sponsor space-based research. Initiate and sponsor independent space-based research.
- Explore opportunities in space commerce by tapping the scientific or technical expertise available at NASA, National Institute of Standards and Technology, the National Academy of Sciences and the National Academy of Engineering, and their respective research centers.
- Initiate and develop a project that will provide needed commercial infrastructure to NASA.
- Evaluate the potential applications of satellites, such as communications, remote sensing, and geopositioning and asset tracking.
- Conduct process or product R&D under contract to a government agency in an area that may lead to new private-sector products, services and markets.
- Invest in space enterprise with long-term objectives.

Chapter 2: Accessing the System

NASA's goal is to join hands with industry to develop the potential of the space environment. This partnership is essential for the promise of commercial space to be realized. Any American company, institution or individual may work with NASA to investigate commercial applications of microgravity or remote sensing research, provided the work is consistent with NASA's objective of fostering public benefits through the commercial use of technology. The organization or individual will be required to furnish NASA with sufficient information to verify peaceful purposes and to ensure safety and compliance with applicable laws and regulations.

NASA supports research aimed at commercial applications of space by providing industry access to NASA research facilities and by promoting NASA/industry information exchanges. Toward that end, NASA provides flight time on the Shuttle (as appropriate and available); technical advice, consultation, data, equipment and facilities; and joint research and demonstration programs in which the Agency and the industry each funds its own participation.

NASA also establishes liaisons with industry and academia through its Centers for the Commercial Development of Space (CCDS's), through commercial application working groups and through workshops for potential commercial users of space.

Chapter 2 provides information on many of these activities and arrangements; what they are, how they work and how commercial enterprises work with them to their advantage. This chapter also provides information about using hardware and carriers that either exist or are created/adapted by the researcher; and safety considerations.

NASA Industry Agreements – Space Flight Operations

NASA encourages the commercial community to consider the economic value of space research and development experiments in areas of particular commercial interest. Toward that end, NASA's Office of Commercial Programs established several types of agreements that offer flight time for applied research until the commercial potential of a product has been established. NASA also protects proprietary interests of participating companies within its working agreements as part of its commercial space incentive efforts. These agreements are negotiated on a case-by-case basis and can be tailored to the specific needs of a given project. The terms typically cover such factors as rights to data and patents, process exclusivity and circumstances for recoupment of NASA's investment. These agreements include:

Technical Exchange Agreement (TEA) – appropriate for companies interested in the application of space technology but not ready to commit to a specific space flight experiment or venture. NASA offers technical information and works with companies to develop an idea or experiment.

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NASA Industry Agreements – Space Flight Operations (continued)

Joint Endeavor Agreement (JEA) – applicable for company-sponsored and directed flight experiments. By offering Shuttle flight time and technical advice, NASA can reduce the cost and risk of product development until the commercial viability of key technologies has been established. NASA also offers a Pre-JEA for organizations in the process of defining applied research goals, not yet ready for the JEA.

Space Systems Development Agreement (SSDA) – NASA offers special provisions for launch service, such as deferred payment schedules and exclusivity, to companies developing new systems associated with the development of space hardware infrastructure. Such ventures must have the potential for significant national economic benefits or other substantial benefits.

Launch Services Agreement (LSA) – appropriate for commercial developers who want to purchase Shuttle launch services. Information on pricing and financial planning may be found in the NASA document "STS Reimbursement Guide" (JSC-11802).

NASA Industry Agreements – Ground Operations

Agreements for ground-based experimental research are made on a case-by-case basis, according to equipment, schedule requirements and availability. Where mutual interest can be established, collaborative research efforts involving scientists from industry and NASA are encouraged. Bringing the unique capabilities and expertise of respective organizations to focus on key elements of the research (such as identification of objectives, experiment definition, experiment protocol, sample preparation and sample and data analysis) has proven to be mutually beneficial.

Each party funds its own ground-based research. Terms and conditions, including division of responsibilities, provisions for sharing results and protection of proprietary data are negotiable. A company may request use of testing facilities such as drop tubes and aircraft, independent of collaborative work with NASA, subject to negotiation of mutually acceptable schedules and operating conditions. NASA facilities charge a nominal fee for independent work.

Centers for the Commercial Development of Space (CCDS's)

A company may develop an experiment and handle all integration and scheduling processes directly through NASA or its Field Centers. A company also may choose to work with one of NASA's Centers for the Commercial Development of Space (CCDS's). There are presently more than 175 U.S. firms associated with the 16 CCDS's now operating in locations throughout the nation. Each CCDS tends to focus on a particular field of space-related research that offers potential for commercial in-space production and/or the creation of new products or technologies with high economic value in Earth-based applications. These centers represent disciplines in the following areas:

- Automation and Robotics
- Life Sciences
- Materials Processing in Space
- Remote Sensing
- Space Power
- Space Propulsion
- Space Structures and Materials

Please refer to Chapter 5 for a listing of all CCDS's and their corresponding points of contact.

Hardware Accommodations and Carriers

A commercial researcher may utilize either existing or custom-made equipment for an experiment. In the latter case, he/she must work closely with NASA engineers during the design and construction of this equipment, to provide assurances on its safety, especially for use on aircraft or the Shuttle.

Once the researcher has determined the nature of the experiment, such as orbital (for example, on a Shuttle flight); or ground-based, he/she then must select the type of hardware apparatus and carrier that will be required to accommodate the project. Gaining access to space requires imagination and realistic planning. Keeping experimental designs simple and well-focused may serve to shorten the waiting periods and hold down costs. Selecting the appropriate apparatus, carrier and/or vehicle is essential for obtaining cost-effective, reliable research data.

Existing Hardware

Sometimes suitable existing hardware can be found in the growing inventories of NASA and industry. Certain apparatus and carriers developed by NASA are available through the Field Center that developed them. (Refer to Chapter 4 for a listing of NASA Field Centers.) Equipment developed by private industry is usually available directly through the originating company. As you use this catalogue, you will find that each piece of hardware has a corresponding point of contact for access. Please use these contacts to determine the availability and suitability of such equipment. Equipment may be adaptable for various applications and should be carefully evaluated and modified to suit the requirements of a particular experiment.

Custom-Made Hardware

A major challenge in developing experiment flight hardware is packaging the basic apparatus in a way that meets your objectives and also satisfies equipment and carrier requirements for operations; and meets the design and safety requirements imposed by the testing facility of choice. The instrument must survive the stresses of the launch and flight environment and operate successfully under the given conditions. Consequently, instrument development is a team effort in which the investigator works in close association with engineers and technicians experienced in hardware development. Development and use of flight hardware goes through several phases, which are delineated below.

The Typical Life Cycle of Flight Hardware

- Concept Definition
- Design and Fabrication
- Functional and Qualification Testing
- Delivery, Shipping, Acceptance
- Payload Integration (e.g., on carrier or satellite)
- Cargo Integration (e.g., on Space Shuttle)
- Launch
- Flight Operations
- Re-entry and Landing
- Cargo and Payload Deintegration
- Data Handling and Analysis

Safety

For the benefit of the flight crew and ground personnel who work with and around the experiment equipment, it is essential that investigators comply with certain safety requirements. These requirements cover both flight and ground equipment as well as flight and ground operations. The document "Safety Policy and Requirements for Payloads Using the Space Transport System" (NHB 1700.7) defines safety policy and basic safety requirements. Several other documents have been developed, both generic and carrier-specific, that define approaches for satisfying these requirements (NASA's Office of Commercial Programs can provide information on a case-by-case basis). Ground safety also is a concern. A safety assessment is performed on ground operations to identify and eliminate, or control, hazards associated with any phases of an experiment planned for the Shuttle or any other facility, as required.

Proprietary Aspects

Efforts required to restrict proprietary information may be affected by the mode of accommodations, complexity of interface or the design of the project hardware. This aspect should be carefully thought through. It is important to early and clearly identify to the supportive organizations what is to be treated as proprietary. Such arrangements should be established and agreed to in writing.

Protection of Intellectual Property

The U.S. Patent System is a means by which some measure of exclusivity can be accorded to successful private endeavors in space. As with all entrepreneurial activity, patents for commercial space development can serve as a protection of the earnings for first-to-market inventions and thereby be an important stimulus to industrial progress in space. The greater the ability to obtain and enforce patent rights, the greater the incentive for private enterprise to commit substantial investments in the high-risk undertaking that is inherent in commercial activities in space.

Consistent with the intent to stimulate private initiative and to provide an incentive to space developments, NASA has developed a flexible policy of protecting property rights while encouraging the dissemination of information to promote utilization of space. NASA's objective is to ensure the achievement of technological superiority through arrangements with private U.S. concerns (the reader is referred to *Presidential Memorandum on Government Patent Policy*, 48 Fed. Reg. 22132-33; 1983).

Chapter 3: Accessing Operations

Operations during the experiment itself vary with the nature of the event. For example, ground-based research might be completed in a matter of seconds, with data recorded and prepared for analysis in minutes. By contrast, research on the Shuttle involves more complex systems and therefore requires more planning and interfacing with NASA engineers and officials, data collection during the mission, retrieval of data and experiments after the mission and follow-up on analysis as appropriate.

Key guidelines in developing payloads are:

- The greater the payload size, number of payload interfaces and requirements, the harder it is to manifest.
- The more complex the payload, the more time and effort is required for payload integration.
- The use of proven subsystems and acceptable materials facilitates the integration process.
- Integration and operations are simplified by the design of an experiment that minimizes astronaut training and on-orbit workload.
- The likelihood of mission success is enhanced for astronaut-supported hardware when operational status can be readily determined and alternate or manual modes of operation can be implemented to backup automated operations.
- The commercial developer must meet safety and interface requirements to protect flight and ground crews, carrier systems and facilities and other payloads.

Beyond these basic requirements, developers must determine the level of effort required to meet mission success objectives. Careful and knowledgeable judgments in this area can result in considerable services with minimal risks.

The Shuttle

Pre-Flight

Throughout the life of the project activity the developer should maintain a clear understanding of the objectives, the data necessary to achieve those objectives and how that data (or samples) will be obtained through the entire flow and completion of mission activities.

Planning activities include: verification, crew training, data handling, payload integration plan (PIP), interface control document (ICD), safety reviews, flight development plan and carrier mission development plan.

To ensure that activities perform smoothly on a Shuttle mission, the flight itself is preceded by extensive operations planning and preparation, including identification of payload requirements, timeline, personnel training (if necessary), ground support equipment setup and contingency planning.

The Shuttle (continued)

To facilitate mission planning, investigators should describe the conduct of on-board activity in terms of functional objectives. They also are responsible for providing operating procedures and other reference data such as experiment description, charts and functional schematics for inclusion in the data file.

During the mission, investigators may use their own special processing equipment in addition to those services provided at the control center. Computer compatibility may be an issue to consider in the planning stage and should be discussed with NASA.

Scheduling

To schedule a flight on the Shuttle, the candidate company or Center for the Commercial Development of Space (CCDS) first must submit a Flight Request Form 1637 to NASA's Office of Commercial Programs (OCP). OCP then submits a NASA Form 1628, Request for Flight Assignment, to the NASA Headquarters Transportation Services Division. Generally, the 1628 form is not submitted until OCP has reviewed and approved the payload proposal.

NASA Headquarters sends Form 1628 to Johnson Space Center (JSC), authorizing initiation of the technical integration process. JSC manages the development and operation of the National Space Transportation System (NSTS). If the payload requires Get-Away Special (GAS) or Hitchhiker accommodations, Form 1628 also is sent to Goddard Space Flight Center (GSFC).

Before technical integration begins, a formal agreement (such as a Joint Endeavor Agreement) must be negotiated between the customer and NASA. This agreement covers all business, policy, legal and financial aspects of the launch. Flight agreements exist between NASA and each CCDS.

The CCDS's and individual firms having agreements with NASA-sponsored activities are typically centered around the development and space flight of a particular hardware configuration designed to accomplish some part of an objective, or more than one objective. Such hardware configurations are called "payloads" and such firms sponsoring the requirements for space flight are called "payload sponsors."

For each payload or payload series (two or more flights of a payload with essentially the same configuration and accommodations requirements) a Payload Representative is identified by the payload sponsor to provide the official and primary point of contact for the activity regarding technical information, and to act as the signature authority for agreements and commitments to NASA regarding integration and mission operations. The payload representative is either an employee of the CCDS or the NASA Agreement Partner sponsoring the payload.

OCP's Commercial Development Division provides technical review and support of candidate flight activities, and the assignment of those activities to specific flight opportunities. During the implementation of activities leading to flight, NASA tracks the progress and problems associated with payload and mission implementation in order to determine potential impact on flight assignments and other support provided.

Once Johnson Space Center receives authorization to begin work on a commercial payload, it assigns a Payload Integration Manager (PIM) who remains the primary point of contact for the payload customer throughout the entire technical integration process. The PIM is responsible for ensuring that the customer's requirements are defined and documented properly. The PIM also coordinates engineering and other technical support required at JSC, including payload safety reviews.

Preparatory and operational phases of a Shuttle mission normally require the customer to participate in experiment activities, including payload integration and checkout at Kennedy Space Center (KSC) in Florida. KSC assigns a Launch Site Support Manager (LSSM) to serve as the customer's point of contact at the launch and landing sites, to handle the launch site support plan and payload processing support.

For payloads requiring GAS or Hitchhiker (see pages 154 and 155) experiment carriers, the customer's initial contact is with the Customer Support Manager (CSM) at GSFC. The customer submits a Payload Accommodations and Requirements document for GAS payloads or a Customer Payload Requirements document for Hitchhiker payloads. These are used to develop a Payload Integration Plan and, if required, an Interface Control Document. These papers, together with Safety Data Packages and other documentation, are submitted to JSC.

After all required data is completed and considered with applicable ground rules, constraints and guidelines, payloads with compatible orbital requirements and configurations are manifested together. Flight assignment of the primary and complex secondary payloads occurs 19 months prior to launch and is referred to as the Flight Definition Requirements Directive timeframe. NASA presents results of a detailed cargo engineering analysis in a Cargo Integration Review about a year before launch. Payload customers are encouraged to participate in this review to ensure all requirements have been satisfied. NASA assigns standard payloads at a Flight Planning and Storage Review, seven months before

The Shuttle (continued)

launch. This is the last review in which payloads can be assigned to a Shuttle flight.

For more information about the Shuttle manifesting process, contact Flight Requirements and Manifesting, Commercial Development Division, NASA/Office of Commercial Programs, Washington, DC 20546, (703) 557-5328. Additional information is included in the NASA Publication, NSTS 07700, Volume XIV.

Integration

The primary goal of any experiment process is to assemble it on a carrier in a way that meets safety requirements and provides the desired level of assurance of meeting objectives. Integration is accomplished in two major phases:

Analytical Integration – involves the planning, analysis and preparatory tasks of payload hardware design.

Physical Integration – includes assembly and check-out of the payload apparatus and carrier hardware.

Flight operations planning and preparations are an essential part of the payload integration process. The researcher submits operations requirements to the assigned NASA manager. These requirements are incorporated into the mission, together with the requirements of other experiments and host carrier elements. A small, independent payload, such as in a Get Away Special (GAS) canister, does not require extensive integration tasks.

Mission planning for integrated payload flight operations begins with the preliminary definition and analysis of individual functional and resource requirements and culminates in the production of a nominal mission timeline, crew activity plan and other flight definition data concerning targets, launch windows, attitudes, etc. A detailed flight operations analysis resolves conflicts and allocates operating times and resources. Once a Payload Integration Plan is agreed upon by all parties, flight preparations proceed. The researcher also may be required to develop flight procedures, assist with crew training, and participate in simulations and in real-time operations.

Post-Flight

When the Shuttle has landed, the researcher has to retrieve and analyze the data or other products generated during the flight.

Normal removal of experiment flight equipment begins about a week after landing. However, special access to remove time-critical data and products or items is possible within days or hours, and should be discussed well in advance with the assigned NASA manager. Experiment hardware is returned to the developer or the NASA inventory, as appropriate, after the deintegration of the payload.

Ground-Based Facilities, Aircraft and Expendable Launch Vehicles

Operations

Operations procedures are as important to tests in laboratories on drop towers, experimental aircraft and expendable launch vehicles as they are on the Shuttle. However, as stated earlier, these operations may be considerably simplified, depending on the design of the experiment and the vehicle or facility being employed. As with all research, the more planning and analysis that is performed prior to the actual testing, the more control and data analysis is possible. Discuss with the facility personnel all variables and concerns of the experiment during the planning process. Such caution will help to avoid last-minute surprises that may force a delay or problem in the testing process.

Scheduling Facilities

Use of facilities such as aircraft and drop tubes may be requested directly through NASA Field Centers (see points of contact in Chapters 4 and 23). Low-gravity flights of KC-135, F-104 and Learjet simulator aircraft are achieved by flying a prescribed parabolic trajectory and are made frequently. Lead-time for scheduling experiments on such flights typically varies from one to six months, depending on the nature of the experiment and aircraft availability. Other facilities, including those at field centers and laboratories, may be similarly requested for use. As stated earlier, negotiations can be made with NASA for the use and cost of facilities and, where sufficient mutual interest exists, collaborative research may be arranged.

While projects that fly on the Shuttle require considerably more planning and documentation than other projects, it is advisable to follow NASA project management practices in conducting any type of experiment.

Ground-Based Facilities, Aircraft and Expendable Launch Vehicles (continued)

Scheduling Facilities (continued)

Typical experiment project documentation includes such items as:

- Payload Integration Plan
- Interface and Control Document
- Ground and Flight Safety Plans
- Crew Timeline Plan

More specific information about the scheduling process for aircraft, drop tubes, sounding rockets or other facilities is available from the Commercial Development Division of the Office of Commercial Programs upon request. It is OCP's mandate to reach out to the commercial community, to offer information, assistance or liaison staff as needed. Obtain as much information as possible about your particular research needs, taking advantage of the experience, advice and materials available from NASA and industry.

Contact: Commercial Development Division
Office of Commercial Programs
NASA Headquarters,
Washington, DC 20546
(703) 557-4626

Section Two: Ground-Based Testing

Performing an experiment in space presents many challenges to the designer in assuring that the hardware – and the experiment – survives the mission. Many facilities have been created to support this endeavor. These facilities support space-related activities, from developing and testing a new material, to research facilities, such as the Microgravity Materials Science Laboratory at NASA/Lewis Research Center. This laboratory has the capability to simulate microgravity conditions. Several experimental research facilities have drop tubes, drop towers and aircraft which also can simulate a microgravity environment for a limited period of time.

Facilities devoted to sensor development, data processing and data distribution play an important role in the Remote Sensing Programs. Remotely sensed information is gathered by space-based and airborne vehicles and instruments. Remote sensing systems include a wide variety of highly sophisticated hardware, software and other subsystems.

Facilities at the NASA Field Centers are grouped into several major classifications. These include basic research, manufacturing processes, commercial applications of remote sensing, materials testing and performance testing, which includes environmental facilities such as vacuum chambers, centrifuges and vibration tubes. In general, the Centers for the Commercial Development of Space (CCDS's), industry and university facilities follow the same grouping, although the commercial facilities also include clean rooms and other space-related fabrication areas.

The commercial developer must test all experiment equipment and design before attempting to place any research project in space. Such testing allows for evaluation of the integrity of the experiment, survivability of the equipment and quality control of all functioning processes and devices to ensure successful results. NASA can advise which approach will best meet the requirements.

Airborne flight facilities provide the opportunity for such testing and evaluation. They also permit research programs of various disciplines, which may not be applicable for space flight. These facilities include sounding rockets, aircraft, helicopters and balloons.

Chapter 4: Facilities at NASA Field Centers

NASA has assembled a large inventory of developmental, research, environmental and test equipment for space-related hardware. Equipment names and/or functions are listed here; further information regarding capacities and other pertinent specifications may be obtained by contacting the NASA Field Center Commercialization Officers listed in Chapter 23. Additional information about NASA facilities may be found in the publication "NASA Facilities Database User's Manual" or by contacting the Office of Commercial Programs, Commercial Development Division, at (703) 557-4626.

Ames Research Center

Located in Mountain View, CA, Ames Research Center covers some 420 acres on land adjacent to the Moffet Field Naval Air Station. Ames specializes in scientific research, exploration and applications aimed toward creating new technology. It houses extensive research facilities, many of them unique, including the world's largest wind tunnel.

The Center's major programs are concentrated in computer science and applications, computational and experimental aerodynamics, flight simulation, flight research, hypersonic aircraft, rotorcraft and powered-lift technology, aeronautical and space human factors, life sciences, space sciences, solar system exploration, airborne science and applications and infrared astronomy.

Life Sciences/Biotechnology Facilities

- 20 G/Human Centrifuge
- Altitude Chambers
- Animal Centrifuges
- Flight Simulation Facilities
- Human Performance Research Laboratory
- Isotope Biogeochemistry Laboratory
- Life Sciences Flight Experiments Facility
- Plant Growth Chambers
- Proximity Operations Simulator
- Psychophysiology Laboratory
- Structural Systems and Bone Mineralization Laboratory

Performance Testing Facilities

- Centrifuge
- Impact Shock and Dynamic Balance Facilities
- Magnetic Test Facility
- Temperature Altitude and Humidity Chamber
- Tensile Test Machine
- Vibration Exciter

Materials Testing Facilities

- Ultrastructure Research Laboratory (Scanning Electron Microscopes)

Contact: Elizabeth Inadomi
Manager of Commercial Programs
NASA/Ames Research Center, MS 223-3
Moffett Field, CA 94035-1000
(415) 694-6472, Fax (415) 694-4004

Ames Aircraft Data Facility

Image Processing Laboratory – The Ames Aircraft Data Facility has an Image Processing Laboratory, concentrating on photographic and electronic data processing, used in conjunction with remote sensing programs. Further information on these capabilities may be obtained from NASA/ARC, Aircraft Data Facility, (415) 604-6252.

NASA High Altitude and Medium Altitude Photography Archive – The Aircraft Data Facility also hosts the NASA High Altitude and Medium Altitude Missions Photography Archive, which contains thorough coverage of the western and eastern states, including Alaska and Hawaii, with significant coverage of the South and Midwest. Urban, suburban, agricultural and even the most remote mountain regions are represented.

Archive photographs present wide ground coverage and precise definition of ground objects: each 9x9 inch or 9x18 inch frame depicts 32 to 256 square nautical miles of the Earth's surface, with a nominal resolution of 5 to 15 feet. Archive film consists of three types: natural color, black and white and color infrared. Color infrared film is the most widely used

Ames Research Center (continued)

because it produces photographs that reveal information from a portion of the spectrum normally not seen by the eye. Color infrared photographs are particularly useful for noting the differences within land cover types (water, soil and vegetation).

Image Selection System – The Aircraft Data Facility maintains a computerized database called the Image Selection System (ISS) for locating specific frames of photography of designated areas. Facility staff use the ISS to specify the area, year, film format, film type and scale of photography of potential interest to archive users. By quickly viewing microfilm versions of frames listed by the ISS, users can verify their selections before accessing rolls of film.

Viewing equipment is provided so that visitors can study specific films of interest. This equipment includes light tables, stereo viewers, a transfer scope and a complete set of U.S. Geological Survey topographical maps of the United States, at a scale of 1:250,000. With the transfer scope, users can overlay a photograph with a map or second photograph and then, while viewing them simultaneously, transfer photo-interpretive data to the map or photo overlay. Archive photography is for on-site use only. However, copies of any frame can be obtained by contacting the Earth Remote Observation Sensing Data Center in Sioux Falls, SD, 57198, (605) 594-6151 (see also EOSAT, Chapter 9).

Contact: Gary A. Shelton
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Ames Dryden Flight Research Facility

The Ames Dryden Flight Research Facility is located at Edwards Air Force Base, CA, in the Mojave Desert. Ground-based facilities include a high-temperature loads calibration laboratory that allows testing of complete aircraft and structural components under the combined effects of loads and heat; a highly developed aircraft flight instrumentation capability; a flight systems laboratory with a diversified capability for avionics system fabrication, development and operations; a flow visualization facility that allows basic flow mechanics to be seen on models or small components; a data analysis facility for processing of flight research data; a remotely piloted research vehicles facility; and a test range with communications and data transmission capability.

Goddard Space Flight Center

Goddard Space Flight Center, at Greenbelt, MD, is a national facility that has the expertise to conceive missions, to design, develop, fabricate and test spacecraft, and to operate flight projects and analyze data returned from them. Engineering laboratories are focused on advanced space technologies for applications to new spacecraft and payload systems. In addition to disciplines such as ultra violet and infrared astronomy, solar physics, high energy astrophysics, planetology, climatology and Earth sciences, scientists and engineers also are developing infrastructure, such as automation and robotics, for space station and exploration applications.

Goddard catalogues and archives its scientific data from experiments at the National Space Science Data Center in the form of magnetic tapes, microfilm and photographic prints. Theoretical research is conducted at the Goddard Institute for Space Studies, in New York City.

Performance Testing Facilities

- Acoustic Test Facility
- Ainsworth Vacuum Balance Facility
- Battery Test Facility
- High Capacity Centrifuge Facility
- High Speech Centrifuge Facility
- High Voltage Test Facility
- Large Area Pulsed Solar Simulator
- Magnetic Field Component Test Facility
- Magnetic Test Facility – 45 ft
- Optical Instrument Assembly and Test Facility
- Radiation Test Facility
- Shielded Room EMI Test Facilities
- Space Simulation Test Facility
- Spacecraft Magnetic Test Facility
- Vacuum Chamber (8 ft x 8 ft)
- Vibration Test Facility

Materials Testing Facilities

- Fatigue, Fracture Mechanics and Mechanical Testing Laboratory
- Metallography Laboratory

Goddard Space Flight Center (continued)

Materials Testing Facilities (continued)

- Organics Analysis Laboratory
- Outgassing Test Facility
- Parts Analysis Laboratory
- Scanning Electron Microscope Laboratory
- X-ray Diffraction and Scanning Auger Microscope Spectroscopy Laboratory

Manufacturing Process Facilities

- Gold Plating Facility
- Optical Thin Film Deposition Facility
- Paint Formulation and Applications Laboratory

Contact: Donald S. Friedman
Chief, Office of Commercial Programs
Goddard Space Flight Center
Mail Stop 702, Building 11, Room C1
Greenbelt Road
Greenbelt, MD 20771
(301) 286-6242, Fax (301) 286-4653

National Space Science Data Center (NSSDC)

NSSDC was established by NASA to serve the Space and Earth Science research communities. It is an active repository for data obtained from space science investigations. Since its establishment, NSSDC has been responsible for the active collection, organization, storage, announcement, retrieval, dissemination and exchange of data received from satellite experiments.

Information on sounding rocket investigations also has been collected. In addition, NSSDC has collected correlative data from ground-based observatories and stations for NASA investigators, and for on-site use at NSSDC, in the analysis and evaluation of space science experiment results.

NSSDC actively collects, organizes, stores, announces, disseminates, exchanges and refers to a large variety of scientific data obtained from spacecraft and ground-based observations. Disciplines represented include:

- Astronomy
- Astrophysics
- Atmospheric sciences
- Ionospheric physics
- Land sciences
- Magnetospheric physics
- Ocean sciences
- Planetary sciences
- Solar-terrestrial physics

A user may request data and documents in any of the following ways:

- Letter request
- Document request form
- Telephone request
- On-site request
- Telex
- Networks

Contact: NSSDC
NASA/Goddard Space Flight Center
Code 930
Greenbelt, MD 20771
(301) 286-6695, Fax (301) 286-4952

Jet Propulsion Laboratory

The Jet Propulsion Laboratory in Pasadena, CA, is a government-owned facility operated by the California Institute of Technology. JPL operates the worldwide Deep Space Communications Complex, a station of the worldwide Deep Space Network, and maintains a substantial technology program to support present and future NASA flight projects and to increase laboratory capabilities.

JPL is engaged in activities associated with deep space automated scientific missions, such as engineering subsystems and instrument development, and data reduction and analysis. It also designs and tests flight systems, including complete spacecraft, and provides technical direction to contractors.

Performance Testing Facilities

- Acoustic and Measurement Laboratory
- Ion Source Laboratory
- Space Simulator – 10 ft
- Space Simulator – 25 ft
- Thermal Vacuum Chamber (7 ft x 14 ft)

Materials Testing Facilities

- Magnetics Test Laboratory
- Materials Characterization Laboratory
- Materials Research Laboratory

Research Facilities-Propellants

- Chemical Synthesis Laboratory

Contact: William T. Callaghan
Manager, Technology Commercialization
NASA/Jet Propulsion Laboratory
M/X 79-21
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-0865, Fax (818) 354-7282

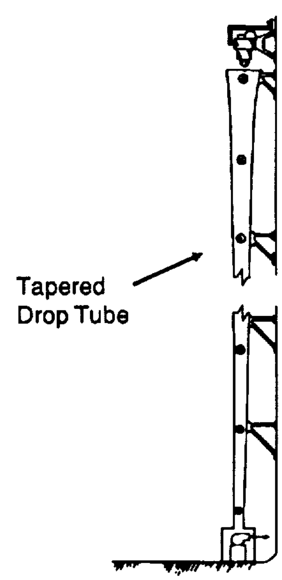
13.1-Meter Force-Free Drop Tube

The 13.1-meter force-free drop tube is used in fluid surface configuration research. The facility provides investigators with a microgravity environment lasting up to 1.6 seconds, but unlike other drop tubes, this one is free of aerodynamic drag. Gravity and air drag distort the subtle characteristics of fluids; under microgravity conditions, these features may be more readily observed.

Operational Characteristics

Sample size:	Up to 5 cm diameter
Tube size:	13.1 m L x 12.7 cm diameter
View port diameter:	5.0 cm
Temperature:	ambient room
Microgravity duration:	Up to 1.6 seconds
Acceleration level:	1 milli-g or greater

Contact: NASA/Jet Propulsion Laboratory,
Applied Sciences and Microgravity Experiments Section
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-7125



Jet Propulsion Laboratory (continued)

13.2-Meter Cryogenic Drop Tube

The 13.2-meter cryogenic drop tube provides a very low-temperature, controlled gas environment for the development of spherical shell technology, fusion target investigations, and the processing of metallic glass and metal alloys.

The sample to be processed in the 13.2-meter cryogenic drop tube is melted in a crucible that also injects the molten material with gas bubbles. The sample begins its 1.7-second free fall through the three temperature zones of the tube as a hollow stream, a cylinder of molten material surrounding a gaseous center. In the first zone of the tube, the sample is cooled to slightly below its melting/liquidous temperature, allowing the stream to pinch off into symmetrical droplets that surround gas bubbles. Each droplet then enters the cryogenic zone where the molten material cools around the gas bubble, forming a spherical shell. This second zone is chilled by a 10.66-meter liquid nitrogen (LN_2) cooling jacket that chills to LN_2 temperature in approximately 2 hours.

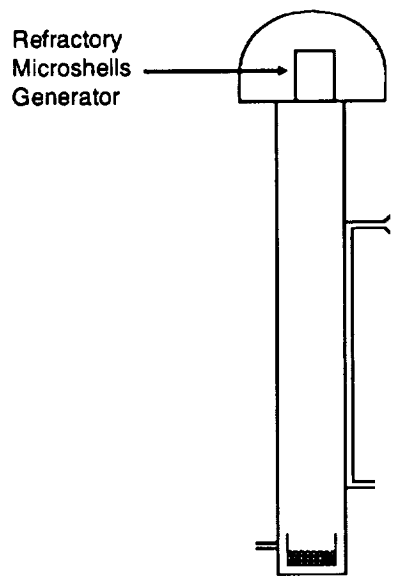
Operational Characteristics

Size of shells produced:	100 microns to 3 mm
Sample materials:	Aluminum, plastics, metal alloys, special glasses
Crucible size:	500 to 1,000 ml
Tube size:	13.2 m L x 12.7 cm diameter
Internal gas pressure range:	1×10^{-5} torr to 1 atm
Microgravity duration:	1.7 seconds

Temperature

Crucible:	Up to 2,000° C
First zone:	Approximately 450° C
Second zone:	Down to -195° C
Third zone:	Ambient room temperature

Contact: NASA/Jet Propulsion Laboratory
Applied Sciences and Microgravity Experiments Section
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-7125



Johnson Space Center

Johnson Space Center is located on 1,620 acres in Clear Lake, TX, about 20 miles from Houston. JSC is the main center for design, development and testing of spacecraft and associated systems for manned flight; selection and training of astronauts; planning and conducting manned missions; and extensive participation in the medical, engineering and scientific experiments carried aboard space flights.

In addition to its primary responsibilities of program management for the Shuttle and development of the Space Station, JSC also has sixteen facilities dedicated to space and life sciences, including planetary and Earth sciences, robotics, artificial intelligence and lunar samples. Engineering facilities include vacuum chambers, an anechoic chamber, antenna range, avionics testing and various structural and environmental test areas.

Life Sciences/Biotechnology Facilities

- Biochemistry Research Laboratory
- Bioprocessing/Cell Biology Research Laboratory
- Crew Systems Laboratory Complex
- Endocrinology Research Laboratory
- Environmental Physiology Laboratory
- Health Physics Laboratory
- Life Sciences Experiments Development, Assembly and Verification Facility

Materials Testing Facilities

- Electron Microprobes
- Electron Microscopy and Photographic Equipment
- Gas Analysis Equipment
- Gas Toxilogical Analysis Equipment
- Thermal Analysis Equipment

Research Facilities – Space Plasma

Space Plasma Simulation Laboratory

Johnson Space Center (continued)

Manufacturing Process Facilities

- Laser/Electro-Optical Laboratory
- Performance Testing Facilities
- Crew Systems Laboratory Complex (6 chambers)
- Space Environmental Effects Laboratory (14 chambers)

Contact: Mark Nolan
Manager of Commercial Programs, Code IC
NASA/Johnson Space Center, EA-111
Houston, TX 77058
(713) 283-5320, Fax (713) 283-5305

Kennedy Space Center

Kennedy Space Center includes 84,031 acres on the East Coast of Florida. The Center is responsible for the assembly, checkout and launch of Space Shuttle vehicles and their payloads, landing operations and the turn-around of Shuttles between missions, as well as preparation and launch of expendable launch vehicles. It supports spacecraft requirements of other NASA Centers, commercial organizations and U.S. government agencies not affiliated with the Department of Defense by providing operational and administrative support.

Life Sciences/Biotechnology Facilities

- Animal Holding Facility
- Biomass Production Chamber
- Biomedical Stress Laboratory

Materials Testing Facilities

- Coating Facility
- Electronic Laboratory
- Failure Analysis Laboratory
- Lubricants Laboratory
- Material Testing Laboratory
- Metallurgical Laboratory
- Metrology Laboratory
- Microchemical Analysis Laboratory

Other Research Facilities

- Artificial Intelligence Laboratory
- Fiber Optics Laboratory
- Gas Chromatography Laboratory
- Robotics Applications Development Laboratory

Performance Testing Facilities

- Liquid Oxygen Test Facility
- Temperature Humidity Chamber

Manufacturing Process Facilities

- Plastic and Elastomers Facility

Contact: Mr. Robert (Bob) Butterfield
Manager, Technology Integration
Code PT-PMO-A
NASA/Kennedy Space Center, FL 32899
(407) 867-3017, Fax (407) 867-2217

Langley Research Center

Located in Hampton, VA, the Langley Research Center occupies nearly 790 acres of government-owned land and shares aircraft runways, utilities and some facilities with neighboring Langley Air Force Base. An additional 3,200-acre marshland is under permit to NASA and is used as a drop zone for model aircraft tests.

Langley's primary mission is basic research in aeronautics and space technology. Major research fields include aerodynamics, materials, structures, controls, information systems, acoustics, aeroelasticity and atmospheric sciences. About 60 percent of the work at Langley is in aeronautical research, with the remainder focused on space research. Space researchers conduct studies in atmospheric and Earth sciences, identify and develop technology for advanced space transportation systems, conduct research in laser energy conversion techniques for space applications and provide the focal point for design studies for large space systems technology and Space Station Freedom activities.

Langley Research Center (continued)

Performance Testing Facilities

- Mast Test Facility
- Potentially Hazardous Test Areas
- Thermal Chambers
- Thermal Vacuum Chamber (8 ft x 15 ft)
- Thermal Vacuum Chamber (55 ft)
- Vacuum Bell Jar Systems
- Vacuum Braxing
- Vacuum Chamber (5 ft x 5 ft)
- Vacuum Sphere – 60 ft
- Vibration Facility – 17,000 lb
- Vibration Facility – 37,000 lb

Materials Testing Facilities

- 5 Megawatt Arc Tunnel
- 20 Megawatt Arc Tunnel
- Carbon/Carbon Fiber Laboratory
- Combustion Tunnel
- LOX Combustion Tunnel

Microgravity Research Facilities

- Flow/Solidification Front Apparatus

Polymer and Fiber Optics Research Facilities

- Gas Permeable Membrane Laboratory
- Gas Phase Chemistry (Mass Spectrometer)
- Sensible Fibers

Contact: Fred Allamby
Commercial Project Manager
NASA/Langley Research Center, MS 356
Hampton, VA 23665-5225
(804) 864-3788, Fax (804) 864-3769

Lewis Research Center

Lewis Research Center occupies 360 acres of land adjacent to the Cleveland Hopkins International Airport, near Cleveland, OH. Lewis is NASA's lead center for research, technology and development in aircraft propulsion, space propulsion, space power and satellite communications. Lewis is responsible for developing the space power system that will provide electrical power necessary to accommodate the life support systems and research experiments planned for Space Station Freedom. The Center also will support the Station in other areas such as auxiliary propulsion systems and communications.

Lewis is the home of the Microgravity Materials Science Laboratory, a facility uniquely designed to qualify potential space experiments. Other facilities include a zero-gravity drop tower, wind tunnels, space tanks, chemical rocket thrust stands and chambers for testing jet engine efficiency and noise.

Microgravity Research Facilities

- Microgravity Materials Science Laboratory
- 145-meter (5.2 second) Drop Tower
- 30-meter (2.2 second) Drop Tower
- Learjet
- General Purpose Crystal Furnaces
- Electromagnetic Levitation Furnace with Drop Tube
- Transparent Crystal Growing Furnaces

Other Research Facilities

- Energy Conversion Laboratory
- Space Power Research Laboratory
- Materials and Structures Laboratory
- Materials Processing Laboratory
- Basic Materials Laboratory
- Thermal Vacuum Test Facilities (up to 31 m diameter x 37 m high)
- Rocket Engine Test Facility
- Power Systems Facility
- Surface Sciences Laboratories
- Materials Characterization Laboratories
- Polymer Science Laboratories
- Glass Laboratory

Contact: Harvey Schwartz
Manager, Office of Industrial Programs
NASA/Lewis Research Center, MS 3-17
Cleveland, OH 44135
(216) 433-2921, Fax (216) 433-5266

Lewis Research Center (continued)

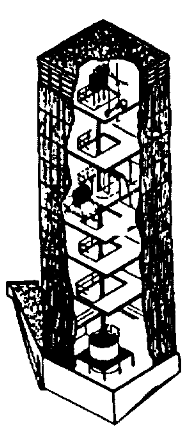
30-Meter Drop Tower

The 30-meter drop tower (also known as the 2.2 Second Drop Tower) at the NASA Lewis Research Center plays a key role in the discipline of Microgravity Science and Applications. This facility allows investigators to test experimental packages in a microgravity environment for a period of 2.2 seconds. It is used extensively by NASA research scientists as well as university investigators. The current focus of the programs utilizing the facility are in the areas of combustion science and fluid physics. The role of the drop tower in these areas includes the execution of ground-based science programs, the performance of tests to define space experiment science requirements and conceptual designs, and to perform tests for space experiment technology development and verification. The drop tower is an ideal research facility as it is operated at a relatively low cost. Engineers participate directly in experiment build-up and testing, and several drop tests (8 to 12) can be performed in one day.

Operational Characteristics

Sample rectangle drop rig:	41 cm W x 96 cm L x 84 cm H
Experiment hardware weight:	up to 125 kg
Drop height:	27 meters
Drag shield dimensions:	51 cm W x 102 cm L x 137 cm H
Microgravity duration:	2.2 second (free fall)
Gravitational acceleration:	Less than 10^{-5} g
Deceleration rate:	40 to 70 g for less than 20 millisec

Contact: Jack Lekan
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-3259



30-Meter Drop Tower

145-Meter Zero-Gravity Research Facility

The 145-meter Zero-Gravity Research Facility, with a vacuum drop chamber, has been developed in support of microgravity research and development programs that investigate various physical sciences, materials, fluid physics, and combustion and processing systems. Large experimental packages can be operated and observed for periods of 5 seconds of microgravity.

Operational Characteristics

Sample cylindrical vehicle

Size:	1.5 m x 1.0 m diameter
Cold gas thrust system:	0.003 to 0.015 g
Experiment payload weight:	Up to 453.6 kg
Total system weight:	1.135 kg

Sample Rectangular Vehicle

Dimensions:	1.5 m L x 0.5 m W x 1.5 m H
Test Specimen Envelope:	1.5 m L x 0.40 m W x 0.45 m H
Cold gas thrust system:	0.003 to 0.037 g (positive) 0.013 to 0.070 g (negative)
Experiment payload weight:	Up to 69 kg
Total vehicle weight:	340 kg

Vacuum Test Chamber

Drop height:	132 m
Ultimate vacuum:	10^{-2} torr (in 1 hour)
Aerodynamic drag:	Less than 10^{-8} g
Microgravity Duration:	5.18 seconds

Deceleration Rate

Mean:	35 g for 150 millisec
Maximum range:	60 g for 20 millisec

Contact: NASA/Lewis Research Center
Space Propulsion Technology Division
Cleveland OH 44135
(216) 433-5485

Lewis Research Center (continued)

Microgravity Materials Science Laboratory

The Microgravity Materials Science Laboratory is a nationally available laboratory open to scientists and engineers from U.S. industry, universities and governmental agencies. It is equipped with experimental hardware with three objectives: it emulates some aspect of a reduced gravity environment (e.g., containerless processing); provides an improved 1-g database for experiments and processes which are candidates for space research; and functionally duplicates hardware which is used on the Shuttle or is being developed for Shuttle/Space Station missions.

The MMSL is designed to give promising experimenters easy access to its specialized facilities. The researcher can evaluate the results of a simple "proof of concept" experiment before a formal program at his/her home laboratory is begun, permitting the researcher's sponsoring organization to do exploratory research without committing large sums of money. Use of MMSL facilities is free of charge for non-proprietary research; cost-of-usage contracts can be negotiated for proprietary work.

The MMSL currently provides experimental capabilities to support research in crystal growth, metals and alloys, ceramics, glasses and polymers.

Available experimental equipment includes an electromagnetic levitator and instrumented, one-second drop tube; a transparent crystal growth furnace; a magnetically damped, high temperature directional solidification furnace; a bulk undercooling furnace; a transparent dendrite growth apparatus; and an acoustic levitator. Additional equipment may be purchased or built to meet user needs.

The MMSL is the home of two of NASA's Advanced Technology Development (ATD) projects. One of these projects centers on furnaces with improved efficiencies; these furnaces will be useful for both ground-based and flight research. The other ATD project is examining the possibility of placing a laser light-scattering instrument on the Shuttle or Space Station. This sensitive characterization tool measures particles in solution which range in size between 30 angstroms and 3 microns and can be used to watch evolving polymerization or agglomeration.

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Marshall Space Flight Center

Marshall Space Flight Center is located on 1,800 acres inside the U.S. Army's Redstone Arsenal in Huntsville, AL. Marshall also manages the Michoud Assembly Facility in New Orleans, LA, where the Shuttle external tanks are manufactured, and the Slidell Computer Complex in Slidell, LA, which provides computer services support to Michoud.

Primarily a launch vehicle development center, Marshall is a multi-project management, scientific and engineering establishment, with much emphasis on projects involving scientific investigation and application of space technology to the solution of problems on Earth. The Center plays a key role in the development of Shuttle payloads, such as Spacelab, a reusable, modular scientific research facility carried in the Shuttle's cargo bay.

Marshall also is involved in the investigation of materials processing in space, including research to understand and improve Earth-based processes and the formulation of space-unique materials. New techniques were demonstrated in past Spacelab missions, such as formation alloys from normally immiscible products and the growth of near-perfect large crystals, impossible to grow on Earth.

Microgravity Research Facilities

- Advanced Space Furnace Technology Laboratory
- Crystal Growth and Characterization Laboratory
- Glass Sciences Laboratory
- Holography and Optical Analysis Laboratory
- Holography Ground System Laboratory
- Low-g Fluid Dynamics Laboratory
- Solidification Processes Laboratory
- Solidification Research Laboratory
- Solution Crystal Growth Laboratory

Manufacturing Process Facilities

- Adhesive Bonding and Composites Development Facility
- Adhesive Technology Laboratory
- Ceramics and Coatings Development and Evaluation Laboratory
- Composite Materials, Adhesives, and Cryogenic Insulation Development and Evaluation Laboratory
- Glass Sciences Laboratory
- Optical Fabrication, Coating and Testing Laboratory

Marshall Space Flight Center (continued)

Manufacturing Process Facilities (continued)

- Optical Material and Coating Laboratory
- Optical/Electro-Optical Systems Laboratory
- Polymer Development and Evaluation Laboratory
- Rubber and Plastics Technology Facility
- Superconductivity Thin Film Laboratory
- Vacuum Plasma Spray Development Facility

Life Sciences/Biotechnology Facilities

- Electrophoresis Laboratory
- Phase Partitioning Laboratory
- Space Chemistry Laboratory (Monodisperse Latex Reactor)

Materials Testing Facilities

- Chemistry Diagnostic Laboratory
- General Purpose Rocket Furnace Test Facility
- Polymer Development and Evaluation Laboratory
- Scanning Electron Microscope Facility
- Tensile Test Facility
- Vacuum Physics Laboratory
- Vacuum UV Laboratory

Performance Testing Facilities

- Acoustic Test Laboratory
- Environmental Test Facility
- Magnetospheric Laboratory
- Modal Test Laboratory
- Nondestructive Evaluation Facility
- Solar Array Laboratory
- Thermal Vacuum and Thermal Chambers
- Vacuum Chamber (Senspot I)
- Vibration Test Laboratory

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100-Meter Drop Tower

The 100-meter drop tower simulates in-flight microgravity conditions for up to 4.2 seconds for containerless processing experiments, immiscible fluids and materials research, pre-flight hardware design test and flight experiment simulation.

The 100-meter drop tower is designed to accommodate large experiment packages, which are provided by the investigator and contain all instrumentation required for sample melting and internal data collection. These packages are housed in a shield to isolate the experiment from aerodynamic drag during free fall.

Operational Characteristics

Sample size:	0.9 m L x 0.9 m W x 0.9 m H
Sample weight:	180 kg maximum
Sample capacity:	0.73 m^3 maximum
Drop tower	
Total drop height:	101.7 m
Free-fall height:	89.5 m
Drag shield	
Size:	7.4 m L x 2.2 m diameter
Test area:	1.8 m x 2.4 m
Weight:	1,642 kg
Drag shield free-fall time:	4.275 seconds
Drag shield deceleration:	25 g
Auxiliary thrust:	34 kg
Low-gravity range:	1 x 10^{-5} to 4 x 10^{-2} g

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Microgravity Projects, Code JA 81
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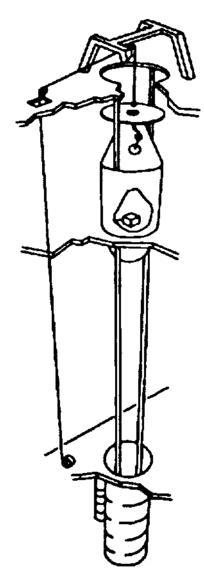

100-Meter Drop Tower

Marshall Space Flight Center (continued)

100-Meter Drop Tube

The 100-meter drop tube simulates in-flight microgravity conditions for up to 4.6 seconds and is used extensively for ground-based microgravity convection research in which extremely small samples are studied. The facility can provide deep undercooling for containerless processing experiments that require materials to remain in a liquid phase when cooled below the normal solidification temperature.

The melting apparatus is housed in a stainless-steel bell jar located directly above a stainless-steel drop tube. After the sample melts, it drops freely through the tube; the melting device does not fall with the sample. The drop tube can be evacuated to a pressure of 10^{-6} torr and accelerations as low as 10^{-6} g are possible for as long as 4.6 seconds.

Operational Characteristics

Sample size:	Up to 5 mm diameter
Sample mass:	Up to 300 mg
Sample shape:	Symmetrical with good aspect ratio
Tube diameter:	25.4 cm
Tube length:	104.0 m

Electron bombardment furnace

Temperature range:	1,600° to 3,500° C
Pressure:	Vacuum environment
Sample shape:	Wire, rod or disc

Electromagnetic levitator furnace

Temperature range:	500° to 3,000° C
Pressure:	Vacuum and low-pressure gaseous environments
Sample weight:	Up to 0.25 g

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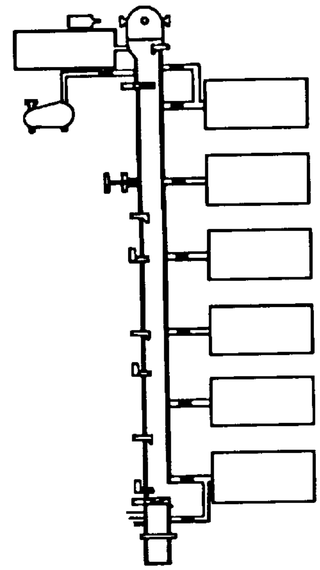

100-Meter Drop Tube

Stennis Space Center

Stennis Space Center is a 13,480 acre complex near Bay St. Louis, MS, that includes industrial, laboratory and specialized engineering facilities to support the testing of large rocket propulsion systems. The main mission of SSC is support of the Shuttle main engine and main orbiter propulsion system testing.

Stennis also has evolved into a Center of Excellence in the area of remote sensing and is involved in Earth sciences programs of national and international significance. The Earth Resources Laboratory develops and manages a balanced research and development program in Earth sciences, remote sensing technique and applications, and sensor and data systems development and operations.

Designated as the lead NASA Center for commercial applications of remote sensing, Stennis has two labs, the Sensor Engineering and Development Lab and the Data Analysis Lab, that assist commercial researchers in participating in the remote sensing arena. SSC features a Visiting Investigator Program (VIP), designed to encourage industry to utilize the Center's facilities. The Earth Observations Commercialization Applications Program (EOCAP) is managed here as well. (continued)

Stennis Space Center (continued)

Remote Sensing Research Facilities

- Sensor Engineering Laboratory
- Sensor Optics Laboratory
- Thermal Infrared Multispectral Scanner
- Thermatic Mapper Simulator
- Zeiss Camera

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Sensor Engineering and Development Laboratory

This laboratory contains the following equipment:

- 10-inch off-axis collimator system (80-inch focal length)
- Visible/IR reference standards
- Scanning monochromator (0.3 to 13.0 m)
- 3-meter optical research bench
- Theodolite with autocollimator
- Fiberscope video camera and monitor
- CAE/IBM-AT PC board layout (D-size plotter)
- Class-1 clean bench
- Spectrophotometers (0.2 to 17.0 m)
- Vacuum station
- VIS/IR laser alignment system
- Electronic test/analysis equipment
- Calibrated standard lamp
- Electronic development system
- 20-inch integrating sphere (0.3 to 1.1 m)
- Fourteen-inch integrating sphere lab standard
- HP-85 Controller with X-Y plotter
- Breadboard focal plane analysis system
- Environmental chamber
- Blackbody calibration standard

Data Analysis Laboratory

The primary R&D production system is a Model 3200 MPS computer system from Concurrent Computer Corporation (formerly Perkin Elmer Data Systems Group). The system uses the OS/32 operating system with an 8-megabyte main memory and a 5800-megabyte disk memory.

Visiting Investigator Program (VIP)

The Visiting Investigator Program is designed to provide an opportunity for industry to utilize the specialized resources at Stennis Space Center (SSC). The VIP offers opportunities for various organizations and commercial entities to incorporate remote sensing technology into their operation. As a result, remote sensing technology is brought closer to the goal of commercialization.

The VIP was initiated in 1988 at SSC and has one or two VIP participants per quarter. SSC has acquired a remote sensing end-to-end micro-based data processing system that supports its commercialization effort.

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Wallops Flight Facility

Operated by the Goddard Space Flight Center, the Wallops Flight Facility at Wallops Island, VA, is dedicated to suborbital research and includes a launch range and a research field. The 6,100 acres of the Wallops Flight Facility comprises three separate sections of property; the Main Base, the Wallops Island Launch Site and the Wallops Mainland. Wallops is responsible for projects using sounding rockets, balloons and aircraft that provide simple, flexible and inexpensive methods of conducting scientific investigations.

Sounding rockets carry scientific instruments hundreds of miles into space, while balloons are capable of carrying payloads of up to 6,000 pounds to altitudes of 30 miles. Aircraft at Wallops are used as platforms for instruments to collect data up to 40,000 feet altitude. In addition, mobile launch, tracking and data acquisition systems are transported to and operated at various world sites to accommodate sounding rocket, balloon and NASA networks mission requirements.

Wallops Flight Facility (continued)

In cooperative and commercial projects, Wallops provides support that includes launching, tracking aircraft flights and data reduction to various segments of DOD, other agencies and commercial and educational ventures.

Performance Testing Facility

- Spin Balance Facility-Dynamic
- Spin Balance Facility-Static

Launch Support Facilities

- Launch Pad 0
- Launch Pad 1
- Launch Pad 2
- Launch Pad 3
- Launch Pad 4
- Launch Pad 5
- Telemetry Station

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Chapter 5: Facilities at the Centers for the Commercial Development of Space

There are some 175 industry partners and 55 university partners participating in NASA's Center for the Commercial Development of Space (CCDS) Program. The primary goals of the program are: to leverage and stimulate industry to consider space as a resource and an alternative to conventional R&D methods; and to stimulate commercialization through cost-effective transportation and infrastructure.

Supporting the development of technologies needed to define markets will stimulate the need for space transportation and infrastructure, which can be acquired in a conventional commercial way. NASA's grant program allows the CCDS's to develop in a totally commercial fashion with equipment, technology and supporting organization and transportation services. It establishes a focus that stimulates expansion in various focused discipline areas. It is expected that as markets mature, specific transportation systems and infrastructional services will be developing together.

NASA's Office of Commercial Programs has a signed fight agreement, called the Center for the Commercial Development of Space Flight Agreement, with each CCDS. This agreement serves to delineate all responsibilities, procedures and activities involved in the use of the Shuttle by the CCDS's, including provisions for Shuttle services at no charge. All projects are driven by industry needs. Any company interested in developing a joint payload may contact any of the sixteen CCDS's. (See additional listing of the CCDS's on pages 242 and 243.)

NASA Centers for the Commercial Development of Space (CCDS's)

Overview by Areas of Main Activities

Automation and Robotics

- Space Automation and Robotics Center (SpARC) – Environmental Research Institute of Michigan
- Wisconsin Center for Space Automation and Robotics (WCSAR) – University of Wisconsin

Remote Sensing

- Center for Mapping – Ohio State University
- Space Remote Sensing Center (SRSC) – Institute for Technology Development

Life Sciences

- BioServe Space Technologies – University of Colorado
- Center for Cell Research (CCR) – Pennsylvania State University
- Center for Macromolecular Crystallography (CMC) – University of Alabama at Birmingham (UAB)

Materials Processing in Space (MPS)

- Advanced Materials Center – Battelle Memorial Institute
- Center for Commercial Crystal Growth in Space (CMDS) – Clarkson University
- Consortium for Materials Development in Space – University of Alabama at Huntsville (UAH)
- Center for Space Processing of Engineering Materials – Vanderbilt University
- Space Vacuum Epitaxy Center (SVEC) – University of Houston

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NASA Centers for the Commercial Development of Space (continued)

Overview by Areas of Main Activities (continued)

Space Power

- Center for Space Power (CSP) – Texas A&M University
- Center for the Commercial Development of Space Power and Advanced Electronics – Auburn University

Space Propulsion

- Center for Advanced Space Propulsion (CASP) – University of Tennessee

Space Structures

- Center for Materials for Space Structures – Case Western Reserve University

Advanced Materials Center/Battelle

Affiliation and Mission

The Advanced Materials Center, located at the Battelle Memorial Institute in Columbus, OH, was one of the first five CCDS's selected by NASA. Founded in 1985, the Center conducts research in advanced materials, including polymers, catalysts, electronic materials, metals, ceramics and superconductors. Opportunities for space commercialization are selected for study with the objective of improving the characteristics of the commercial product, improving the process by which the product is made, or gaining additional information about the material which could improve processing on Earth.

Focus

- Polymers – Key areas of emphasis include membranes, multiphase composites and plasma polymerization of thin films.
- Industrial Catalysts – Research is being conducted in the area of zeolites, mixed oxides and metal alloy catalysts.
- Electronic Materials – Research activities to date have been focused on growth of large cadmium telluride (CdTe) crystals.

In addition to the three major programs above, Battelle also is conducting research in other areas, including amorphous metallic catalysts, superconductor materials and hydrothermally grown crystals.

Achievements

Battelle's strength lies in its successful combination of research and flight programs. In April 1990, Battelle's polymer membrane experiment, Investigations into Polymer Membrane Processing (IPMP), flew on STS-31. Other membrane experiments are scheduled to follow. A zeolite experiment from Battelle's industrial catalyst program is being built for flight on the first U.S. Microgravity Laboratory (USML-1) mission in 1992. Two additional Shuttle experiments (solution growth of crystals and float zone growth of CdTe) are being developed for flights in the 1993-94 time frame. In addition to the Shuttle flight experiments, other polymer experiments are being conducted utilizing drop towers, experimental aircraft and sounding rockets.

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BioServe Space Technologies

Affiliation and Mission

BioServe Space Technologies, headquartered at the University of Colorado in Boulder, is broadly oriented toward research and development in life sciences. BioServe combines expertise from the College of Engineering at the University of Colorado and the Division of Biology at Kansas State University, as well as expertise from over 30 participating industrial affiliates. Numerous projects are being conducted in biomaterials processing, biomedical testing during space flight, controlled ecological life support systems and development of enabling flight hardware.

Focus

- Biomaterials Processing
- Biomedical Models of Earth-borne Diseases
- Controlled Ecological Life Support Systems
- Hardware Development
  - AGBA (Autonomous Generic Bioprocessing Apparatus) for automated mixing in microgravity, which has flown successfully on sounding rockets
  - BIMDA (BioServe/Instrumentation Technology Associates, Inc. Materials Dispersion Apparatus) supports bioprocessing activities in space and is qualified for flight on the Shuttle Middeck
  - GBA (Generic Bioprocessing Apparatus) permits the use of a variety of methods for processing biological samples, including multiple mixing regimes, controlled incubation, real-time data acquisition, sample visualization and storage of processed materials
  - Plant lighting, nutrient delivery systems, containment control technology and advanced monitoring for Closed Environment Life Support System (CELSS) applications
  - Bioreactor development for waste management using cultivated microorganisms
  - Management of development of a re-entry system for COMET (COMmercial Experiment Transporter)

Achievements

BioServe has established a broad spectrum of life sciences research projects, including ground based models and controls. The CCDS also has flown numerous successful biomaterials processing experiments on NASA's KC-135 aircraft, testing effects of reduced gravity on hardware proposed for use in CELSS.

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Center for Advanced Space Propulsion (CASP)

Affiliation and Mission

The Center for Advanced Space Propulsion is affiliated with the Calspan Center for Aerospace Research at the University of Tennessee. Its mission is to stimulate research in and contribute to those propulsion technologies considered prime in achieving the three basic flight mission objectives for the next few decades. These objectives are:

- Economic and reliable access to space and Space Station
- High-performance systems for lunar and interplanetary missions
- Effective means for transfers between Low Earth and Geostationary Orbits

Focus

- Advancing chemical propulsion
- Artificial Intelligence/expert systems and hypertext propulsion system applications
- Microgravity fluid management
- Electric propulsion systems
- Propulsion system laser materials processing

Achievements

Investigators designed and constructed hardware for a cryogenic fluids transfer experiment for flight on a KC-135. Ground experiments in 1990 successfully demonstrated the basic concepts and verified the computer code used in the design. Among other research, the Center also is testing an ion thruster in a vacuum facility.

The Center for Advanced Space Propulsion is responsible for program management of the COMmercial Experiment Transporter Program (COMET), a joint effort of the CCDS's.

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Center for Cell Research (CCR)

Affiliation and Mission

The Center for Cell Research was established at Pennsylvania State University in 1987. Its primary goal is to promote commercial life sciences space ventures by providing research expertise and access to NASA flights aboard rockets, satellites and the Shuttle.

Focus

The Center for Cell Research (CCR) investigators are working with pharmaceutical and biotechnology firms, instrumentation companies and lighting manufacturers to help them take advantage of the commercial opportunities the microgravity environment provides. CCR commercial partners receive spaceflight access, flight planning expertise, payload planning, access to flight-certified hardware plus ground-based research support.

Current CCR research programs include, but are not limited to:

- Defining the effects of microgravity on mammalian cells, tissues, organs and systems
- Establishing parallels between microgravity-induced effects and human disease on Earth
- Using the microgravity environment as an aid to separation and purification of valuable molecules, cells and subcellular particles
- Designing equipment for space-based life science research, development, testing and analysis
- Studying the effects of visible light on the immune and endocrine systems for applications in lighting design for human habitation in space and on Earth

Achievements

The Center for Cell Research and Genentech, Inc., of South San Francisco, CA, is conducting experiments aboard the Shuttle to investigate the biological changes caused by weightlessness and how closely those changes resemble Earth-based medical problems.

The Penn State Biomodule (see page 82), a robotic, minilab capable of testing eight biological samples automatically, was successfully flight-tested in 1990. The Biomodule is scheduled to be aboard a suborbital rocket flight every six months and is available for commercial projects.

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Center for Commercial Crystal Growth in Space

Affiliation and Mission

The Center for Commercial Crystal Growth in Space is a consortium of universities, companies and national laboratories, founded in 1986 and managed by Clarkson University. The Center's main goal is to develop the technology for commercial growth of crystals in space. Such crystals have applications to high-speed integrated circuits, infrared sensors, optical communications and radiation sensors.

Focus

The Center for Commercial Crystal Growth in Space is organized into three teams, by growth technique:

- Vapor growth: cadmium telluride and mercury halides
- Solution growth: triglycine sulfate and l-alanine phosphate
- Melt growth: gallium arsenide, cadmium telluride and indium antimonide

The National Institute of Standards and Technology, one of the Center's members, characterizes crystals with high resolution short exposure X-ray topography on the National Synchrotron Light Source at Brookhaven National Laboratory.

Achievements

Projects at the Center have included:

- Discovery of additives to triglycine sulfate (TGS) that dramatically improve TGS's performance as an infrared sensor
- Discovery of additives to zeolite crystallization mixtures that greatly increase crystal size
- Development of improved mixing techniques and formulations for zeolite crystallization
- Automated hardware for zeolite crystallization in space
- Reproducible techniques yielding greatly accelerated vapor growth of high quality cadmium telluride crystals

Center for Commercial Crystal Growth in Space (continued)

Achievements (continued)

- Development of techniques for vapor growth of cadmium telluride in space
- An improved ampoule treatment technique for directional solidification of gallium arsenide
- Development of liquid encapsulated floating zone melting for growth of single crystal gallium arsenide
- Determination of factors influencing contamination of gallium arsenide by liquid encapsulants
- Elucidation of defects in undoped and indium-doped gallium arsenide
- Discovery that the major factor determining the stress level and dislocation formation in directional solidification is the degree to which the crystal sticks to its ampoule
- Measurement of contact angle and surface tension of GaAs and CdTe on various surfaces
- Determination of the gas circulation pattern in vapor growth of mercury halides
- Determination of the influence of g-level on directional solidification in a large human centrifuge

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Center for the Commercial Development of Space Power and Advanced Electronics

Affiliation and Mission

The Center for the Commercial Development of Space Power and Advanced Electronics was established at Auburn University in 1987. The overall objectives of this Center are to identify the critical technological impediments to the economic deployment of power systems in space, advance these technologies and develop new products to meet the power generation, storage, conditioning and distribution needs. The goal is to provide quality power and reliability to the space customer by assuring that the products are space rated, cost effective, efficient, fault tolerant and autonomous.

Focus

The Center is taking the output from a variety of primary sources and providing the components and systems necessary for the efficient transmission, conditioning and distribution of electrical power in a space environment, in a form suitable to match the load requirements of commercial ventures in space and at costs which are commercially viable. This involves a synergistic interaction between space science, technology research and product development, not only to support these objectives, but also in the domain of component and system health maintenance.

Research areas include:

- Power distribution, control and management
- Power transmission
- Discrete power/energy storage sources
- Power conditioning
- Sensors, system reliability and parallel processing

Achievements

Each research project within the Center offers the promise of commercial potential. At the same time, complete systems are required for space power applications. This necessitates integration of all research areas in the program with the result being an overall technology focus.

Current research will provide the basis for developing complete power system packages, tailored to specific user needs. An example of this work deals with the design and fabrication of power conversion equipment. This project involves the investigation of candidate circuit topologies for specific applications to determine their impact on such issues as weight, efficiency, component stress and reliability.

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The Center for Macromolecular Crystallography (CMC)

Affiliation and Mission

The Center for Macromolecular Crystallography (CMC), established at the University of Alabama at Birmingham in November 1985, was among the first five CCDS's created by NASA. The goals of the Center are to develop the potential of the low-gravity environment of space for protein crystal growth research, to help its industrial, academic and governmental affiliates gain access to space, and to provide a variety of research capabilities in protein crystallography to industrial groups.

The wide range of services available through the CMC has made it possible for pharmaceutical, biotechnology and chemical firms to become more actively involved in commercial applications of macromolecular crystallography, an involvement that eventually will lead to commercial applications of protein crystal growth in space.

Focus

- To design and construct, in partnership with industrial affiliates, protein crystal growth hardware that will permit large-scale protein crystallization in microgravity on Shuttle missions
- To develop hardware that will permit protein crystal growth experiments in microgravity to be monitored and controlled in elaborate and automated detail on both Shuttle and freeflyer missions
- To conduct fundamental studies in protein crystal growth, including detailed studies of nucleation processes by laser light-scattering techniques; crystallization studies with various types of proteins; design and construction of prototype advanced protein crystal growth hardware that permits real-time monitoring of growth solutions; and research toward the design of automated protein crystal growth systems which permit dynamic control of crystallization processes
- To conduct crystallographic studies of proteins of basic importance to biomedical research, leading to practical applications of crystallography, particularly in the area of drug design and protein engineering

Achievements

Macromolecular crystallography is a powerful research tool in the pharmaceutical, chemical and biotechnology industries for drug design and protein engineering. Through a series of eight Shuttle flights during 1985-1990, the Center's protein crystal growth experiments have demonstrated that microgravity-grown crystals are larger, display more uniform structures, and yield X-ray diffraction data to significantly higher resolutions than the best crystals of these proteins grown on Earth.

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Center for Mapping

Affiliation and Mission

The Center for Mapping, established at Ohio State University in 1986, conducts research in the areas of remote sensing and geographic information systems. Its main goal is to assist the U.S. private sector in the development of commercial remote sensing products and services.

Focus

This CCDS was created to address problems associated with the tremendous volume of remotely sensed data now becoming available, its compatibility with other types of data, its general utility and its marketability. The overall theme of the Center research projects is spatial digital data processing, however research projects can be broken down into five categories:

- Natural resource and farm management
  - design of a forest land use allocation model
  - development of an agricultural yield and production information system
  - establishing new criteria for gold exploration
- Digital image processing and computer vision
  - extracting three-dimensional information from aerial imagery and determining digital elevation models
  - developing strategies for dynamic, 3-D cartographic displays
- Satellite services
  - improving ocean routing using altimetry data
  - applying global positioning systems to transportation planning

Center for Mapping (continued)

Focus (continued)

- Disaster assessment
  - monitoring landslide hazard from snowmelt
- Energy and power production
  - determining feasibility of selected satellite applications to the gas and pipeline industry
  - integrating satellite, airborne and surface geophysics for global hydrocarbon exploration

Achievements

The Center for Mapping is developing a mobile workstation (i.e., mounted in a van) that combines satellite positioning signals with digital photographic images to automatically map and record crucial features of the nation's highways. The data and information generated from this workstation will be used by government transportation agencies to monitor road conditions and improve planning for highway maintenance. This research effort is expected to produce a range of commercial products. Moreover, it has the potential to revolutionize the data entry problem because the system can be mounted in airplanes, boats and other platforms and ensures the accuracy and homogeneity of digital data.

General Facilities

- Cray Y-MP/24 Supercomputer
- Digital VAX 8530
- Sun 3/150C-4-P5
- Intergraph 6000
- Intergraph 3050 (2)
- Apollo 4500
- Textronix 4129/DI-3000 3-D
- Trimple 4000SX GPS Receivers (5)
- Eikonix A80-A 4K x 4K Camera
- 80386 PC Image Processing/GIS Systems (3)

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Center for Materials For Space Structures

Affiliation and Mission

The Center for Materials for Space Structures, established at Case Western Reserve University in 1987, is focused on providing materials which are capable of being processed in space and withstanding the space environment. In addition to their direct use in space structures, these new materials are being developed commercially for Earth-bound applications.

Focus

- Organic composites
- Metallic (aluminum and magnesium alloy) composites
- Low cost ceramic composites
- Inorganic and organic protective coatings
- Space structure material environmental stability

Materials are being developed for use in structures that will be made and/or assembled for use in the space environment.

Specific Requirements:
Key Applications of Low Earth Orbit Space Materials
a. Minimum of 30 Years Life
b. Environmental and Mechanical Attack
c. Mechanical Considerations
d. Thermal Fluctuations
e. Space Environmental Effects
f. Manufacturing Processes
g. Cost

Mechanical Properties of Interest:
Specific stiffness, specific strength, fracture properties, fatigue properties, thermal considerations, space environment materials degradation.

Space Flight Program

Materials produced by Center projects will be verified for space environment stability by testing on future space flights beginning in 1991 and continuing through 2005. The Space Flight Program concentrates on using existing and planned Space Transportation Systems to facilitate exposure of materials while reducing costs.

Center for Materials for Space Structures (continued)

Equipment

The Center for Materials for Space Structures currently houses the following equipment:

- JEOL-JSM-840A Scanning Electron Microscope
- Thermal Fatigue Testing Unit
- Variable Angle Spectroscopic Ellipsometer (VASE) (J. A. Woollam Company)
- ASTM E-595 Low Outgassing Test Service (McGhan Nusil performs this test as a service to the Aerospace Community. The company also supplies the CV24 Volatility Test Bench to companies wishing to purchase this testing apparatus.)
- RF Plasma Ashing Apparatus
- Infrared Spectrometer (Nicolet System 800)
- Acoustic Microscope
- Low-Voltage Scanning Electron Microscope Facility
  - Model JSM-840
  - Magnification range: 10x to 300,000x
- Thermal Fatigue Testing Unit Facility
  - Temperature Range: +250° F to -200° F

Achievements

The Materials for Space Structures at Case Western Reserve University maintains an extensive materials research program.

The Space Flight Program provides a cost-effective manner for industry, government and academia to access space for materials evaluation on a limited cost-share basis.

Contact: Eric Baer, Director
Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Avenue
Cleveland, OH 44106
(216) 368-4202, Fax (216) 368-3209

Center for Space Power

Affiliation and Mission

The Center for Space Power, established at the Texas A&M University in 1987, conducts research relevant to space power, and develops and demonstrates technology associated with the commercial use of space. Its goal is to demonstrate that providing power in space is an attractive commercial venture. Towards this end, the Center's objectives are to conduct research critical to the commercial success of industry and related to space power needs, stimulate technology interchanges and the training of space technology professionals, enhance educational programs and achieve economic viability independent of NASA funding.

Focus

The Center for Space Power sponsors research and product development in the areas of space power requirements, power generation and conversion, power system design, power conditioning and control, energy storage, power transmission, materials and thermal management.

Achievements

The Center for Space Power is developing flight experiments onboard the Shuttle to evaluate microwave power transmission, frozen startup of a heat pipe in microgravity, micro heat pipes, Rankine cycle power systems and solid polymer electrolyte fuel cells.

Contact: Alton D. Patton, Director
Center for Space Power
Texas A&M University
Wisenbaker Engineering Research Center
Room 223
College Station, TX 77843-3118
(409) 845-8768, Fax (409) 845-8857

Conduction Heat Transfer Laboratory

This laboratory consists of several high vacuum test facilities, in which steady-state thermal contact resistance tests can be conducted; a periodic contact resistance test facility for evaluating transient and periodic contact resistance; a guarded hot plate for making steady-state thermal conductivity measurements; and the facilities for testing and modeling a wide range of heat pipes, passive high conductance devices, utilizing the latent heat of vaporization for heat transfer.

The steady-state thermal contact resistance test facility is comprised of three test chambers with loading capabilities of 2,000, 1,000 and 100 pounds. The high vacuum systems allow measurements to be made in a wide variety of gaseous environments or under vacuum pressures as low as 10^{-8} torr.

Center for Space Power (continued)

The periodic contact test facility is used to evaluate transient and periodic contact resistance phenomena and provide information on the influence of the cycle period on other parameters that have an impact on the thermal contact resistance.

The guarded hot plate test facility is designed for a sample size ranging from two to three inches in diameter and a maximum power input of 100 watts.

Contact: L. S. Fletcher
Center for Space Power
Wisenbaker Engineering Research Center
Texas A&M University
College Station, TX 77843
(409) 845-7270

Tribiology Laboratory

This laboratory studies the compound and fretting wear characteristics of metals and alloys. Two wear machines are available for studying the interactions of forces, sliding velocities, impact frequencies and frictional characteristics of materials.

The equipment fits within a conventional laboratory setting. The compound wear tester occupies approximately 15 square feet and weighs about 700 pounds.

Contact: R.B. Griffin
Center for Space Power
Wisenbaker Engineering Research Center
Texas A&M University
College Station, TX 77843
(409) 845-1251

Center for Space Processing of Engineering Materials

Affiliation and Mission

The Center for Space Processing of Engineering Materials at Vanderbilt University was one of the five initial CCDS's established in 1985. The goals of the Center at Vanderbilt are to establish the technical feasibility and commercial potential of the space environment for materials processing research and manufacturing applied to high value-added engineering materials and highly leveraged Earth-based processes.

Focus

- Advanced thermal gradient processing technology for solidification processing of metals, alloys, semiconductors and oxide crystals
- Earth-based applications of the NASA/CCDS-developed containerless processing technologies for ultrapure materials and rapid solidification processing

Achievements

The Center has been allowed a composition-of-matter patent for a new permanent magnet material that significantly increases the resistance to demagnetization of magnets based upon alloys of platinum-cobalt. This development may induce the application of platinum-cobalt permanent magnets into entirely new series of devices.

The Center developed and is installing a pilot plant for coupling the proven benefits of rapid solidification processing with NASA/CCDS-developed containerless processing technologies. It is expected that this new facility will demonstrate significant processing advantages for many materials of industrial interest.

The Center is undertaking the development of a freeflying solar furnace for advanced thermal gradient processing of metals, alloys, semiconductors and oxide crystals. Evaluations are proceeding to demonstrate the technical feasibility of the unique approach, define the parameters of the space-based facility and illustrate the economics involved.

Contact: Tony Overfelt, Director
Center for Space Processing
of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7054, Fax (615) 322-7062

Consortium for Materials Development in Space (CMDS)

Affiliation and Mission

The Consortium for Materials Development in Space was established at the University of Alabama at Huntsville in 1985. Its mission is to stimulate investigations in space as a means to develop new materials and processes that benefit from the unique attributes of space. Projects rely on innovative applications of physical chemistry materials transport and their interactions.

Focus

- Commercial materials
- Commercial applications of physical chemistry and material transport
- Prompt and frequent experiments and operations in orbit

Achievements

Principal activities of the Consortium include physical vapor transport growth of highly non-linear optical inorganic and organic crystals and thin films; surface coatings and surface particle inclusions by electrodeposition; material preparations and longevity in hyperthermal atomic oxygen; physical properties of immiscible polymers and unique polymer production; and powdered meter sintering.

Another major activity undertaken by the Consortium is the first development of a material with a transition temperature to superconductivity above the temperature of liquid nitrogen. Researchers are evaluating the application of superconducting devices and circuits in commercial satellites cooled passively by thermal radiation to space.

The Consortium launched the first rocket requiring a Department of Transportation commercial launch license on March 29, 1989. The flight, called Consort-1, provided over seven minutes of low gravity for a variety of materials experiments. A second launch, Consort-2, did not achieve microgravity. However, a third launch, Consort-3, flew on May 16, 1990 and was considered very successful. Ten of the twelve microgravity experiments aboard operated as planned and offered results in the 14-minute flight that provided about seven minutes of microgravity.

Plans for a new series of longer duration low gravity flights are underway. The Joust series will provide between 13 and 15 minutes of low gravity, beginning in 1991.

Contact: Charles Lundquist, Director
Consortium for Materials Development in Space
University of Alabama/Huntsville
Research Institute Building
4701 University Drive
Huntsville, AL 35899
(205) 895-6620, Fax (205) 895-6791

Space Automation and Robotics Center (SpARC)

Affiliation and Mission

The Space Automation and Robotics Center (SpARC) (formerly, the Center for Autonomous and Man-Controlled Robotic and Sensing Systems) is located at the Environmental Research Institute of Michigan, in Ann Arbor, and is affiliated with the University of Michigan.

SpARC's goal is to be the nation's premier center to promote and facilitate the development and application of space-related automation and robotics technologies by U.S. industry.

Focus

- Promotion of space automation and robotics technologies; maintain and disseminate information on all aspects of space automation and robotics technologies; and promote an appropriate environment for the propagation and utilization of these technologies by networking and collaborating with U.S. industry, NASA and other organizations and individuals in related areas
- Development of automation and robotics technologies; initiate and conduct major projects with U.S. firms and other NASA Centers to link and integrate the components of space automation and robotics technologies and extend their boundaries
- Provide a complete range of services to help U.S.-based companies in selecting, adapting and applying appropriate space automation and robotics technologies to solve particular problems and gain a competitive edge

SpARC focuses on the following technologies:

- Tele-sciences (robot-control, tele-robotics and perception and information assimilation), artificial intelligence (particularly distributed AI), knowledge-based systems, machine learning and expert systems), computer vision and signal interpretation, human interfaces, mobile robots and system integration

Space Automation and Robotics Center (SpARC) (continued)

Focus (continued)

Possible application areas include: manufacturing automation, material processing, pharmaceuticals, environmental restoration/waste management, medical imaging, earth resource applications, geographic information systems, service robotics, satellite communication, intelligent vehicles, Mars & lunar missions and space stations.

Achievements

SpARC has initiated more than twenty projects, many of which have been completed successfully, including:

- Design For On-Orbit Spacecraft Servicing (DFOSS) Handbook
- Development of a photo-bioreactor and green cell lines for Closed Environment Life Support System (CELSS)
- Space Technology Education Program (STEP)
- Tele-Autonomous Multiple Arm Control and System Infrastructure
- Optical estimation of absolute spatial positions of a robot
- Tele-perception concept development

Contact: Ramesh Jain, Director
Space Automation and Robotics Center
Environmental Research Institute
of Michigan (ERIM)
P.O. Box 8618
Ann Arbor MI 48107-8618
(313) 994-1200 x2457, Fax (313) 665-6559

Space Remote Sensing Center (SRSC)

Affiliation and Mission

The Space Remote Sensing Center is a division of the Institute for Technology Development (ITD) and is located at the NASA/Stennis Space Center in Mississippi. Its objective is to provide commercial technology applications development of satellite remote sensing, image processing and geographic information systems.

Focus

Through its close relationship with Stennis Space Center, numerous universities and private organizations, and other government agencies, this CCDS is exploring ways to increase the operational productivity and efficiency of professionals involved in land planning and resource management through the utilization of remote sensing images and data.

Achievements

The Space Remote Sensing Center conducts an applications development program aimed at end users and a technology innovations program aimed at the valued-added services and support industry. This program is creating advanced techniques for agriculture crop monitoring, forest mensuration, environmental assessment, facilities monitoring and land use planning. Economic benefits are gained directly from improved operational planning, which can lead to lower project cost.

The Center has been designated as the official support center for the U.S. Army Corps of Engineers Construction Engineering Research Laboratory's software package called Geographic Resources Analysis Support System (GRASS). The geographic information and image processing system was ported to the Apple Macintosh II personal computer through the Center's Apple Developer partnership. This has enabled many potential users of remote sensing and geographic information to access this data on a low-cost system. An example of this effort is the development and presentation of a short course in the use and applications of MacGRASS 3.1, which includes lectures, individual tutorials and extensive hands-on experience.

Consulting Capabilities

- Image data processing
- Geographic Information System (GIS) applications
- Specialization in forestry, agriculture and other Earth resources

Data Processing Facility

- MASSCOMP 6650, 5600 and 5450
- Apple Macintosh
- Astronautics ZSI mini-super computer
- Colcomp and geophysics digitizer tables
- Matrix camera
- Image processing workstations (5)
- VerseTec wide-bed plotter

Contact: George May, Director
ITD Space Remote Sensing Center
Building 1103, Suite 118
NASA/Stennis Space Center MS 39529
(601) 688-2509, Fax (601) 688-2861

Space Vacuum Epitaxy Center (SVEC)

Affiliation and Mission

The Space Vacuum Epitaxy Center, established at the University of Houston in 1986, is unique in its focus on the ultra-vacuum aspect of space for materials processing and purification.

Major research efforts are in the areas of definition of epitaxially-grown compound semiconductor materials for enhancement under space ultra-vacuum conditions; and the definition and development of superconducting epitaxially grown films with Low Earth Orbit space-enhanced characteristics.

Focus

- Adaptation of the Molecular and Chemical Beam Epitaxy (MBE/CBE) process to space
- The production of new electronic, magnetic and superconducting thin film materials and devices as well as materials purification in terrestrial laboratories and space for commercial exploitation
- The development of commercial space hardware (for example the Wake Shield Facility) for research and development and enhanced access to space

Current Research and Development activities include:

- CBE Growth of Compound Semiconductors
- MBE Growth of High-T_c Materials
- MBE Growth of InGaSb/InAs Superlattices
- Induced Magnetic Field Quantization in Low-dimensional Systems
- Atomic Layer Epitaxy of InGaSb/InAs SLS
- Surface Science of High-T_c Materials
- STM Studies of Ge/Ge and Ge/GaAs
- RHEED Studies of MBE Growth Kinetics
- Laser Deposition of High-T_c Materials
- Disordered Superlattice Studies
- MOCVD Growth of High-T_c Materials
- Wake Shield Facility Development

Achievements

The Center is placing major emphasis on helping to increase access to, and utilization of, the space ultra-vacuum. This ultra-vacuum can be achieved by deployment of a Wake Shield Facility (WSF) in a Low Earth Orbit. SVEC and Space Industries, Inc., of Houston, TX, are jointly developing the flight hardware for the Shuttle-deployable Wake Shield Facility.

Researchers expect the disk-shaped wake shield to produce an ultra-vacuum in the order of 10^{-14} torr in its wake. The first experiment, scheduled for flight on the Shuttle in 1993, will go as a freeflyer, allowing the facility to have about sixty hours of freefly epitaxial growth runs before being retrieved by the Shuttle's Remote Manipulator System. The experiment will include GAS canisters as part of the WSF structure. These "Smart Payload Canisters" will provide on-board command and control as well as power.

Contact: Alex Ignatiev, Director
Space Vacuum Epitaxy Center
University of Houston
Science & Research Building I
4800 Calhoun Road
Houston TX 77204-5507
(713) 749-3701, Fax (713) 747-7724

Wisconsin Center for Space Automation and Robotics (WSCAR)

Affiliation and Mission

The Wisconsin Center for Space Automation and Robotics was established at the University of Wisconsin in 1986. Its mission is to conceive, demonstrate and stimulate commercial opportunities in automation and robotics technology for use in space for Astrobotics™, Astroculture™ and Astrofuel™.

Focus

The Center's three-prong program is focused as follows:

- Astrobotics™ – automation and robotic technologies for performing functional tasks required of humans to live, travel and explore in space
- Astroculture™ – agriculture technologies for the production of food supplies and waste recycling to support humans' existence in space
- Astrofuel™ – acquisition of helium-3 (He-3) from lunar and planetary sources for supplying fusion energy for use on Earth and in space travel

Achievements

The Wisconsin Center for Space Automation and Robotics conducts research in laboratory facilities throughout the University of Wisconsin/Madison campus. Talent is drawn from university faculty and staff in engineering, agriculture, medicine and the physical sciences, together with industrial consortium members.

Since its inception, WSCAR has achieved the following accomplishments:

- High performance grippers and intelligent grasping units
- Robot finger tip force and torque sensors
- Telerobotic performance analysis system
- Adaptation of technologies for the physically impaired
- Humidity control and water recovery system
- Plant lighting system based on LEDs
- Water and nutrient delivery system for plants
- Completion of a lunar He-3 resource assessment
- Study of environmental effects of He-3 recovery from the moon
- Analysis of the financial factors governing the profitability of a lunar He-3 venture
- Equipment and operational concepts for recovery of volatile materials from lunar regolith

Contact: John Bollinger, Director
Wisconsin Center for Space Automation and Robotics
University of Wisconsin
1357 University Ave.
Madison WI 53715
(608) 262-5524, Fax (608) 262-6707

Chapter 6: Other Ground-Based Facilities

In addition to NASA and the Centers for the Commercial Development of Space, several companies and universities have identified facilities which are available to other users. Included along with specific items of hardware are "clean rooms" and other facilities which form a necessary step in fabricating and testing a unit of space flight hardware.

Acoustic Thermal Test Facility (ATTF)

This test facility can be used to test spacecraft, space vehicles or structures requiring space systems cleanliness levels and environmental standards. It offers the largest integrated high-intensity acoustic and temperature cycling chambers now in operation.

Acoustic Thermal Test Facility – Main Structure

Dimensions:	130 ft x 80 ft x 60 ft H
Square footage:	10,000 ft^2
Overhead crane:	10-ton traveling bridge crane
Main Control Room:	41 ft x 46 ft
Main entry:	30 ft x 50 ft H
Building conditioning:	Class 100,000 clean room
Buildup/staging area	
Security/controlled access	

Acoustic Chamber

Dimensions:	33 ft x 40 ft x 50 ft H
Volume:	65,000 ft^3
Frequency range:	25 to 10,000 Hz
Sound pressure level:	154 dB
Data acquisition:	200-Channel Digital Acquisition System

22,000 Gal Cryogenic Tanking Abilities

Thermal Chamber

Dimensions:	30 ft x 31 ft x 50 ft H
Volume:	46,500 ft^3
Temperature range:	-40° F to +185° F with humidity control
Temperature rate change:	1° F/minute
Data acquisition:	200-Channel Graphic Display/Plots

Contact: D. A. Nirschl, Director
Test and Evaluation, MZ 23-8370
General Dynamics Space Systems Division
P.O. Box 85990
San Diego, CA 92186-5990
(619) 573-999

Antenna Test Facilities

Range length is 1,700 feet.

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Assembly and Integration Facility

Certified clean area – 4,000 ft^2
Storage area
General work area
5-ton bridge crane (2)
7 1/2-ton gantry crane
Optical alignment system
Assembly and flight hardware handling equipment

Contact: Karole G. Monks
Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807-5301
(205) 726-5613

Environmental Test Facilities

Static Load Test Facility
Vibration Test Facility
Space Simulation Facility
Space Chamber

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Ground-Based Containerless Processing Facility

The Intersonics' laboratory equipment can be reconfigured and optimized for various materials. The multidisciplinary team at this facility is engaged in equipment development and containerless property measurement and processing research. The laboratory presently operates a 5 kW electromagnetic levitator (pressures from high vacuum to 2 Bar), two aerodynamic levitators (with gas mixture handling), a prototype high pressure acoustic levitator and a breadboard high temperature acoustic levitator. The high temperature acoustic levitator is equipped with xenon-arc lamp beam heating and can be used onboard the KC-135 aircraft. The facility includes a 300 W CO_2 heating laser and a 100 W, 2.45 GHz microwave generator for processing or heating, a tunable dye laser for laser-induced fluorescence analysis, a mass spectrometer for gas analysis, a laser polarimeter for optical property measurement and pyrometers for temperature measurement.

Contact: Richard Weber or Robert Schiffman
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL. 60062
(708) 272-1772

Satellite Assembly and Test Facilities

Class 10,000 clean room

11.9-meter diameter thermal-vacuum chamber

High-bay class 1B area

Class 100,000 clean room-final integration with a KR-85 leak tester

Anechoic chamber

Contact: T. A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Space Hardware Environmental Qualification and Testing Facilities

This facility provides ground-based and space flight hardware environmental qualification testing and analysis.

A partial list of environmental qualification analyses/tests available includes:

- space flight-acceleration (high/low frequency and on-orbit)
- on-orbit load, random vibration, shock, vibroacoustics, thermal vacuum, operational and non-operational environments, i.e., temperature, pressure, humidity
- Transport/storage packaging-temperature pressure humidity, fungus, salt spray, rain, hail, snow, solar radiation, ozone, sand/dust, vibration, handling shock

Contact: Robert A. Hall, Manager-Space Programs
Wyle Laboratories
P.O. Box 1008
Huntsville, AL 35807-5101
(205) 837-4411

Space Simulation Chamber/Laser Diagnostics

Cylindrical Vacuum Chamber (9 ft diameter x 20 ft long)

- 2 kw helium refrigerator
- 2 stage helium compressor
- LN_2 Heat Shield and gaseous He finned array
- Two 16" cryopumps/mechanical and diffusion pumps
- Vacuum Instrumentation
- Optical Quality Ports

Power Supplies/Instrumentation for Testing Electric Thrusters and Performing Plasma Diagnostics

Laser Systems

- Subpicosecond Laser System
- Picosecond Excimer Laser
- CO_2, Argon Ion, Tunable Dye, Nd:YAG, HeNe

Computer Systems

Image Analyzers

Contact: George W. Garrison, Director
Center for Advanced Space Propulsion
University of Tennessee/Calspan
P.O. Box 1385
Tullahoma, TN 37388
(615) 454-9294

Space Simulation Chamber/Pulsed Power Facility

Cylindrical vacuum chamber
(1.8 m diameter x 2.4 m L)

Energy storage system for pulse testing

Allen-Bradley computer

IBM-PC-AT computer

Contact: D. A. Fikse, Manager
Electromagnetic Applications
Westinghouse Science and Technology Center
1310 Beulah Road
Pittsburgh, PA 15235-5098
(412) 256-2312

Subsystems Test Facilities

Three-axis Servo Table

Class 100,000 laboratory

Battery/cell test area

Solar Array facility

Electromagnetic Compatibility/Interference facilities

Contact: T.A. Dougherty, Manager
Space Station Power Programs
Ford Aerospace Corporation
Space Systems Division
3939 Fabian Way
Palo Alto, CA 94303-4697
(415) 852-6108

Sycamore Canyon Hazardous Test Facility

The Sycamore Canyon test facilities can be used for large scale cryogenic tests and limited ordnance testing deemed too hazardous for metropolitan areas. It offers various sizes LH_2 test stands, remote block houses and personnel experienced in hazardous test operations. These facilities offer:

Liquid hydrogen testing combined with other environments
Liquid nitrogen testing
Cryogenic proof and burst testing
Cryogenic cycling tests
Cryogenic vacuum testing
Other hazardous propellants considered
Leak testing
Flow testing
Large-scale structural testing
Staging ordnance testing
Small SRM test firings
Instrumentation landlines
Security

Contact: D. A. Nirschl, Director
Test and Evaluation, MZ 23-8370
General Dynamics Space Systems Division
P.O. Box 85990
San Diego, CA 92186-5990
(619) 573-9991

Underwater Test Facility (UWTF)

The Underwater Test Facility is a large, optically clear tank of water used to conduct neutral-buoyancy simulation of the weightless environment encountered in space. Experiments, in either EVA or IVA mode, addressing assembly, maintenance or repair of hardware elements, can be performed in the tank. Extravehicular Mobility Units (EMU Space Suits) are available to support EVA simulations. A high-fidelity full-scale Shuttle cargo bay mock-up is used to support experiments associated with Shuttle payloads. Underwater video cameras are used for data acquisition and assessment of operational procedures. Full duration EVA or IVA proposed tanks can be simulated by the use of neutral buoyancy techniques in the tank. The tank also can be used for other hardware development or test activities requiring a large, environmentally controlled body of water.

Operational Characteristics

Dimensions:	70 ft diameter x 36.5 ft deep, in ground
Volume:	approximately 1 million gallons of water
Overhead Crane:	5-ton capacity
Water:	Optically clear and thermally conditioned
Data Acquisition:	Audio and video

Contact: D. A. Forge or A. W. Maddox
McDonnell Douglas Space Systems Co.
MS 38-2
5301 Bolsa Avenue
Huntington Beach, CA 92647
(714) 896-5544

Lujan Center for Space Telemetering and Telecommunications Systems

The mission of this Center is to support the development of technology for space-based telemetering and telecommunications systems through research, consulting and educational activities. Research areas include:

- Bandwidth-efficient coding and modulation techniques
- Packet telemetry protocols and processing
- Optical communications
- Digital image processing

The Center has laboratories for:

- Design of communications hardware
- Optical communications
- Computer-based simulation and modeling

Contact: Frank Carden, Director
New Mexico State University
Box 30001, Dept. 3-0
Las Cruces, NM 88003-0001
(505) 646-3012, Fax (505) 646-3549

Physical Science Laboratory

The mission of this facility is to design, fabricate and test space-qualified support hardware with particular emphasis on microcomputer-controlled systems, high voltage power supplies, altitude control systems, and electronic data and telemetry systems. The lab is especially applicable to commercial developers who are utilizing Get-Away Special (GAS) canisters, SPARTAN carriers, satellites, rockets or balloon-borne systems. Activities also include operational and program management support.

Contact: Bernard M. McCune
Chief, Space Payload Section
Physical Science Laboratory
New Mexico State University, Box 30002
Las Cruces, NM 88003-0002
(505) 522-9100, Fax (505) 522-9434

Solar Furnace Facility

- 90.25 ft^2 flat heliostat
- 5-ft diameter parabolic concentrator
- 192-ft^2 data acquisition and office building
- HP-87 computer

Contact: Dan O'Neil
Georgia Tech Research Institute
Atlanta, GA 30332
(404) 894-3589

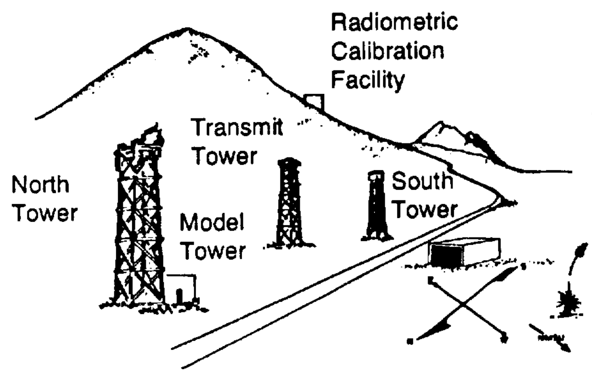
Physical Science Laboratory Outdoor Antenna Range

The Antenna Range is a free space elevated range, centered around three principal towers. These towers are of wooden construction, about 82 feet tall, with elevators for lifting large heavy structures (up to 700 pounds). The towers are arranged in a line with the central tower about 320 feet from the north tower and 160 feet from the south tower. Each tower has an associated control building which contains a receiver, chart recording equipment and positioner control console.

To facilitate small antenna design and development efforts, a model tower is elevated 35 feet and 130 feet from the center tower. The model range tower tilts 90 degrees for easy access to the positioner head, which rotates a full 360 degrees. The tower rotates a full 360 degrees and is capable of lifting 200 pounds.

Additional range legs are provided from the central tower. An auxiliary remote illuminator tower is located on a hillside about 3,000 feet away. Concrete pads are available for placing positioners 1,500, 2,200 and 3,000 feet away from the center tower. Many standard elevation, azimuth and polarization positioners are available for antenna system testing. Many of these positioners can be mounted on either the 82-foot towers or any of the additional range legs. A very large positioner suitable for ground operation also is available. It can accommodate up to 40,000 pound devices with moments up to 600,000 foot-pounds.

Contact: Bernard M. McCune
Chief, Space Payload Section
Physical Science Laboratory
New Mexico State University, Box 30002
Las Cruces, NM 88003-0002
(505) 522-9100, Fax (505) 522-9434



Chapter 7: Airborne Facilities

Aircraft and balloons provide the opportunity to conduct research related to remote sensing, climatology, microgravity and other activities. NASA supports these activities with aircraft flown from three NASA Centers: Ames Research Center, Wallops Flight Facility and Stennis Space Center; and with balloons supported by Wallops.

Like satellites, airborne instruments observe atmosphere, ocean and land. However, unlike satellites, airborne instruments are available for modification. Virtually all satellite-borne sensors used in Earth sciences were developed first as airborne instruments.

Airborne facilities that provide microgravity environments for limited periods of time include sounding rockets, aircraft with parabolic flight paths and high-altitude balloons. The use of these facilities may be considered an interim step between ground-based and space-based research; or it may serve as a cost-efficient opportunity to test out a theory. Both experiment design and hardware construction also may be tested in the limited capacities of airborne facilities. (Note: Sounding rockets are described in Chapter 20.)

Balloons

Balloons provide platforms that carry payloads with scientific instruments to make measurements at altitudes of up to 30 miles. They provide much longer flight times than sounding rockets, without the rigors of rocket liftoff, vibration and g-forces, permitting laboratory-quality equipment to be flown.

Balloons are made of thin, polyethylene material .8 mil thick and up to 30 million cubic feet in volume at full inflation. Historically, the thickness ranges from 0.5 mil to 1.5 mil and up to 50 million cubic feet in volume. Payloads up to 5,500 pounds can be accommodated and flight durations may vary from one to 60 hours. A new capability in the form of long-duration flights of several weeks or months is under development. A tethered balloon system also is used and can carry a 400-pound payload to a one-mile (5,280 ft.) altitude. High-altitude balloons can provide up to a minute of microgravity for experiment payloads.

Capabilities and benefits for scientific research that cannot be duplicated by other methods are possible. Use of balloons offers measurements in areas too low for sounding rockets or satellites and too difficult for aircraft which cannot sustain flight for long periods or reach the required heights. Payloads may be recovered for reuse of instruments and data-gathering. Balloons allow for multidisciplinary experiments, vertical profile measurements at a specific altitude at a specific time, or measurements at multiple locations over a particular time period. They also allow for satellite data verification using systems launched in coordination with orbital coverage and for flight testing of materials, instrumentation and experiments destined for future space missions.

Balloon-Borne Drop Capsule MIKROBA

This microgravity facility is filling the gap between drop-towers and parabolic flight missions on one hand and sounding rockets on the other. The drop capsule is attached to a stratospheric balloon and carried up to altitudes of between 40 and 46 km. After reaching the operational altitude, the capsule is released via telecommand. During the free fall, microgravity conditions are realized inside the MIKROBA capsule. The increasing aerodynamic drag is compensated by a controllable cold gas thrust system. Up to 60 seconds of microgravity in the region of 10^{-3} g are achieved. Parachute activation at an altitude between 20 and 14 km terminates the period of microgravity and guarantees a soft landing. The capsule is returned to the launch site by helicopter or car.

After cut-off of the MIKROBA capsule from the balloon, the g-level switches from 1 g to nearly zero g. During increasing airdrag the thrust compensation keeps the g-level at $+/-10^{-3}$ g.

Operational Characteristics

Microgravity period:	about 60 seconds
Duration of ascent:	up to 4 hours
Atmospheric environment at ceiling:	p ~ 2HPa T ~ 250 K
Maximum velocity:	approx. Mach 2.4
Maximum load during parachute inflation:	up to 7 g
Final descent:	below 7 m/s
Total capsule envelope:	6.00 m total length; 0.45 m outer diameter; 500 kg total mass (maximum)
Payload envelope:	2.00 m length; 0.42 m diameter of experiments; 200 kg payload mass

Telemetry/Telecommand

Downlink (Data):	128 KBits/s
Uplink (Commands):	Up to 14 telecommands can be routed to experiments

Typical Experiment Data

Platform diameter:	0.42 m
Experiment length:	approximately 0.60 m
Experiment weight:	approximately 40 kg
Battery package:	10 Ah/28 V, Battery packs can be combined to satisfy larger power requirements

Data acquisition

Analog data:	32 channels
Signal level:	+/-10 V
Resolution (word length):	12 bit
Sampling rates:	781.8 words/s 381 words/s 95 words/s 6.61 words/s
Digital data:	36 channels

Available: Now

Contact: James L. Rand
Winzen International, Inc.
12001 Network Blvd., Suite 200
San Antonio, TX 78249
(512) 692-7062

NASA Balloon Program

Wallops Flight Facility in Virginia manages the NASA Balloon Program, including management of NASA's National Scientific Balloon Facility (NSBF) in Palestine, TX. Through NSBF, Wallops provides balloons, helium and operational support for launches from many sites, including Palestine, TX; Fort Sumner, NM; Holloman Air Force Base, NM; Laramie, WY; Barking Sands, HI; Poker Flat Research Range, AK; Ainsworth, NE; Wallops Island, VA; and from foreign countries such as Australia, Canada and Brazil. Wallops provides the technical direction of the program, the research and development support, and selected tracking and data acquisition and processing. The Balloon Program supports about 50 launches a year with an overall success rate of about 85 percent.

Available: Now

Contact: H. Ray Stanley
NASA/Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1479

StratoFilm Free Floating Balloons

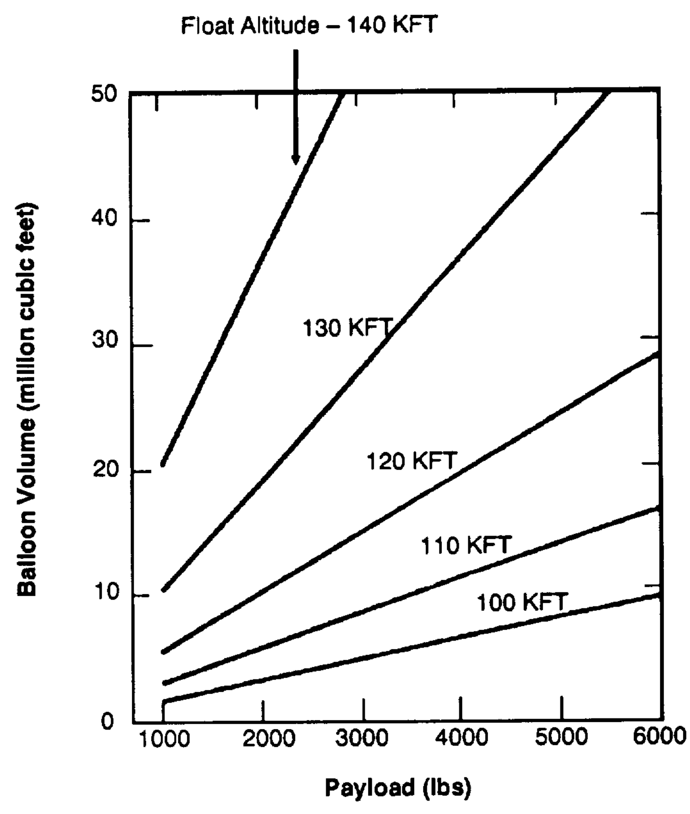
StratoFilm is a uniquely formulated polyethylene thin film that will remain ductile at temperatures below -90° C even when extruded to thickness less than 12 microns (.5 mil). When this film is used in conjunction with stringent quality control techniques and patented table designs, a family of balloons may be manufactured with a 100-percent flight success record. These stratospheric platforms are routinely used to carry payloads up to 7,000 pounds and have reached altitudes in excess of 170,000 feet. Typical applications include atmospheric sampling, ozone observation and cosmic ray research, as well as various astronomical observations.

Proven design techniques for the "natural shaped" balloon result in a system which may stay aloft for several days with the use of a variety of ballasting techniques. These systems may be quite large with gore lengths routinely exceeding 600 feet. When launched from the ground, the lifting gas will occupy less than one percent of the volume of the balloon. As the balloon ascends to its designed altitude, the gas expands to completely fill the balloon and vent any excess gas. StratoFilm balloons have been flown successfully from Antarctica to Canada and Sweden.

New balloon systems are being developed for longer duration missions. The unvented "superpressure" balloon is designed to remain aloft for one year. A unique manufacturing technique has been developed that permits the payload capacity to increase to be comparable to "natural shaped" balloons in the future. The Engineering Division is available to design a unique system for virtually any payload and altitude requirement.

Available: Now, with newer models under development

Contact: James L. Rand
Winzen International, Inc.
12001 Network Boulevard, Suite 200
San Antonio, TX 78249
(512) 692-7062



Aircraft

Helicopters and aircraft provide a variety of flight performance and payload-carrying ability. Research missions are conducted locally and on a regional or global basis. Helicopters offer support for small scientific instrument packages which need to operate at low speeds and low altitudes. Large turboprop aircraft can carry payloads of more than 10,000 pounds and often are deployed to underfly satellites and/or study phenomena peculiar to specific sites.

The traditional use of research aircraft has set the pace for progress in several areas of the atmospheric sciences, such as air flow dynamics, air chemistry, radiation and cloud/aerosol physics, and air pollution. The capability of conveying a variety of sensors to critical parts of the atmosphere to make in situ measurements has allowed fundamental discoveries concerning how physical quantities correlate with stormy and quiescent conditions. Such observations can be compared with data from surface-based or satellite-borne remote sensors. In one scenario, the aircraft may measure the same quantity as the remote device, thus providing a calibration of remote-sensing technology, or it may measure quantities which cannot be determined remotely.

The aircraft's ability to carry sophisticated remote-sensing instruments to the region of interest, for a carefully planned study or a quick observation of newly developed phenomena – such as a storm, a volcano, a polluted basin, a region of sea ice, drought-stricken crops, a warm ocean current or a forest fire – together with its ability to remain on station several hours, makes it an ideal platform for gathering data.

Three types of aircraft generally are used for microgravity experiments, the KC-135, the F-104 and the Learjet. They all achieve temporary states of microgravity by flying parabolic flight patterns. During the free-fall period, gravitational effects in the range of 10^{-2}g can be obtained. In most cases, parabolic trajectories are repeated so that several periods of weightlessness are possible. The typical time lead for scheduling experiments varies between one and six months, depending upon the nature of the experiment and aircraft availability.

NASA encourages commercial developers to fly with their payloads to operate the experiments and observe the results as they occur. An alternative to direct user involvement is provided by Payload Systems, Inc., of Cambridge, MA, who performs turnkey operations for its clients, including payload integration and operations.

Microgravity Research

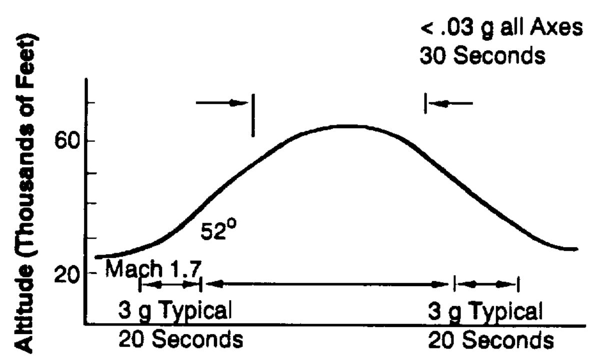
F-104

The F-104 is a modified supersonic, 2-man jet fighter. By flying in a parabolic trajectory between 25,000 and 65,000 feet, it is capable of a variable low-g period of approximately 60 seconds.

The experimental package must be capable of surviving a 3-g acceleration and is restricted in size and weight by the F-104's small experimental compartment. The equipment is limited in volume to an area 10 inches by 15 inches by 21 inches and in weight to 35 pounds. All equipment is restrained during flight and not accessible after 30 minutes before takeoff; therefore, all experiments must be fully automated except for on-off functions and limited to one parabolic maneuver per flight.

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



Low G Time: <.1 g – 60 Seconds
<.03 g – 30 Seconds

KC-135 Aircraft

The KC-135 can simulate up to 40 periods of low-gravity for 25-second intervals during one flight. The aircraft accommodates a variety of experiments and is often used to refine space flight experiment equipment and techniques.

The KC-135, like other microgravity research aircraft, obtains weightlessness by flying a parabolic trajectory. The plane climbs rapidly at a 45-degree angle (pull-up), slows as it traces a parabola (pushover) and then descends at a 45-degree angle (pull-out). The forces of acceleration and deceleration produce twice the normal gravity during the pull-up and pull-out legs of the flight, while the brief pushover at the top of the parabola produces less than 1 percent of the Earth's gravity.

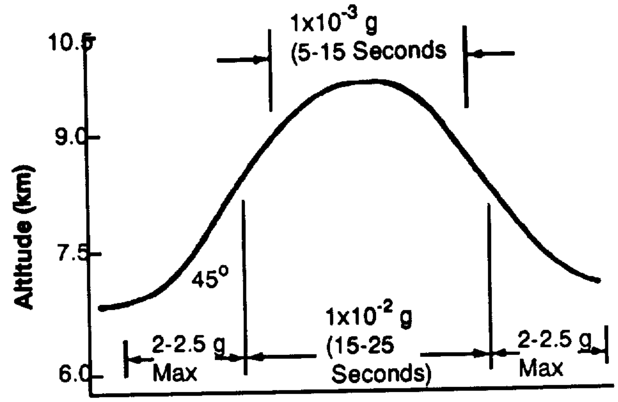
The KC-135 flies its 40 parabolic trajectories between 7.32 and 30.37 kilometers. The KC-135 is located at Johnson Space Center in Texas.

Operational Characteristics

Bay dimensions:	3.04 m x 16.4 m
Bay overhead clearance:	1.8 m
Maximum floor loading:	90 kg per 0.09 square meters
Acceleration:	2.5 g
Microgravity duration:	25 seconds
Number of maneuvers/flight:	40

Available: Now, with advanced scheduling

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



Learjet

The Learjet Model 25 aircraft provides investigators with a cost-effective way to conduct and observe experiments in simulated microgravity. The aircraft allows 18 to 22 seconds of 0 g, (10^{-2} accuracy*) and somewhat longer times at other selected reduced gravity levels.

The Learjet, like other microgravity research aircraft, achieves weightlessness by flying a Keplerian trajectory. Starting with maximum forward velocity, the aircraft is positioned 50 to 55 degrees nose high (2.0 to 2.5 g pull up). At this point the x, y and z axis are zeroed and maintained until the aircraft reaches approximately 30 degrees nose low.

Cabin cross-section is 52 inches high and 48 inches wide and approximately 6 feet of length is available for experiment use. Although not required, research apparatus is normally mounted in Lewis-furnished instrument racks (maximum of 2) with dimensions of 35.75 inches high x 20.75 inches wide x 24 inches long. Experiments mounted in these racks are limited to 188 pounds maximum weight and 3,272 in pounds overturn moment.

Operational Characteristics

Bay dimensions:	48 in x 72 in
Bay overhead clearance:	52 in
Acceleration:	Pull up: 2.5 g Pull out: 2.5 g
Microgravity accuracy:	10^{-2} Gz*
Microgravity duration:	22 seconds
Number of maneuvers/flight:	6

** Measured and recorded on each trajectory ("x" and "y" axis of comparable or better quality for the entire trajectory)*

Available: Now

Contact: NASA/Lewis Research Center
Aircraft Operations
21000 Brookpark Road, MS 4-2
Cleveland, OH 44135
(216) 433-2023

Remote Sensing Research

C-130B, Lockheed

A suite of sensors is provided for use on this multi-purpose remote-sensing platform, including weather radar, radar altimeter, closed-circuit television and data acquisition used for hydrological, ecological and geological research, climate research, oceanography, land processes and sensor development. The C-130 supports geologic, ecologic and hydrologic research, ocean and scatterometer research, wetlands studies and biomass combustion work.

Performance

Altitude:	25,000 feet (max)
Range:	2,200 nautical miles
Duration:	8 hours at 22,000 feet
Speed:	150-330 knots True Air Speed
Payload:	20,000 lb

Accommodations

Zenith and Nadir Viewports
External Antenna Attachment Mounts
Optical Windows
19-inch Panel Equipment Racks

Support

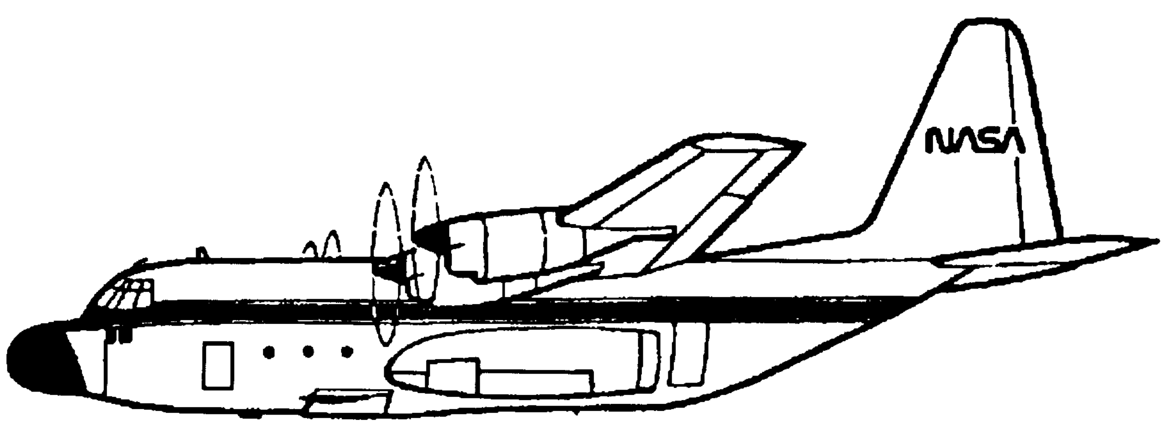
Navigation Flight and Environmental Data Recorded Automatically and Available to Investigator
Dew/Frost Point Hygrometer
Radar Altimeter
Weather Radar
Inertial Navigation
Time Code Generator
Housekeeping Distribution

Sensors

Metric Cameras
Multispectral Scanner
Walk-on: Eight Stations Provided for Investigator Supplied and Operated Sensors

Available: Now

Contact: Bruce Coffland
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffet Field, CA 94035-1000
(415) 604-6252



The C-130B

ER-2, Lockheed

There are three ER-2 aircraft available at the NASA/Ames Aircraft Data Facility. These high-altitude aircraft, or instrument platforms, accommodate an extensive group of sensors used for upper atmospheric measurements. The ER-2 also accommodate a complement of sensors maintained by Ames Research Center for observations of the Earth's surface. The high altitude missions involve collection of data in three principal areas: atmospheric data within the stratosphere, Earth and celestial observations using electronic sensors and photographic data acquisition.

Performance

Altitude:	70,000 feet (max)
Range:	3,000 nautical miles
Duration:	8 hours (Nominal 6.5 hours)
Speed:	410 knots True Air Speed
Payload:	600 lb, Nose; 750 lb, Q-bay; 1,360 lb, Wing pods

Accommodations

Q-Bay Instrumentations Area and Payload Pallets (Pressurized) Wing Mounted Instrumentation Pods (Pressurized)
Nose Cone Instrumentation Area (Pressurized)
Zenith and Nadir Viewing Capability

Support

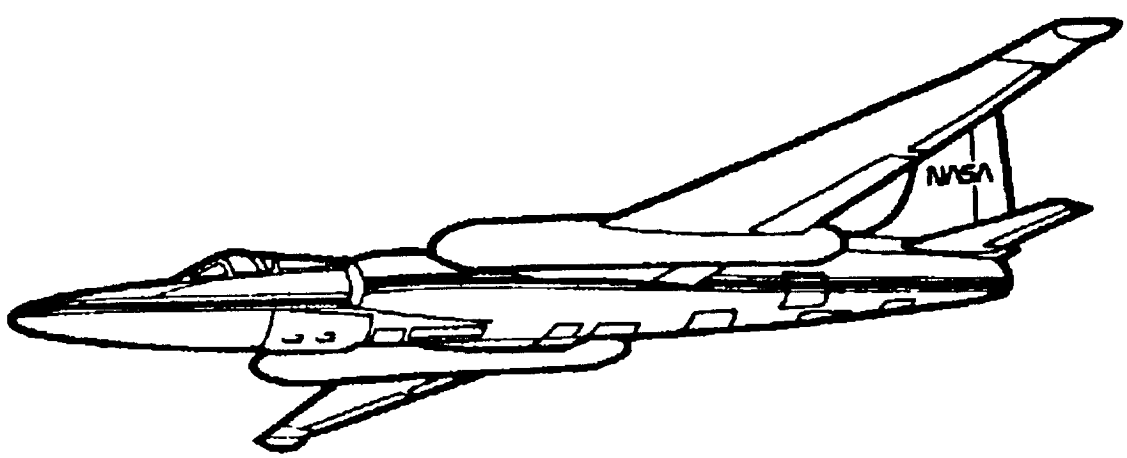
Inertial Navigation
Satellite NBS Time Code Receiver
Navigation Data Recording System

Sensors

High Altitude Multispectral Scanner
Thematic Mapper Simulator (TMS)
Airborne Ocean Color Scanner (AOCI)
Multispectral Atmospheric Mapping Sensor (MAMS)
JPL Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
Electro-Optical Camera
High-Resolution Panoramic Cameras

Available: Now

Contact: Bruce Coffland
Aircraft Data Facility
NASA/Ames Research Center, MS 240-6
Moffet Field, CA, 94035-1000
(415) 604-6252



The ER-2

Electra L-188, Lockheed

The Electra supports a major atmospheric science program for NASA called the Global Tropospheric Experiment (GTE).

Operational Characteristics

Altitude:	25,000 ft
Range:	2,000 miles
Endurance:	7.5 hours
Payload weight:	19,000 lbs
Payload power:	40.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804)824-1448

Gates Learjet, Model 23-049

The Stennis Space Center operates a Learjet in support of NASA's Earth Sciences Program. The Learjet flies two instruments: the Calibrated Airborne Multispectral Scanner (CAMS), used to study coastal geomorphology and evapotranspiration, and the Thermal Infrared Multispectral Scanner (TIMS), used for geology studies and land cover classification.

Operational Characteristics

Altitude:	41,000 ft
Range:	1,000 miles
Endurance:	3.0 hours
Payload weight:	750 lbs
Payload power:	4.0 kW

Available: Now

Contact: Patrick Kelly
NASA/Stennis Space Center
Stennis Space Center, MS 39529
(601) 688-1919

Lockheed P-3A and P-3B

The P-3 supports regional and local studies and instrument development work. The P-3B provides enhanced range and endurance.

P-3A Orion

Altitude:	25,000 ft
Range:	2,000 miles
Endurance:	7.5 hours
Payload weight:	13,600 lbs
Payload power:	33.0 kW

P-3B Orion

Altitude:	28,000 ft
Range:	3,000 miles
Endurance:	12.0 hours
Payload weight:	13,600 lbs
Payload power:	33.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804) 824-1448

Rockwell T-39 Sabreliner

The Sabreliner provides the capability of reaching altitudes nearer to the stratosphere. The aircraft is being modified with an upward-looking window for atmospheric research.

Operational Characteristics

Altitude:	41,000 ft
Range:	1,400 miles
Endurance:	3.25 hours
Payload weight:	1,500 lbs
Payload power:	3.0 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1448

Short Brothers SC-7 Skyvan

The Skyvan's primary role involves mid air retrieval of rocket-launched payloads. However, the aircraft also is used to support Earth resources studies and instrument development work.

Operational Characteristics

Altitude:	15,000 ft
Range:	650 miles
Endurance:	4.0 hours
Payload weight:	5,000 lbs
Payload power:	2.8 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA 23337
(804) 824-1448

Bell UH-1B Helicopter

This helicopter is used as an instrument platform for Earth resources work.

Operational Characteristics

Altitude:	10,000 ft
Payload weight:	2,000 lbs
Payload power:	3.5 kW

Available: Now

Contact: Roger L. Navarro
NASA/Wallops Flight Facility
Wallops Island, VA, 23337
(804) 824-1448

Section Three: Hardware & Equipment

Flight-qualified experiment apparatus, support hardware and payload services are available to commercial researchers for use in materials processing, life sciences and biotechnology, remote sensing, automation and robotics, combustion engineering and other disciplines.

This equipment is used for ground-based testing, such as in labs or drop towers; in the air, on balloons or aircraft; or in space, on the Shuttle, expendable launch vehicles or on-orbit facilities. Some of the entries on the following pages can be accessed through NASA, while others are offered commercially. Some have been designed, flight-tested and are available; others are conceptual designs or prototype hardware. These indications are noted for each entry. Note that all equipment must satisfy the safety or integration requirements of the applicable carriers. The equipment is subject to manifesting or scheduling constraints and the integration lead times of those carriers.

The chapters in this section are assigned to Microgravity Research; Remote Sensing; and Support Products and Services.

Chapter 8: Microgravity Research

Microgravity is a state in which the force of gravity experienced is significantly less than that on the surface of the Earth. Process variables behave differently in microgravity: buoyancy-driven forces such as sedimentation and convection can be virtually eliminated. Weak surface forces, otherwise suppressed by gravity, are exaggerated. The prospect of an environment in which these variables can be controlled has attracted the interest of researchers in such fields as biotechnology, electronics, glass and ceramics, polymers, and metals and alloys.

Microgravity research already has led to significant advances in materials science, to improved ground-based production methods and to other industrial applications. The field holds potential in numerous areas, such as pharmaceuticals, semiconductors, new alloys, materials separation and composites, and containerless processing. Continued research is expected to lead to commercially viable products, uniquely suited to space-based production; it may be possible to produce materials in space that cannot physically or cost-effectively be produced on Earth. The knowledge pool is just beginning to accumulate.

The most sophisticated microgravity research facility is the Shuttle. While microgravity experiments are limited to periods of a few seconds in a sounding rocket, aircraft or ground-based drop tube, they are conducted for a few hours or days aboard the Shuttle, with or without the hands-on attention of crew members. The development of new on-orbit platforms and, particularly, recoverable payload systems is expanding the researcher's opportunities. Sponsorship for a flight program may be obtained in several ways. NASA itself sponsors many projects, as do other agencies, universities, industries and foreign governments. (See Scheduling, Chapter 3.)

The equipment described in this chapter supports ground-based, airborne and spaceborne research for materials processing (beginning on page 66), life sciences and biotechnology (both beginning on page 93). Microgravity research is a relatively new space science that demands rigorous preparation and planning. Because gravity is a dominating force on Earth, designing experiments to operate in the near absence of gravity is a challenge. Any researcher planning to experiment in the microgravity environment should consider the possibility and benefits of using existing equipment.

Materials Processing

A major emphasis of commercial research in microgravity has been in the area of materials processing. Microgravity offers an ideal environment for containerless processing, which may result in the production of materials with unique properties. The field of processing within a container in a microgravity environment also shows potential because in space there is no natural convection as there is on Earth. A result of this characteristic is the production of composite materials which are much more uniform in composition and microstructure.

Emphasis in metals research includes single-crystal alloys, intermetallic compounds, refractory metals and composite materials for use in engine components. Polymer matrix composites are being investigated for potential use in motors, structures and other applications. Ceramic research is seeking to better understand and control the microstructure/property relations in high-temperature structural ceramic systems. Ceramic and metallic coatings are being developed to provide protection for components in high-temperature, corrosive/erosive environments. Tribological experiments will yield a better understanding of the behavior of interfaces (e.g. solid-to-solid contact) in mechanical systems such as engines, components and mechanisms.

All of these research activities are supported by facilities and laboratories which provide analysis and documentation of the chemical composition and microstructure of advanced materials, metals and nonmetals. They also are supported by the experiment equipment and hardware that is designed for efficiency, survivability and productivity.

Furnaces

Advanced Automated Directional Solidification Furnace (AADSF)

The advanced design of the AADSF for improved temperature control between the hot and cold ends of the sample allows a nearly planar interface to be maintained between the melt and solid states of a sample alloy. This expands the capabilities of studies that examine gravity limits and how convection influences the homogeneity and defects of a crystal.

The apparatus contains a multi-zone furnace and a mechanism that moves the sample through the furnace. The furnace may be configured to compensate for changes in temperature as a sample adjusts to its steady-state value, changes in thermal conductivity between solid and melt and energy disposition. One sample per furnace of approximately 1.5 cm diameter by 25 cm in length is planned.

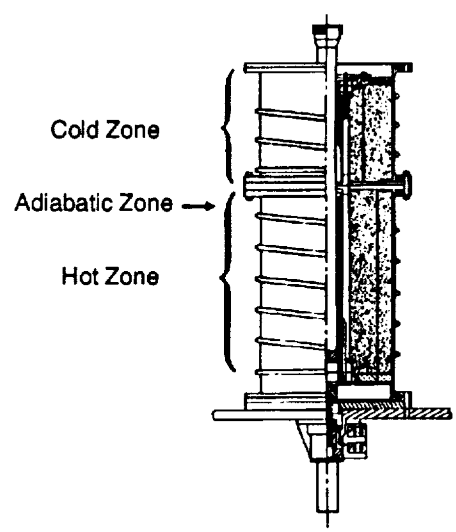
Operational Characteristics

Temperature range:	200° to 1600° C
Translation rate:	0.5 to 50.0 mm/hour
Furnace size:	130 cm H x 43 cm diameter
Furnace weight:	120 kg

Carrier: Materials Science Laboratory (MSL)

Available: Engineering prototype completed.

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-0196



ATAKSAK-1, Atmosphere Furnace

ATAKSAK-1 is a high-temperature controlled atmosphere furnace designed to rapidly heat materials to high temperatures (above 1800° C). Current system configuration (designed for sounding rocket flights) allows the furnace chamber (2 inch diameter x 4 inches deep) to be heated to a moderate temperature (approx. 1300° C) using 1 kW of off-board AC power. During flight, the furnace is energized using on-board batteries. The temperature can be pulsed to above 1800° C in less than one minute. The present controller design allows the soak temperature to be maintained for up to 7 minutes.

As configured, the furnace is suited for the synthesis of materials at high temperature, for the production of microcrystalline materials at the laboratory scale and in situations where available power is limited. Depending on the particular application, the configuration can be extended to include other features such as longer soak time, programmable ramps, atmosphere control and larger furnace chambers.

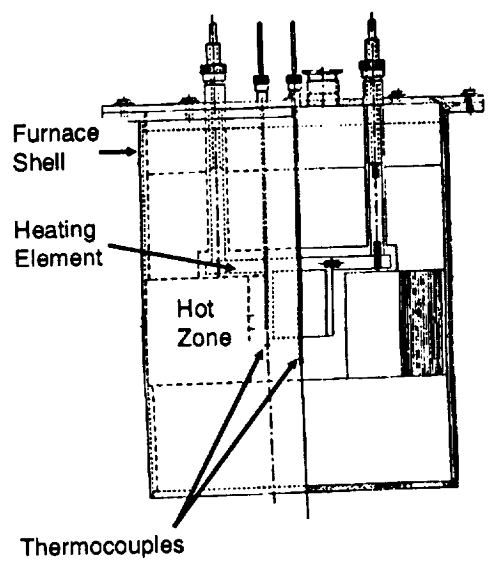
Operational Characteristics

Furnace chamber:	4 in L x 2 in diameter
Furnace shell:	15 in L x 14.5 in diameter
Controller:	12 in x 12 in x 8 in
Furnace mass:	24 lb
Controller mass:	10 lb

Power: 1 kW to 1300° C, 1-9 kW to >1800° C
Pulse time, 1300° C to 1800° C: <1 min on battery operation

Available: Available for ground-based testing and configured for sounding rocket flight.

Contact: A. Pant or C. Bell
Ceramics Kingston Inc.
P.O. Box 655
Kingston, Ontario, K7L 4X1, Canada
(613) 548-7253, Fax (613) 542-2856



Bulk Undercooling Furnace

The Bulk Undercooling Furnace (BUF) is a three-zone furnace designed to study the effects of undercooling on the microstructure of metal alloys. The temperature is sampled using a thermocouple and controlled using a small computer.

Operational Characteristics

Operating Temperature:	25° to 500° C
Max. Power/zone:	300 W
Cooling fluids:	Argon, helium, nitrogen, air, water
Sample Shape:	Cylindrical
Sample Length:	12 cm maximum
Max Diameter:	3.5 cm

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory (MMSL)

Available: Now

Contact: T. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road, MS 105-1
Cleveland, Ohio 44132

Crystals-By-Vapor Transport (CVT) Furnace

Each Crystals-By-Vapor Transport Furnace is used to grow up to two samples simultaneously. A two-zone heater coil for each sample is used to establish and control a temperature gradient for the desired growth conditions of each particular material. The diameter and pitch of the coil may be modified to accommodate the desired temperature profiles of a wide range of materials.

Current furnace system configurations allow for visual observation and man-in-the-loop control of the growth nucleation and processing. This viewing feature is achieved with the use of a gold-coated quartz tube, which reflects heat but is transparent to visible light and viewports in the outer containment shell. The system provides for the majority of the processing to be automated. This is achieved with the use of a stepper motor drive which provides quasi-continuous pulling of the ampoule in 3 micron increments. Approximately 5 grams of source material can be processed in a two-walled ampoule with an inner diameter of up to 25 mm.

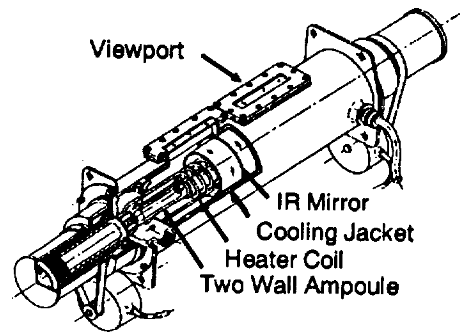
Operational Characteristics

Operating temperature:	Up to 900° C
Furnace size:	7 in x 7 in x 40 in (holds 2 samples)
3-Furnace system size:	20 in x 70 in x 16 in (fits in single standard rack)
Weight:	490 lbs
Power requirement:	Up to 1 kW (for current systems)

Carrier: Shuttle-middeck accommodation rack

Available: Presently available for the Shuttle middeck. Minor modifications are needed for use in the Shuttle cargo bay and for the Freeflyer/Space Station.

Contact: V. A. Swebert or D. M. Garman,
Boeing Commercial Space
Development Company
P.O. Box 3707, M/S 8C-64
Seattle, WA 98124
(206) 773-5176



Crystal Growth Apparatus (CyGA-400)

The CyGA-400 is a low cost, low weight, modular device designed for growing crystals of proteins, drugs and other organic and inorganic materials in the microgravity environment of Low Earth Orbit. This device can be used in conjunction with the COR Aerospace re-entry recovery vehicles and MaRP* Process for protecting the crystals until they are harvested for analysis in ground-based laboratories.

This device can hold up to 400 individual samples with easy access of solution and removal of crystals. The unit is modular, such that a different number of units may be assembled, providing a high volume of individual crystal growth chambers in a compact space. The maximum number of units utilized depends on the size of the re-entry recovery vehicle. For example, the Deliver-24* vehicle can accommodate up to nine CyGA-400* modules giving a total of 3600 individual crystal growth chambers and (using the COR Aerospace temperature control and MaRP devices) still leaving up to one cubic foot of payload volume for other experiments. The CyGA modules can be custom-tailored with a different number of individual crystal growth chambers from 100 (CyGA-100) to 1000 (CyGA-1000) per module, depending upon user needs.

**CyGA-"X", Deliverer-24, and MaRP are trademarks of COR Aerospace Corporation*

Operational Characteristics

Size of Unit:	10 cm x 10 cm x 10 cm
No. of Samples:	Up to 400
Sample Volume:	Range of 50 to 500 microliters
Temperature:	4° to 50° C with +/-0.3° C control

Available: Now

Contact: COR Aerospace Corporation
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 676-2474

Electromagnetic Levitation/Float Zone Furnace (EML/EFZ)

This facility uses an induction furnace in two modes. As a levitation furnace, it levitates and melts small metal alloy samples. As a float zone furnace, it can process small diameter metallic sample rods. In both modes the furnace can maintain vacuum or an inert gas atmosphere.

Operational Characteristics

Power:	0 to 25 kW
Frequency:	100 to 450 kHz
Vacuum:	to 10^{-6} torr
Inert gases:	Argon, helium

Sample Shape

EML:	Spherical or cylindrical (height=diameter)
EFZ:	Rod

Sample Size

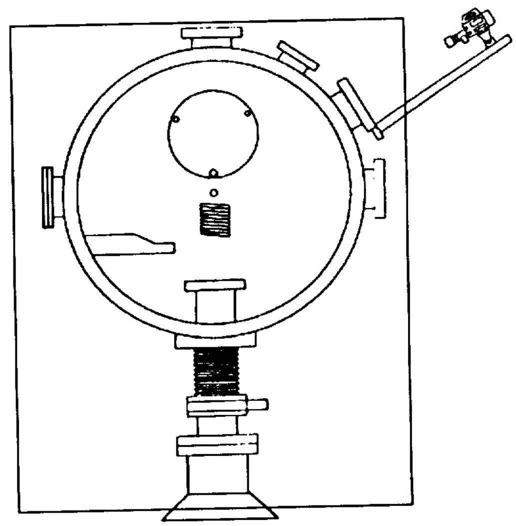
EML:	0.5 to 4 cm^3, up to 30 g
EFZ:	approx. 5 mm diameter

Sample Type: Any material that can be levitated and/or heated inductively

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory

Available: Now

Contact: T. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road, MS 105-1
Cleveland, Ohio 44132



Electromagnetic Levitation Furnace

The Electromagnetic Levitation Furnace is used in a containerless process to melt metallic samples of up to about one gram. The device allows the investigation of various physical phenomena including vacuum purification, undercooling, solidification kinetics, rapid solidification and the formation of metastable phases. Significant stirring occurs in the samples due to the RF-induced eddy currents. The samples can be cooled at a controlled rate by blowing helium gas over them after which splat quenching is possible with a light, trigger-activated, double anvil splat quencher. The temperature of the sample can be monitored with a two-color pyrometer. Samples can be processed in a vacuum of 2×10^{-5} torr or various gases up to 1 atm.

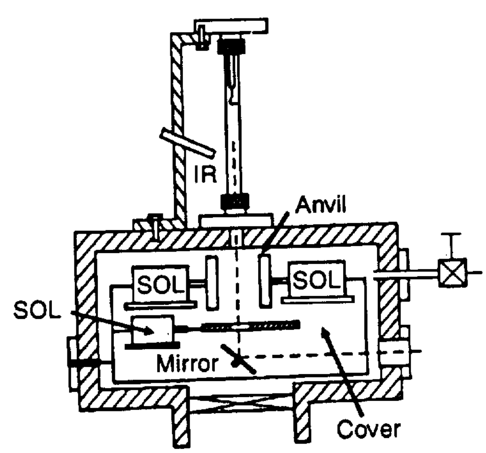
Operational Characteristics

Sample sizes:	Approximately 1 gram
Vacuum level:	2×10^{-5} torr
Controlled cooling:	Yes
Splat quenching:	Yes

Carrier: Designed for ground-based research only

Available: Now

Contact: Center for Space Processing of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7053



Flat Plate Heater

The Flat Plate Heater is used to heat a flat sample 114 mm x 114 mm square. Variable thicknesses of samples are accommodated. The heater operates by a single set point controller. Heat-up rate depends on the power supplied to the heater pads which are on both sides of a sample. Maximum operating temperature is 200° C. Heat-up time to 200° C is approximately two minutes. The device can be used to cure epoxy resins.

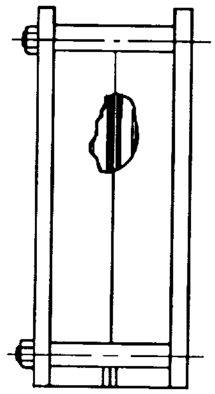
Operational Characteristics

Size:	153 mm x 163 mm x 80 mm
Weight:	1.6 kg
Power:	2 heaters, requiring approx. 6 amps each at 28 Vdc
Operating temperature:	200° C

Carrier: Sounding rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620



Gradient Furnace for the Get-Away-Special Canister (GFGAS)

The GFGAS was developed to provide a low-cost, quick turn-around furnace for fundamental studies of transport phenomena in crystal growth processes. The furnace recrystallizes a previously grown gallium arsenide (GaAs) crystal by thermal gradient transport. High-quality GaAs crystals may prove to be the basis for a new high-speed semiconductor technology.

In each of two furnaces, an Earth-grown GaAs seed crystal is melted back to 2.54 cm, then regrown to 7.62 cm. The recrystallization is accomplished by passing a thermal gradient along the length of the sample, resolidifying the crystal. Sample size is 22 mm diameter by 10 cm in length.

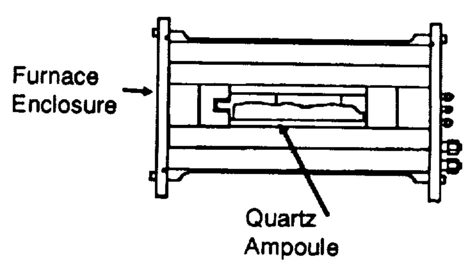
Operational Characteristics

Temperature:	1,330° C maximum
Furnace size:	60.96 cm H x 50.16 cm diameter
Furnace weight:	90 kg

Carrier: GAS canister for use in Shuttle cargo bay

Available: Now

Contact: Richard W. Lauver
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2860



Ground-Based Acoustic Levitator (Beam Heated)

This facility is a high-temperature acoustic levitator for precursor experiments in low gravity. It can be flown aboard the KC-135 aircraft and the design could be adapted to a sounding rocket carrier. Beam heating by xenon arc or laser will provide rapid sample heating to temperatures exceeding 2000° C, depending on sample characteristics. Sample sizes ranging from 2-6 mm can be accommodated. Control of sample rotation and oscillation is possible. The samples may be processed in various inert or reactive environments.

Video and thermal imaging is available in orthogonal directions. Thermal imaging at several different optical wavelengths provides the user with non-contact temperature measurement capabilities.

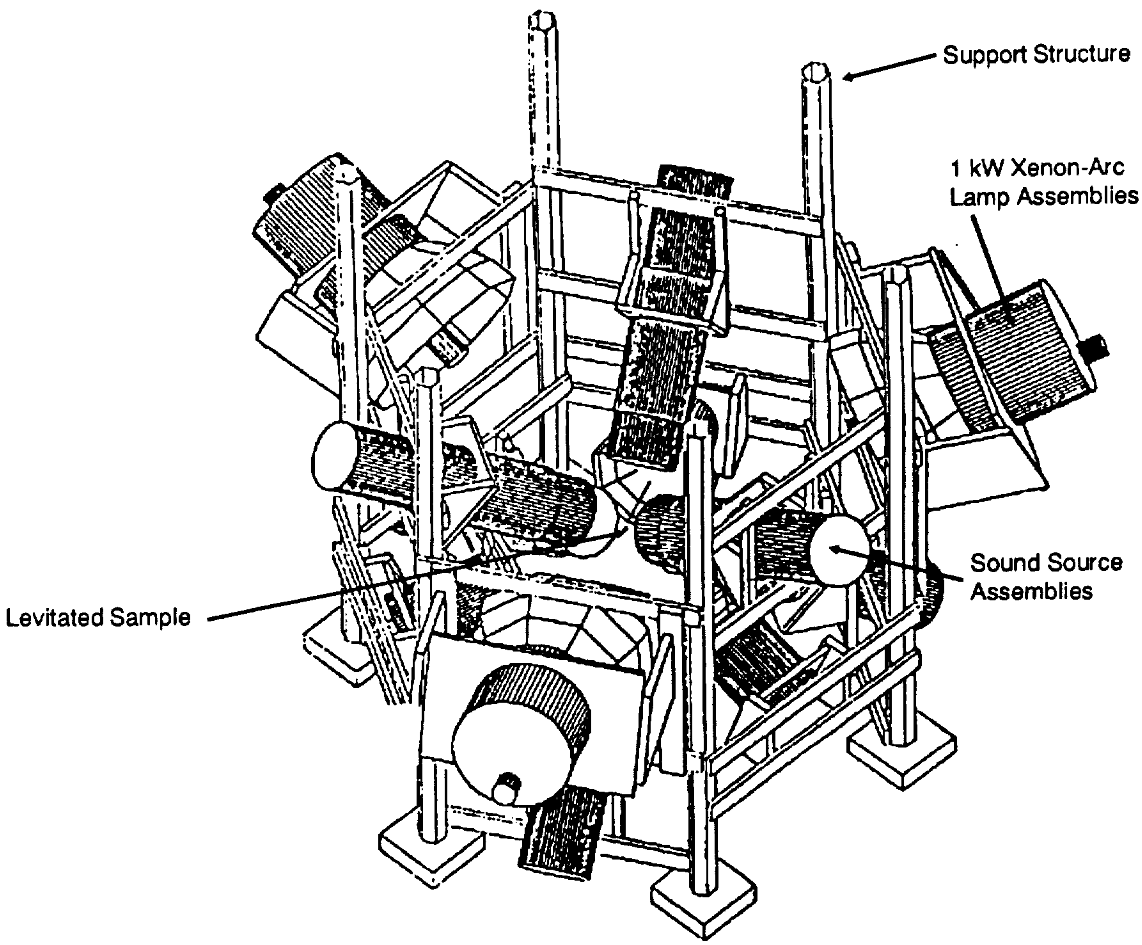
Operational Characteristics

Temperature for sample heating:	2000^{o+} C
Sample size:	2 to 6 mm

Carrier: KC-135 and sounding rockets

Available: A breadboard version of this facility has been developed at Intersonics, Inc. and tested in a laboratory and on the KC-135 aircraft.

Contact: Dennis Merkley
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Test Facility Aboard KC-135

High Temperature Acoustic Levitator (HAL)

The High Temperature Acoustic Levitator (HAL) is a containerless processing module which uses a 3-axis acoustic positioning system in order to contain non-conducting as well as conducting liquid and solid materials. This acoustic positioning system has the capabilities for providing accurate specimen positioning and for producing a quiescent, spin-free and stable specimen state.

HAL uses xenon arc or laser beam heating for high-temperature containerless testing and processing studies of glass, ceramic, metal and alloy samples in microgravity. It has capabilities of processing, heating, melting, soaking, cooling and solidifying samples without the physical contact of a container. Advantages of this system include extremely stable sample positioning utilizing optical feedback, and fast heating and cooling rates. Samples may be processed in a very high purity, particle free, inert, oxidizing or reducing gaseous environment. The device can accept nominally spherical samples, 2-6 mm in diameter, and can perform a large number of experiments sequentially.

The sound pressure level is electronically monitored and controlled by a computer. This can be used to modulate the shape of a liquid sample in order to study fluid dynamics of drops or to measure physical properties, such as surface tension and viscosity. By properly phasing the acoustic signals between transducers, controlled spin of the specimen can be attained.

The open architecture of the levitator allows convenient access for both invasive and non-invasive diagnostic equipment.

Operational Characteristics

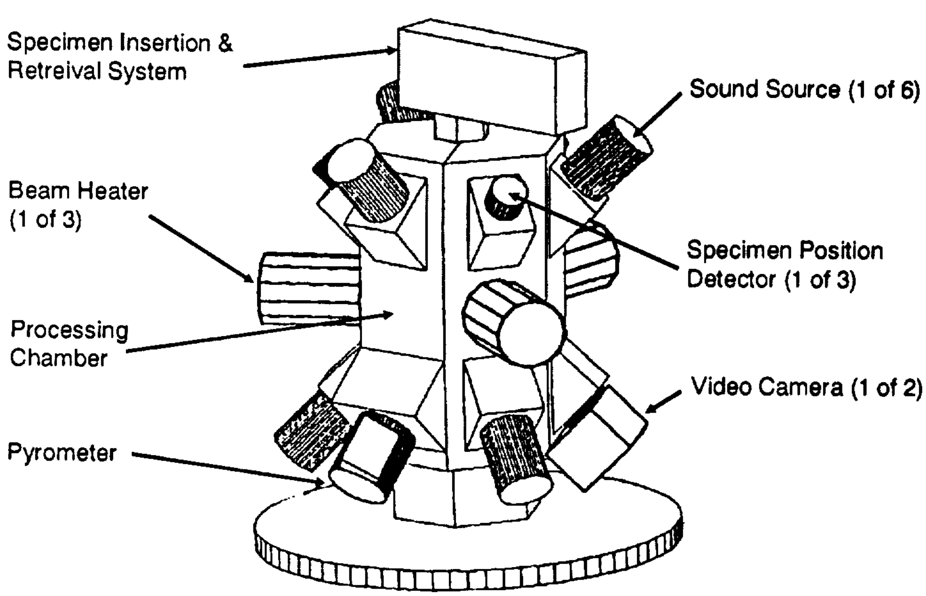
Temperatures*:	30° to 2,000° C
Design Goal:	up to >2700° C
Isothermality*:	Good
Temperature Control Precision:	To be determined
Design Goal:	1° C
Gas Purity and Particulate Contamination:	Excellent (as good as process gas)
Process Gas:	Oxidizing, reducing or inert
Specimen Motion:	<1 mm (electronically controlled)
Specimen Density:	0 to 22 gm/cm^3
Position Accuracy:	<+/-1 mm
Heating Rates*:	0 to 200° C/second or higher
Cooling Rates*:	0 to 200° C/second or higher
Spin Control:	Zero, or very low spin
Optical Access:	Convenient
Heaters:	Xenon arc, laser beam, RF, microwave

** Dependent on sample properties and size*

Carrier: Sounding rocket, freeflyer or Shuttle cargo bay

Available: Design has been developed through the breadboard stage and tested on the KC-135

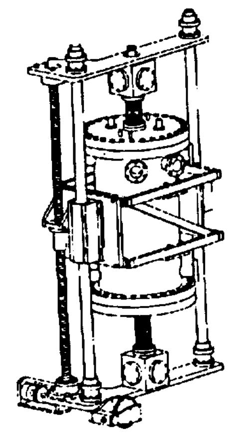
Contact: Charles A. Rey
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Module

High Temperature Directional Solidification Furnace

The High Temperature Directional Solidification Furnace allows directional solidification experiments on materials with melting temperatures over 2,000° C. Dual water-cooled copper blocks with helium gas convective cooling provides thermal gradients in excess of 200° C/cm. The superior electrical, magnetic or mechanical properties of high melting point samples with unique, directionally solidified structures can be investigated with this apparatus.



Operational Characteristics

Temperature:	1,000° to 2,500° C
Translation speed:	0.01 to 30 mm/minute
Fast quench:	30 mm/second
Sample size:	20 cm L x 1.2 cm diameter

Carrier: Designed for ground-based research only

Available: Now

Contact: Center for Space Processing of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7054

High Temperature Directional Solidification Furnace

The High Temperature Directional Solidification Furnace is designed to perform directional solidification experiments on metal samples at much higher temperatures than those used in the Transparent Directional Solidification Furnace. The sample is sealed in a quartz ampoule and the furnace heating coil assembly is moved along the length of the tube. The sample is exposed to a large magnetic field to reduce convective flow.

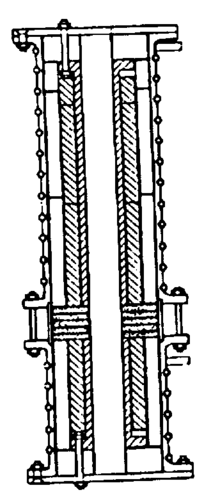
Operational Characteristics

Oven temperature:	Air 200° to 1100° C, Inert atmosphere 200° to 1400° C
Hot zone length:	20.32 cm
Cold zone length:	10.16 cm
Quench zone length:	10.16 cm
Translation rate:	25.4 to 0.10 cm/second
Temperature gradient:	10,200 and 400° C/cm
Sample shape:	Cylindrical
Sample diameter:	12.7 or 28 mm
Sample length:	20 cm to 26 cm
Ampoule length:	Approximately 100 cm

Carrier: Designed for ground-based research only at the Microgravity Materials Science Laboratory

Available: Now

Contact: Mary Jo Meyer
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-8165



Isothermal Casting Furnace

This high-temperature furnace has a helium quench gas to resolidify the sample during flight.

Operational Characteristics

Operating temperature:	200° to 1350° C
Cooling rate:	1° to 50° C/second
Power:	7.0 amps
Voltage:	28 Vdc
Size:	61 cm L x 43 cm H x 31 cm diameter
Mass:	24 kg
Sample size:	2.0 cm L x 1.0 cm diameter maximum

Carrier: Designed to fly on TF-104G research aircraft. May be modified to fly on KC-135 if necessary.

Available: Now

Contact: I. C. Yates
NASA/Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
(205) 544-1997

Isothermal Multipurpose Furnace Modules (TEM 01)

This module contains either four or six heating chambers that can be controlled independently of each other and have separate cooling systems that operate independently. The module can be used to implement any kind of melting experiment which requires isothermal conditions. The furnaces are sealed and can be filled with any inert gas atmosphere. The furnaces are activated during the countdown phase until the proper temperature is attained.

Applications include melting experiments with alloys, dispersion alloys, skin technology, glass experiments, metal foams, directional solidification, eutectics, crystal experiments and soldering experiments.

Operational Characteristics

Type of furnace:	PtRhPt heater
Maximum temperature of heater:	1600° C
Diameter of heater:	15 mm to 20 mm usable for sample
Heated length of heater:	65 mm
Isothermal zone:	22 mm
Isothermal condition:	+/-5° C depending on sample
Gradient:	10° to 40° C/cm depending on sample
Number of temperature measurements:	2 to 4
Type of thermocouples:	NiCrNi, PtRhPt
Cooling system:	Helium gas (during the microgravity phase)
Cooling rate:	100-300° C/minute
Heating rate:	6° C/second maximum
Programming:	Independently

Power System

Electronic:	NiCad 28 Vdc/2.5 Ah
Furnaces:	28-35 Ag/Zn SHV 500 cells 1.2 V/cell for each furnace
Maximum current:	30 A (for a short time)

PCM-System

Data transmission:	Real-time
Resolution:	0 to 5 V, 10 bit 0/1 event status
Number of analog channels:	64
Number of digital channels:	60

Sample

Length:	50 mm maximum
Diameter:	12 mm to 18 mm maximum
Temperature:	1500° C maximum

Carrier: Sounding rockets

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Mirror Furnace Modules (TEM 02)

The TEM 02 experiment module is equipped with a rotationally symmetric ellipsoid mirror furnace. The sample, sealed in a 20-mm quartz ampule, is located at the first focus of the ellipsoid and is heated, without contact, by a lamp at the second focus of the ellipsoid. The maximum sample length is 90-mm. The sample may be observed during flight by a B/W or color TV and may be photographed by a remotely operated camera. The module provides the capability for in-flight telecommand control of the furnace (12 channels) and accommodates three different modes.

Applications include crystal growth, eutectics, directional solidification, acoustic positioning and electrostatic positioning.

Module TEM 02-2
This module is a mirror furnace that can be equipped with a 450 to 1000 W lamp for pure melting experiments. It can be utilized in connection with an ultrasonic positioner or an electrostatic positioner.

Module TEM 02-3
This module is used for crystal growth experiments. In addition to the mirror furnace, it has two motor systems needed for sample rotation and sample translation.

Module TEM 02-4
This module is almost identical to the TEM 02-3 module, but contains only one motor for sample translation. This module is used for crystal growth experiments as well as for directional solidification experiments. It is possible to integrate a cooling device to the bottom of the sample.

Mirror Furnace
The mirror furnace is a monoellipsoid type: a halogen lamp is located in the first focus and the sample is located in the second focus. Melting of the sample is performed by drawing it through the illumination zone of the focus. The ellipsoid can be filled with different gases, depending on the sample requirements.

Lamps/Temperatures
Halogen lamps, used for the melting process, operate at temperatures of up to 3300° C. The highest temperature used in the mirror furnace to date has been 1500° C.

Sample Movement and Positioner System
Two independently controlled motors with tachometer generators are installed to translate and to rotate the sample holder. Adjustments are possible within the following ranges:

- Translation: 1 to 10 mm/min
- Rotation: 1 to 10 rpm/min

In order to perform a containerless melting process, the motor system can be replaced by:

- Ultrasound positioner system, or
- Electrostatic positioner system

Power System

Electronic:	NiCad 28 Vdc/2.5 Ah
Lamp power:	SHV 500 Ag/Zn cells, 1.2 V/cell, 450 W lamp 40 cells 1000 W lamp 120 cells
PCM-System:	32 analog channels, 0 to 5V, 10 bit 30 digital channels, 0/1 event status
Timer:	1 x 16 independent events extension to 2 x 16 events is possible
External/Internal:	1 unit for electronic power
Switch:	1 unit for lamp power

Carrier: Sounding rockets

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Module (TEM 03)

The module TEM 03 is a gradient furnace with two independently controlled heaters within the furnace. The gradient for the sample is achieved in a baffle zone between the heaters by moving the furnace slowly over the sample. The highest temperature of the sample may be up to 1200° C and the established gradient, in the order of 20 to 120°/cm. The established gradient and temperature are very strong and depend on the sample size and material properties of the sample and cartridge. Therefore, the given data have to be considered as preliminary. The arrangement of heaters and baffle has to be adapted, depending on experiment requirements, and verified by a number of ground tests, before the flight unit is well adjusted concerning heater, sample size and translation velocity. The data given below are generated for tests with a GeGa test sample.

Planned module length: 1,000 mm
Planned module weight: 72 kg

Furnace

Diameter:	330 mm
Length:	680 mm
Heater:	Two heaters made from PtRhPt
Heater 1:	145 mm length
Heater 2:	70 mm length
Temp. Heater 1:	1300° C
Temp. Heater 2:	700° C

A gas or water system can be adapted to the lower heater (#2).

The baffle zone, being the insulation zone between the two heaters, measures about 20 mm. Within this baffle zone, a very flat solidification front can be established.

Furnace Velocity: Adjustable range of 0.1 mm/min to 10 mm/min

Power Supply

Electronic:	NiCad 28 Vdc/2.5 Ah
Furnace:	Ag/Zn SHV500 1.2 V/cell

Number of cells to be determined by required temperature/time profile.

Sample/Cartridge
The sample consists of a cartridge and the sample material itself.

Cartridge:	Length: 300 mm Diameter: 13 mm
Material:	Tatalium
Sample:	Length: 100 mm Diameter: 10 mm Material: GeGa

The drawing length of the sample during the process is 70 mm. The TEM 03 furnace positions only the drawing process in microgravity, because it uses material already melted before on the ground.

Temperature Measurement
Heater temperature control is performed by one NiCuNi element per heater. Gradient measurement within baffle zone is done by 2 NiCuNi elements, designed as slide contact elements, and measures temperature on the surface of the cartridge motor system.

Pulse Marker
A pulse marker can be adapted to the sample material in order to measure the fluid/solid interface during the drawing process.

Pulse

Amplitude:	50A DC
Duration:	Maximum 100 μs
Sequence:	Adjustable

Carrier: Sounding rockets

Available: This module is in the development phase and planned for the TEXUS 27/28 flight. Final technical descriptions will be made available in 1991.

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Multi-Mission Mirror Furnace Module (M4)

The furnace is designed for short-duration microgravity applications in sounding rockets, making it necessary to have a very rapid furnace, both in heating up and cooling down performances. Therefore, a mirror furnace concept with as low thermal mass as possible was chosen.

This module contains two advanced isothermal mirror furnaces, standing along the center axis. In the lower end of the cylinder is an aluminum panel on which the furnaces rest. On the other side of the panel the power transistors are maintained, using the panel as a heat-sink. On the walls of the outer structure, the four (or two) gas vessels for quenching the samples are mounted. The furnace computers and control electronics are mounted on two lids in the structure, and between the gas vessels is mounted a box containing batteries for electronics and a box for housekeeping functions of the module.

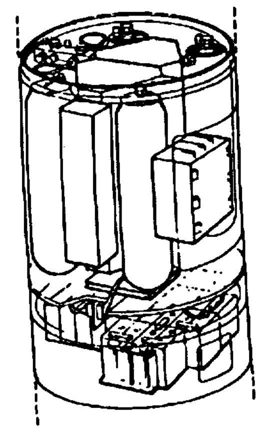
Operational Characteristics

Size:	765 mm L x 438 mm diameter
Weight:	75.5 kg including battery module and 2 gas vessels
Material:	Outer structure is magnesium casting; inner structure is aluminum panel
G-forces:	Approx. 14 g maximum
Number of furnaces:	2
Sample size:	160 mm L x 15 mm diameter
Operation temperature:	50° to 1,000° C
Isothermal properties:	+/-0.5° C along the whole sample length

Carrier: Sounding rockets

Available: Now

Contact: CONATEC, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088



Multi-Zone Furnace

This multi-zone furnace (24-independent zones) originally was designed for directional solidification crystal growth. The furnace, tubular in shape, is translated around the sample. State-of-the-art computer-controlled operations allow adjustments of the temperature profile to vary throughout the sample and to be programmed over time. Thermocouples throughout the system allow the temperature versus time and versus location to be displayed as programmed. The flexibility of the system is such that this furnace is ideal not only for directional solidification, but also for other methods of crystal growth, such as vapor transport and gradient freeze.

Operational Characteristics

Operating temperature:	Up to 1,600° C with control stability to +/-0.2° C
Furnace size:	60 in L x 20 in W x 2 1/2 in bore
Furnace system size:	Semicylinder, 8 ft L and 36 in diameter
Weight of system:	<2000 lb
Power:	<1.75 kW

Carrier: Originally designed for mounting on an across-the-bay structure such as the Microgravity Material Science Laboratory carrier. Redesigned to be mounted on 2 Get-Away Special beams on the Shuttle side wall. Could be adapted to middeck (major modification).

Available: Tested on a ground system which was designed for flight requirement. A specific flight configuration would need modifications.

Contact: Joseph Alario
Grumman Space Systems Division
A05-025, Grumman Corporation
Bethpage, NY 11714
(516) 575-2433

Physical Vapor Transport Crystal Growth Furnace

The Physical Vapor Transport Crystal Growth Furnace is a transparent multi-zone furnace. It has a sample translation system designed to provide slow movement of the sample between the heating coils. The sample is sealed into a quartz ampoule and attached at the top to a guide wire connected to the sample translation device. The guide wire is used to move the sample between the two heated areas of the furnace very slowly. Crystals are grown in the upper end of the furnace as the vapor produced by the material under study contacts the glass.

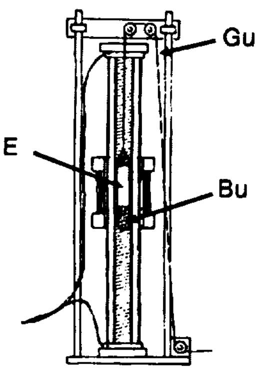
Operational Characteristics

Growth rates:	50 nm/sec to 50 microm/sec
Thermal gradient:	20° C/cm
Maximum furnace temperature:	600° C
Sample shape:	Cylindrical
Mass:	100 g

Carrier: Designed for ground-based research only (MMSL)

Available: Now

Contact: Bruce Rosenthal
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5027



Sheet Float Zone Furnace (SFZF)

The Sheet Float Zone Furnace (SFZF) is a materials processing furnace specifically designed and built to make use of the 20 to 25 seconds of low gravity provided by parabolic flight aircraft (such as the KC-135). The SFZF uses a unique sample format and heater arrangement providing the capability to melt and resolidify bulk quantities of material during this short low gravity period. The resulting resolidification is both directional and containerless.

The SFZF uses movable focusing infrared line heaters to apply heat to a narrow band along a sample. A typical sample is preheated by scrolling the heater back-and-forth during the interval between low gravity periods to bring it to near its melting temperature. As low gravity conditions begin, the heaters are brought together, doubling the heat flux to the center of the sample and the melt is established. The heaters are scrolled apart to spread the melt along the sample's length in both directions and the material resolidifies directionally behind the melt fronts. Since the resolidifying mass is suspended between two liquid zones, the transmission of vibrations and disturbances to the critical area is minimized and resolidification occurs in a containerless mode.

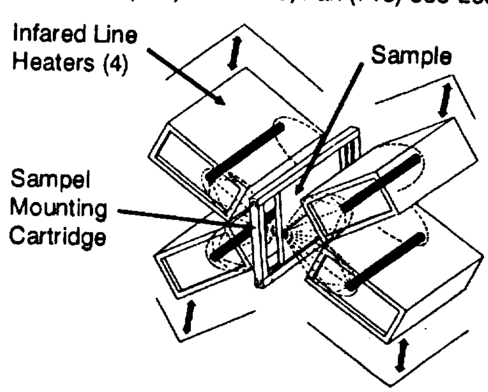
The SFZF is the result of a collaborative effort among Space Industries Inc., Calspan and the Los Alamos National Laboratory. Operation of the furnace has been used primarily for high temperature superconductor research.

Operational Characteristics
Approximately 1270 watts/cm^2 heat flux (controllable)
Heater translation rates from 0.06 to 5 cm/second (controllable)
Furnace walls maintained at less than 30° C
Various furnace purge gases
Sample Size: (Generally a thin sheet) 0.1 in thick x 2.5 in W x 4.5 in L maximum

Carrier: Experimental aircraft, such as the KC-135

Available: Now

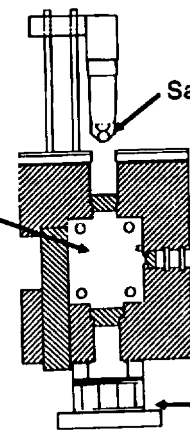
Contact: Wilson M. Fraser, Jr., Manager
Sheet Float Zone Furnace Program
Space Industries International, Inc.
711 West Bay Area Blvd., Suite 320
Webster, Texas 77598
(713) 338-2676, Fax (713) 338-2697



Single Axis Acoustic Levitator (SAAL)

Containerless processing may make possible the preparation of ultrapure glasses used in optical and electrical applications. Since some glasses require a melt temperature of up to 3,000° C, no unreactive containers are available on Earth as the container reacts with the melt, causing impurities. Acoustic processing on Earth is impossible because the sound waves cannot overcome gravity. The SAAL can levitate, melt at temperatures up to 1,500° C and resolidify glass samples acoustically.

Eight glass samples can be processed sequentially and automatically in the SAAL. The samples are positioned one at a time without wall contact in the furnace cavity by acoustic energy. The sample is then melted and cooled to solidification.



Operational Characteristics

Sample size:	4 to 10 mm spherical diameter
Operating temperature:	1,600° C
Furnace size:	93.50 cm H x 40.5 cm diameter
Furnace weight:	81.6 kg
Processing chamber:	10.2 cm x 10.2 cm x 11.4 cm

Carrier: Materials Science Laboratory (MSL)

Available: Now

Contact: NASA/Marshall Space Flight Center
Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-2728

Stabilized Electromagnetic Levitator (SEL)

The Stabilized Electromagnetic Levitator is a highly stable multi-coil levitator for melting and undercooling studies in the microgravity environment. It is characterized by independent control of heating and positioning. The SEL is a single-axis system powered by modified, commercially available, high efficiency, solid-state, radio frequency amplifiers. Both highly or poorly conductive materials, metallic or non-metallic, may be levitated. By varying the signals between coils, sample stability and oscillation can be controlled. Independent heating will allow undercooling without sample instability.

High frequency induction heating of samples to 2700° C or greater is possible. Samples may be processed in a vacuum or in controlled atmospheres.

The open architecture of the device allows access for diagnostic and process control equipment, such as noncontact temperature and optical property measurement. Precise temperature, surface tension and viscosity measurements would be possible in the stable quiescent sample.

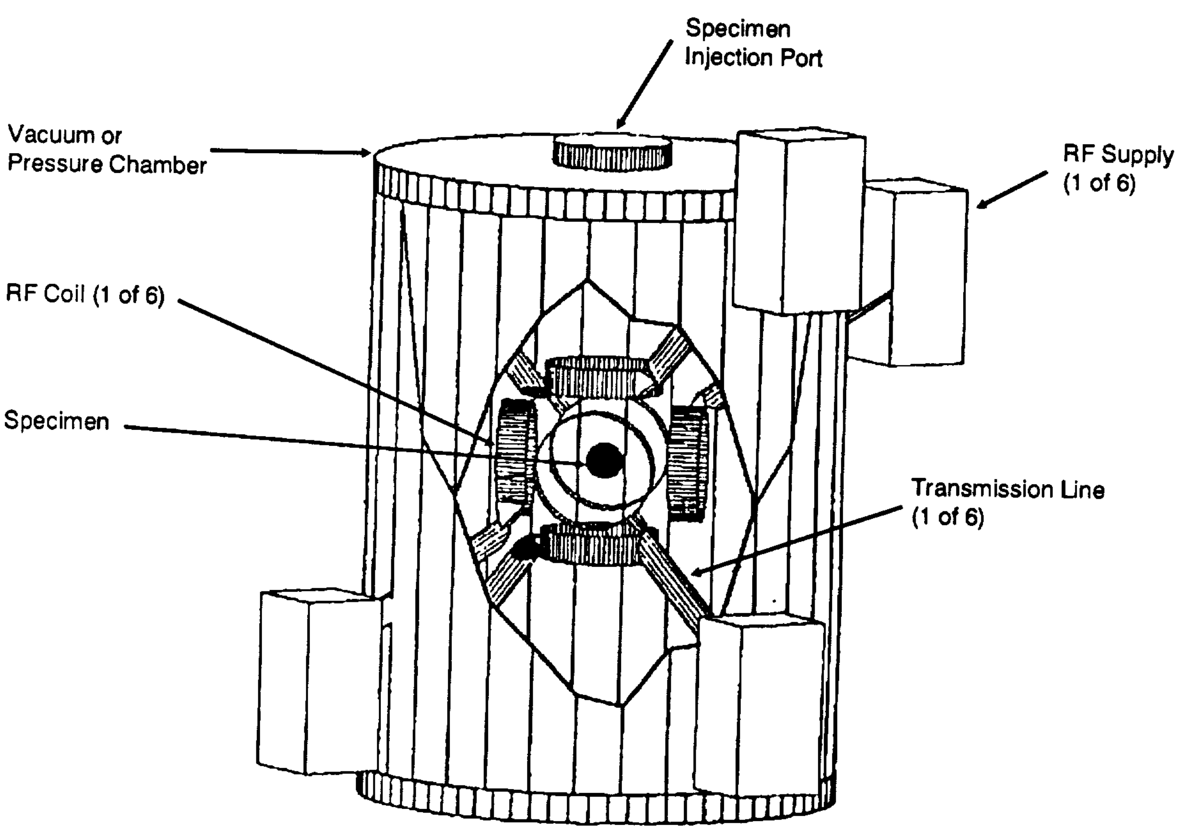
Tentative Capabilities

Temperatures*:	30° to 2700° C or higher
Isothermality*:	Good
Temperature Control	
Precision:	To be determined
Design Goal:	+/-5° C
Gas Purity and Particulate Contamination:	Excellent (as good as process gas)
Process Gas:	Vacuum, reactive or inert
Specimen Size:	2-6 mm
Specimen Motion:	+/-1 mm
Position Accuracy:	<+/-1 mm
Heating Rates*:	0° to 200° C/second or higher
Cooling Rates*:	0° to 200° C/second or higher
Spin Control:	Near zero or very low spin
Optical Access:	Versatile
Heaters:	Inductive heating
Supplemental Beam Heating:	Possible

**Dependent on sample properties and size*

Available: Now

Contact: Tom Danley
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772



Transparent Directional Solidification Furnace (TDSF)

The TDSF provides the capability to perform directional solidification experiments on transparent samples at relatively low temperatures. The furnace consists of slotted heating and cooling elements into which the sample is placed, in a rectangular transparent container. The heating and cooling is done with a pair of circulating constant temperature baths. The upper, heated portion of the furnace is separated from the lower, cooled portion with a slot through which the interface can be viewed. The furnace assembly is translated in order to move the interface through the sample.

Operational Characteristics

Oven temperature range:	Upper oven ambient to 150° C, Lower oven -20° to 20° C
Oven temperature accuracy:	+/-0.1° C
Oven translation speed:	720 mm/hr maximum
Oven step size:	100 nm
Optical magnification:	1X to 64X
Sample shape:	Rectangular
Sample size:	10 mm L x 10 mm W x 15 mm H

Carrier: Designed for ground-based research only (Microgravity Materials Science Laboratory)

Available: Now

Contact: Thomas K. Glasgow
NASA/Lewis Research Center, Code 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5014

Vapor Transport Furnace for Organic Crystals and Films

The vapor transport furnace is capable of operating on several experiment carriers on the Shuttle or on Space Station. The furnace consists of two concentric aluminum tubes with a vacuum space between them. A glass ampoule containing the chemicals for crystal growth is placed inside the inner aluminum tube. Special design considerations allow the furnace to operate at a 413° K (140° C) interior temperature with a power consumption of less than 2 watts when operated in a 293° K (20° C) environment. Gold coatings decrease the radiation heat transfer. A special support mechanism between the two aluminum tubes causes the heat transfer by conduction to be inconsequential. The design is versatile enough to allow its use in solution crystal growth, polymer reactions, melt growth and other applications in addition to vapor transport crystal growth.

Operational Characteristics

Size:	350 mm x 105 mm x 122 mm
Weight:	2 kg without controller
Power:	3 watts at 140° C
Operating temperature:	200° C maximum

Carrier: Get-Away-Special canister, experiment apparatus container, Shuttle middeck locker, middeck rack, Spacelab rack

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Zone Refining Furnace (ZoReF-1200)

ZoReF-1200 is a compact, adjustable temperature, zone-refining type furnace using a cylindrical design for melting and cooling materials in the microgravity environment. The device may have different applications for lower and higher temperature material processes. It is designed to be used with Deliverer-"X" and CHEOPS-"X" reentry recoverable vehicles. Samples may be preheated below the melting temperature to reduce the amount of time required for melting. Current furnace design utilizes passive cooling of the samples.

Operational Characteristics

Preheating and Melting

Zone Temperature:	500° to 1200° C range
Translation Speed:	5 cm^3/ <30 seconds
No. of Samples:	Up to 10 different samples

Carrier: Deliverer-X and CHEOPS-X reentry vehicles

Available: Under development

Contact: COR Aerospace Corporation
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 6760-2474

Other Materials Processing Devices
(See also pages 98 and 161.)

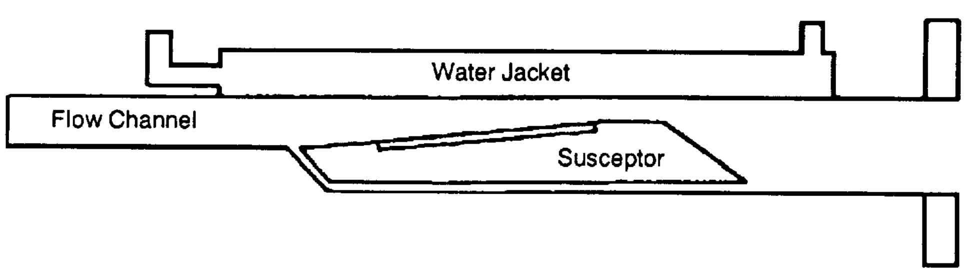
Chemical Vapor Deposition Facility (CVDF)

This facility is intended for flow characterization of chemical vapor deposition reactors in the microgravity environment. The plan is to demonstrate the CVDF for non-reacting flows and then determine the feasibility of fluorescent measurement techniques. The sample size is 50 cm^3.

Carrier: Cross-bay carrier in Shuttle cargo bay

Available: Ground-based facility (non-surfacing flares) is available. A flight unit is proposed.

Contact: I.O. Clark
NASA/Langley Research Center
Hampton, VA 23665
(804) 865-3777



Commercial Refrigerator/Incubator Module (C-R/IM)

The C-R/IM provides a low cost and easily integrated temperature-controlled storage volume for many types of experiment samples such as protein crystals, living cells, organisms and materials. The C-R/IM is an active unit with a temperature range from 4 to 40° C, within +/-0.5° C, with a set point adjustment to 0.1° C. The version shown, is designed to accommodate existing Vapor Diffusion Apparatus (VDA) trays for current crystal growth experiments. Other versions can be made available.

Operational Characteristics

Control temperature:	4° to 40° C
Nominal power:	100 W at 28 Vdc
Ambient Air:	18° to 35° C
Empty Weight:	14.5 kg
Payload Capacity:	17.3 kg (middeck)
Internal size:	25.7 cm W x 16.5 cm H x 37.1 cm D
External size:	46 cm W x 27 cm H x 54 cm D

(Replaces one standard middeck locker volume)

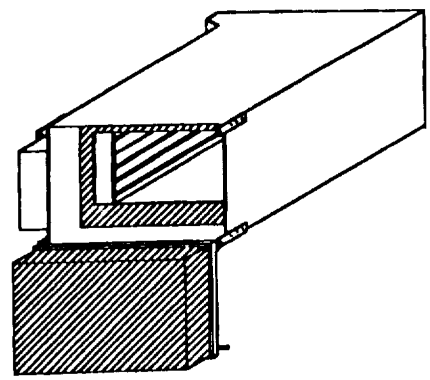
Set points:	every 0.1° C

Data Logger available

Carrier: Shuttle middeck

Available: Under development

Contact: Space Industries Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX, 77598-4001
(713) 338-2676



Critical Fluid Light Scattering Experiment Apparatus (CFLSE)

The highest temperature at which a gas can be liquified by pressure alone is called the critical temperature. However, due to the effect of gravity, the physical characteristics which have been described theoretically, as the critical temperature is approached, are difficult to observe.

The CFLSE measures the decay rates and correlation lengths of critical density fluctuations in Xenon, a nearly ideal model fluid, very near its liquid-vapor critical points, using laser light scattering and photon correlation spectroscopy. The fully automated system permits continuous operation for up to 100 hours of data collection. Temperatures will cover the range of 1° Kelvin to 100° microKelvin from the critical point.

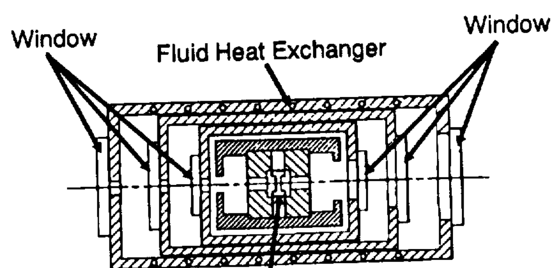
Operational Characteristics

Sample:	Xenon at approximately 57.6 atm
Sample size:	2 cm^3
Apparatus size-2 units:	0.9 m L x 0.6 m W x 0.45 m H 0.3 m L x 0.6 m W x 0.6 m H
Apparatus weight:	410 kg overall

Carrier: U.S. Microgravity Payload (USMP)

Available: 1991

Contact: Richard W. Lauver
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2860



Dendrite Growth Apparatus

This apparatus measures dendrite growth velocities, tip radii and side-branch spacing. Materials studied are organic; they serve as models for metal alloy dendrite growth. A material is melted and then supercooled to desired temperature, at which time the growth of a free dendrite is initiated at the tip of a capillary injector in the center of the growth chamber. Growth chamber is submerged in a thermostatic isothermal bath capable of maintaining temperatures within +/-0.002° C.

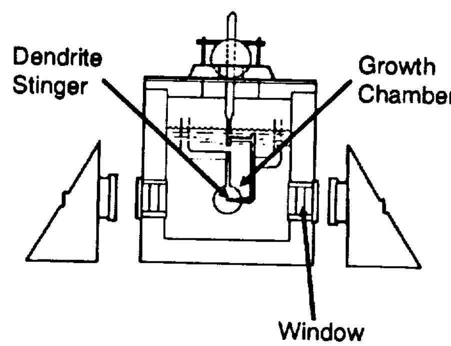
Operational Characteristics

Operating temperature:	4.0° to 80° C
Temperature accuracy:	+/-0.002° C
Photogenic resolution:	+5 micrometers
Sample capacity:	One growth chamber
Sample chamber size:	1 cm to 8 cm diameter

Carrier: Designed for ground-based research only (MMSL)

Available: Now

Contact: NASA/Lewis Research Center
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5013



Diffusive Mixing of Organic Solutions (DMOS) Apparatus

The 3M DMOS apparatus is used for crystal growth from solution, chemical reactions or fluid mixing experiments in the microgravity environment. Modifications are feasible to fit customized needs, i.e., quartz windows added for optical measurements.

The DMOS apparatus includes six independent, modular cells each having three 83-ml chambers separated by gate valves. The gate valves have a maximum 4.5 cm^2 open area. The experiment cells are fabricated from stainless steel and teflon-coated on the interior to provide a chemically inert environment. The flight-proven apparatus contains three levels of hermetic containment: this allows experimentation with hazardous materials while avoiding any hazard to the crew. The DMOS apparatus can be supported by the 3M Generic Electronics Module (GEM/2) which enhances payload control functions and provides data acquisition and crew interface.

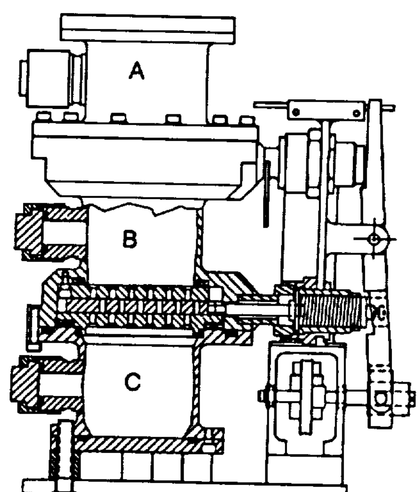
Operational Characteristics

Operating temperature:	Ambient to 45° C (higher temperatures possible with modifications)
Modular cell size:	13.7 cm x 17.3 cm x 22.3 cm
Total apparatus size:	Two middeck locker spaces
Modular cell power requirements:	5 W
Modular cell weight:	4.8 kg
Total apparatus weight:	60.6 kg with EAC

Carrier: The DMOS unit is housed within an Experiment Apparatus Container and can be mounted into the Shuttle middeck or cargo bay carriers, Spacelab or SPACEHAB facilities.

Available: Now

Contact: E. L. Cook
3M Space Research and Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



3-Chambered Modular Cell

Electrodeposition and Codeposition Apparatus

This system allows production of metal deposits and metal codeposits (composites) at controlled rates. A programmable microprocessor-controlled electronic unit powers the entire package. Thirteen cells are arranged in a bank. Each cell contains an electrolytic solution to sustain an electro-deposition process and produce metal coatings. Five of the cells are equipped with small stirring motors to agitate inert particles in the solution and produce metal composites. This process is recorded with a 35mm camera controlled by the unit electronics. The cells are operated at constant current or voltage. Current and voltage data are stored. Sampling rate is controlled by the unit software. The unit is thermally controlled.

Operational Characteristics

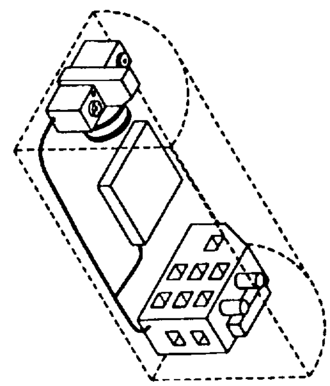
Size:	700 mm x 200 mm x 230 mm
Weight:	10 kg

Power: Approximately 20 watts to drive motors, cells, camera and flash

Carriers: KC-135 parabolic flights, Get-Away-Special canisters, sounding rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620



Fluid Science Module (FSM)

The Fluid Science Module is designed to house three experiments. Two of these experiments are intended for investigation of the Marangoni convection effect, where one will make use of thermocapillary drop motion under microgravity, and the other will study mass transfer from liquid to gas phase. Each of these experiments is monitored by a TV-system from which the pictures are transmitted to ground via an S-band Video Link. The third experiment is for study of thermal conductivity of liquids by means of a transient hot-wire technique under microgravity.

The Inner Experiment Mounting Structures is composed of two aluminum panels mounted along the module. In principle, each experiment is built on a panel which comprises self-contained units that can be assembled, handled and tested independently. However, the thermal conductivity experiment comprises two test cells that are mounted directly to the cylindrical structure wall.

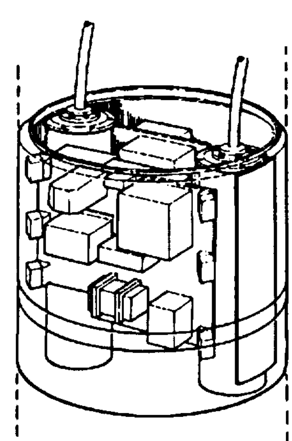
Operational Characteristics

Size:	390 mm L x 438 mm diameter
Weight:	38.6 kg
Material:	Outer structure – magnesium casting Inner structure – aluminum panels
Type of joints to neighboring modules:	Radax joints
G-force:	Approximately 14 g maximum
Thermal environment for the experiments:	13° to 23° C

Carrier: Sounding rockets

Available: Now

Contact: CONATEC, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088



Foam Formation Apparatus

A nitrogen cylinder actuates one of two piston/cylinder assemblies, injecting the contents of the first cylinder into the second. The contents of the second cylinder are then mixed by a motor-driven propeller. After a few seconds of stirring the mixture is expelled through a conical exit containing a screen. A 35 mm camera with flash attachments captures the foaming process. Mirrors on each side of the exit funnel allow a rear view. A thermistor mounted on the exit funnel records the temperature profile of the experiment.

Operational Characteristics
Size: 648 mm x 368 mm x 254 mm
Weight: 16.1 kg
Power: 2.1 Amps at 28 Vdc, approximately 20 watts power required to operate camera and flash
Gas operating pressure: 34 atm

Carrier: Sounding Rockets

Available: Now

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Fourier Transform Infrared Spectrometer Apparatus

The 3M Fourier Transform Infrared Spectrometer is used for experimentation involving materials processing and studies of dynamic chemical systems in microgravity. Some examples of the many applications of the spectrometer for recording data are polymerization, melt crystallization and phase separation. The apparatus utilizes a Michaelson interferometer to provide a unique opportunity for recording, in real-time, the dynamic effects of microgravity on these chemical systems. In its current configuration, the apparatus provides 20 sample positions, can be thermally controlled up to 250° C and operates in the transmission mode. Modifications to the apparatus for accommodating alternate sample configurations are available. Interferograms can be acquired every 4 seconds and stored in the mass memory of an auxiliary computer, such as the 3M Generic Electronics Module (GEM/2), or transformed into IR spectra and displayed on-orbit.

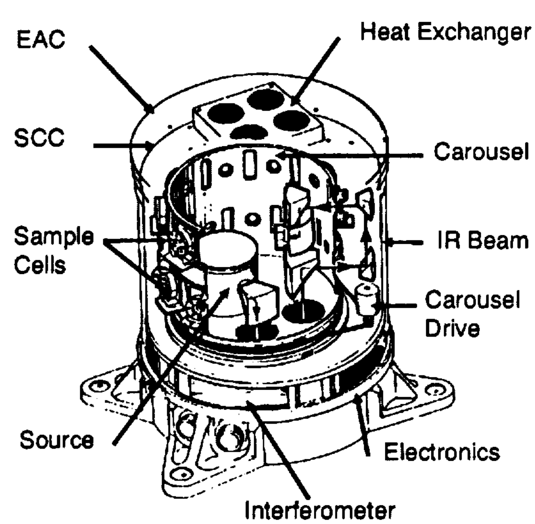
Operational Characteristics

Wavenumber range:	5,000 cm^{-1} to 400 cm^{-1}
Wavenumber precision:	0.01 cm^{-1}
Resolution:	4 cm^{-1}
Power:	110 W
Size:	2 middeck locker spaces
Weight:	54.5 kg

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: E. L. Cook, Director
3M Space Research and Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



Isothermal Dendritic Growth Experiment Apparatus (IDGE)

The IDGE allows investigators to measure dendritic growth in microgravity where heat transfer is a more dominant factor in crystallization than fluid motion; and to study the effects of melt supercooling and acceleration on dendritic growth rate, tip radius, side branch spacing and general morphology. The materials studied are transparent, crystalline organics such as pure succinoitrile (SCN) and SCN alloys. One sample is contained in an isothermal growth chamber, where it is melted, then cooled, and injected with a dendrite in the center. Twenty different supercool temperatures per flight are possible.

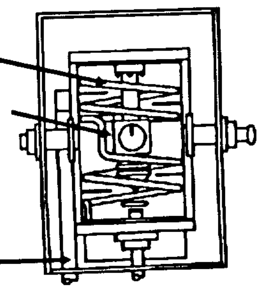
Operational Characteristics

Sample size:	4 cm to 6 cm diameter
Sample volume:	11 to 35 cm^3
Temperature range:	30° to 60° C
Apparatus size:	100 cm L x 86 cm W x 94 cm H
Apparatus weight:	Approximately 310 kg

Carrier: U.S. Microgravity Payload (USMP)

Available: Under development

Contact: Edward A. Winsa
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2861



Low Gravity Mixing Equipment

The low gravity mixing equipment can be used to mix liquid phase materials at room temperature in suborbital research applications. Up to four samples can be mixed on each of six possible parabolic trajectories per experiment. The complete experiment package, which consists of an upper containment chamber, sample vial rack, delivery lines, metering pump, electromagnetic pump, video camera and videocassette recorder, power/fuse box and associated support structures, is housed in an instrument rack. The experimenter has the flexibility to control the amount and timing of material delivered to the 4 ml sample vials, the frequency and amplitude of vibration and the timing of video recording needs.

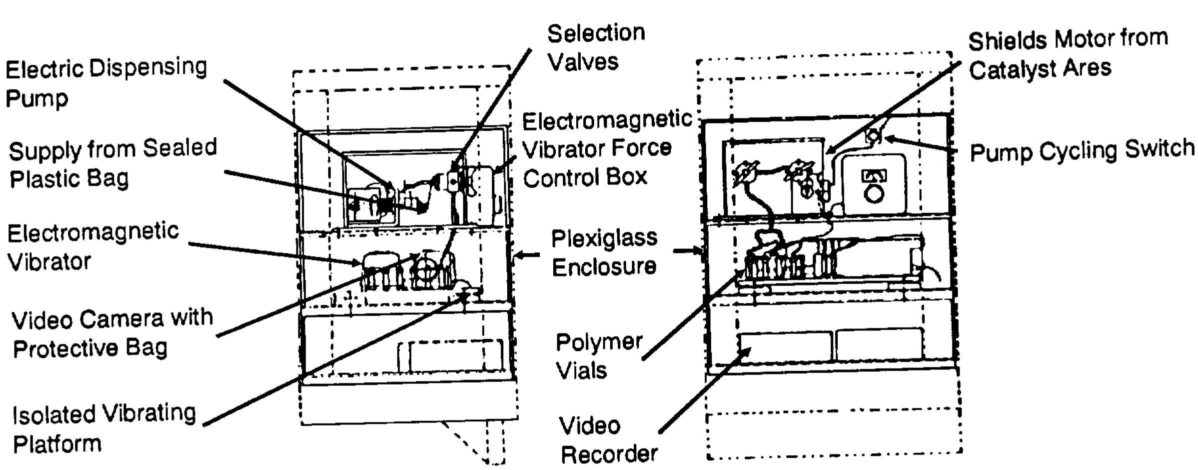
Operational Characteristics

Equipment size:	Housed in 61 cm L x 91 cm H x 53 cm D instrument rack
Mass:	85 kg
Sample size:	Up to 4 ml per vial
Modularity:	Can be adapted to experimenter's needs

Carrier: Suborbital research aircraft instrument rack

Available: Now

Contact: Advanced Materials Center/Battelle
505 King Avenue
Columbus, OH 43201-2693
(614) 424-6376 or (614) 424-4146



Low-Temperature Research Facility (LTRF)

The LTRF provides a capacity to conduct experiments that require temperatures as low as 1.5° K and acceleration forces of less than 10^{-4} g. The first two flights of the LTRF were planned to investigate the bulk properties of superfluid helium and the behavior of superfluid helium at the Lambda transition. Results will test the theories of cooperative phase transitions.

The cryostat of the LTRF accommodates a sample of 20.32 cm diameter by 73.66 cm length, with a weight limit of 31.50 kg. The experiment can be preprogrammed over a proposed 168-hour on-orbit lifetime.

Operational Characteristics

Apparatus size:

3 units:
- 137.16 cm L x 102.87 cm W x 86.36 cm H
- 81.28 cm L x 60.96 cm W x 55.88 cm H
- 45.72 cm L x 40.64 cm W x 20.32 cm H

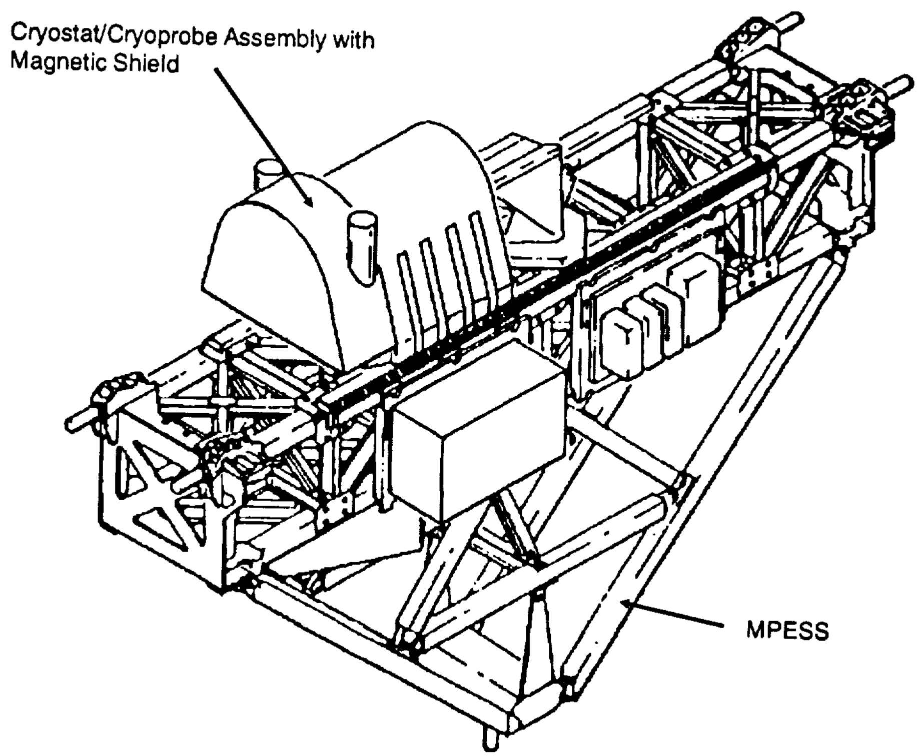
Apparatus weight: 376.65 kg overall plus sample

Sample temperature range: 1.5° to 4.5° K

Carrier: Materials Science Laboratory (MSL)

Available: Now

Contact: NASA/Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-4818



Organic Separation

This apparatus consists basically of several glass cuvettes (1.5 ml) containing immiscible liquids and stirring bars that are spun by a small motor. The progress of demixing is then followed photographically. The block holding the cuvettes contains a heater and a thermistor for temperature control of the block. A camera photographs the 12 cuvettes which are back lit by a photo flash.

Operational Characteristics

Size:	457 x 178 x 170 mm
Weight:	6.5 kg
Power:	12 stirring motors require approx. 100 ma at 3 vdc each. Heater requires approx. 5 watts at 28 vdc. Power needed to operate camera and flash

Carrier: Shuttle, Get-Away-Special canister, sounding rockets, KC-135

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of ALabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Multipurpose Experiment Modules (TEM 06)

The TEM 06 modules are suitable for the implementation of experiments from almost any scientific discipline. The module consists of an experiment platform for mounting the experiment, power supply and the electronics package. The experiments are individually configured and installed in this module type. A number of standard components are available for setting up the experiments, including:

- Pneumatic-hydraulic assemblies for the movement of parts
- Electromotor assemblies to move and position experiment hardware
- Supporting devices for optical components
- Various cameras:
  - Film cameras (16 mm) with a picture frequency of up to 400 fps and time registration up to 1/100 second
  - Miniature camera
  - Video cameras applying the tube and CCD Techniques with the associated ground support equipment such as monitors, recorders and transparent overlay of data/text
- Specific experiment cells
- Optical diagnosis appliances such as:
  - Top view/transmitted light illumination
  - Schlieren optics
  - Laser optics with beam filtering for diffraction measurements
  - Laser light band optics
  - Differential interferometer
  - Microscope for transmitted light phase contrast or dark field with remote-controlled focusing
- Pressure sensors, temperature sensors and position sensors
- Control and measurement electronics
- Data acquisition: 32 or 64 analog channels, 10 bits, 4 Hz standard; for rapid processes up to some TBD kHz.

Standard Power System

Electronic:	NiCad 28 Vdc/2.5 Ah Extension to 2 x 28 Vdc/ 2.5 Ah is possible

PCM System: 32 analog channels, 0 to 5 V, 10 bit
Extension to 64 channels possible
30 digital channels, 0/1 event status bits
Extension to 60 channels possible

Timer: 16 independent events
Extension to 2 x 16 events possible

External/Internal Switch: 1 unit for electronic
Extension for 2 units possible

Module TEM 06-9
This module (of the TEM 06 series) is designed to investigate a variety of experiments in the fluid dynamics area. It is applicable to the investigation of the establishment of a floating zone with silicon oil. The primary experiment chamber contains an integrated fluid storage system which may be used to enhance the experiment performance in a variety of applications. The goal is to observe the process of zone establishment using different velocities and the oscillation of the zone during the process. The chamber is illuminated by field illumination and the process is recorded by 16-mm color film camera.

Multipurpose Experiment Modules (continued)

Module length: 679 mm
Module weight: 45.0 kg

Carrier: Shuttle middeck

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Reaction Injection Molding (RIM) Apparatus

RIM is a polymer process in which stoichiometric proportions of liquid monomers or oligomers are mixed intensively by impingement, then injected into a mold where polymerization commences. RIM can also be referred to as reaction injection chemistry (RIC) since this apparatus can accommodate a wide variety of reactive chemistries. The unit also can be used to conduct other experiments, such as polymer blends.

The basic operation of the RIM system is initiated by pressurizing each of two reactants which are then guided to one of four mixing heads, where mixing occurs by impingement. Molecular level observations and chemical kinetics of the ensuing polymerization can be achieved in real-time when the RIM system is interfaced with the 3M Fourier Transform Infrared Spectrometer (FTIR).

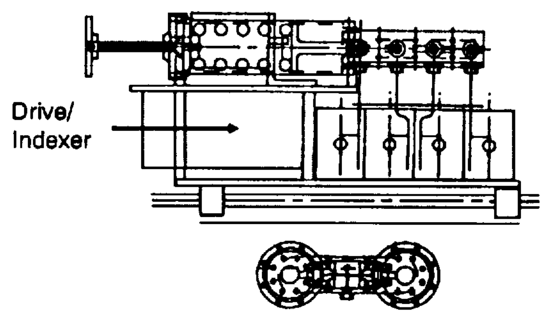
Operational Characteristics

Pressure:	0 to 2,000 psi
Temperature:	Ambient to 175° C (higher temperatures possible with modifications)
Weight:	15 kg to 18 kg
Size:	0.03 m^3
Capacity:	1 ml to 70 ml

Carrier: This unit is designed for use in the KC-135 aircraft; modifications are underway for use in the Shuttle middeck or cargo bay carriers (Spacelab or SPACEHAB).

Available: Now

Contact: E. L. Cook
3M Space Research and
Applications Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



Rigid Gas-Permeable Plastic Material

The purpose of this development is to investigate the possibilities of producing an improved, rigid, gas-permeable plastic material for contact lenses by polymerization in zero-g. Polymerization should result in more uniform polymer matrix for enhanced permeability. This material can then be used in extended-wear contact lenses and lenses for pilots and astronauts.

Carrier: Shuttle middeck experiment

Available: Under development

Contact: B.T. Upchurch
NASA/Langley Research Center
Hampton, VA 23665

Solid Surface Combustion Experiment Apparatus (SSCE)

The SSCE will investigate mechanisms that control flame spreading on solid fuel surfaces to improve the understanding of material flammability and burning characteristics. In the SSCE, thermally-thin fuel samples (e.g, ashless filter paper) and thermally-thick fuel samples (e.g., polymethyl-methacrylate) are ignited and burned in a sealed chamber. This permits the study of the processes that influence the vapor phase of solid fuel combustion in the absence of buoyant or forced gas-phase flow.

Operational Characteristics

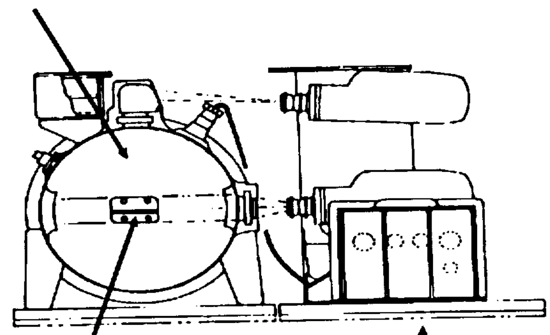
Sample size

Thermally-thick fuel:	0.18 cm x 3.0 cm x 11.1 cm
Thermally-thin fuel:	0.315 cm x 0.630 cm x 2.000 cm
Oxidizer (air):	35%, 50% and 70% O_2
Overall dimensions:	55.6 cm L x 93 cm W x 53.5 cm H
Chamber dimensions:	51.3 cm x 34.3 cm ID
Weight-overall:	55 kg

Carrier: Shuttle middeck

Available: Now

Contact: John M. Koudelka
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2852



Surface Tension-Driven Convection Experiment Apparatus (STDCE)

Experiments conducted in the STDCE will enhance the study of transient and steady state thermocapillary flows in fluids. These flows result from the variations of surface tension with surface temperature. Oscillations in the velocity of thermocapillary flows may have deleterious effects on solidification, crystal growth and containerless processing in space. The data obtained from this experiment will verify mathematical modeling and allow investigators to complete the numerical model. This will lead to improved crystal growth and solidification processing techniques.

The STDCE consists of a circular container filled on-orbit with silicone oil producing a flat free surface. The oil is heated at the surface with a CO_2 laser or internally with a submerged cartridge. Surface temperatures are measured with a scanning IR imager. Particles in the oil are illuminated with a laser diode light sheet and velocities measured by computer analysis of video tape.

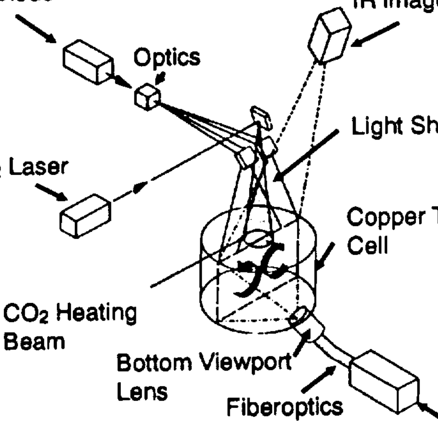
Operational Characteristics

Sample:	10 cs silicone oil
Sample volume:	400 ml
Sample chamber:	5 cm H x 10 cm diameter
Temperature range:	10° to 65° C (delta)
Apparatus size:	50 cm L x 50 cm W x 100 cm H
Apparatus weight:	227 kg overall

Carrier: Spacelab-Double Rack

Available: Under development

Contact: Thomas P. Jacobson
NASA/Lewis Research Center
Space Experiments Division
Cleveland, OH 44135
(216) 433-2872



Surface Tension-Driven Convection Experiment Concept

Thin-Film Reactor System

The thin-film reactor system was developed to investigate thin films of thermosetting resins containing a rubber-dispersed phase under low gravity conditions. The basic unit of the thin-film reactor is a digital timer and sequence controller to be controlled independently with regard to sequence and event duration. Additionally, there are several solenoids and positive stops to control the motion and position of events during the experiment: an ultraviolet source, a temperature-process controller and heating coil, a mixing motor and a chamber rotational motor.

The operating procedure involves removal of the thin-film ring from the mixing chamber and curing the sample, shutting down the mixing motor, rotating the process chamber to the post-cure chamber and lowering the ring into the post-cure chamber.

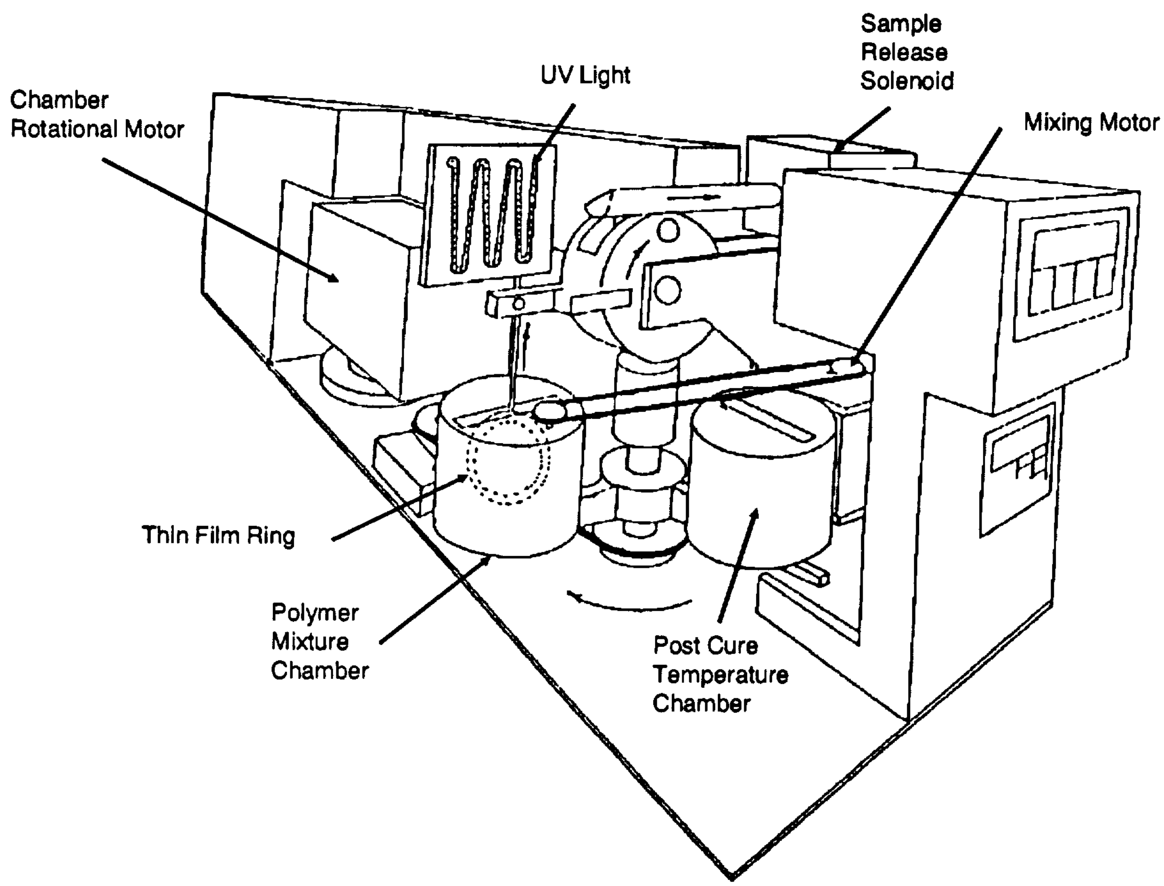
Operational Characteristics

Size:	76 cm L x 36 cm W x 46 cm H
Weight:	50 kg
Modularity:	Experiment can be adapted to experimenter's needs

Carrier: Drop towers; could be modified for suborbital aircraft testing

Available: Now

Contact: Advanced Materials Center/Battelle
505 King Avenue
Columbus, OH 43201
(614) 424-6376 or (614) 424-4146



Life Sciences/Biotechnology

In addition to materials processes, the microgravity environment is helping us to advance our knowledge of how living systems function. Gravitational biology research focuses on determining how the near weightlessness of space affects both plant and animal species from fertilization through birth, maturation and death; we need this knowledge not only to increase our understanding of terrestrial life, but also in preparation for future long-term journeys and habitation in space.

Space offers a unique materials processing environment because it provides microgravity and also near-zero temperatures, a high vacuum, a sterile environment, and heat and solar energy from sunlight. Space-based biotechnology takes advantage of these characteristics to produce protein crystals and purer and more potent drugs such as isoenzymes and antibiotics. Materials separation, for example, utilizes processes such as electrophoresis, isoelectric focusing and suspension cell culturing to produce pharmaceutical products with greater efficiency and higher purity. Crystals up to a hundred times larger than those produced on Earth can be made in microgravity by using various processes such as floating zone, vapor crystal growth and liquid crystal growth.

Equipment for life sciences and biotechnology experiments share a large inventory as a result of the ongoing human and non-human research developed for the Shuttle and Spacelab programs. Some of the entries that follow deal with investigations not necessarily involving a human or primate subject and therefore may be of interest to commercial developers exploring other related areas. In low gravity, the influences of thermal turbulence, buoyancy and sedimentation are reduced, much to the advantage of investigations exploring protein crystal growth, the separation of biological materials and cell culture.

Biotechnology

Automated Generic Bioprocessing Apparatus (AGBA)

The AGBA was developed as a tool to study a variety of biomaterials processes in reduced gravity. In the configuration flown on the Consort-3 sounding rocket in 1990, the payload weighed 40 pounds, occupied 1.1 ft^3 and processed 120 individual samples.

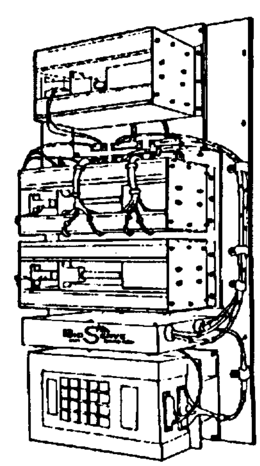
Fluid samples are stored in misaligned wells machined into six sets of polycarbonate blocks. Each set of blocks consists of a fixed and sliding part, housing from 12 to 28 sets of sample wells. Each set of sample wells consists of three wells with process precursor, initiator and terminator materials, respectively. During operation, the precursor and initiator materials are brought into contact and allowed to mix through diffusion during the microgravity episode. At the completion of the experiment, processed materials are brought into contact with the terminator materials.

Temperature can be controlled above ambient for some of the samples. Thermistors are used to record temperature during and after flight. In addition, 32 sets of samples are instrumented with LED's and photocells for recording of optical density changes in real time. Data are stored in the AGBA and telemetered to the ground.

Carrier: Sounding rocket

Available: Now

Contact: BioServe Space Technologies
University of Colorado
Campus Box 429
Boulder, CO 80309
(303) 492-1005



BioModule, PSU

The PSU BioModule can be used to study any reaction requiring instantaneous mixing to initiate a process of interest. Its uses include study of biological systems as well as chemical reactions. Simple modifications can be made to allow study of diffusion processes, such as crystal growth.

The BioModule provides simple and reliable addition of two separate fluids to a main chamber. Fluid transfer from reservoirs (up to 150 microliters) to the main chamber (300 microliters) is accomplished via mechanical pressure on a T-shaped silicone bag network with time of transfer during the flight under computer control. The BioModule unit contains separate silicone T's. These basic units can be reconfigured to satisfy new payload requirements.

In the current model, four BioModule units, with auxiliary electronics and on-board computer, fit into a space 9 in x 11 in x 13 inches and weigh less than 14 pounds. Firing each solenoid for mixing consumes about 2 amp for 0.2 second. The BioModule is scheduled to be aboard a Consort or Joust rocket mission once every six months. The Consort flights provide about seven minutes of microgravity. The Joust flights provide 15 minutes. Using this equipment, commercial clients can have samples go from their laboratory to space in about 18 hours. A new late-access policy on Consort missions allows biological samples to be placed on board just three hours before launch.

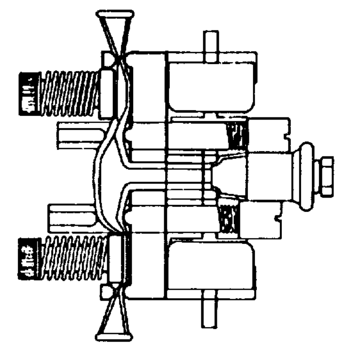
Operational Characteristics

BioModule size:	2 in x 6 in x 2 in
BioModule weight:	1.5 lbs
Power requirements:	2 amp for 0.2 seconds per solenoid
Reservoir size:	Up to 150 microliters
Main chamber size	300 microliters

Carrier: Sounding rocket, Shuttle, ELV

Available: Now

Contact: Roy Hammerstedt
Center for Cell Research
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407



Continuous Flow Electrophoresis System (CFES)

The CFES apparatus separates and purifies living cells and macro-modules without the gravity-induced influences of thermal convection and sedimentation. Processing of cells and proteins in the CFES indicate that biological substances can be separated into pure forms in space in large quantities; the CFES can separate over 400 times the quantity of material separated on the ground.

The samples of biological material are injected into a buffer solution that flows through an electrical field in the electrophoretic chamber. The product of interest is collected in the Fluid System Module (FSM) and returned to Earth. The CFES processes one large 2-liter volume sample for a period of up to 3 hours.

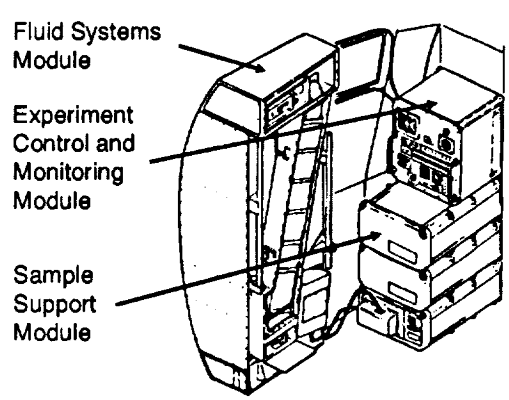
Operational Characteristics

Operating temperature:	12° to 16° C gradient
FSM Size:	76.2 cm L x 65 cm W x 201.7 cm H
Support equipment:	48.9 cm L x 49.1 cm W x 27.9 cm H
Apparatus weight:	371.47 kg overall

Carrier: Shuttle middeck

Available: Now

Contact: Wesley C. Hymer
Center for Cell Research
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407



Experiment R/IM Carrier (ISERC) and Power Supply/Controller

The ISERC payload carrier and power supply/controller, designed to fit inside the Refrigerator/Incubator Module (RIM), provides a structural, thermal interface for NASA's R/IM for user provided payloads. Developed for ITA's Material Dispersion Apparatus (see page 96), the carrier and power supply/controller can accommodate many middeck experiment payloads requiring a constant thermal environment, or can be redesigned to meet specific payload requirements. Payload elements are integrated with the carrier and power supply/controller. The carrier is then installed in the R/IM for integration with the Shuttle middeck. Both the carrier and power supply/controller have been tested and shown to meet the Shuttle vibration environmental specification.

Operational Characteristics

Carrier weight:	5.5 lbs
Allowable payload dimensions/volume:	10.00 in W x 6.22 in H x 14.25 in D/.513 ft^3
Power supply:	16.8 Vdc, 90 watt hrs (zinc air cells)
Power supply/controller mass:	2.5 lbs
Power supply/controller dimensions/volume:	5.0 in W x 3.38 in H x 3.9 in D/.038 ft^3

Carrier: Shuttle middeck R/IM

Available: Now

Contact: Jaak Holemans
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569

Fluids Experiments Apparatus (FEA)

The FEA is designed to provide the industrial user with a convenient, low-cost, modular experiment system for fundamental space-processing research in biology, chemistry and physics. With the FEA, investigators can conduct basic and applied processing or product development experiments in general liquid chemistry, crystal growth, fluid mechanics and thermodynamics, and cell culturing of biological materials and living organisms.

This general-use, adaptable facility can be configured to manipulate a wide variety of experiments including gaseous, liquid or solid samples, expose samples to vacuum conditions, and heat and cool samples. A number of specialized subsystems are planned for the FEA, including low- and high-temperature furnaces, custom-designed heaters, special sample containers and a specimen centrifuge. These modules will allow FEA hardware and operations to be customized to support a wide range of experiment requirements.

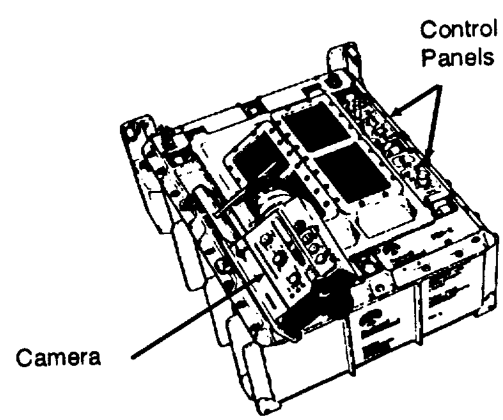
Operational Characteristics

Sample capacity:	Depends on sample
Apparatus size:	47.2 cm L x 36.8 cm W x 18.8 cm H
Weight:	11.7 kg

Carrier: Shuttle middeck locker

Available: Now

Contact: Michael J. Martin
Microgravity Projects FC25
Rockwell International
12214 Lakewood Boulevard
Downey, CA 90241



Generic Bioprocessing Apparatus(GBA)

The Generic Bioprocessing Apparatus (GBA) is a self-contained enclosure module designed to support experiments in microgravity. The GBA occupies the space of one middeck locker and will support payloads up to 2 ft^3 in volume and 40 pounds in weight. The inherent features of the GBA include: total access to the payload volume through the slide drawer design, data acquisition and control module (DACP), RS232 communication to the Shuttle grid, user defined from panel for experiment control and video downlink capability. Optional power packs also are available to supplement the standard 28 Vdc Shuttle power supply.

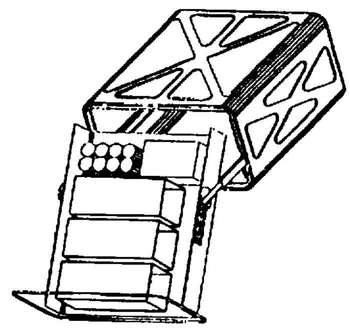
Operational Characteristics

Size:	One middeck locker
Payload size:	2 ft^3 volume and 40 lbs weight

Carrier: Shuttle middeck locker

Available: Now

Contact: BioServe Space Technologies
University of Colorado
Campus Box 429
Boulder, CO 80309
(303) 492-1005



Materials Dispersion Apparatus (MDA) Minilab

The Materials Dispersion Apparatus (MDA) Minilab is a lightweight device specifically engineered for materials processing such as protein crystals, thin film membranes, biomedical materials and others. The MDA operates on the principles of liquid-to-liquid diffusion and vapor diffusion (osmotic dewatering). The MDA is capable of automatically mixing up to 150 separate samples of virtually any two, three or four fluids in space and each test well cavity can accommodate fluid samples in the 50 to 400 microliter range. Multiple data points can be obtained on a single Shuttle, sounding rocket or ELV/satellite recovery capsule flight.

The MDA operates on the following principle: Two blocks of inert material each with a compatible number of test wells in the upper and lower half are held together in a lightweight aluminum housing. The test wells are misaligned prior to launch, thus separating the fluids to be mixed. After microgravity is achieved, the blocks are moved into alignment allowing the fluids to contact. An option exists to mix a third fluid to fix the process prior to reentry and/or to cast thin film membranes while still in the microgravity environment.

The MDA has flown on the Consort 1, 2 and 3 Sounding Rocket Flights and is manifested to fly on the Shuttle.

Operational Characteristics

Size:	3.3 in x 2.4 in x 10 in
Weight:	4.0 lb
Volume:	0.047 ft^3
Voltage:	16 Vdc
Power:	Two 3 watt/5 second pulses provided externally or with ITA's MDA controller and power supply
Nominal test wells:	140
Nominal test well capacity:	100 microliters

Carrier: Middeck lockers, sounding rockets, COMET recovery capsule, GAS cans, Hitchhiker, Spacelab, Spacehab and ITA Standardized Experiment Modules (ISEM's)

Available: Now

Contact: John M. Cassanto
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569

Matrix Reinforced Payload Process Method and Device (MaRP Process)

MaRP is a process method and device designed for protecting sensitive materials that are processed in the microgravity environment. Applications include, but are not limited to, biological materials such as proteins or other crystals, thin films and cellular structures. This process method is carried out subsequent to the completion of the materials process to protect the materials both for recovery in reentry vehicles and subsequent transport to a given location for analysis.

The Matrix Reinforced Payload Process is initiated following completion of the processing of the materials in Low Earth Orbit. The sample is encased in a small volume of an inert polymer matrix which protects it from g-loading and other vibrational forces. The payload, which is contained in Deliverer-"X" or CHEOPS-"X" reentry vehicle, is de-orbited, recovered and transported to a given location for subsequent analysis.

The device is a simple slow-flow injection system which delivers an uncured polymer matrix to the sample (e.g. a protein crystal). The inert polymer matrix then cures at a rate defined by the concentration of the curing agent and temperature of the process (4° C to 50° C), encasing the sensitive material. The polymer matrix can be removed to extract the sample for subsequent analysis in the Earth-based laboratory.

Carrier: Deliverer-"X" or CHEOPS-"X" reentry vehicle

Available: Now

Contact: COR Aerospace
270 Farmington Avenue, Suite 305
Farmington, CT 06032
(203) 676-2474

Phase Partitioning Experiment Apparatus (PPE)

The PPE measures the spontaneous demixing of liquid-liquid, aqueous polymer two-phase systems. Two-phase separation is universally used to separate biological cells and proteins. PPE permits the study of altering volume ratios, viscosity, interfacial tension, interfacial bulk phase potential, phase composition on the kinetics of demixing and the effects of chamber geometry, materials and wall coating of the foregoing parameters.

The PPE is configured to study natural coalescence and surface tension, two methods of phase separation. It also allows variations in interfacial tension, phase volume ratio, phase system composition and added particles. Up to 24 separate cavities can be filled with small quantities of two different polymers in simple water/salt solutions. The apparatus is shaken and photographed to record phase separation.

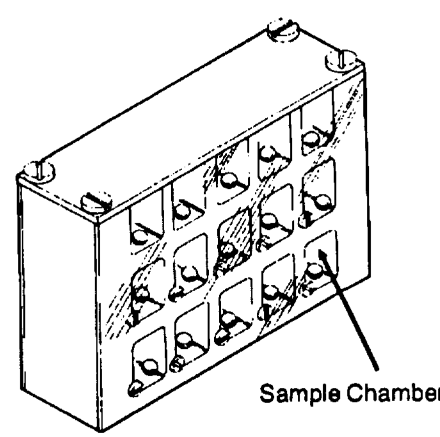
Operational Characteristics

Sample chamber:	1.4 cm L x 1.4 cm W x 1.4 cm H
Assembly size:	14.0 cm L x 3.3 cm W x 9.0 cm H
Assembly weight:	0.7 kg
Assembly volume:	526.7 cm^3

Carrier: Shuttle middeck locker

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-2728



Physical Vapor Transport of Organic Solids Apparatus (PVTOS)

The 3M PVTOS hardware is used for growing crystalline solids and thin films by gaseous diffusion, and for studying vapor phase transport phenomena in microgravity. Nine individual cylindrical cells, each roughly 3 inches in diameter and 12 inches long, contain a vacuum insulated heater core surrounding a specialized reactor tube, a heat-pipe-cooled substrate within the reactor tube and thermocouples to monitor the temperature at various locations.

PVTOS is designed to operate nominally at 400° C. The cell design intrinsically provides double hermetic confinement of the source material, utilizing all metal-to-metal seals. Modifications are feasible to fit customized needs.

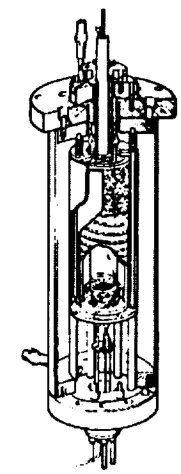
Operational Characteristics

Operating temperature:	400° C (higher temperatures possible)
Power:	50 W
Size:	2 middeck locker spaces
Weight:	56.7 kg with EAC

Carrier: The unit is housed within an Experimental Apparatus Container and can be mounted into the Shuttle middeck or cargo bay carriers, Spacelab or SPACEHAB facilities.

Available: Now

Contact: E. L. Cook
3M Space Research and Applications
Laboratory, Bldg 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357



Individual Cylindrical Cell

Protein Crystal Growth Experiment Apparatus (PCG)

Protein crystals grown in the PCG apparatus, because of their potential size, degree of purity and quality, are highly valued for crystallographic analyses.

The PCG carrier assembly accommodates three trays, each of which can hold one or more Vapor Diffusion Apparatus (VDA) units. Each VDA holds 20 PCG experiments, which are activated simultaneously, and the crystals are returned to Earth for analysis.

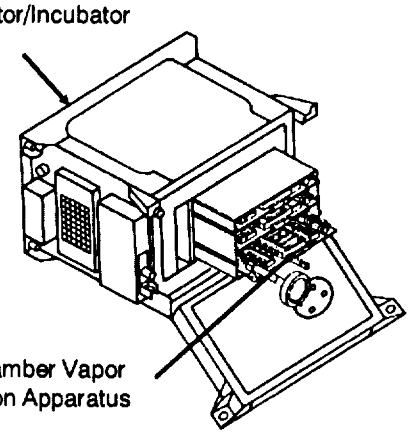
Operational Characteristics

Sample capacity:	Up to 100/flight
Droplet size:	Up to 80 microliters
Precipitant reservoir:	1 ml
Apparatus size:	38.8 cm L x 25.7 cm W x 16.2 cm H
Apparatus weight:	13.7 kg
Temperature range (R/IM):	0 to 50° C

Carrier: Shuttle middeck, Refrigerator/Incubator Module

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812
(205) 544-1988



C-2

Refrigerator/Incubator Module

This apparatus is an active unit with a temperature range from 0° to +40° C. The temperature is set using a front-mounted variable potentiometer. Switching between the refrigeration and incubation modes occurs automatically.

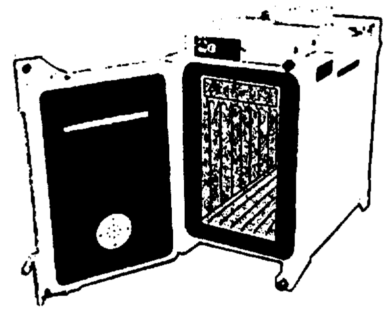
Operational Characteristics

Control temperature:	0° to 40° C (+/-0.5° C)
Ambient range:	2° to 50° C
Weight size:	19.35 kg
Internal size 2 sections:	16.4 cm x 25.88 cm x 36.98 cm, 4.27 cm x 13.97 cm x 16.41 cm
External size:	27.89 cm x 49.15 cm x 48.9 cm

Carrier: Shuttle middeck locker or Spacelab

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736



Life Sciences

Animal Enclosure Module (AEM)

The AEM supports up to six 350-gram rats and fits inside a standard middeck locker. A removable divider plate provides two separate animal holding areas, if desired. The AEM may be removed in orbit for viewing or photographs. It also will fit within the General Purpose Work Station (see page 88). The current unit has a 1500 cc and 2000 cc capacity automatic watering unit.

Operational Characteristics

Size:	24.5 cm x 43.69 cm x 51.05 cm
Floor space:	125 in^2
Weight, loaded:	26.8 kg
Temperature:	Shuttle or Spacelab ambient

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736

Experiment Module TEM 06-16

This module has been used for investigation of flow pattern within algae roots and to research the influence to the g-sensors of the algae in the roots. The module is designed to carry 5 different experiment cells containing the algae roots. One cell is used to observe the flow pattern within the root under microgravity. The other 4 cells are used to observe the delocation of the g-sensors in the roots. Experiment evaluation takes place after the flight by special preparation and evaluation of the algae roots.

Operational Characteristics

Module length:	462 mm
Module weight:	34.0 kg

Carrier: Shuttle middeck

Available: Now

Contact: SpaceTech
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Frog Environmental Unit (FEU)

The FEU is a gravitational biology/embryology experiment package containing a centrifuge, adult frog holding unit and an 0-g egg storage chamber.

The centrifuge rotates at approximately 60 rpm and yields 1-g, providing a control environment for embryos developing at 0-g. The adult frog chamber will accommodate four female frogs, is removable, and usable at the General Purpose Work Station (see following entry). The egg chambers are small acrylic structures (3.0 in x 3.0 in x 3.5 in) with valves for syringes accessible during experiment operations. Up to 56 chambers can be housed in the FEU.

Operational Characteristics

Size:	Fits lower portion of Spacelab rack, approx. 33 in H
Weight:	160 kg
Chambers:	56 – 28 on the centrifuge, 28 in trays in 0-g storage

Carrier: Spacelab

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736

General Purpose Work Station (GPWS)

The GPWS is a broad range support facility for general laboratory operations in the Spacelab. It can support animal experiments, biological sampling and microbiological experimentation.

The GPWS provides working space and accommodates the laboratory equipment and instruments required for many life sciences investigations. The unit is self-contained and has a rack-mounted, retractable cabinet with a large front door, allowing experimental hardware to be mounted in the cabinet.

Operational Characteristics

Size:	One double Spacelab rack, approx. 41.5 in W x 108 in H x 30 in D
Weight:	765 lbs

Carrier: Spacelab (double rack)

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736

Get-Away-Special Type Container for Middeck Locker Usage

The space qualified container is modular in concept and, except for an On-Off switch, requires no Shuttle interaction. The container consists of an experiment compartment and an instrumentation compartment. The current experiment compartment contains 18 experiment chambers. Each is readily accessible and is temperature and humidity controlled. The experiment compartment can be tailored to accommodate a variety of experiment requirements. The instrumentation compartment has provisions for two tape recorders and video recording. There also are audio and temperature sensing capabilities controlled by a programmable microprocessor.

Designed for PROJECT ISAIAH, an investigation of the effects of microgravity on the ability of a species of hornets to sense gravity, the apparatus has provision for creating day-night lighting, temperature and humidity control, food, audio pickups and optics for video recording. A filter system eliminates fumes or odors. In the event of launch delay, individual experiment chambers can be opened and the insects replaced in less than two hours.

The complete complement of equipment includes a similar container for the ground test which is conducted simultaneously with the flight test, an electrical test set for check-out purposes and shipping containers. A modular packaging approach offers the opportunity to tailor the system to other experiment requirements.

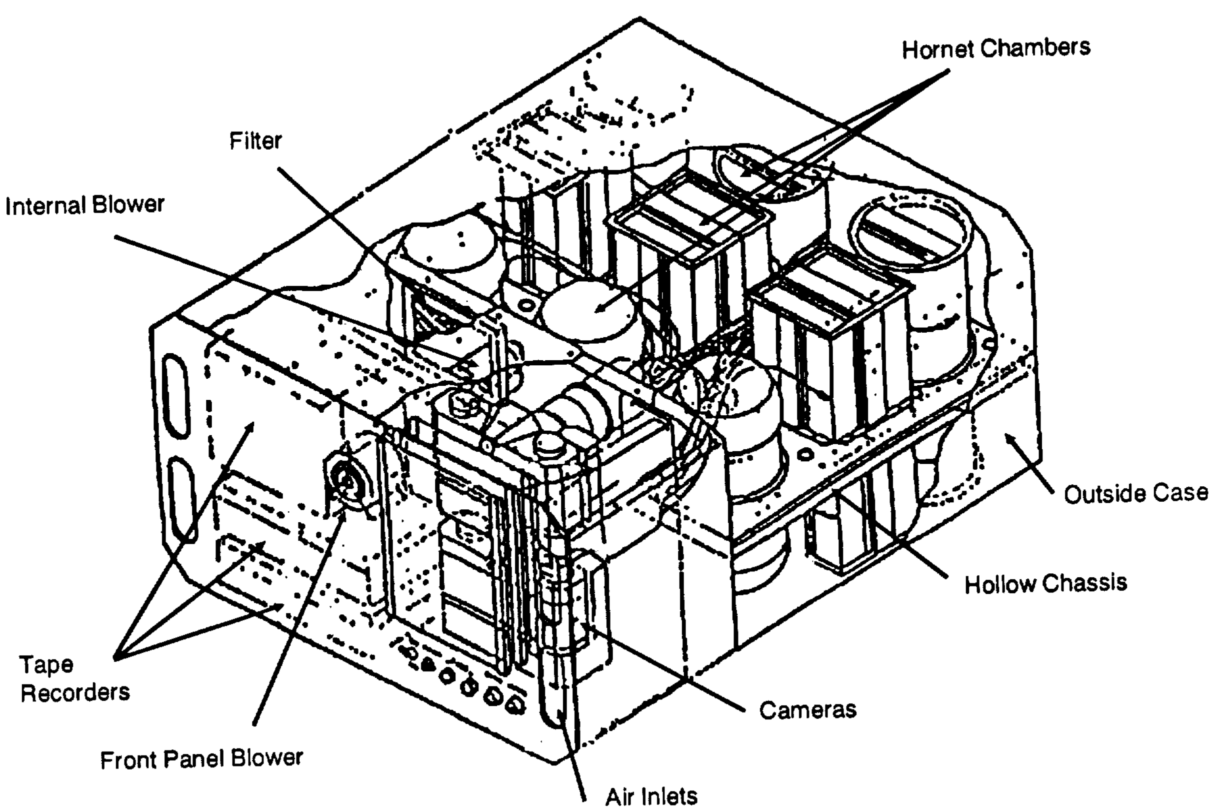
Operational Characteristics

Temperature control:	Independent closed loop
Two Analog Tape Recorders:	Provides 14 channels for 3 hours of sound recording
Data Recording:	Non Volatile Memory 32 Kbyte, expandable
Fail Safe Real Time Clock	
Electronics System:	24 digital output lines; 40 digital input lines
3 Digit Display Monitor	
Power Required:	28 Vdc, 43 W
Weight:	25 kg

Carrier: Shuttle middeck accommodation rack

Available: Now; modifications may be required for Free Flyer/Space Station

Contact: Robert Schecter
IAI INTERNATIONAL INC.
1700 North Moore St.
Arlington, VA 22209
(703) 243-2227, Fax (703) 242-1726



Gravitational Plant Physiology Unit

The Gravitational Plant Physiology Unit is designed to perform two specific gravitational plant physiology experiments, but may be adapted to other gravitropic, phototropic or circumnutational studies.

The culture rotor assembly contains two 1-g centrifuge rotors, each designed to hold 16 plant cubes. The test rotor contains two variable-gravity centrifuge rotors. Each rotor has 16 positions to hold plant cubes. The test rotors operate independently and provide a range from 0-g to 1-g.

The unit provides for time-lapsed photography of the plant seedlings before and after light stimulus.

Operational Characteristics

Capacity:	32 plant cubes
Size:	1 double Spacelab rack, approx. 41.5 in W x 108 in H x 30 in D

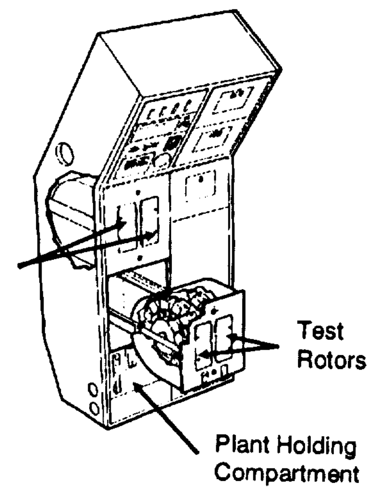
Weight

Culture rotor:	64.7 lbs
Test rotor assembly:	80.5 lbs
Total:	363.7 lbs

Carrier: Spacelab

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736



Initial Blood Storage Experiment Apparatus (IBSE)

When blood is stored on Earth, cell-to-cell and cell-to-container interactions cause sedimentation lesions, which may be harmful to blood elements. Sedimentation causes platelets to settle to the bottom of the container while other blood components die. The IBSE can be used to compare blood components stored in orbit with like blood stored on Earth, thereby improving the understanding of basic blood cell physiology.

The IBSE supports experiments which can evaluate the fundamental cell physiology of erythrocytes, platelets and leukocytes during storage in space in three discrete polymer/plasticizer formulations using standard blood bags.

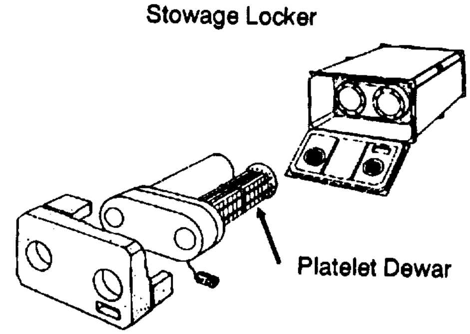
Operational Characteristics

Cold dewar module capacity:	6 standard blood bags: 3-250 ml whole blood, 3-75 ml leukocytes
Warm dewar module capacity:	10 standard blood bags: platelets
Temperature	
Cold dewar:	4° to 6° C
Warm dewar:	21° to 23° C
Size:	44.6 cm L x 39.2 cm W x 18.4 cm H
Weight:	46.4 kg total (both dewars)

Carrier: Shuttle middeck (1 locker)

Available: Now

Contact: NASA/Johnson Space Center
Flight Projects Engineering Office, Code ID
Houston, TX 77058
(713) 282-1830.



Orbiter Centrifuge

The function of the laboratory centrifuge is to perform separations inherent in blood-related life sciences research. The centrifuge provides a minimum relative centrifugal force of 1400 g's when fully loaded. There is an automatic shutdown time that may be manually set for operating durations to 99 minutes in increments of one minute. An override is available so that manual starting and stopping can be initiated without intervention by the timer. The centrifuge is mounted by two suction cups. The head can be modified to accommodate different specimens.

Capacity of Tubes	12 available
Nominal value:	15 ml
Optional value:	10 ml
Outside diameter:	17 mm
Length:	133 mm

Operational Characteristics

Size:	49 cm L x 41 cm W x 23 cm H
Weight:	11.36 kg
Volume:	4.62×10^{-1} cm^3
Time of test:	Variable in 1-minute increments to 99 minutes

Carrier: Spacelab

Available: Now

Contact: NASA/Johnson Space Center
Life Sciences Experiments Program
Houston, TX 77058
(713) 483-7328

Plant Growth Facility Two, PGF-2

The PGF-2 is a small, middeck locker-sized plant growth chamber configured as a simulator of the Lockheed PGU (see Plant Growth Unit, below) flight hardware for low-cost experiment development with small plants or plant parts. The unit is designed for maximum access and flexibility in operation. Construction is sheet metal, fastened with a minimal number of screws, and all major cover panels are attached with 1/4-turn fasteners. Inner dimensions and mounting surfaces are basically the same as the Lockheed PGU with a capacity for six Lockheed Plant Growth Chamber (PGC) plant culture vessels or an equivalent volume (14.5 in W x 8.5 in D x 10.0 in H). The internal volume also is adjustable with respect to height to accommodate developing experiments and experiment-specific instrumentation.

The PGF-2 is controlled by a small, IBM PC XT compatible Intel WildCard-88 based computer with RS-232 communications interface, 640 K bytes of battery-backed static RAM memory, 3.5 inch 1.44 Mbyte floppy disk and handheld terminal with display. It serves also as a data acquisition system with 16 single-ended A/D channels with 12 bit output for temperature control, fluid management, light cycle and sensor inputs. Plant growth lights are in two configurations: a standard light box consisting of three fluorescent tubes in the Lockheed PGU configuration and a unit for higher light requirements in which each PGC is served by a set of three six-watt fluorescent tubes. Thermal control is to +/-.5° C of set point from 1° above ambient to 35° C.

Operational Characteristics

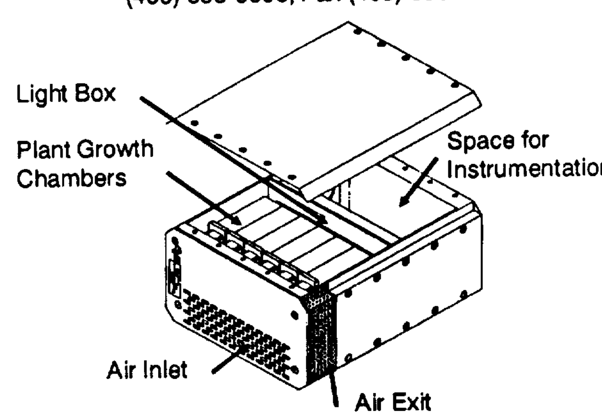
Dimensions:	10.5 in x 18 in x 21 in, (approx. Shuttle locker dimensions)
Volume:	approximately 2 cubic ft
Weight:	45 lbs approximate dependent upon PGC weight
Power:	75 W – 3 tube light configuration 125 W – 18 tube light configuration
Cooling:	above ambient by regulation of air flow

Accessory Equipment: 1. Several configurations of small plastic and aluminum plant growth chambers (PGC). 2. Fluid management module for water, nutrient or atmospheric control in the chambers. 3. Detachable trunions and stand. 4. 28 Volt Shuttle simulator power supply

Carrier: Shuttle middeck locker

Available: Now

Contact: H. W. Scheld, Director of Research
PhytoResource Research, Inc.
707 Texas Ave., Suite 101-E
College Station, TX 77840
(409) 693-8606, Fax (409) 696-3451



Plant Growth Unit (PGU)

The PGU is self-contained and designed to hold six removable plant growth chambers. Each chamber contains 16 seeds and seedlings. The chambers are placed in the PGU where the environment is controlled. Diurnal cycles are adjustable. Temperature is controllable only above ambient.

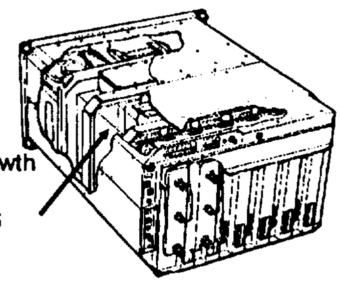
Operational Characteristics

Size:	52 cm L x 45.9 cm W x 27.4 cm H
Chamber size:	19 cm L x 5 cm W x 22 cm H
Weight:	27.2 kg

Carrier: Shuttle middeck locker

Available: Now

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736



Research Animal Holding Facility (RAHF)

The RAHF is a general purpose facility for housing small animals. The unit can accommodate a combination of 24 350-gram rodents or four 1-kg squirrel monkeys. The module provides structural support, air ducts, lights, animal water system components and temperature and humidity sensors. The animals are fed automatically. Waste is collected in removable trays and protection against cross-contamination between crew and animal is provided through bacteriological isolation.

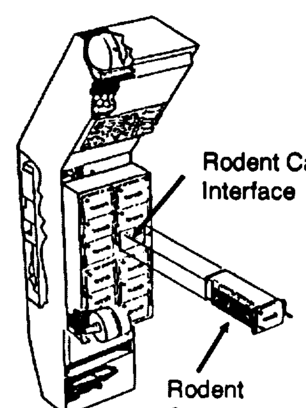
Operational Characteristics

Capacity:	24 350-gram rodents or 4 1200-gram primates
Size:	Approx. 1.5 Spacelab racks 41.5 in W x 108 in H x 29.92 in D
Weight:	About 400 kg

Carrier: Spacelab

Available: Now

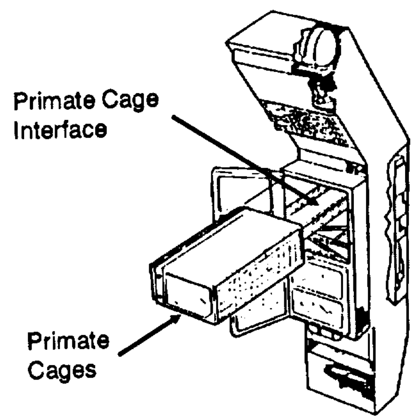
Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736



Rodent Configuration

Research Animal Holding Facility Primate Cage

The primate cage houses one 1200-gram animal; four cages will fit into the RAHF unit (page 104). The individual cages can contain a primate restraint system, venous and arterial infusion systems with blood-pressure sensor, urine collection system and a feeding and watering system. Water is available and food is dispensed by the subject on a pre-trained program. The unit also may be used to transfer a variety of other biological specimens as required.



Squirrel Monkey Configuration

Operational Characteristics

Cage Size: 21.69 cm W x 36.91 cm H x 53.34 cm D

Weight: 18.3 kg (empty)

Carrier: Spacelab

Available: Under development

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffett Field, CA 94035
(415) 604-5736

Other Support Equipment Available from Ames Research Center

Ambient Temperature Recorder
This unit is a totally self-contained, battery-operated device that may be placed in any environment to provide a history of its own surface temperature.

Autogenic Feedback System (AFS)
The AFS is an ambulatory physiological monitoring system designed to monitor and record eight human physiological parameters.

Biotelemetry System (BTS)
The BTS is a general-use system to monitor physiological functions of mammals. One to four parameters can be recorded per unit.

Compound Microscope
The compound microscope is a modified Carl Zeiss-type WL unit. It supports cardiovascular investigations and is generally mounted on the General Purpose Work Station in the Spacelab module.

Dissecting Microscope
This microscope supports dissecting investigations and is mounted on the General Purpose Work Station. It is a Zeiss stereomicroscope, Model SV8, with supporting equipment.

Plant Canister
The units are designed to hold 15 corn plants each. They are carried in a foam cutout in the Shuttle middeck locker during launch and then placed in a freezer during the mission.

Primate Biorhythm 8-Channel Recorder
This system consists of transducers and a recorder for measuring skin, deep-body and ambient temperature, and heart rate for two restrained Rhesus monkeys.

Primate Restrain Chair
This chair will maintain a small squirrel monkey under stable physiological conditions. It is intended for use within the Research Animal Holding Facility in the Spacelab module.

Rodent and Primate Activity Monitors
Each rodent and primate cage compartment within the Research Animal Holding Facility contains one activity monitor consisting of an infrared light source and a sensor.

Rodent Restrainer
The restrainer will confine a rat with minimal stress while interperitoreal and tail injections, blood sampling and cardiovascular measurements are performed.

Veterinary Kit
This kit contains provisions that can be used for emergency care of squirrel monkeys and rodents during flight. It is stowed in either the Shuttle middeck or Spacelab.

Contact: NASA/Ames Research Center
Space Life Sciences Payloads Office
Moffet Field, CA 94035
(415) 604-5736

Other Support Equipment Available from Johnson Space Center

GN2 Passive Freezer
This freezer is employed to freeze experiment samples and can keep them frozen until Shuttle landing and recovery.

Pocket Voice Recorder
This is a miniature, pocket-type, battery-powered voice recorder. It is a flight-qualified Olympus Pearlcorder Model E420.

Rail Clamp
This device provides a means of placing hardware or equipment items at a convenient location during non-operating times. It attaches to Spacelab rack handrails.

Contact: NASA/Johnson Space Center
Life Sciences Experiments Program
Houston, TX 77058
(713) 483-7328

Chapter 9: Remote Sensing

Space provides us with a vantage point, a means of drawing away from the Earth to see it as a whole. Satellite studies of our own and other planets provide comparative data that we are using to better understand our world and its solar system. From such studies, we have learned that Earth is unusual in our solar system; it is the one place where both life and liquid water exist. The living and physical components of Earth are involved in a complex interplay of inextricably linked physical, chemical and biological processes. From this global perspective, we have begun to synthesize the dynamic interactions between life and its environment into an integrated concept. Many studies are leading us to ask some very practical questions about the habitability of our own and other solar systems, as we lay the foundation for a new home beyond the familiar confines of our planet.

Operational systems, such as spacecraft, aircraft and ground systems, have provided a wealth of data on Earth resources. A value-added company has the potential of marketing selected sets of data, merged with photographic data or data generated by other sources. An example of this application is the data obtained from the LANDSAT series of satellites, whose wealth of data is marketed by the Earth Observation Satellite Company (EOSAT) (see page 114).

Commercial applications of remote sensing technology are providing valuable information to farmers, mining companies, surface transportation companies, environmentalists and urban planners. Collected and relayed data is used for crop forecasting, forestry, hydrology, mineral exploration, land use management, aquaculture harvesting, navigation aids, weather observation and forecasting, archeological findings and other activities. Observations may be made optically with camera components, or through various wave length modes, such as X-ray or ultra-violet.

Data interpretation, image enhancement and value-added services play as important a role in the remote sensing industry as data collection. Therefore, ground-based research is a widely evolving activity as the requirements and uses of remote sensing data are becoming fully realized. In addition, commercial applications are planned in the testing of advanced sensor technology, large-scale cameras, data relay devices, data reduction techniques and others (see also EOCAP information on page 5).

Remote Sensing Cameras

A-3 Configuration

The A-3 package consists of two HR-732 cameras, each with a 24-inch focal lens cone. This configuration provides for multi-emulsion or multi-spectral coverage of the same ground scene.

Operational Characteristics

Package:	2 HR-732 cameras
Lens data:	24 in f/8.0
Format:	9 x 18 in
Frame coverage @ 65,000 ft:	4 x 8 nmi
Vertical scale @ 65,000 ft:	1:32,000
Nominal ground resolution:	2 ft to 15 ft

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

A-4 Configuration

The A-4 package consists of one RC-10 metric camera with interchangeable 6- or 12-inch focal length lens cones and one HR-732 camera with a 24-inch focal length lens cone. This configuration provides for both medium and large scale coverage centered over the same scene.

Operational Characteristics

Package:	1 Wild-Heerbrugg metric RC-10 camera 1 HR-732 camera
Lens data:	6-in f/4.0 (RC-10) 12-in f/4.0 (RC-10) 24-in f/8.0 (HR-732)
Format:	9 x 9 in (RC-10)
Frame coverage @ 65,000 ft:	16 x 16 nmi (RC-10, 6-in) 8 x 8 nmi (RC-10, 12-in) 4 x 8 nmi (HR-732)
Nominal ground resolution:	15-25 ft (RC-10, 6-in) 5-25 ft (RC-10, 12-in) 2-8 ft (HR-732)

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Dual RC-10 Metric Camera System

This package consists of two RC-10 metric cameras with interchangeable 6- or 12-inch focal length cones. This arrangement provides for dual scale or dual emulsion for the same scene.

Operational Characteristics

Package:	2 Wild-Heerbrugg metric RC-10 cameras
Lens data:	6-in f/4.0, 12-in f/4.0
Format:	9 x 9 in
Frame coverage @ 65,000 ft:	16 x 16 nmi (6-in) 8 x 8 nmi (12-in)
Vertical scale @ 65,000 ft:	1:130,000 (6-in) 1:65,000 (12-in)
Nominal ground resolution:	15-25 ft (6-in) 5-25 ft (12-in)

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

IRIS II Panoramic Camera

This package consists of an ITEK IRIS II panoramic camera with a 24-inch focal length lens cone. This configuration provides for high resolution, wide-area coverage in mono/stereo modes.

Operational Characteristics

Package:	Itek IRIS II camera
Lens data:	24 in f/3.5
Format:	4.5 x 34.7 in
Frame coverage @ 65,000 ft:	2.0 x 21.4 nmi (90 degree scan)
Vertical scale @ 65,000 ft:	1:32,000
Nominal ground resolution:	1 to 5 ft

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Large Format Camera (LFC)

The Large Format Camera (LFC) is a special mapping camera built for NASA to meet the demands of performance at orbital altitudes. The LFC primary mode of operation is to provide precise vertical stereoscopic photographic imagery of the Earth in a wide-field synoptic mode at very high resolution. The LFC is a precision cartographic camera with high geometric fidelity and has an advanced image motion compensation mechanism. It has a 305 mm image format with the long dimension oriented in the direction of flight. The LFC has been mounted in the Shuttle's cargo bay but also may be mounted in a free flying spacecraft or in an aircraft.

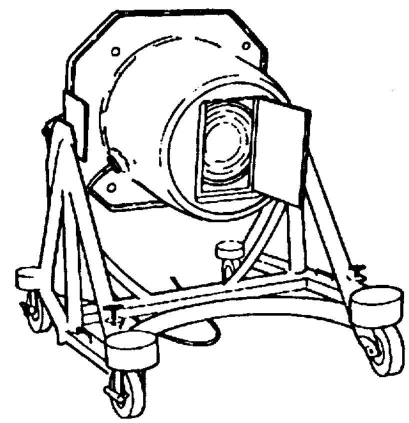
Operational Characteristics

Focal length:	30.5 cm
Aperture:	f/6
Film capacity:	2,400 frames
Weight:	340 kg
Resolution:	80 lines/mm (about 20 m at operational altitudes)

Carrier: Learjet, Shuttle cargo bay

Available: Now

Contact: NASA/Stennis Space Center
Commercialization Branch
Science and Technology Laboratory
Stennis Space Center, MS 39529
(601) 688-2042



Remote Sensing Scanners

Aerial Data Acquisition Program

The Aerial Data Acquisition program uses a Daedalus 1260 Multispectral Scanner (DMS). This scanner offers one broad thermal infrared, one near infrared and 8 visible bands. Types of studies and projects where multispectral scanner data can contribute vital information include:

Detection and mapping: thermal effluents, coal refuse fires, surface faults and fractures

Detection of: rooftop heat loss and moisture damage, problems in buried streamlines, condensate return hot water lines

Detection and monitoring: dam and levee seepage; ground water discharges into lakes, rivers and oceans; sewage disposal pollution into waterways

Studies: water dynamics, site selection, satellite support, cooling pond efficiency and seepage

Carrier: Learjet

Available: Now

Contact: George A. May
ITD Space Remote Sensing Center
Building 1103, Suite 118
Stennis Space Center, MS 39529
(601) 688-2509

Airborne Ocean Color Imager

The Airborne Ocean Color Imager (AOCI) is a high altitude multispectral scanner designed for oceanographic remote sensing. It provides 10-bit digitization of eight bands in the visible/near-infrared region of the spectrum, plus two 8-bit bands in the near and thermal infrared. The bandwidths are as follows:

Channel	Wavelength, *um*
1	0.436-0.455
2	0.481-0.501
3	0.511-0.531
4	0.554-0.575
5	0.610-0.631
6	0.655-0.676
7	0.741-0.800
8	0.831-0.897
9	0.989-1.054
10	8.423-12.279

Sensor/aircraft parameters

Instantaneous Field of View:	2.5 mrad
Ground Resolution:	163 ft (50 meters at 65,000 ft)
Total Scan Angle:	85°
Swath Width:	18nmi (33.3 km)
Pixels/Scan Line:	716
Scan Rate:	6.25 scans/second
Ground Speed:	400 kts (206 m/second)

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA
(415) 604-6252

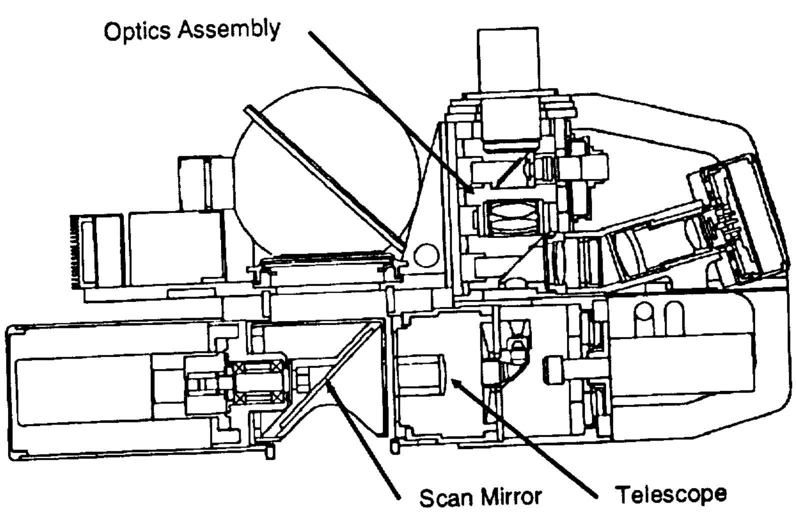
Calibrated Airborne Multispectral Scanner (CAMS)

The CAMS is a nine-channel, airborne imaging device that samples electromagnetic energy in several spectral regions. Scan speeds are adjustable from 6 to 80 scans per second in one-scan increments, providing an instantaneous field-of-view angle of 100 degrees. All channels of data contain information derived from onboard references. During data acquisition, each reference source is viewed by the CAMS and the appropriate information is recorded for later use. For a typical data acquisition mission at an altitude of 2 kilometers above terrain elevation, the pixel size is 5 meters on a side of 2.33 kilometers.

Carrier: Learjet

Available: Now

Contact: NASA/Stennis Space Center
Commercialization Branch
Science and Technology Laboratory
Stennis Space Center, MS 39529
(601) 688-2042



NS001 Multispectral Scanner

The NS001 Multispectral Scanner (MS), flown on the C-130B aircraft, contains the seven LANDSAT-D Thematic Mapper bands plus a band from 1.13 to 1.35 micrometers. The specific bands are as follows:

Band	Spectral bandwidth, um
1	.458-.519
2	.529-.603
3	.633-.697
4	.767-.910
5	1.13-1.35
6	1.57-1.71
7	2.10-2.38
8	10.9-12.3

Sensor specifications

Instantaneous Field of View:	2.5 mrad
Total Scan Angle:	100 degrees
Pixels/Scan Line:	699

The format of the flight data consists of 838 eight-bit words per frame (data for one wavelength band throughout a scan line). Of these, 699 are the video information and the remainder are information on Greenwich time, scan line number, calibration lamp voltage and current, blackbody temperatures, etc.

Carrier: C-130 Aircraft

Available: Now

Contact: Rube Erickson
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Thematic Mapper Simulator

The Daedalus Thematic Mapper Simulator (TMS) is a high altitude multispectral scanner, flown aboard NASA's ER-2 aircraft. It simulates spatial and spectral characteristics of the seven LANDSAT-D Thematic Mapper bands. The specific bands are as follows:

Daedalus Channel	TM Band	Wavelength, um
1	A	0.42-0.45
2	1	0.45-0.52
3	2	0.52-0.60
4	B	0.60-0.62
5	3	0.63-0.69
6	C	0.69-0.75
7	4	0.76-0.90
8	D	0.91-1.05
9	5	1.55-1.75
10	7	1.55-1.75
11	6	8.5-14.0 low gain
12	6	8.5-14.0 high gain

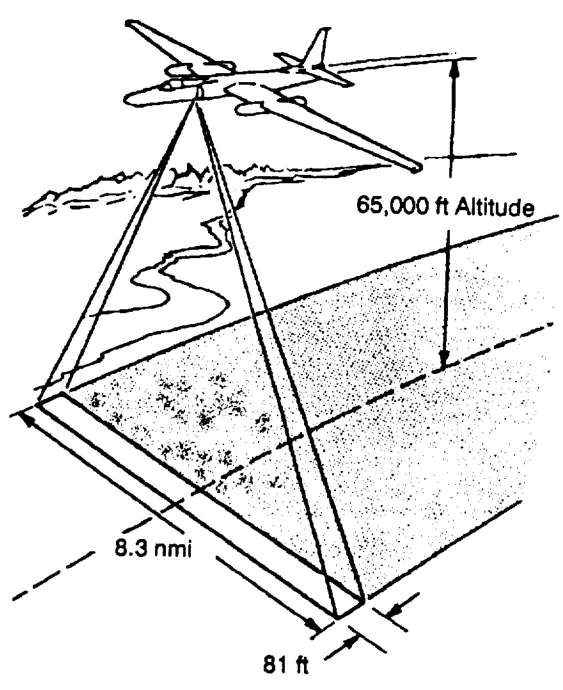
Sensor/aircraft parameters

IFOV:	1.3 mr
Ground Resolution:	91 ft (28 meters at 70,000 ft)
Total Scan Angle:	43°
Swath Width:	9.0 nmi (16.6 km at 70,000 ft)
Pixels/Scan Line:	716 (750 following rectification)
Scan Rate:	12.5 scans/second
Ground Speed:	400 kts (206 m/second)

Carrier: ER-2 Aircraft

Available: Now

Contact: Gary Shelton
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-6252 or 604-5344



Thermal Infrared Multispectral Scanner (TIMS)

The Thermal Infrared Multispectral Scanner (TIMS) is an experimental system developed by the Jet Propulsion Laboratory and Daedalus Corporation. The TIMS is flown frequently on C-130 missions and has been adapted for use on ER-2 high altitude aircraft. The sensor collects thermal data in six discrete channels of the spectrum from 8.2 um to 12.2 um. Used as an airborne geologic remote sensing tool, the TIMS collects mineral signature data which permits the discrimination of silicate rocks, carbonate rocks and hydrothermally altered rocks. The TIMS has acquired geologic data over Big Horn Basin, WY, and volcanology data over the island of Hawaii and the Cascade Range in Washington, Oregon and California. The TIMS instrument is configured as follows:

Channel	Wavelength, *um*
1	8.2-8.6
2	8.6-9.0
3	9.0-9.4
4	9.4-10.2
5	10.2-11.2
6	11.2-12.2

Sensor specifications

Instantaneous Field of View:	2.5 mrad
Scanner Field of View (FOV):	76.56°
Ground Resolution:	25 ft (7.6 m at 10,000 ft aircraft attitude)
Pixels/scan line:	698
Swath width:	2.6 nmi (4.8 km at 10,000 ft aircraft attitude)
Scan rates:	7.3, 8.7, 12, and 25 scans/ second (selectable)

Carrier: ER-2 Aircraft

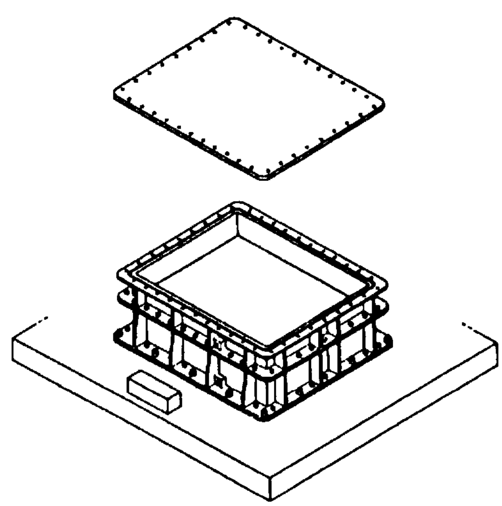
Available: Now

Contact: Rube Erickson
High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035-1000
(415) 604-5344

Other Remote Sensing Equipment and Services

Cosmic Ray Determination (Nuclear Track Detectors)

The hardware consists of a stack of plates (X-ray film) 400 x 500 x 194 mm (typical plate thickness is 1 to 2 mm) enclosed in an aluminum chamber. A self-contained data logger powered by its own internal battery pack is employed as part of the experiment. This unit can function on a variety of carriers.



Operational Characteristics

Size:	522 x 592 x 222 mm
Weight:	229 kg
Power:	Entirely passive
Carrier:	To be determined

Contact: Francis C. Wessling
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620

Earth Observation Satellite Company (EOSAT)

The Earth Observation Satellite Company (EOSAT) markets data from the LANDSAT series of satellites. The LANDSAT archive contains over 2.5 million images, 185 x 170 km in size. The primary data source is the Thematic Mapper (TM) instrument, which records seven measurements for every quarter-acre of land.

TM data are available in two product lines; digital products and photographic products. EOSAT also markets RSVGA, a software package for use with the floppy disk digital product.

Digital Products

Geocoded Products
9-track computer compatible tape
6250 Bpi
Any USGS-supported map projection
Choice of Earth ellipsoid
Choice of pixel size (from 25 to 240 meters)
Full scenes, 185 x 170 km
Quadrant scenes, 100 x 100 km
Map sheet, 1/2° x 1°

Standard Products
9-track computer compatible tape
6250 Bpi (1600 Bpi with surcharge)
SOM or UTM/PS projection
International 1967 Earth ellipsoid
28.5 meter pixels
Full scenes, 185 x 170 km
Quadrant scenes, 100 x 85 km
Movable sub-scenes, 100 x 100 km
Movable mini-scenes, 100 x 50 km or 50 x 100 km

Floppy disk products
360K, 5.25 inch disks
MS/DOS and PC/DOS format
Seven disks, one band per disk
512 x 512 pixels (14.6 x 14.6 km)

Photographic Products, Color

Full scene	
Positive transparency	1:1,000,000 scale
Paper prints	1:1,000,000 scale
	1:500,000 scale
	1:250,000 scale
Quadrant scene	
Positive transparency	1:500,000 scale
Paper prints	1:500,000 scale
	1:250,000 scale
	1:100,000 scale
Quad-of-a-quad	
Paper prints	1:50,000 scale

Data Search Service

A free search of LANDSAT data of a particular area is available by request from the EOSAT Customer Services Department. Areas of interest may be specified as follows (one of three ways):

- latitude and longitude coordinates for the center point or the corners of the area
- path/row designation in the Worldwide Reference System (path/row maps are also available free of charge from Customer Services)
- name of a major geographic feature, such as a city

When requesting a data search, specify maximum acceptable cloud cover, year and time of year desired and minimum quality rating acceptable.

Contact: EOSAT Customer Services
4300 Forbes Boulevard
Lanham, MD 20706
(301) 552-0537, Fax (301) 552-0507
(800) 344-9933 USA, Canada,
Virgin Islands

Image Film Recorder

A high resolution film recorder with variable size and gamma control flexibility provides remote sensing images as received directly from the satellite sensor or image enhanced/processed scenes. Images may be stacked within a frame for easy comparison and evaluation. This recorder, based on direct electron beam film exposure, provides outstanding first generation quality from LANDSAT, SPOT, et al., image digital data. Stereographic data can be recorded to match stereo instrumentation used.

Recorder Characteristics

Film width:	5 in
Resolution:	4 to 16 micrometers
Gamma:	.5 to 2
Density:	0.05 to 3.0 du
Polarity:	Positive or Negative

Available: Now

Contact: Putnam Morgan
Image Graphics, Inc.
917 Bridgeport Avenue
Shelton, CT 06484
(203) 926-0100

METPRO

METPRO is a professional atmospheric and meteorological information processing system. METPRO processes real-time data from geostationary and polar-orbiting weather satellites, weather radar, conventional surface and upper-air sensor, lightning detection systems and wind profiler networks.

METPRO is capable of supporting turn-key data capture, processing and data product development. The heart of the METPRO system is its user-friendly applications software package. The NASA-developed Transportable Applications Executive Plus (TAE+) provides a transparent interface to functions. METPRO's perspective and 3-D imagery supplement standard maps and fully integrated image products. METPRO is modular in design and can be customized to meet the user's needs.

METPRO performs more than 100 parametric calculations, including:

- potential temperatures and mixing ratios
- geopotential height and geostrophic wind
- horizontal divergence and relative vorticity
- convective condensation levels and stability indices
- total precipital water
- specific and relative humidity
- thermodynamic functions

Available: Now

Contact: Edward J. Hurley
Business Development
General Sciences Corporation
6100 Chevy Chase Drive, Suite 200
Laurel, MD 20707
(301) 953-2700

Observer Remote Sensing Satellite

OBSERVER is a small, commercial remote sensing satellite that is designed to provide wide coverage, high resolution Earth images in the 0.5-0.73 spectral band. The baseline design for the satellite fits the Pegasus launch vehicle (see page 207).

OBSERVER'S payload consists of two modified Schmidt cameras with linear charge coupled device (CCD) image sensors. The CCD's are staggered at the focal plane, along the pitch axis, to provide continuous swath imaging, in a push broom fashion. Image scanning is accomplished electronically by operating the proper set of CCD's; OBSERVER, therefore, has no mechanically moving parts. Patented image compression hardware and software are implemented on board the spacecraft allowing up to 12:1 image compression and reducing the data storage, downlink bandwidth and power requirements. (See illustration, page 116.)

Operational Characteristics

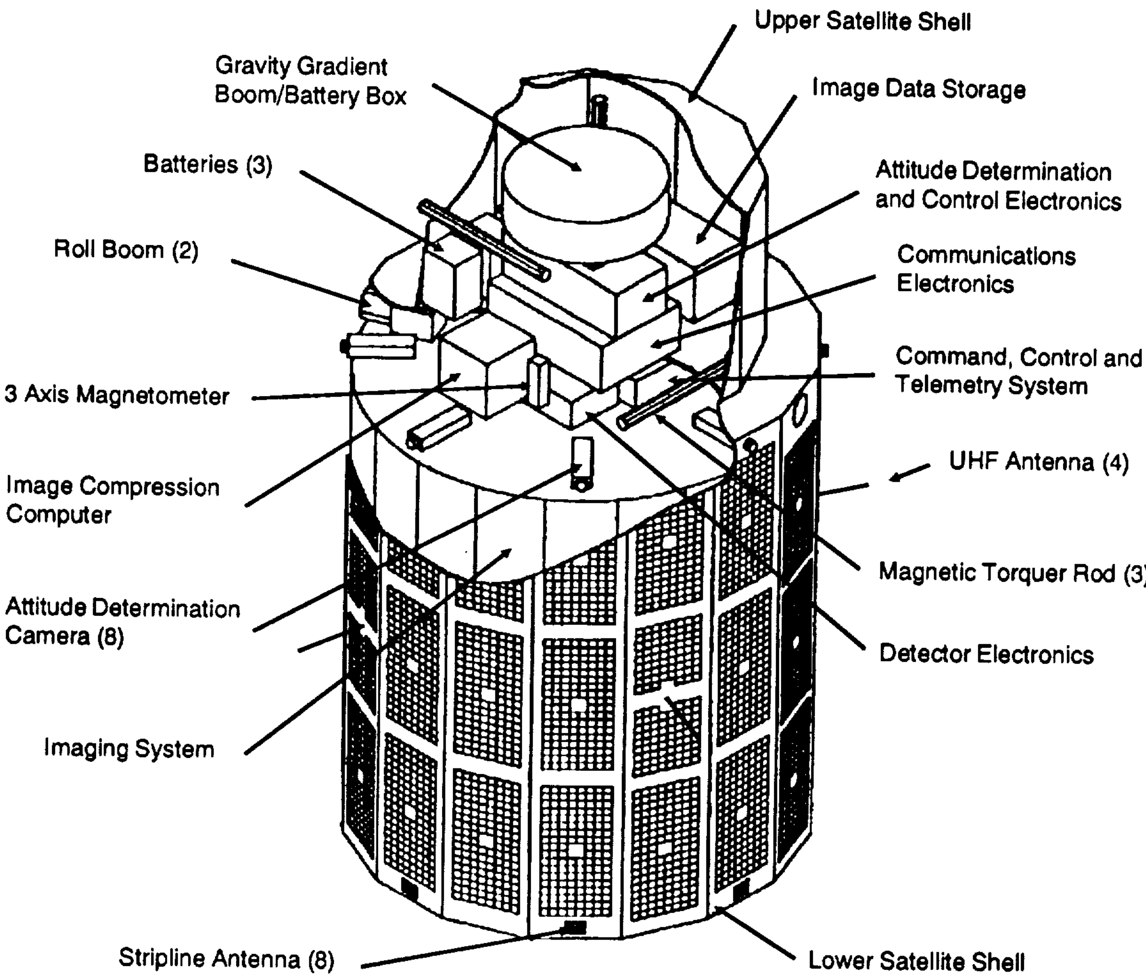
Mass: 200 kg
Shape & Dimension: 16 side-cylinder, 42 inches in diameter stepped in at 52 inches to a 12 side-cylinder 32 inches in diameter and 18 inches long

Power:	Average 85 watts
Attitude control:	+/-2°
Attitude determination:	+/-0.1°
Thermal control:	Passive
Temperature range:	Near room temperature
Orbit:	700 km altitude, Polar orbit
Coverage:	98% coverage every 3 days 100% coverage every 5 days
Field of View:	53°
Resolution:	5 meters
Swath width:	700 km
Image size (frame):	60 km x 60 km
Number frames/day:	200

Available: Now

Contact: Bill Claybaugh
Globesat, Inc.
1740 Research Park Way
Logan, UT 84321
(801) 753-2303

Observer Remote Sensing Satellite (continued)



Chapter 10: Support Equipment and Products

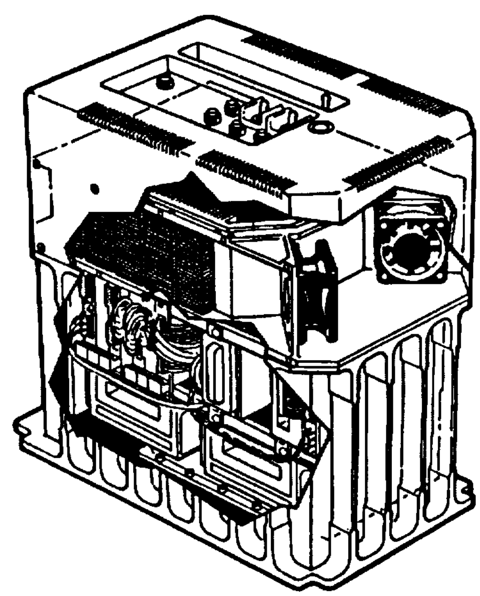
As flight hardware and experiment equipment is being developed, tested and flown, additional secondary pieces of hardware have evolved in support activities. Foremost among these are a number of measurement and recording devices designed to support manned flight experiments.

Several NASA Centers have developed devices which can be adapted for many applications to commercial experiments in space. Several companies also offer interfaces, measurement and recording equipment for experimental apparatus, some of which provide the needed channels of data to assure experiment operations and verification or to lessen the load on the Shuttle facilities.

Computers and Related Equipment

3M Generic Electronic Module (GEM/2)

The GEM/2 is a general purpose, process control and data acquisition computer that supervises and operates payloads flown on any crew-tended space system or unmanned space platform. Any experiment requiring a high-level microprocessor can be supported by the GEM/2, which is based on a VME bus Motorola 68020 format. Hardware options include A/D converters, 32 bit digital I/O, serial ports 20 Megabyte hard disk, 4 Gigabyte mass memory for data storage, DC/DC converters and a PGSC interface for crew interaction. The GEM/2 is housed in a sealed container, has an integral heat exchanger, replaces one middeck locker and mounts to the standard NASA payload mounting panel.



Operational Characteristics

Power:	140 W
Size:	one middeck locker space
Weight:	29.2 kg plus PMP

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: E. L. Cook
3M Space Research and Applications
Laboratory, Building 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357

Computational Materials Laboratory

This laboratory specializes in modeling and predicting the effects of gravitationally driven convection on crystal growth from the liquid and vapor. It has considerable computing power based around a set of local engineering workstations and a supercomputer shared by the research center.

Hardware

File Server:	Sun 4/260 4 MBy file server with 4 GBy of mass storage space
Workstations:	12 Sun 4/110 workstations or SPARCstations with graphics display hardware

Graphics
Silicon Graphics Workstation
3/4 inch videotape animation recorder and controller
16 mm animation camera
High resolution color printers

Software
General Purpose modified
transport codes: NEKTON, FIDAP, FLUENT
Scientific libraries
Graphics Packages
Animation and rendering software
Customized code for specific problems

Carrier: Designed for ground-based research only

Available: Now

Contact: Thomas K. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road, MS 105-1
Cleveland, OH 44135
(216) 433-5014

Data Logging Engines

The Tattletale line of low power data logging engines are designed to minimize the cost and development of a portable controller/logger. The all-CMOS design is ideal for battery-based applications, while the TTBASIC or TXBASIC operating system permits operation and program development from any terminal computer. Each Tattletale features:

- Analog and digital I/O, including UART, individually programmable I/O lines, counter, square wave generator and three-wire RS-232 serial interface
- CMOS SPU, 32K to 256K of CMOS RAM for storing programs and logging data and EPROM or battery-backed RAM for non-volatile program storage
- Data storage for storing the results of measurements or received data
- Voltage regulator, for connecting the board directly to a battery unregulated source

The Tattletale's TTBASIC operating systems simplifies application software, reducing development time. Its 32-bit integer math allows precision calculations without sacrificing speed. The new, powerful TXBASIC, available for the models 2B and 6, includes two parts: a tokenizer/compiler/assembler that runs on a host machine (Macintosh or PC) and the TXBASIC interpreter in the Tattletale. It is dual tasking and features a fully integrated multi-pass symbolic assembler, which is source code compatible with conventional stand-alone cross-assemblers.

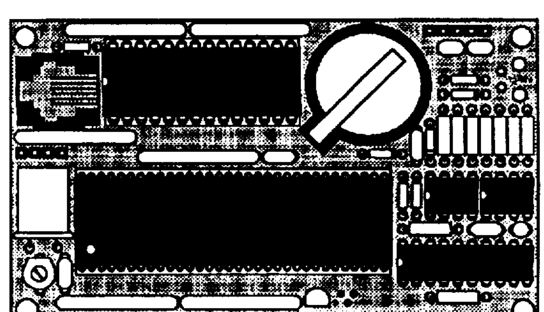
Signal conditioning electronics can be built on an interface board that mounts directly above each Tattletale, connecting to pin strips on the board that bring up power and the digital and analog I/O lines. All Tattletales permit access to the board's internal bus for applications that require substantial hardware expansion.

Operational Characteristics

Size	
Model V	1.4 in x 2.0 in x 0.8 in to
Model 6/200MByte	4 in x 6 in x 2.5 in
Weight	
Model V	1 oz to
Model 6/200 MByte	2 lbs
Current Drain	
Operating:	3-24 MA;
Lower power modes:	30 uA-200uA

Available: Now

Contact: Onset Computer Corp.
199 Main St.
North Falmouth, MA 02556
(508) 563-9000, Fax (508) 563-9477



Graphics System – Satellite Tool Kit (STK)

Satellite Tool Kit is a two-dimensional graphics system for computing, displaying and analyzing satellite, aircraft, ship and terrestrial vehicle paths. Satellite orbits are calculated using a 2-body Keplerian ephemeris generation technique while other ground tracks are produced using great-circle arc algorithms. Alternatively, the track data may be generated by other sources, and displayed and analyzed using the Satellite Tool Kit. STK computes and displays vehicle antenna, sensor swaths and line-of-sight in-view periods. Computed data may be displayed graphically and/or textually at the workstation. The data can be displayed in polar or cartesian coordinates and in all common units. Ground stations, launch sites, targets and other Earth-fixed objects can be displayed on the map using icons and/or target boundaries. Version 1.2 adds solar terminator, sub-solar point and bearing, elevation and range calculation, as well as enhances many capabilities.

Equipment Requirements: runs on Sun Microsystems Sun3, Sun4 and SPARC computers and NeXT computers.

Carrier: Designed for ground-based use

Available: Now

Contact: Paul Graziani
Analytical Graphics, Inc.
P.O. Box 1206
King of Prussia, PA 19406
(215) 337-3055

Imaging Workstations (Corabi)

Corabi International Telemetrics is a telemedicine company that produces imaging workstations for such medical disciplines as pathology, radiology and internal medicine plus biological and other research applications. The workstations include specialized software for the robotic control of microscopes, dynamic HDTV imaging and digital freeze-frame technologies.

Carrier: Ground-based and Space Station applications

Available: Now

Contact: Ann Regan-Jean, Vice President, Marketing
Corabi International Telemetrics
890 South Pickett St.
Alexandria, VA 22304
(703) 823-4753

NPS 2000 Image Processing Integrated Circuit

The Neighborhood Processing Stage (NPS) 2000 implements high-performance machine vision and image analysis functions. Image data may be treated in several different ways by the NPS 2000: as eight independent binary bit-planes, as multiple bit-plane encoded states, as 8-bit greyscale images or as three-dimensional "range image" screen representations. A completely pipelined 20 MHz system is capable of continuous video-rate (80 frames per second for 512 x 512 images, 20 frames per second for 1K x 1K images) processing. Also available as a VME bus plug-in module for the SUN-3 or SUN-4 workstations.

Carrier: For ground-based research

Available: Now

Contact: David L. McCubbrey
Environmental Research Institute of Michigan (ERIM)
P.O. Box 8618
Ann Arbor, MI 48107-8618
(313) 994-1200

Orbiter Display Unit

The Orbiter Display Unit is a high-brightness CRT, 5 x 7 inches, qualification-tested for Shuttle applications.

Available: Now

Contact: Norden Systems Inc.
P.O. Box 5300
Norwalk, CT 06856

SC-2/SC-3 Spaceflight Computers

The SC-2 and SC-3 computers are flight-qualified units that make use of the 80C86/8087 (SC-2) and 80386/80387 (SC-3) processor combinations. These computers are constructed as a simple card cage that can hold up to 16 bus-oriented interface cards. All computer functions, including CPU, memory, timers, interrupts and input/output are implemented using these plug-in cards. The modular design provides flexibility and economy in configuring each unit to accommodate specific user requirements. Most internal circuits utilize CMOS circuitry and high levels of integration, which contribute to small overall size and low power consumption. The SC-2/SC-3 computers are most useful when ease of configuration or high-speed processing are important to the user.

Operational Characteristics

Central Processor:	80C86/8087 (SC-2), 80386/80387 (SC-3)
Clock Frequency:	8 MHz (SC-2), 12 MHz (SC-3)
Operating System:	various available
Expansion Cards:	Memory with EDC (EEPROM, UVPROM, and RAM)

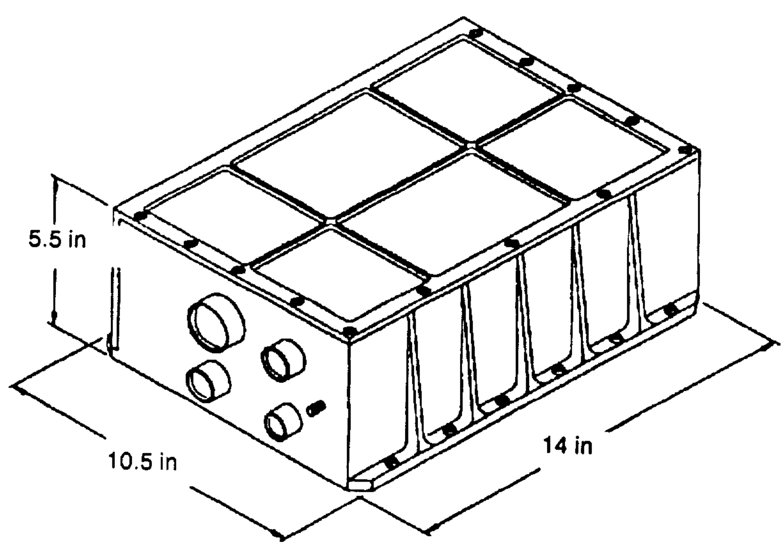
Parallel Input/Output
MIL-STD 1553 Interface
Serial Communications (RS-232, 422, and 485)
High Rate Multiplexer I/F
Remote Acquisition Unit I/F
D/A and A/D Conversion
Timer/Interrupt
Custom Interface Configurations

Size:	14 in x 10.5 in x 5.5 in
Weight:	16 lb (approximate)
Power:	28V @ 25W (approximate)

Carrier: Shuttle cargo bay, freeflyer, Space Station

Available: Now

Contact: Mark V. Muller, Senior Research Engineer
Southwest Research Institute
Instrumentation & Space Research Division
6220 Culebra Road, Div. 15
San Antonio, TX 78228-0510



SC-4 Spaceflight Computer

The SC-4 is a flight-qualified computer designed specifically as an experiment controller for use in middeck lockers of the Shuttle. This 10 MHz, 80C186-based computer has the ability to run either the MS-DOS or VRTX operating systems. Standard capabilities include multiple interrupts and user programmable counters, direct processing of analog and digital signals and on-board access of up to 24 Mbytes of error detect/correct memory. Several types of interface ports are available in the standard configuration and additional expansion is available through the use of an internal daughterboard connector. All of these features reside in a notebook-size package that weighs about 5 lbs, uses only 5 watts of power and costs less than conventional units.

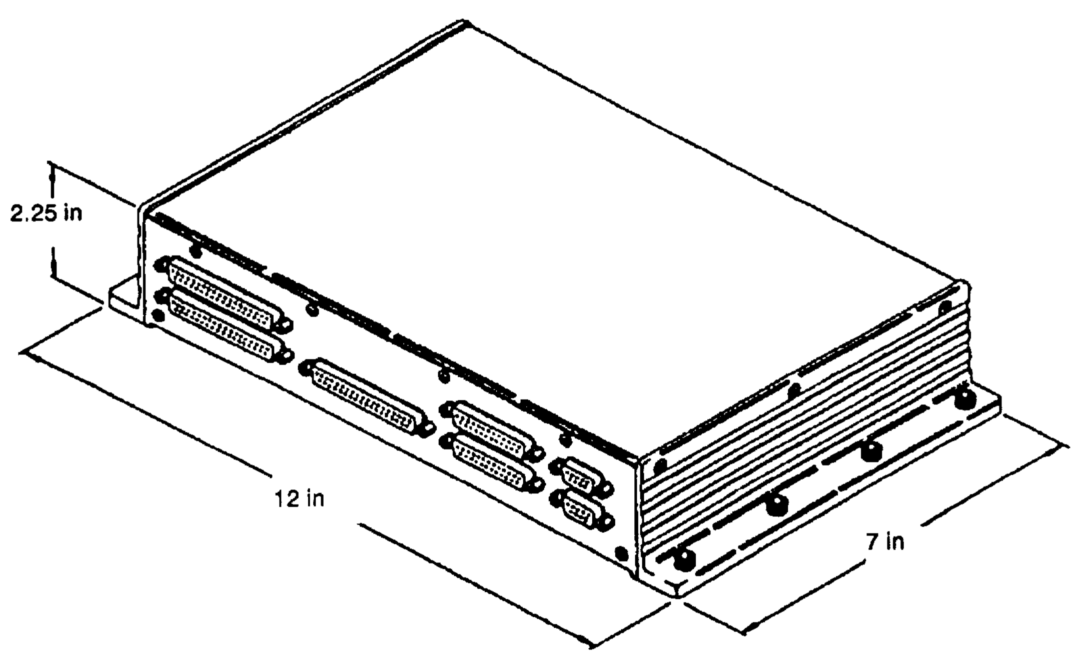
Operational Characteristics

Central Processor:	80C186/80C187 16 Bit
Clock Frequency:	10 MHz
Operating System:	MS-DOS and VRTX Compatible
Onboard Memory:	RAM: 512 Bytes w/EDC; EEPROM: 256K Bytes w/EDC; UVPROM: 64K Bytes w/EDC
Hardware Vectored Interrupts:	16 user configurable
Timer/Event Counters:	8, software configurable, 120 ns granularity
Input/Output# Capability:	Parallel I/O: 16 Input, 16 Output; Analog Input: 32 Channels, 12-bit Resolution; Analog Output: 4 Channels, 12-bit Resolution
RS-422 Serial I/O:	2 Channels
SCSI Interface:	1 Port
Software Controlled Power Switch:	4 Each
Mass Storage	24M Bytes, Read/Write Non-volatile
Expansion:	Internal Daughterboard Connector
Size:	7 in x 12 in x 2.25 in
Weight:	5 lb (approximate)
Power:	28V @ 5W (approximate)

Carrier: Shuttle-middeck locker, cargo bay, freeflyer, Space Station

Available: Now

Contact: Mark V. Muller, Senior Research Engineer
Southwest Research Institute
Instrumentation & Space Research Division
6220 Culebra Road, Div. 15
San Antonio, TX 78228-0510



SensorNet Experiment Computer (SEC)

Shuttle middeck and Spacelab experiments benefit from the use of the SensorNet Experiment Computer (SEC) for experiment control, data acquisition and storage. Space-qualified in the 1990s, the SEC is designed to control the Middeck Zero-G Dynamics Experiment (MODE), acquire digital and analog data, and store the data to a write-once, read-many (WORM) optical side drive with 200 Mbytes of storage per cartridge. For Spacelab use, a High Rate Multiplexer (HRM) interface module is available for real-time downlink of experiment data.

Standard configurations of this distributed processing modular computer are available for experiment control with analog and digital data acquisition and storage. Other I/O options include: IEEE-488, RS-232, SCSI modules, Analog Output and Digital Signal Processing. The system operates with embedded system software for real-time operations. Experiment control and application development libraries together with an integrated debugging environment assure quality software development.

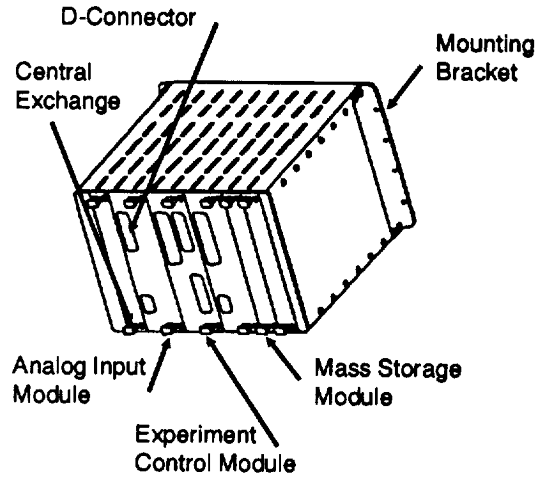
Operational Characteristics

Dimensions:	5.750 in H x 8.625 in W x 7.750 in D
Volume:	384.35 cu in
Weight:	7.25 lbs
Power:	14 watts; 36 watts with WORM drive
Cooling:	Forced Convection

Carrier: Shuttle middeck locker, Spacelab

Available: 1991-92

Contact: Payload Systems, Inc.
276 Third Street
Cambridge MA 02142
(617) 868-8086



SoMat 2000 Field Computer

The SoMat 2000 Field Computer is a microprocessor-based digital data acquisition system designed for easy data collection in a variety of test environments. A basic system consists of a processor module, power and communications module and the Test Control Software (TCS) to setup, calibrate and display data. Users may choose from several different signal conditioning/data acquisition modules to add to the system and configure it accordingly.

A basic SoMat 2000 system includes:

- SoMat 2000 Processor base unit
- Power/Communications module (including three 9-volt batteries)
- Top cover
- Modules (e.g., signal conditioning, memory, filter)
- Cables: serial, power, transducer
- Spare parts kit
- SoMat II Test Control Software (both 5.25 and 3.5 diskettes)
- SoMat II Test Control User's Guide

Important features of the system include:

- Stand-alone operation for unattended long-and short-term data acquisition
- Menu-driven software for easy test setup, operation and analysis
- Modular hardware for expandable memory and signal conditioning
- Multiple channels
- Low power consumption for internal or external battery-powered operation
- Small, portable size (2 in x 3 in x 5 in) in a rugged aluminum package
- IBM-PC compatible software

SoMat 2000 Field Computer (continued)

Hardware
The SoMat 2000 Hardware is a series of stackable computer modules arranged in a bus-like architecture and packaged in an aluminum case for rugged field testing applications. The user can configure a system from an array of standard modules:

- Processor
- Power/Communications
- Strain Gauge Signal Conditioning
- Analog Transducer
- Pulse Counter
- Digital Input/Output
- Programmable Filter
- Extended Memory

An initial SoMat 2000 System is expandable by adding one or more modules as testing needs grow. Provisions have been made for safe shut-down and restarting in the event of power failure, and memory is backed up with a separate battery so that no data is lost. Power is automatically shut off to any transducer in which a short circuit is detected so that the system can continue to function on the remaining channels. The SoMat 2000 was specifically designed with features required for the rugged conditions encountered in field testing.

Operational Characteristics

Weight:	0.6 lbs (260 grams) per module
Module Dimensions:	3 in x 4.25 in x 0.375 in (76 mm x 108 mm x 9.5 mm)
Battery Power:	up to 1000 mA at +5 V
Backup battery life:	2.5 years
Operating temperature:	-20 to +70° C
Vibration:	10-2000 Hz up to 60 g's loading

5-volt excitation to transducer; pulsed and steady
Internal 350 Ohm completion resistors
Low pass programmable filtering
Remote start/stop and event detection
Automatic software controlled zero and gain adjust
Data
collect, store, transfer and protect
Sample rate up to 5000 samples/sec/channel
High-speed low-power CMOS RAM
Data transfer rate up to 57,600 baud
RS 232C interface

SoMat II Test Control Software (TCS)
The SoMat II Test Control Software program (TCS) is an easy-to-use, menu-driven interface between the user, the SoMat 2000 Field Computer, and an IBM-compatible PC. TCS can set up a test; initialize hardware; calibrate transducers; select data acquisition modes; start and stop a test; collect and store test data; manipulate test data; upload data to a larger computer; and display test results (real-time if necessary).

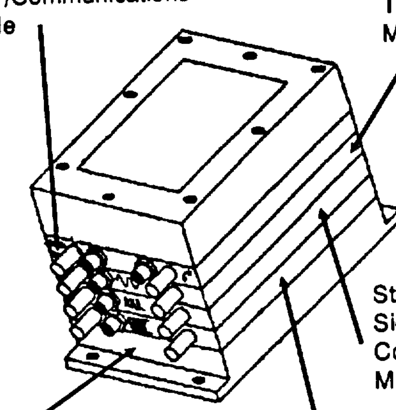
TCS is intuitive and organized in the order of a typical field test, requiring no special programming skills to operate. The program allows the user to select data acquisition modes from a library including: time history, burst time history, sequential peak valley, time at level matrix, rainflow matrix and peak/valley matrix. Multiple data modes may be used simultaneously on the same or different channels.

To run TCS on an IBM PC or compatible, the computer must meet all of the following requirements:

- IBM PC/AT compatible
- 640K RAM
- Video graphics card (e.g., CGA, MCGA, Hercules, EGA, VGA)
- Serial port
- Printer port (optional)
- 2 disk drives, one of which is at least 720K

Available: Now

Contact: Scott Pickard, Vice President
SoMat Corporation
702 Killarney
Urbana, IL 61801
(217) 328-5359



Spacelab Experiment Interface Device (SEID)

The SEID simulates electrical and logical connections of the Spacelab Remote Acquisition Unit to provide experiment and Spacelab hardware/software verification.

Available: Now

Contact: Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807-5301
(205) 726-5613

Telescience Testbed

The telescience testbed is designed to allow researchers to estimate the communications requirement for materials science experiments that are candidates for being teleoperated. Model experiments can be remotely observed and controlled from either on site or from an experimenter's home laboratory.

Equipment

Computers: IBM/AT compatible computers with Video Digitizers
IEEE-488 interface

Stepper-motor controller

Communications

Ethernet
Video network cable
9600 baud modem

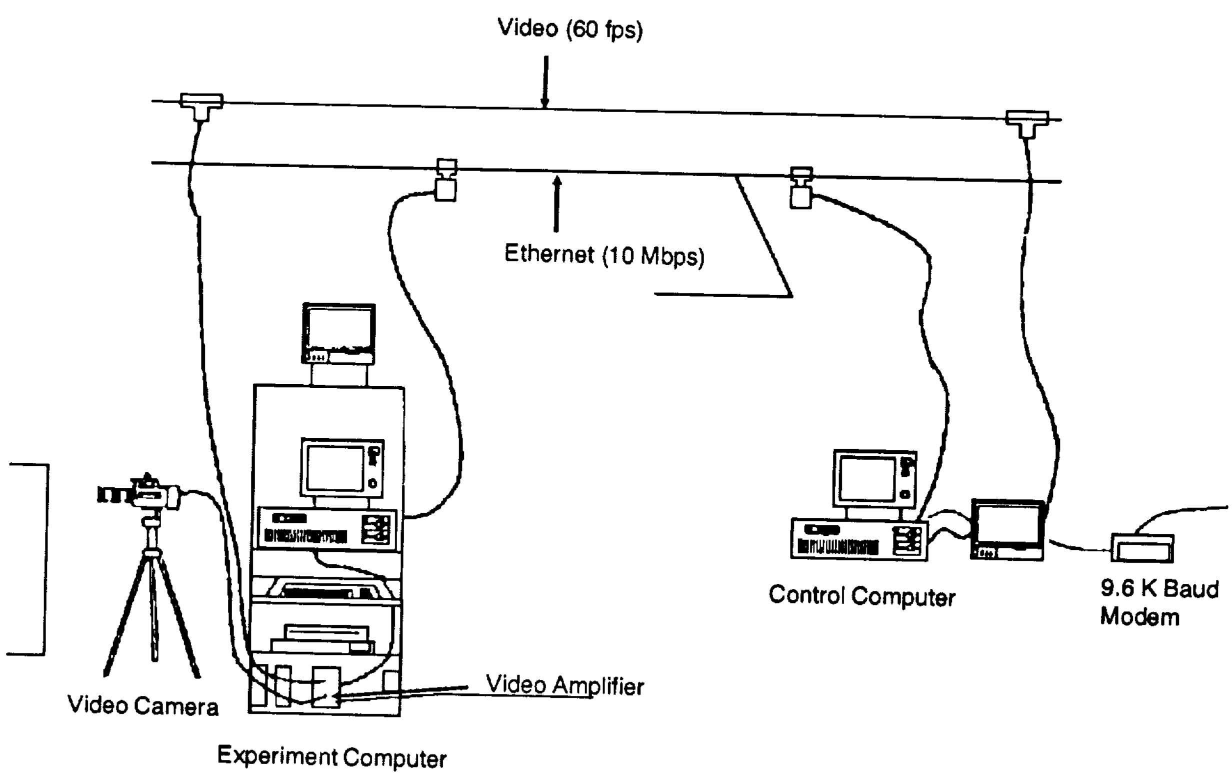
Miscellaneous Hardware

Remotely controllable microscope
Three axis positioner

Carrier: Designed for ground-based research only

Available: Now

Contact: Thomas K. Glasgow
Processing Science & Technology Branch
NASA/Lewis Research Center
21000 Brookpark Road MS 105-1
Cleveland, OH 44135
(216) 433-5014



μgNET MMSL Data/Video Network

Recorders

Digital Data Recorder

The Sony DIR-1000 Digital Data Recorder employs the technology of digital rotary head recording and enables high-density, high speed, recording and reproduction. The DIR-1000 can record up to approximately 100 GBytes (770 Gbits) of data on a large cassette tape (19mm width) at 32 MBytes/second. This corresponds to the storage capacity available on 500 magnetic tapes of the types commonly used for data storage at a recording rate of approximately ten times the speed of a MT drive. The DIR-1000 can operate with the small, medium and large D-1 cassette tapes commonly used by broadcasters. The maximum storage capacities available on small and medium cassettes are approximately 14 and 44 MBytes respectively. The DIR-1000 is designed to permit remote control and status monitor via RS-422, GPIB or RS-232C Interfaces. The unit's built-in self-diagnostics makes it possible for the DIR-1000 to isolate problems and highlight which boards need replacing. The DIR-1000 conforms to the specifications of the ANSI (American National Standard Institute) ID-1 Format.

Available: Now

Contact: Data Recording Products
Sony Business and Professional Group
3 Paragon Drive
Montvale, NJ 07645
(201) 358-4213

Instrumentation Recorder

The Sony PC-108M Instrumentation Recorder employs Pulse Code Modulation (PCM) to provide high-fidelity recording. Designed to receive data from a variety of inputs, the PC-108M receives analog data signals from a range of sources such as process monitoring equipment and measurement devices. The unit's PCM system converts the analog signals which are recorded on tape. DAT technology enables high-definition recording on metal tape of 3.81 mm in width; the unit's error correction system corrects for random and burst error.

The PC-108M's 16-bit linear quantization ensures that the signal to noise ratio is radically improved by as much as 20 dB over conventional FM systems, thus permitting the unit to record signals that otherwise would remain inaccessible. Signals of discrete frequency ranges can be recorded simultaneously or reproduced by offering multiple band/channel modes from 2 channels x 20 kHz up to 8 channels x 5 kHz. The characteristics of the analog filter are improved and total phase difference is significantly reduced by incorporating 1/2 decimation digital filters in the recording block and double over-sampling filters in the reproduction block.

Separate control functions allow for self check, search, auto repeat and digital dubbing information to be displayed. In the self-check mode the PC-108M's key functions are examined for faults. The search function allows the user to access any part of the tape at up to 200-times playback speed by specifying a counter value, address, ID, time code or event marker on the LCD display. Digital-to-digital dubbing is possible with an optional digital dubbing cable.

Information may be recorded and reproduced simultaneously with the data, such as address, ID, memo, time code, event marker, start ID, voice memo, multiple B/C modes, attenuator and coupling. The PC-108M's design permits GP-IB control of the unit's functions from a personal computer while EXT control is available to govern the operation of the tape transport. An optional RM-108 remote control unit also can be used for these purposes.

Available: Now

Contact: Data Recording Products
Sony Business and Professional Group
3 Paragon Drive
Montvale, NJ 07645
(201) 358-4213

Ultra High Density Tape Recorder

This longitudinal magnetic tape recorder, developed for Very Long Baseline Interferometry, is capable of recording data at rates greater than one Gigabit per second and storing nearly one Terabyte of data on a single tape reel.

The Ultra High Density Digital Tape Recording System, Model DR-101A, may be configured with either software error correction for high-volume, low-data rate applications, or with hardware error correction for wide-bandwidth requirements. In the latter case, a configurable user-to-storage interface unit eliminates the usual magnetic tape difficulties associated with formatting, error correction, modulation, recording interface and user interface. A chief benefit to using the DR-101A is its extremely high volume bit density. Adopting such a system reduces the expense of maintaining archival records in usable condition. A Terabyte tape has a significant volume bit density advantage over other archive media, such as optical disks, and can be duplicated in less than an hour.

Operational Characteristics

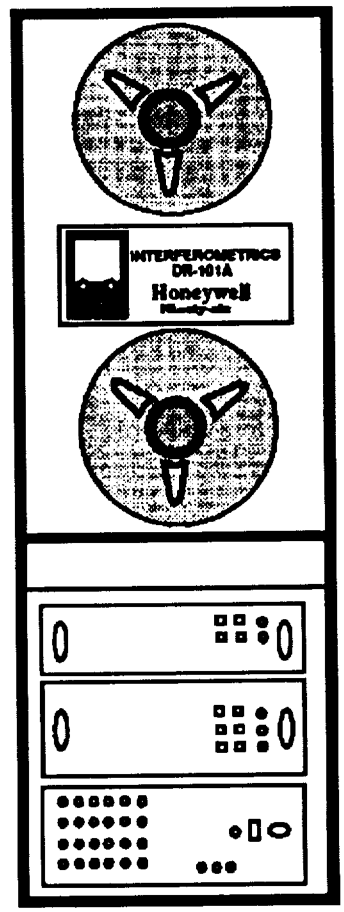
Up to 1 Terabyte of data on one tape (8 x 10^{12} bits)
1 inch video or D1-type tape; reels to 16 in

Area bit density:	27 Mbit/square inch; 36 tracks per headstack; up to 4 headstacks
Record rate:	315 Mbit/second unformatted

Modular expansion to 1300 Mbit/second
Selectable record and playback rates down to 4 Mbit/second
Honeywell Model 96 tape transport with special modifications to enhance tracking repeatability to 1 micron
Embedded VME microprocessor control of transport and piezoelectric head motion actuator
RS-232C communications interface with ASCII protocol
Head life typically 10,000 hours continuous operation at maximum record rate
MTBF 10,000 hours
Recording media costs $0.60 per Gigabyte

Available: Now

Contact: Dino A. Lorenzini, V.P., Operations
Interferometrics, Inc.
8150 Leesburg Pike, Suite 1400
Vienna, VA 22182-2799
(703) 790-8500, Fax (703) 848-2492



Satellites

Interferometric Satellite Tracking System

Designed to track NASA's TDRS satellites, this system includes the requisite hardware and software to track commercial satellites operating at Ku-Band, from 11.7 GHz-12.2 GHz. Completely passive techniques are employed and normal satellite signals are treated as noise by the correlation circuitry. The tracker is comprised of three remotely controlled field stations, which transmit data to the central processing site in Vienna, VA.

Operational Characteristics

Passively tracks satellites operating in either the TDRS (13.4 – 14.1 GHz) or Domsat (11.7 GHz – 12.2 GHz) bands
Absolute tracking accuracy is 20 meters
Interferometer consists of three 1.8 meter offset antennas mounted on polar mounts with both declination and hour angle remotely controllable
Dual-band linearly polarized front end
Each measurement site is remotely controllable from a central site

Carrier: Designed for ground-based operations

Available: Now

Contact: Dino A. Lorenzini, V.P., Operations
Interferometrics, Inc.
8150 Leesburg Pike, Suite 1400
Vienna, VA 22182-2799
(703) 790-8500, Fax (703) 848-2492

Satellite Master Ground Station

This Personnel Access Satellite Terminal is capable of communicating with Low Earth Orbit satellites. The battery-powered terminal can communicate with Interferometrics' Eyesat spacecraft and a number of other "Microsats" that operate in the UHF/VHF band.

Operational Characteristics

Portable unit:	Fits in a briefcase
Weight:	Approximately 25 lbs
Cost:	Less than $10,000
Operation:	Controlled by a personal computer
Power:	Less than 10-Watt transmitter
Setup:	Omni antenna; doppler corrected

Potential Applications

Dedicated data link between central site and worldwide field offices
Data relay from remote monitoring sites
Mobile Communications Terminal

Carrier: Designed for ground-based operation

Available: 6 Months after receipt of order

Contact: Dino A. Lorenzini, V.P., Operations
Interferometrics, Inc.
8150 Leesburg Pike, Suite 1400
Vienna, VA 22182-2799
(703) 790-8500, Fax (703) 848-2492

Miscellaneous Items

2 Axis Gimbal

This two axis gimbal is used to stabilize and steer an airborne telescope. The gimbal was designed and manufactured as part of a fast turn-around program.

Operational Characteristics

	Roll	Pitch
Rotation	+/-60 degrees	+/-41 degrees
Rate	110 deg/sec	90 deg/sec
Acceleration	400 deg/S2	400 deg/S2
Accuracy	7 Arc Minutes	

Available: Now

Contact: Versatron Corporation
103 Plaza Street
Healdsburg, CA 95448
(707) 433-8244, Fax (707) 433-7110

2 Axis Gimballed Mirror

This two axis gimbal uses mirrors to direct a laser to scan for poison gases in the atmosphere.

Operational Characteristics

	Roll	Pitch
Rotation	+/-63 degrees	+/-16 degrees
Rate	100 deg/sec	80 deg/sec
Acceleration	600 deg/S2	2000 deg/S2
Accuracy	1 Arc Minute	

Available: Now

Contact: Versatron Corporation
103 Plaza Street
Healdsburg, CA 95448
(707) 433-8244, Fax (707) 433-7110

2 Axis Optical Gimbal

This spaceborne optical gimbal is used with a laser radar system. It is both a transmitting and a receiving system. The system features space ruggedized electronics.

Operational Characteristics

	Roll	Pitch
Rotation	+/-2.5 degrees	+/-5.0 degrees
Rate	160 deg/sec	160 deg/sec
Acceleration	5500 deg/S2	5500 deg/S2
Accuracy	8 Arc seconds	
Bandwidth	5Hz @ +/-5 degrees	

Available: Now

Contact: Versatron Corporation
103 Plaza Street
Healdsburg, CA 95448
(707) 433-8244, Fax (707) 433-7110

Accelerometer Package

The function of the accelerometer package is to: measure low-g accelerations along three orthogonal axes; generate output signals proportional to these accelerations; provide 3 levels of g measurement- 1 x 10^{-2} , 1 x 10^{-4} and 1 x 10^{-6}; provide signals to the ground via telemetry and to on-board experiments when a specified low level of acceleration in all three directions is obtained; display the microgravity levels on the ground in real-time and; store the data both on-board and on the ground for later detailed analysis.

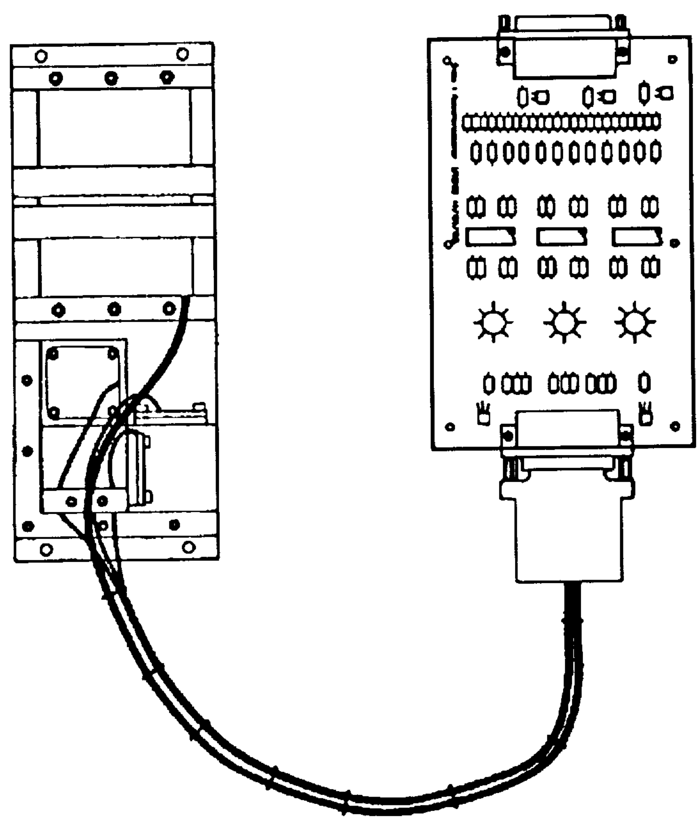
Operational Characteristics

Size:	216mm x 83mm x 95 mm and 107mm x 236mm x 24 mm
Weight:	1.5 kg
Power:	26-30 Vdc, 5.4 W power consumption

Carrier: Suborbital Rockets

Available: Now

Contact: Jan Bijvoet
Consortium for Materials Development in Space
University of Alabama in Huntsville
Research Institute Building, Room M-65
Huntsville, AL 35899
(205) 895-6620



Compact Smart Accelerometer

Small enough to be located with a broad range of microgravity experiments, this accelerometer has real-time, standard digital data output that can interface with any standard computer to provide useable data. Optional software features include frequency and power spectrum analysis, event detection, background measurement, averaging and immediate access to the data in flight or on Earth. The unit can be used for materials processing and life sciences experiments, on-orbit microgravity measurements, reentry acceleration measurements and vibration detection. May be customized to meet specific requirements.

Software options

- Coordinate transformation
- FFT spectral analysis of oscillatory disturbances
- Averaging program for steady state forces
- Event detection for transient acceleration
- Cataloguing of events

Operational Characteristics

Measurement

Range:	10^{-6} to 10^{1} g
Resolution:	1 μg
Bandwidth:	10^{-5} - 10^{2} Hz

Physical Characteristics

Mass:	<2 kg
Volume:	<.0015 cubic m (75 cubic in)
Maximum sampling rate:	800 Hz
Axis alignment:	within 2,000 urad
Supply voltage:	28 V
Power requirements:	15 W
Data:	RS-422 serial interface
Location:	Ground-based and on-orbit experiments

Available: Now

Contact: Michael D. Barg
Payload Systems Inc.
276 Third Street
Cambridge, MA 02142
(617) 868-8086, Fax (617) 868-6682

Dispenser for Carbonated Beverages

The space dispenser is designed to provide astronauts with carbonated beverages without foaming. It features a unique internal dispensing mechanism that compensates for zero-gravity. It has a drinking spout, a screw-on safety cap, a valve safety lock, a liquid flow adjustment screw, a cap retainer cord and a Velcro fastener strip. The dispenser is counter-pressurized to about 50 psig by carbon dioxide gas.

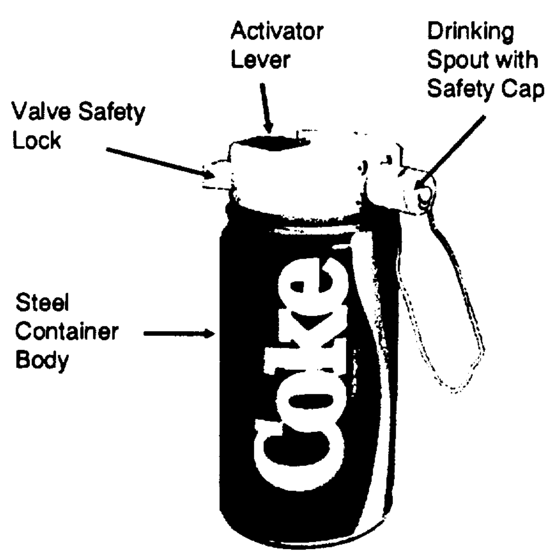
Operational Characteristics

Size:	5.75 in H x 2.5 in diameter
Full weight:	500 grams
Counter pressure:	50 psig
Pressure at nozzle:	Less than 1 psig
Flow rate:	5 ml per second
Power requirement:	None

Carrier: Shuttle middeck

Available: Now

Contact: A.S. Gupta
The Coca-Cola Company
P.O. Drawer 1734
Atlanta, GA 30301
(404) 676-4454



Division of Amplitude Polarimetric Pyrometer (DAPP)

The DAPP is a device for the measurement of surface emissivity and thermodynamic temperature of specular and partially specular surfaces. It employs laser reflection techniques based on the principles of polarized light reflection. The emissivities, indices of refraction and extinction coefficients are obtained at the laser wavelength. Concurrently, the spectral radiance of the surface is measured. The thermodynamic temperature is then determined to a high level of accuracy. The DAPP technology can be adapted to containerless processing systems for the highest accuracy temperature measurements.

This device employs a laser, operating at 0.6328 um, and can measure true surface temperatures in the range 1,000° to 2,500° K. The detection system consists of a special polarimeter capable of measuring all four Stokes vectors of reflected and emitted light instantaneously. The error in the emittance measurement is about 1%, the maximum error in temperature measurement is +5°K at 2,000°K. The temperature resolution is about 1°K at 1,000°K and the instrument response time is typically 0.1 second.

Operational Characteristics

Operating temperature range:	1,000° to 2,500° K
Surfaces which can be analyzed:	Specular or partially Specular
Design Wavelength:	0.6328 um
Response time:	<100 milliseconds
Resolution:	1° K at 1,000° K
Error in emittance:	+/-1%
Error in true thermo-dynamic temperature:	<+/5° K at 2,000° K

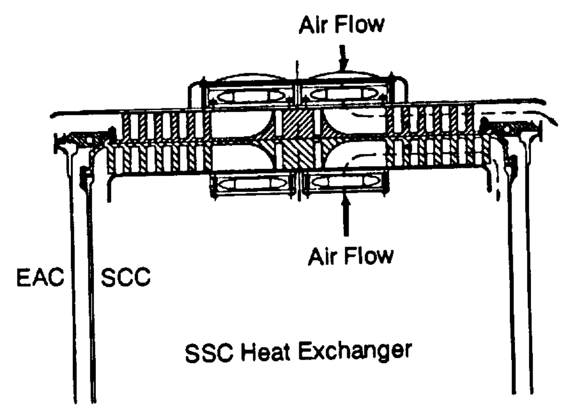
Available: Under development

Contact: Shankar Krishnan
Intersonics, Inc.
3453 Commercial Avenue
Northbrook, IL 60062
(708) 272-1772

Experiment Apparatus Container (EAC) Heat Exchanger

The EAC heat exchanger is a heat removal system for the standard NASA Experiment Apparatus Container (EAC) and the 3M Second Containment Canister (SCC). The apparatus replaces the standard EAC and SCC covers and provides a fan-driven air-to-air heat exchange from the apparatus across two levels of hermetic containment to the cabin air. Examples of the temperature differential across the interface during continuous heat transfer are 9° C and 13° C at 150 Watts.

EAC Heat Exchanger



SSC Heat Exchanger

Operational Characteristics

Power:	14 W
Size:	11 cm thick
Weight:	adds 6 kg to cover weight

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: E. L. Cook
3M Space Research and Applications Laboratory, Bldg. 201-2N-19
3M Center
St. Paul, MN 55144
(612) 733-4357

Honeywell In-Space Accelerometer (HISA)

The HG1120AA Honeywell In-Space Accelerometer (HISA) is a three-axis microgravity accelerometer instrument developed to monitor oscillatory and transient accelerations onboard spacecraft. The HISA is designed to be co-located with materials processing equipment to continuously record accelerometer event data, sampling time and temperature. A space-qualified version of the HISA has flown on previous Shuttle missions.

Features

Force rebalance accelerometers (3)
Internal temperature sensors for thermal compensation
Low-power, 8 bit measurement and control computer
Resolution less than 1 micro-g
Delta velocity digitization
Zero DC bias effect
Small size (64 in^3)
Three-pole roll-off filter response
Internal power supply (+28V required)
ASCII communications format

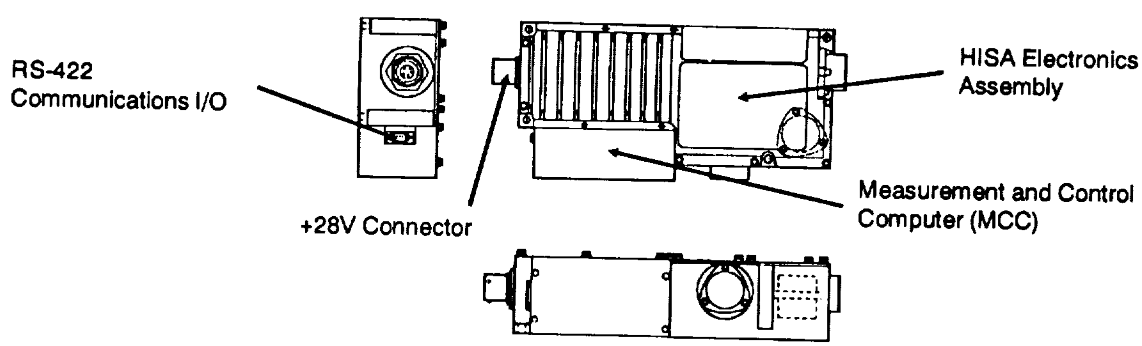
Operational Characteristics

Orientation:	Three-axis orthogonal
Range:	10^{-6} to 10^{-2} g (increments of 1.0 x 10^{-6} power g) at 1 Hz; 10^{-5} to 10^{-2} g (increments of 9.0 to ten^{-6} g) at 50 Hz
Accuracy:	+/-(1%[reading] + 0.00002) g
Resolution:	<1.0 micro-g at 1 Hz 8.7 micro-g at 50 Hz
Frequency Response (+/-5%):	0.025 to 19.500 Hz
DC Bias:	None (AC output)
Sample Data Rate:	50 Hz, 1 Hz
Communications:	RS-422/ASCII format
Size:	8.0 in x 3.8 in x 2.1 in. (64 cubic in.)
Weight:	4.0 lb
Power:	5.6 W (@ 28V)

Carrier: Various locations on the Shuttle

Available: Now

Contact: Jeff Schoess
Honeywell Corporation
3660 Technology Drive
Minneapolis, MN 55418
(612) 782-7359



Infrared Scanning Pyrometer

As presently configured, this instrument measures surface temperatures above 200° C by means of calibrated IR (5um) measurements. An electromagnetically driven mirror permits repetitive, selectable linear scans across sample surfaces. Designed for use in furnaces using quartz-halogen heating lamps, the pyrometer has been flight tested in microgravity conditions.

Carrier: Shuttle middeck

Available: Under development

Contact: Walter H. Wurster
Calspan Corporation
Advanced Technology Center
P.O. Box 400
Buffalo, NY 14225
(716) 631-6846

IONGUARD

IONGUARD signifies a series of ion implantation processes designed specifically for the needs of the aerospace industry. It is a process by which a precise quantity of atoms of a desired element can be physically injected into the surface of a material. The result is that the corrosion, oxidation, wear and friction performance all are improved. This is accomplished without any change in product color or dimension.

The IONGUARD process is used on finished products and is ready for use immediately after treatment. The ion implantation process will not change any of the bulk properties but is a unique method by which the user can alter the surface properties of a material to meet tribiological and chemical requirements.

Products employing the IONGUARD process include bearings for the Shuttle main engine, various types of radial and 4-point radial arch bearings used in satellites, landing gear materials, cryogenic bearings and components. Materials which have been treated include, 440C stainless steel, 52100 titanium, aluminum, as well as a host of other materials. Products may range in size from 0.1 inch diameter up to 36 inch diameter.

Available: Now

Contact: Spire Corporation
Patriots Park
Bedford, MA 01730
(617) 275-6000

Laser Light Scattering Instrument

This instrument allows characterization of particles in the range of 3 nanometer to above 3 microns. Dynamic light scattering probes mean size distributions, transport coefficients and interactions in colloidal dispersions. Classical light scattering can provide information on the structure and orientation of macromolecules in suspension.

Operational Characteristics
Light Source Modules
Solid state and semiconductor lasers (multiple laser option)

Power output:	>20 m Watts
Beam size dictated by laser:	approx. 1.53 mm diameter
Laser Linewidth:	<80 MHz

Mode Output Single, TEM_{00}
Zero mode hopping after warm-up
Excess Auto-correlations <0.04%

Coherence length:	>3.75 meters
Polarization:	500:1 if possible

Detector Modules
Avalanche photodiodes suitable for both dynamic and static laser light scattering.

Dark count rate:	<300 cts/sec
Dead time:	(<20 ns)
Count rate stability:	<+/-1/2% over experimental time
Quantum efficiency:	>25%
Count rate linearity up to	10 MHz
Afterpulsing:	<0.04%

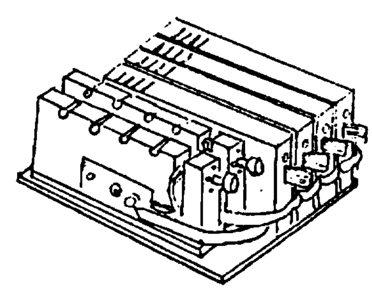
Power consumption <6 Watts
Anti-lock-up after saturation

Sample Cells: Interchangeable-Single or multiangle; Peltier temperature control; Fiber optic probe connections

Carrier: Shuttle and Space Station

Available: Under development

Contact: W. Meyer, R. Ansari
NASA/Lewis Research Center, MS 105-1
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 433-5011



Lasers and Detectors

Nearfield Antenna Measurement System

The NSI 200 series of portable Nearfield Antenna Measurement Systems provides complete antenna performance measurements of medium and high-gain microwave antennas even while the antenna is attached to a spacecraft. Typical applications include flight qualification tests and antenna/spacecraft interaction tests with operating frequencies between 1 and 100 GHz. The systems are portable, easily shipped across country and readily setup and used in a spacecraft high bay area.

The Nearfield Measurement System consists of a microwave probe, scanning mechanism, network analyzer and an IBM PC-based computer. Zero G antenna performance measurements are simplified, as no motion of the antenna or vehicle is required. The equivalent farfield antenna performance is derived from the measured electromagnetic Nearfield and a Fourier transform process. Additional holographic processing can be used to create images of antenna distortions.

Available: Now

Contact: Dan Slater
Nearfield Systems, Inc.
1330 East 223 RD ST No. 524
Carson, CA 90745
(213) 518-4277

Radiative Cooler

A radiative cooler cools detectors, such as infra-red or gamma ray detectors, by rejecting thermal energy to deep space. Temperatures in the 85° K to 110° K range can be achieved with detector thermal loads ranging from 10 to 40 mw. These devices require no electric power from the spacecraft except for monitoring instrumentation. They do require, however, a clear field of view ranging upward from a 100 degree solid cone. For best results, the clear field of view should be totally free of any warm object, such as an antenna, solar panel or the Earth. Precise optical alignment can be maintained. More than 30 coolers have been produced for Air Force and NASA instruments and when deployed have functioned in orbit.

Operational Characteristics

Weight:	3 to 15 pounds, depending upon size
Size:	12 in diameter x 7 in long-to-18 in diameter x 8 in L

Materials typically used in construction: aluminum, magnesium, stainless steel

Carrier: On-orbit spacecraft

Available: Now. If an existing design can be used, construction time is about 8 months. A new design generally requires at least one year for delivery.

Contact: Art Post
Arthur D. Little, Inc.
20 Acorn Park
Cambridge, MA 02140
(800) 677-3000

Self-Luminous Materials

Encapsulating phosphor particles and tritium gas within glass microspheres makes possible the production of a self-luminous paint. Once the active elements have been encapsulated, the microspheres can be mixed in a clear resin, silicone or similar binder to produce a long-lasting paint. The tritium-phosphor microspheres require no electrical connections or external power, do not consume oxygen or evolve soot or fumes. Potential applications in space are vehicle identification, interior capsule lighting for both instrument panel and exterior wall surfaces.

Operational Characteristics

Particle size:	0.1 mm (approximate)
Maximum intensity:	Visible Light
Color:	Green/yellow (other choices possible), 530 to 570 Nanometers
Physical Properties:	Bulk Density: 1.6 to 1.9 g/cc
Operational Temperature Range:	-30° to +120° C
Operational Pressure:	6.9 MPa (1000 psi)

Chemically Inert (the only external surface is Borasilicate Glass)

Safety: The tritium/phosphor u-sphere, as a system, is intrinsically safe. The glass is inert. The phosphor is similar to that used in fluorescent lights and TV picture tubes, requiring no special considerations. Because the u-sphere is so small it contains a minuscule amount of tritium, approximately 134 x 10^{-9} cc.

Available: Under development

Contact: Omtek Inc.
3722 Calle Cita
Santa Barbara, CA 93105
(805) 687-9629

Signal Conditioner

ELDEC Dedicated Signal Conditioner (DSC) provides signal conditioning and sensor excitation power supply for operational sensors. The modular design is available in 15, 20 and 30 module enclosures. Each module has four channels of signal conditioning/excitation.

A full range of modules are available including:

- Pulse rate to DC converter
- Resistance to DC converter (linear)
- Resistance to DC converter (non-linear)
- AC to DC converter
- AC level to logic level converter
- 5V logic level and switch closure detector/isolator
- DC Instrumentation amplifier/exciter with integral sensor excitation

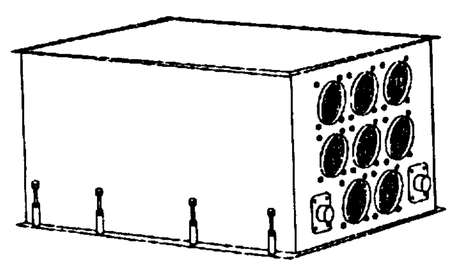
Operational Characteristics

Modules	15	20	30
Dimensions L (in)	10.1	11.8	15.8
Dimensions W (in)	7.9	7.9	7.9
Dimensions H (in)	7.0	7.0	7.0
Cooling:	Not required		
Environmental Operating Temperature:	-55° C to +93° C		

Carrier: Shuttle cargo bay

Available: Now

Contact: ELDEC Corporation
Monitor and Control Division
16700 13th Avenue West
Lynnwoood, WA 98037-8503
(206) 743-1313



Solar Cell Coverglasses

Coverglasses are used to protect solar cell arrays from ultra-violet, electron and proton irradiation damage. Pilkington Space Technology Coverglasses are manufactured from ultra thin cerium-doped glass.

The following table summarizes solar cell coverglasses available from Pilkington:

Glass Type	Bonding Suitability	Qualification Status
CMX Industry Standard	Conventional Silicone Adhesives	Space-Qualified
CMZ Thermal Expansion matched to silicon	Conventional Adhesives Teflon Bonding to Silicon Electrostatic Bonding to Silicon	Space-Qualified
CMG Thermal Expansion matched to Gallium Arsenide	Conventional Adhesives Teflon Bonding to GaAs Electrostatic Bonding to GaAs	In Qualification

All glass types contain a nominal 5% cerium dioxide for radiation stability and ultraviolet absorption. Available in sizes from 5 x 5 mm up to 100 x 100 mm as standard.

Compatible with PST coverglass coatings and available in a range of thicknesses from 0.050 mm (2 mils) to 0.500 mm (20 mils) as standard. Other thicknesses upon request. Strength can be enhanced for better handling.

Available: Now

Contact: Terence S. Griffiths
Business Development Director
Pilkington Optronics, Inc.
7550 Chaponan Avenue
Garden Grove, CA 92641
(714) 373-6061

Space Acceleration Measurement System (SAMS)

The SAMS can measure, condition and record low-g accelerations of the microgravity environment experienced by Shuttle experiments.

Available: Now

Contact: NASA/Lewis Research Center
Microgravity Materials Science Laboratory
Cleveland, OH 44135
(216) 422-5285

Space Structure Coatings

The industrial process of chemical vapor deposition is a cost-effective method of protecting graphite-epoxy composites from the degrading effects of atomic oxygen and ultraviolet light in orbit. The process provides low temperature metal coatings applied to composite and other material space structures.

Inflatable structures in space can be coated by a gas containing a metal species. Upon contact with the heated inner wall of the structure, the gas decomposes and deposits a metal film, making the inflated structure rigid. The coatings of aluminum and steel alloys can be applied on various shapes and sizes of components on Earth, or the systems can be deployed on spacecrafts.

Available: Now

Contact: Richard Westfall
President and Director of Research
Galactic Mining Industries, Inc.
4838 Stuart St.
Denver, CO 80212-2933,
(303) 433-5935

Temperature Sensor, Platinum Resistance

Model 118MF is a general purpose sensor designed to measure temperature over the range -260° C to +400° C. The sensing element is made of pure platinum wire mounted in ceramic insulation to ensure stain-free operation. It may be mounted by cementing or clamping in place.

Model 118MF is available with ice-point resistances varying from 100 to 2000 ohms in 100 ohm increments. Unless otherwise specified, the ice-point resistance tolerance shall be +/-2.0%. Unless otherwise specified, each sensor is calibrated at the ice point (0° C) accurate to +/-0.04° C. Additional calibration at -268.95° C, -195.87° C, -182.97° C, 100° C and 260° C is available. All calibration is traceable to the National Institute of Standards and Technology.

This sensor can withstand 20 consecutive temperature shocks from liquid nitrogen to room temperature trichlorethylene after which calibration at 0° C changes no more than +/-0.1° C. The insulation resistance between any sensor lead and the plate exceeds 10 megohms with 100 volts DC applied.

The time required for 63.2 percent response of an unmounted sensor, to a step change in temperature from room temperature air to #200 Dow Corning 1.5 CTSK oil flowing transverse to the sensing surface at 3 fps and at 76+/-4° C is less than 0.5 seconds. This response time is given because it represents a convenient reproducible laboratory condition. The in service response of the unit will depend upon how it is mounted and the environment in which it is used.

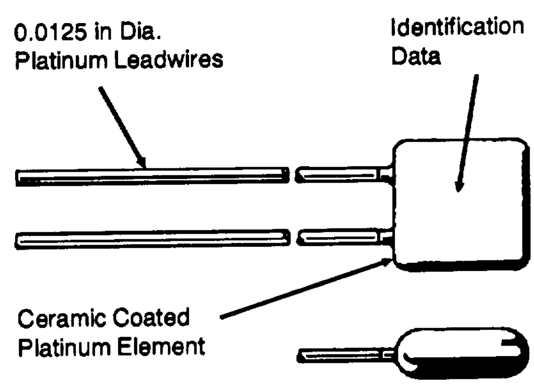
An unmounted sensor is capable of dissipating an I2R power of 46 milliwatts with a temperature rise of less than 1° C when submerged in #200 Dow Corning 1.5 CTSK oil flowing transverse to the sensing surface at 3 fps and at 25+/-5° C.

When the sensor and leads are firmly attached to a surface, the sensor withstands at least 80 g's peak or 0.5 inch double amplitude in any axis when cycled from 20 to 2000 Hz over a 15-minute time interval.

Model 118MF is suitable for use in any fluid or environment that is compatible with platinum and a ceramic composed of metal oxides. It is not susceptible to moisture absorption in moderate humidity atmospheres if the leads are suitably protected.

Available: The sensor is available in two, three or four lead wire configurations

Contact: Paul Bayer, Marketing Engineer
Temperature Group
Rosemount Inc., Aerospace Division
1256 Trapp Road
Eagan, MN 55121
(612) 681-8977, Fax (612) 681-8991



Time-Temperature Monitor

Time-temperature monitors measure and record fluctuation in temperature that occurs during transportation or storage of temperature-sensitive products. Temperature changes are sensed by a temperature-reactive element. Readings are registered either in digital form that can be downloaded into a computer, or directly on a paper chart.

Ryan TempMentor measures temperature variations in experiments in macromolecular crystallography. The TempMentor makes temperature measurements at 16 sampling rates from 1 per second to once every 2 hours, with maximum deployment of 530 days. Logs up to 6,361 temperature measurements.

Several types of temperature monitors are available.

Operational Characteristics
Range: -32° C to + 70° C

Available: Now

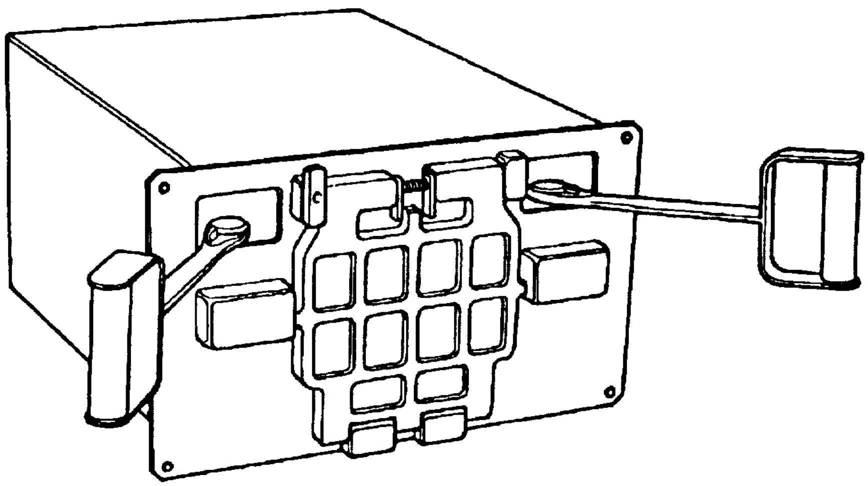
Contact: Ryan Instruments
8801 148th Avenue, NE
P.O. Box 599
Redmond, WA 98073-0599
(800) 999-7926

TRASHMASHER

TRASHMASHER is a manually-operated trash compactor that is self-contained and requires no power or hookups. It compacts trash in a specially developed wet trash bag to 25 percent of the original volume of the trash. Wet trash bags are provided to contain the trash, liquids, odors and biologically active substances in all gravity fields. TRASHMASHER was developed for use in the middeck of the Shuttle. It occupies the same volume and weight as a standard stowage locker, and is mounted the same way as a locker.

Available: Now

Contact: Johnson Engineering Corporation
3055 Center Green Drive
Boulder, CO 80301-5406
(303) 449-8152



Section Four: Experiment Carriers

To launch an experiment in space using an expendable launch vehicle or the Shuttle, the commercial developer must design the experiment, develop or select equipment to contain/operate the experiment and then integrate the package with an appropriate carrier. Carriers range from the no-frills class, such as the Get-Away-Special (GAS) canisters, to a middeck locker or the SPACEHAB module, to the full-service accommodations of Spacelab. Some carriers, such as SPACEHAB, are pressurized. Other carriers are not.

Most experiment carriers and support structures are developed for use in the middeck and cargo bay areas of the Shuttle. However, some carriers are adaptable for use on expendable launch vehicles or sounding rockets and can offer alternatives to the Shuttle. Several advantages and operational restrictions are unique to each situation and, therefore, influence experiment design, choice of carrier and the means of interfacing experiment hardware to the host facility. For example, Shuttle middeck payloads are carried in one or more middeck storage lockers and may have crew involvement. Carriers having manned or man-tended environments are so noted. Many payloads use carriers that are self-contained and operate independently of the Shuttle's resources, while others draw upon these resources for power, data gathering, etc. Each entry in this section offers operational characteristics for each carrier, assembly or rack, indicating specifications and location possibilities.

The Shuttle middeck is a confined space located directly below the flight deck and adjacent to the cargo bay. Resources available on the middeck are limited in both power and heat-rejection capability. The standard power available is 28 volts DC, 115 Watts. While space also is limited, advantages of experimentation on the middeck include potential for more frequent flight opportunities; reduced payload integration time and cost; late access to and early recovery of the experiment package; and crew interaction with the experiment, if required.

Greater power and heat-rejection capabilities are available to an experiment located in the cargo (or payload) bay than in the middeck, and larger experiments can be accommodated. Integration time and cost may increase when using large carriers; however, the cargo bay also has provisions for small, self-contained payloads that can be integrated and assembled with other, similar payloads, on a carrier such as the Multi-Purpose Experiment Support Structure (MPESS).

With the exception of research conducted in the Spacelab carrier, all experiments in the cargo bay area are activated remotely by the crew from the Aft Flight Deck or operated from the ground. The Spacelab carrier, however, offers a shirt-sleeve environment in which the crew can participate in experiments requiring real-time analysis and process modification. These crew-interactive experiments are housed in modular units designed to fit in standard Spacelab racks. At present, most accommodations in the Spacelab are committed through 1992. As a result, commercial researchers interested in using the Spacelab must consider scheduling far in advance.

Chapter 11: Manned/Man-Tended Environment Carriers

Experiments requiring operation, interaction or observation are considered manned or man-tended payloads, depending on the requirements and accommodations. In some cases, the astronaut merely switches on-off levers to initiate or terminate a process. In other cases, however, the astronaut may conduct research by manipulating equipment, testing samples or creating effects.

This chapter features equipment that supports manned and man-tended experiments that fly on the Shuttle, or as freeflyers, satellites or platforms. Each of these carriers offers variable accommodations such as volume, weight, power, cooling, etc.

Experiment Support Platform (ESP)

The ESP is a lined-sized aluminum sheet container designed to support flight experiments within the Shuttle middeck locker. The interior is fitted with mounting bars tapped for 4-40 screws on 1-inch centers for attachment of experimental apparatus. Available mounting fixtures include several configurations of slotted-angle and channel, a 1/4-20 tapped optical bench and a similarly tapped 1/8-inch floor plate. The unit is fitted with fans mounted in the side tubes to allow movement of cooling air through the system. For shipping or storage, the ESP may be collapsed into component identical side tubes, top and bottom covers, and front and back plates. Attachment is by 1/4-turn fasteners. A number of interior and exterior cover plates may be fabricated to order. A matching set of locker-modified door panels has been fabricated and is available to accommodate the air handling and power interfacing needs of the unit.

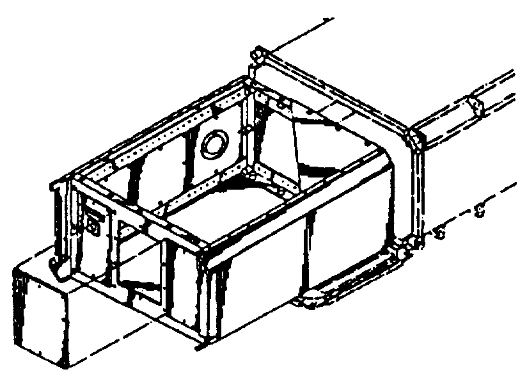
Operational Characteristics

Dimensions:		9.7 in x 17 in x 20 in dimensions of Shuttle middeck locker liner – 1/2 or full locker sizes
Volume:	full locker 1/2 locker	approximately 2 ft^2 or 1 ft^2
Weight:	full locker 1/2 locker	11 lbs or 9 lbs without fans and mounting fixtures
Power:		Experiment specific, connector to front panel through a standard 12-pin Shuttle connector
Cooling:		By fans located in the side tube

Location: Shuttle middeck locker

Available: Now

Contact: H. W. Scheld, Director of Research
PhytoResource Research, Inc.
707 Texas Ave., Suite 101-E
College Station, TX 77840
(409) 693-8606, Fax (409) 696-3451



Industrial Space Facility (ISF)

The Industrial Space Facility (ISF) is a man-tended freeflyer facility. Eventually, the ISF is expected to be a co-orbiting facility with the NASA Space Station. It is designed to provide basic utilities, primary power, cooling, communications and vacuum/venting to its users and other attached facilities requiring a power source. The facility is intended to serve as a microgravity research laboratory and, ultimately, as a materials processing facility. It also is suitable for a variety of other purposes such as storage, test bed, assembly platform and accommodation of attached payloads. The ISF will be man-tended and will provide a pressurized environment for equipment servicing and resupply in a "shirt-sleeve" manner, when docked with the Shuttle. The ISF will operate in a fully-automated mode between Shuttle servicings.

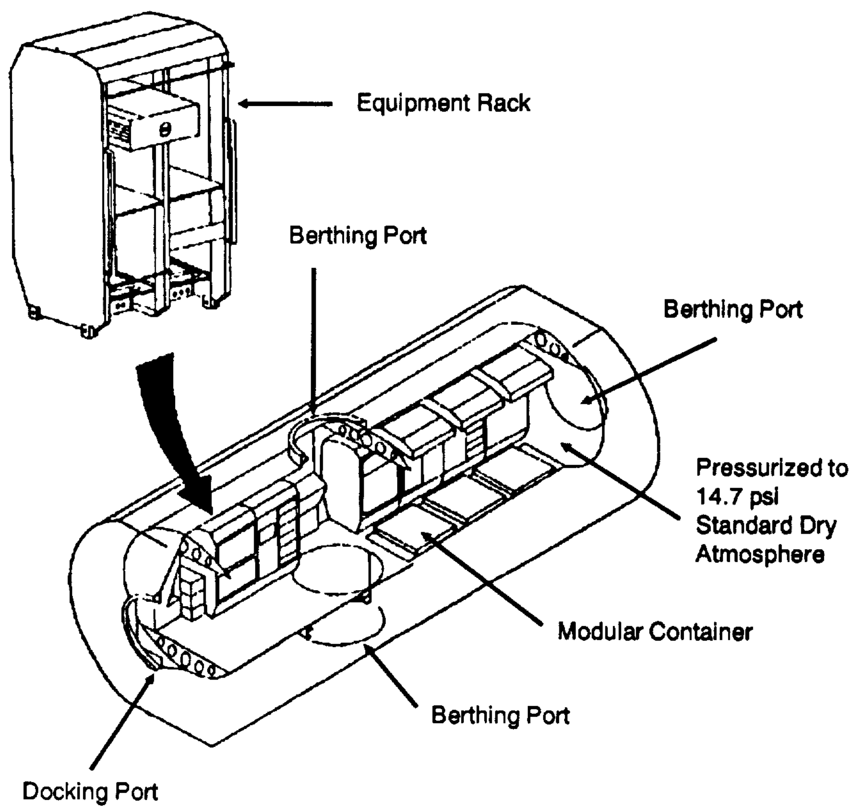
Operational Characteristics

Dimensions:	35.0 ft L x 9.5 ft diameter
Volume:	332 ft^3
Weight:	6,500 to 13,500 lbs
Power:	11 kW
Cooling:	11.0 kW L, 5.0 kW A
CMD & TLM:	2 kbs, 50 kbs

Carrier: Shuttle

Available: Under development

Contact: Space Industries, Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX 77598-4001
(713) 338-2676



Lower Rack Stowage Drawers

The stowage drawers are similar to the stowage trays. They have the same exterior front panel and may have similar interior restraint mechanisms. However, they have inner slides attached to the sides which are inserted into outer slides, attached to the interior of the rack. The inner slides have a snap lock which holds the drawers in place when they are pulled out a maximum of 22 inches from the front panel of the rack. The snap lock may be depressed to remove the drawer from the rack; however, this is not usual during normal usage.

The stowage drawer has standard dimensions for width and depth, which are approximately 16 inches and 24 inches, respectively. The height of the drawers varies with the number of front panel units (1.75 inches) required.

Available sizes:

7 panel units:	11.66 inches
6 panel units:	9.91 inches
5 panel units:	8.16 inches
4 panel units:	6.41 inches
3 panel units:	4.66 inches

Carrier: Shuttle middeck

Available: Now

Contact: NASA/Johnson Space Center
Life Sciences Experiments Program
Houston TX 77058
(713) 483-7328

Middeck Accommodations Rack (MAR)

The MAR increases the space available for small payloads and experiments in the Shuttle middeck by supplementing the volume occupied by middeck stowage lockers. The MAR is designed as a versatile experiment integration facility with the equivalent volume of five middeck lockers. Standard middeck trays or payloads specially sized to the MAR's capacity can be integrated in the carrier. Power distribution and active thermal control options are available.

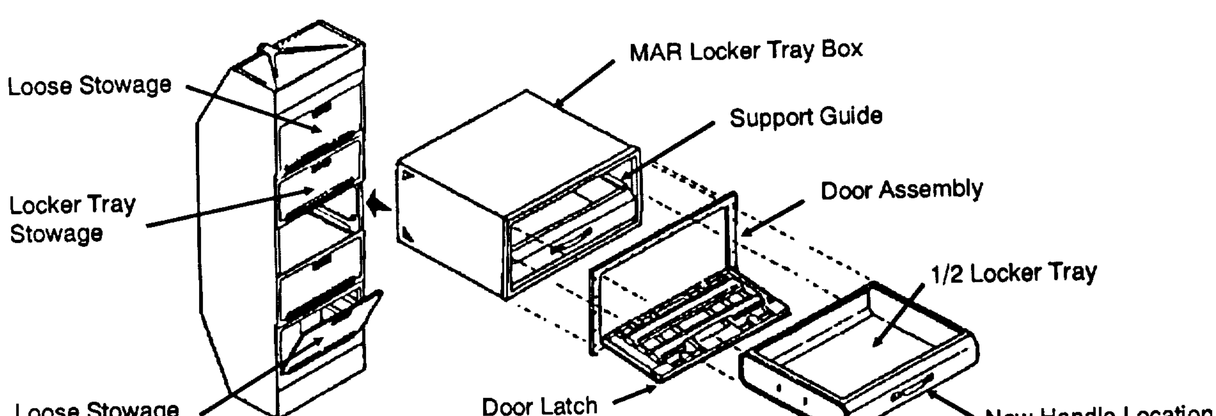
Operational Characteristics

Dimensions:	76 in H x 21 in W x 18 in D
Volume:	17 ft^3
Weight:	500 lbs including carrier (about 150 lbs)
Power:	1 kw (dc plus ac)
Cooling:	2 kW Liquid, 1 kW Air
CMD & TLM:	None, None

Location: Shuttle middeck

Available: Under development

Contact: NASA/Johnson Space Center
Customer Integration Office, Code TC4
Houston, TX 77058



MAR Locker Trays Installation

Middeck Experiment Apparatus Container (MD EAC)

EACs are convenient, economical devices that provide protective housing for experiment apparatus. Middeck EACs may be cylindrical or rectangular and contain experiments that weigh less and have lower power requirements than EAC experiments in the Shuttle cargo bay. Because middeck EACs offer an enclosed and sealed environment, certain safety waivers may be granted to the materials of components enclosed.

Four kinds of middeck EACs are available. Two are removable, cylindrical housings that can accommodate a variety of experiment apparatus. These have two sections: a cylindrical base on which the experiment is mounted and a taller component that encloses the experiment. One cylindrical EAC has a dome top, the other has a flat lid. A third middeck EAC is rectangular and provides a more rigid housing for experiment apparatus than either of the cylindrical containers. The fourth middeck EAC also is rectangular and provides accommodations for experiment electronics. Middeck EACs are designed for spaces normally occupied by middeck stowage lockers.

Operational Characteristics

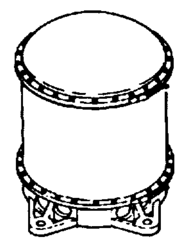
Dimensions:	14.45 in H x 16.6 in diameter
Volume:	1.8 ft^3
Weight:	TBD
Power:	0.27 kW
Cooling:	0 kW Liquid, 0 kW Air
CMD & TLM:	TBD, TBD

Location: Shuttle Middeck, SPACEHAB

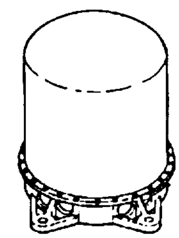
Available: Now

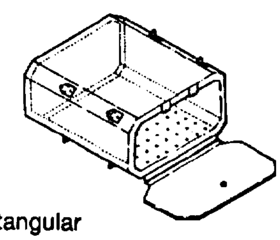
Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812

Flat Top Cylindrical EAC

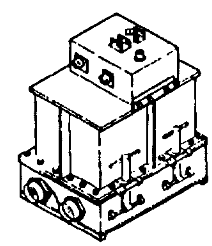


Dome Top Cylindrical EAC





Rectangular Locker Type EAC



Experiment Electronic Package

Middeck Locker (MDL)

The primary purpose of modular stowage lockers is to store crew food, clothing and payload support equipment. However, unused lockers may be made available for small, low-power experiments on a mission-by-mission basis. There are typically 13 MDLs located in the Shuttle middeck area which can be used with or without full or half-locker storage tray inserts. A double stowage locker also is available. Experiments contained in these lockers may be operated or observed by crew members.

If a larger space in the middeck is required, one or more modular stowage lockers may be removed and replaced by single or double adapter plates. These plates allow the direct mounting of experiment apparatus that are contained in appropriate hardware, e.g., an Experiment Apparatus Container. These adapter plates, along with modified locker doors, power cables and connectors, are provided by NASA as a part of the middeck payload accommodations.

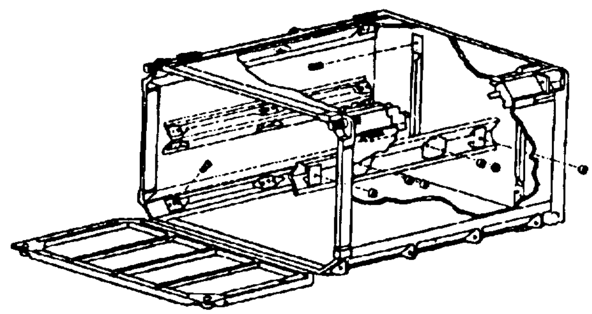
Operational Characteristics

Dimensions:	10.0 in H x 17.2 in W x 20.0 in D
Volume:	2.0 ft^3
Weight:	60.0 lbs
Power:	1 kW (total middeck)
Cooling:	0 kW Liquid, 1 kW Air (total middeck)
CMD & TLM:	N, N

Location: Spacelab, Shuttle Middeck, SMIDEX

Available: Now

Contact: NASA/Johnson Space Center
Customer Integration Office, Code TC4
Houston, TX 77058



Modular Container (MC)

The Modular Container, designed for the Industrial Space Facility (ISF) (see page 142), will have a capacity of 4 Shuttle middeck locker trays in a 2x2 configuration. The ISF can contain up to 6 modular containers in the Facility Module configuration.

Operational Characteristics

Dimensions:	12.0 in H x 36.0 in W x 40.0 in D
Volume:	11.0 ft^3
Weight:	375 lbs (payload capacity)
Power:	0.8 kW
Cooling:	0 kW Liquid 1.5 kW Air
CMD & TLM:	2 kbs, 50 kbs

Location: Industrial Space Facility (on orbit)

Available: Under development

Contact: Space Industries, Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX 77598-4001
(713) 338-2676

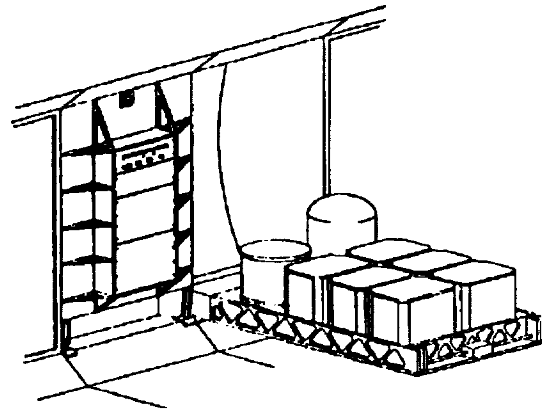
"Quick is Beautiful" Facility (QIB Facility)

The QIB facility is a multipurpose, small payload carrier that will provide easy access to space for small- to medium-sized microgravity research projects allowing proof-of-concept type investigations. Access to host resources (Shuttle or Space Station) is provided to experimenter/payloads through designed-in interfaces of the QIB facility. Examples of these resources are electrical power, air and water cooling, data, command and control, vacuum/vent, source gases, ultra-pure water and other special resources/consumables.

Location: Shuttle, Space Station

Available: Under development

Contact: Wyle Laboratories
7800 Governor Drive W.
Huntsville, AL 35807
(202) 837-4411



One of the QIB Facility Concepts Shown in the Space Station Laboratory Module

Shuttle Middeck

The middeck contains mounting space for 42 lockers, some of which are available for commercial payloads.

Equipment available for use in the middeck include modular stowage lockers, Experiment Apparatus Containers (EACs), the Middeck Accommodations Rack (MAR) and the Refrigerator/Incubator Module (R/IM). The Space Acceleration Measurement System (SAMS) also may be available to investigators using middeck facilities.

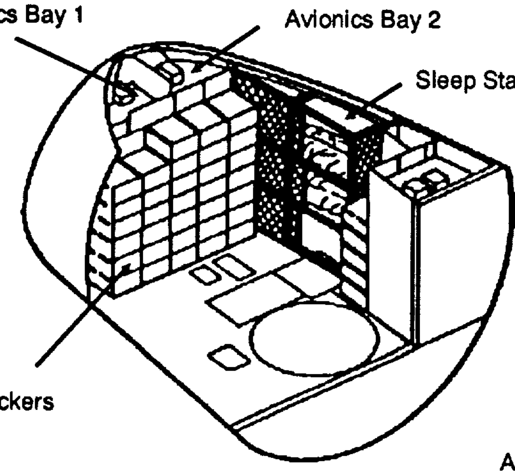
Operational Characteristics

Power:	0.6 to 0.9 kW each
Cooling:	0 L, 1 kW A
CMD & TLM:	N, N

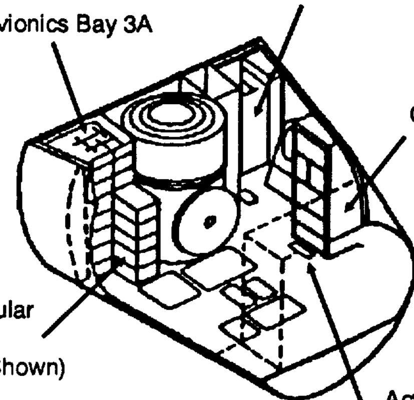
Location: Shuttle

Available: Now

Contact: NASA/Johnson Space Center
Customer Integration Office, Code TC4
Houston, TX 77058



Middeck (Looking Forward)



Middeck (Looking Aft)

Space Station Freedom

Space Station Freedom will be a permanently manned multi-purpose facility for science and applications programs. Now scheduled for completion in the late 1990s, the Station is a joint project of the United States, Canada, Japan and the nations of the European Space Agency. When the Station is completely assembled and operational, a broad spectrum of research in all the disciplines of life sciences, materials sciences, astrophysics, planetary sciences, Earth observation, commercial applications, etc. will be conducted. These activities will be accomplished with both manned and unmanned elements.

Plans for the Station presently feature four large pressurized modules clustered at the center of a trusswork boom, with two pairs of rectangular solar arrays attached to each end to supply electrical energy. Experiments, equipment and robotic arms for handling payloads can be attached to the boom and freeflying, instrumented platforms may add additional capabilities. These facilities, offering weightless periods measured in months and years rather than hours, minutes and seconds, will create new and greater opportunities for extended microgravity research.

One of the modules will serve as a habitation area and include a galley and sleeping quarters and other facilities where residents will live and relax. The others will serve as laboratories, where crew members can work in a shirt-sleeve environment, exploring the basic laws of physics that govern the delicate interaction between gravity, humans and materials.

The U.S. laboratory is designed to handle projects that need a stable microgravity environment for materials research as well as R&D in basic physics, chemistry and biology. The European and Japanese modules are designed primarily for research in fluid physics, life sciences and materials processing. Another component of the station will be the Canadian Mobile Servicing Center.

The Station will be located approximately 200 miles from Earth in a low-inclination orbit of 28.5 degrees to the equator. It will be built, serviced and supplied by the Shuttle, which also will ferry passengers up to and down from the orbiting base. Users will include any individuals, groups or agencies responsible for the development or operation of a payload, experiment, instrument or mission utilizing a component of the program.

The value of the Station is its utility for the 21st century; state-of-the-art research will create technological breakthroughs that will benefit people worldwide. While some of these benefits may become apparent during the first year of operation in orbit, many technology spinoffs may take as long as a decade to make the technology transfer and influence our daily lives. Space Station Freedom promises to be a major stimulation force for American industry. In addition, it ultimately will serve as a way station for space-bound missions, such as to the Moon and Mars.

Location: On orbit

Available: Late 1990s

Contact: Ken Taylor
Mail Code PS05
NASA/Marshall Space Flight Center
Huntsville, AL 35812
(205) 544-0640

SPACEHAB

SPACEHAB is a commercially-developed middeck augmentation module which expands the pressurized volume of the Shuttle and provides increased opportunity for astronaut-tended research and development. Two SPACEHAB flight modules are in production. Eight flights are scheduled under a Space Systems Development Agreement (SSDA) with NASA, with the first mission targeted for September 1992. SPACEHAB is mounted in the forward quarter of the Shuttle cargo bay and remains attached throughout the flight, connected to the middeck by a short tunnel.

The SPACEHAB module may be outfitted with up to 71 middeck-type lockers, identical in dimension and volume to those in the Shuttle middeck, or a combination of lockers and SPACEHAB-designed experiment racks. The racks are intended to be similar to those planned for Space Station. User-provided experiment support payload capacity in the forward bay position is 3000 pounds. Access to SPACEHAB module volume and associated services is commercially available to space experimenters worldwide through SPACEHAB, Inc.

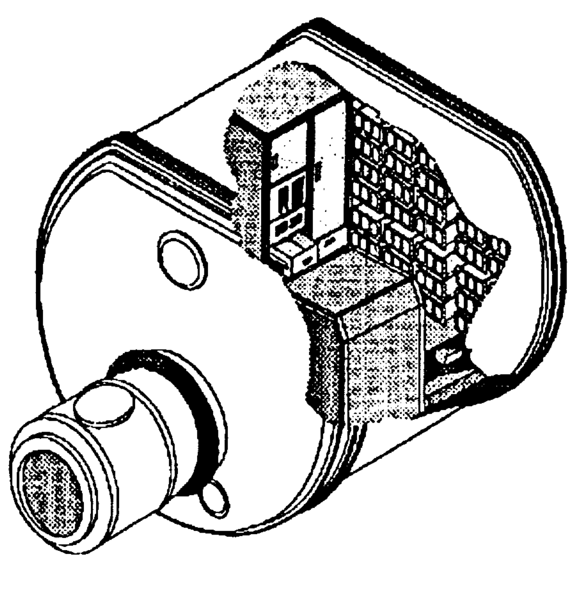
Operational Characteristics

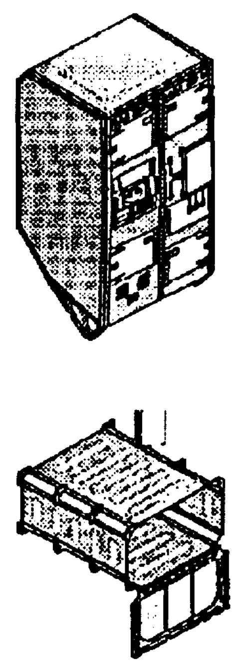
Dimensions	
Module:	10.0 ft L x 13.5 ft diameter
Rack:	35.0 in L x 41.5 in W x 89.4 in H
Locker:	21.1 in L x 18.4 in W x 10.6 in H
Volume	
Module:	1100 ft^3
Rack:	45.0 ft^3 payload
Locker:	2.0 ft^3 payload
Weight	
Module:	9,200 lb (3,000 lb payload)
Rack:	1,400 lb (1,250 lb payload)
Locker:	78 lb (60 lb payload)
Power (Payload)	
DC:	1.4 to 3.15 kW
Asc/Des:	625 W
AC:	690 VA
Cooling (Payload):	4.0 kW Liquid, 2.0 kW Air
CMD & TLM:	2 kbps, 16 kbps
Vacuum Vent:	Available

Location: Shuttle cargo bay

Available: 1992

Contact: James Ball
SPACEHAB, Inc.
600 Maryland Avenue SW, Suite 530
Washington, DC 20024
(202) 488-3483





Spacelab Middeck Experiments (SMIDEX)

The Spacelab Middeck Experiments (SMIDEX) concept was developed to fly middeck-type experiments on Spacelab, adding flight opportunities as well as an alternative to the limited space in the Shuttle's middeck. SMIDEX provides for the installation of four mounting plates into the double rack section, accommodating as many as eight middeck lockers, and up to four experiment Apparatus Containers (EACs) with Experiment Electronic Packages (EEPs) in the upper rack section. The SMIDEX structure and design allow for front access, an advantage for late experiment changeout, electrical cabling and crew interfaces. Since the mechanical and electrical interfaces between the experiments and the SMIDEX mounting plates are the same as for the middeck, no modifications of the experiments or lockers are required when flown in the Spacelab.

Up to three DC power sources and one AC power source from the Spacelab Experiment Power Switching Panel will provide power to those items requiring power via generic AC and DC cables, which are installed and routed in the rack. The cables are sized to carry 3 amps AC and 7 amps DC.

SMIDEX Load Capability

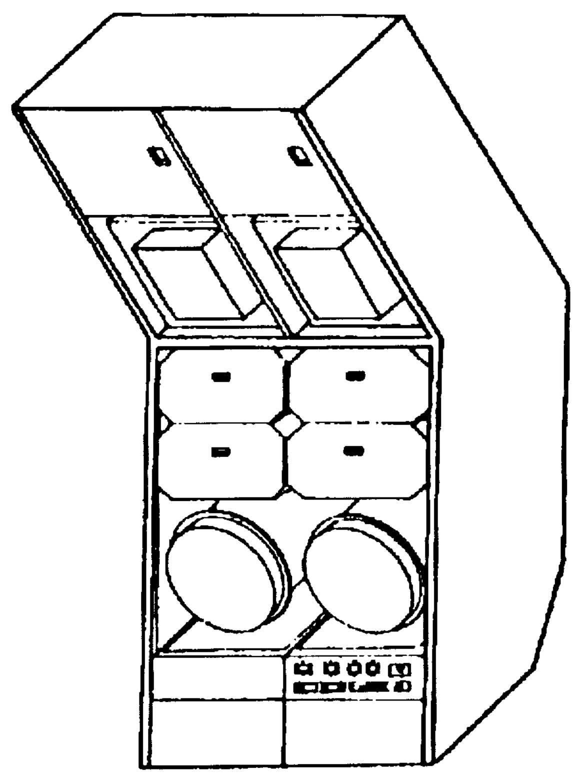
Cg*	Experiment Weight
14 in	125 lbs
13 in	133 lbs
12 in	139 lbs
11 in	142 lbs
10 in	145 lbs

*inches from late center line

Carrier: Spacelab

Available: Now

Contact: NASA/Johnson Space Center
Customer Integration Office, Code TC4
Houston, TX 77058



Spacelab Module (SL)

Spacelab is a versatile research center that provides a shirt-sleeve laboratory aboard the Shuttle as well as accommodations for instruments that require direct exposure to the space environment or no crew interaction. It can be tailored to meet the needs of multidisciplinary and dedicated discipline missions: it accommodates both large, complex facilities and smaller apparatus. Using Spacelab, investigators may interact with their experiments in several ways: by participating as Payload Specialists; by communicating from the ground with Payload Specialists in space; or by operating experiments by remote control from the ground.

The SL configuration as flown on Spacelab-1 consists of a core segment, experiment segment and endcones, without the airlock. In the laboratory module, experiment apparatus can be contained in the experiment racks, overhead containers, areas beneath the floor, stowage containers or attached to the center aisle. A Spacelab Short Module consists of only the core segment.

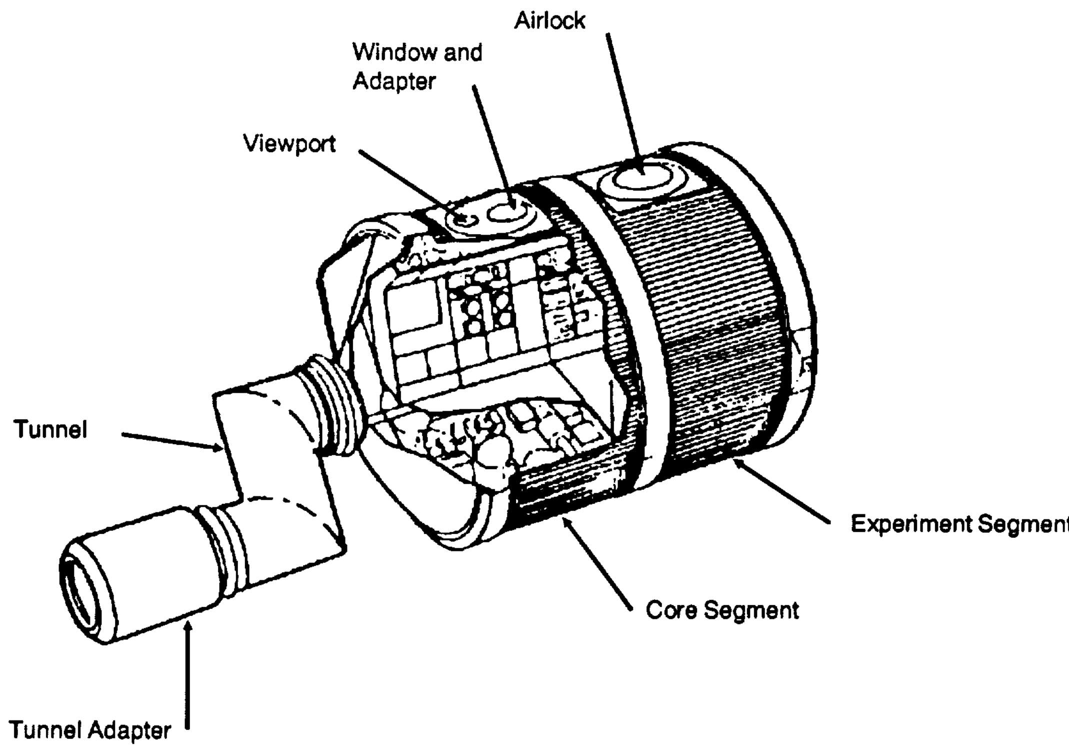
Operational Characteristics

Dimensions:	22.8 ft L x 12.1 ft D
User Volume:	285 ft^3
User Weight:	10,033 lbs
User Power:	3.4 kW (cont), 7.7 kW (peak)
User Cooling:	4.1 kW (ave) Liquid, 5.2 kW (peak) Liquid, 3.1 kW Air
CMD & TLM:	70 kbs, 50,000 kbs max

Location: Shuttle cargo bay

Available: Two carriers are available with long lead scheduling

Contact: NASA/Marshall Space Flight Center
Code JA41
Marshall Space Flight Center, AL 35812



Spacelab Rack

The Spacelab Rack is a flight-qualified structure lining both sides of the Spacelab Module. Up to six double racks and four single racks can be installed in the long module. In addition, each module configuration contains a control center rack (part of the Command and Data Management subsystem) and a workbench rack (work space for the crew).

An Experiment Power Switching Panel (EPSP), a Remote Acquisition Unit (RAU) and the Spacelab signal interface unit are located in each rack to serve the user. Also, air cooling is provided to each rack; however, front panels must be sealed to permit satisfactory performance of the cooling loop.

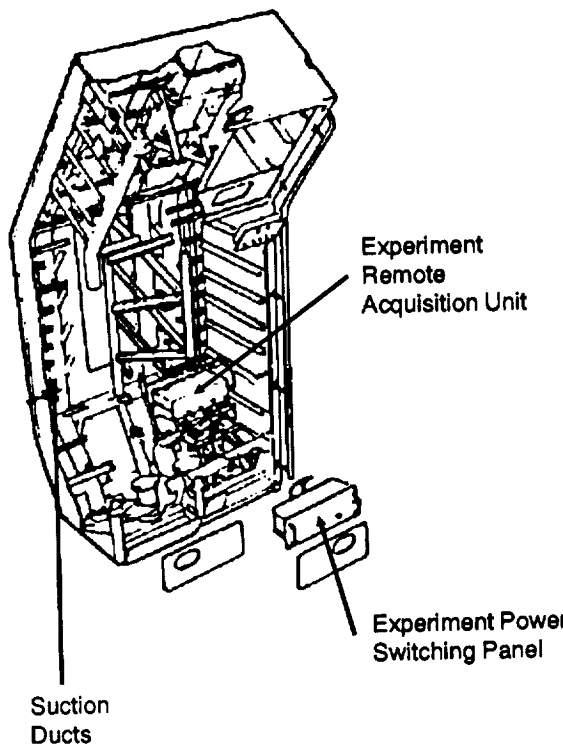
Operational Characteristics

Single Rack	
User Dimensions:	70.0 in H x 17.42 in W x 24.09 in D
User Volume:	17.32 ft^3
User Weight:	640 lbs
User Power:	3.4 kW (cont), 7.1 kW (peak)
User Cooling:	4.0 kW L, 4.5 kW A
CMD & TLM:	Mission dependent
Double Rack	
User Dimensions:	87.5 in H x 36.68 in W x 24.09 in D
User Volume:	41.3 ft^3
User Weight:	1,279 lbs
User Power:	3.4 kW (cont), 7.1 kW (peak)
User Cooling:	4.0 kW Liquid, 4.5 kW Air
CMD & TLM:	Mission dependent

Location: Spacelab module

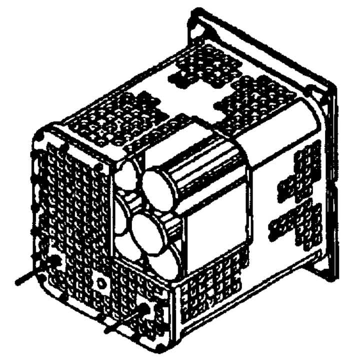
Available: Now

Contact: NASA/Marshall Space Flight Center
Spacelab Management Office, Code JA41
Marshall Space Flight Center, AL 35812

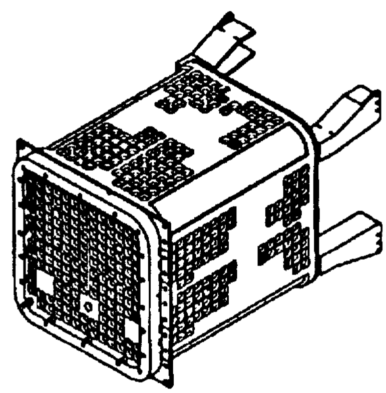


Universal Small Experiment Container (USEC)

USEC is a multipurpose experiment carrier compatible with multiple Shuttle accommodation locations and provides on-orbit access capability. USEC is qualified as a pressure vessel designed for safe handling of hazardous materials and adheres to NASA safety requirements. The lease package for USEC includes the USEC hardware and mission support related to preparation and maintenance of USEC acceptance data package. The USEC is compatible with 19-inch rack interface and middeck/SPACEHAB interface. There is a modular design for custom front and rear door utility configuration; power, data, vacuum/vent, avionics air, water and other fluids. The USEC provides on-orbit access for sample change-out and payload maintenance and servicing.



Middeck/SPACEHAB Configuration



Spacelab Rack Configuration

Operational Characteristics

Dimensions:	19 in H x 17.4 in W x 20.0 in depth
Weight of middeck version:	Approximately 70 lb
Weight of rack version:	Approximately 60 lb
Payload volume:	3.2 ft^3

Location: Shuttle middeck and cargo bay carriers

Available: 1991

Contact: Ronald E. Giuntini
Manager of Space Engineering
Wyle Laboratories
7800 Governors Drive W.
Huntsville, AL 35807
(205) 837-4411

Upper Rack Stowage Trays

A stowage tray structural enclosure is designed to house the stowage trays. It has dimensions of approximately 20 inches long by 16 inches wide by 12 inches high, is slide-mounted into the rack and attached to the front of the rack by fasteners. On the interior, metal tray guides are installed for smooth insertion of stowage trays. Metal strikers attached to the front of the enclosure are provided to mate with the latching mechanism of the trays.

Stowage trays may be removed completely from the enclosure. They have front panels with spring latches which mate with the strikers located on the enclosure. Compartments for each item of equipment may be cut out of foam to provide restraint for the contents. The mass load capability for flight use of stowage drawers or trays is 30 pounds per cubic foot of available stowage volume.

The trays are completed for 2, 5 and 7 panel unit sizes. Trays of five other sizes may be constructed. All trays have a width of 15.24 inches and depth of 19.72 inches; the heights of the trays range from 2.13 inches to 11.23 inches.

Carrier: Shuttle middeck or Spacelab

Available: Now

Contact: NASA/Johnson Space Center
Life Sciences Experiments Program
Houston, TX 77058
(713) 483-7328

Chapter 12: Shuttle Cargo Bay-Related Carriers

The Shuttle's cargo bay accommodates many kinds of experiments that do not require an astronaut's attention or manipulation. As a result, the equipment designed to support such experiments function independently of other astronaut or Shuttle activities. The user determines this selection according to the requirements of the experiment and availability of the mission.

Get-Away-Special Bridge (GAS Bridge)

The GAS Bridge is an adaptation of the Multi-Purpose Experiment Support Structure (MPESS) (See page 142). The GAS Bridge can accommodate up to 12 Get-Away-Special (GAS) cans. The advantage of this structure is that if additional space develops late in the integration process for a particular flight, the MPESS can be integrated into the cargo bay and accommodates up to 12 GAS cans.

Operational Characteristics

Dimensions:	9.38 ft H x 2.79 ft W x 14.24 ft L
Volume:	12 GAS cans @ 5.0 ft^3 each
Weight:	4,800 lbs
Power:	0 kW
Cooling:	0 kW Liquid, 0 kW Air
CMD & TLM:	N, N

Location: Shuttle cargo bay

Available: One carrier now available

Contact: NASA/Goddard Space Flight Center
Shuttle Small Payloads Project
Payloads Division, Code 740
Greenbelt, MD 20771

Get-Away-Special Canister (GAS can)

The GAS can is a standardized, cylindrical aluminum container that can be evacuated and/or pressurized. It includes an insulated exterior on the bottom and sides for thermal control (an insulated top end cap is available). A standard experiment mounting plate is used with each GAS can. While this plate may not be altered, it does include adequate provisions for the attachment of experiment packages.

GAS can operations are independent of the Shuttle other than three on/off controls activated by the crew. The user is responsible for providing electrical power, heating/cooling and data acquisition systems and must consider thoroughly the effects of temperature, vibration, acoustics, acceleration and pressure during design.

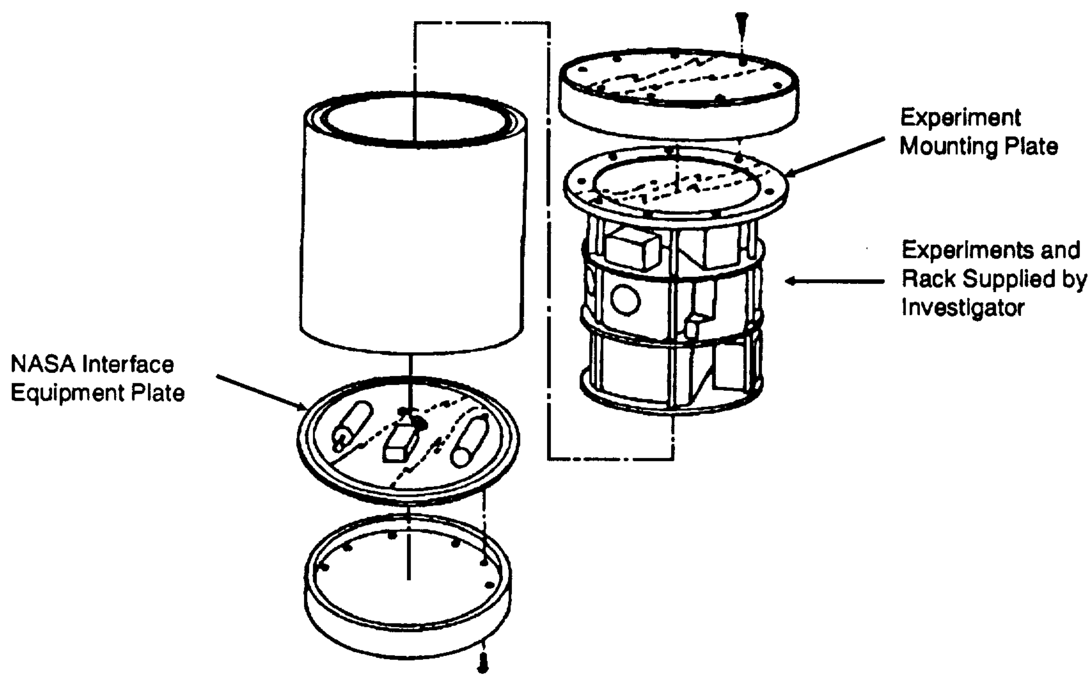
Operational Characteristics

Dimensions:	28.5 in H x 20.0 in diameter
Volume:	5.0 ft^3
Weight:	200 lbs
Power:	0 kW
Cooling:	0 kW Liquid, 0 kW Air
CMD & TLM:	N,N

Carrier: Hitchhiker-G & -M, GAS Bridge on Shuttle cargo bay

Available: Now

Contact: NASA/Goddard Space Flight Center
Shuttle Small Payloads Project
Special Division, Code 740
Greenbelt, MD 20771



Hitchhiker-G (HH-G)

Hitchhiker-G can carry up to six customer payloads weighing a total of up to 750 pounds, mounted on the side of the cargo bay. Hitchhikers are nominally carried in "bays" 2 and 3 near the forward end. Hitchhiker-G is side-mounted on the starboard side to avoid interference with the Remote Manipulator System (RMS), which is normally carried on the port side. Hitchhiker is designed with standard pre-defined electrical interfaces and also has special transparent data system features to perform electrical integration and check-out of the customer hardware on the carrier. Mechanical interfaces are simple and consist of a flat vertical plate with a 70 mm grid hole pattern or a canister similar to GAS (with or without a motorized door).

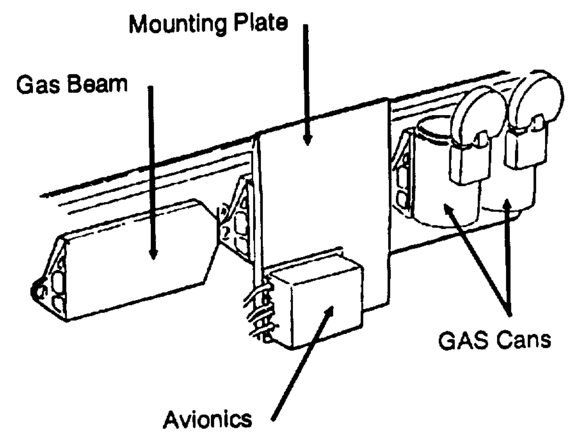
Operational Characteristics

Dimensions:	5.0 ft H x 10.0 ft L
Mtg. area:	4.2 ft x 5.0 ft plate or 2.4 ft x 3.33 ft plate (2)
Volume:	2 GAS cans
Weight:	750 lbs
Power:	1.3 kW
Cooling:	0 kW Liquid, 0 kW Air
CMD & TLM:	TBD, 1,300 kbs

Location: Shuttle cargo bay

Available: Two carriers now available

Contact: NASA/Goddard Space Flight Center
Shuttle Small Payloads Project
Payloads Division, Code 740
Greenbelt, MD 20771



Hitchhiker-M (HH-M)

Hitchhiker-M has services identical to HH-G and can carry up to 1,200 pounds of customer equipment mounted on a Multi-Purpose Experimental Support Structure (cross-bay bridge type). Hitchhikers are considered secondary payloads and should not interfere with primary payload requirements on the same mission. Unique crew activity and attitude (pointing) requirements of a limited nature (e.g. several hours) usually can be accommodated.

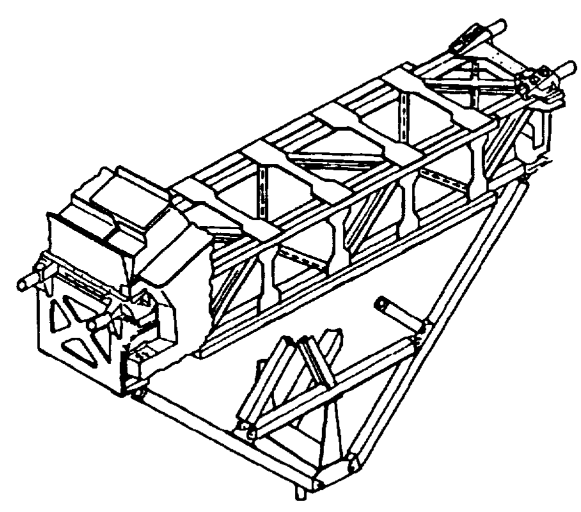
Operational Characteristics

Dimensions:	9.38 ft H x 2.79 ft W x 14.24 ft L
Mounting area:	4 plates @ 2.8 ft x 3.33 ft ea. 7 plates @ 2.4 ft x 3.33 ft ea.
Weight:	1,170 lbs
Power:	1.3 kW
Cooling:	0 kW Liquid, 0 kW Air
CMD & TLM:	8.064 kbs, 1,300 kbs

Location: Shuttle cargo bay

Available: One carrier now available

Contact: NASA/Goddard Space Flight Center
Shuttle Small Payloads Project
Payloads Division, Code 740
Greenbelt, MD 20771



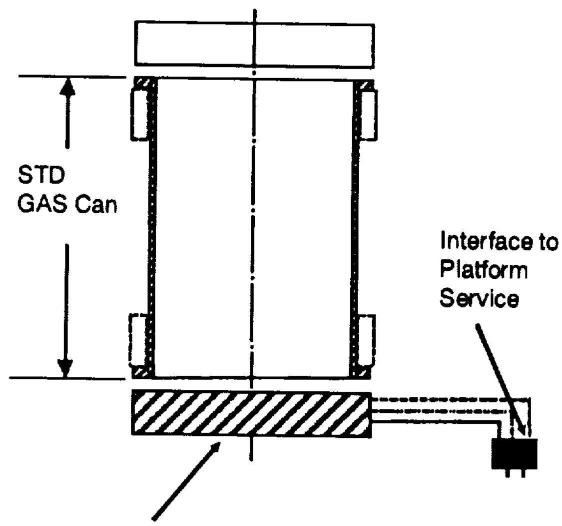
Long Duration GAS Canister with "Smart Lid"

The OUTPOST Platform (see page 171) will offer an attach location in orbit for long duration GAS Cans using a specialized container lid, which enables the user to plug directly into the OUTPOST Platform's power, communications and other subsystems. The special lid, or "Smart Lid," allows the transfer of power, command and control signals, sensor information and other services on an "as needed" basis or as part of several standard packages.

Location: Outpost Platform

Available: 1993-94

Contact: William A. Good
GLOBAL OUTPOST, Inc.
P.O. Box 4321
Highlands Ranch, CO 80126
(303) 791-6277



Smart Lid with Electronics, Interface Equipment, Wiring to Power and Communications on Platform

Materials Science Laboratory (MSL)

The Materials Science Laboratory (MSL) can accommodate a maximum of three experiment apparatus. Designated experiment equipment and subsystems mounted on the Multi-Purpose Experiment Support Structure (MPESS) form a specific configuration known as the Materials Science Laboratory. An experiment may be operated by crew members using a control panel in the Shuttle Aft Flight Deck, by the investigator who can uplink commands from the ground or by automatic programmed commands.

The MSL accommodates a variety of microgravity science apparatus and is especially adapted for large, heavy payloads. It provides structural support, power, environmental control and command and data handling, reducing the complexity of designing an experiment for a Shuttle flight.

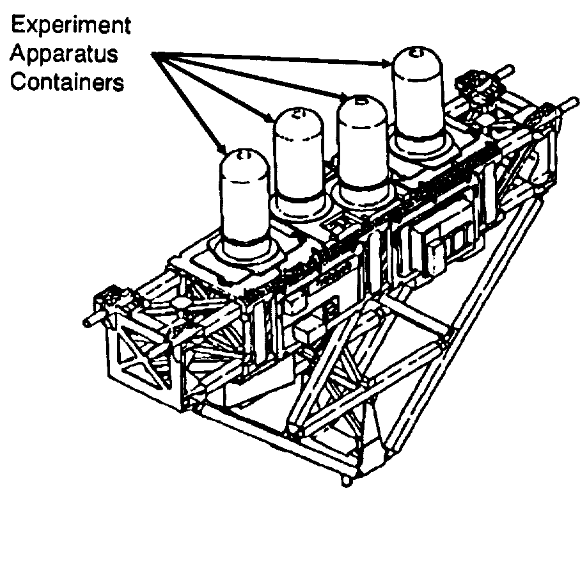
Operational Characteristics

Dimensions:	9.19 ft H x 2.92 ft W x 14.47 ft L
Mtg. area:	3 plates @ 2.8 ft x 3.33 ft ea. 3 plates @ 2.4 ft x 3.33 ft ea.
User weight:	2,040 lbs
User power:	1.41 kW (cont), 2.6 kW (peak)
User cooling:	7.5 kW Liquid, 0 kW Air
CMD & TLM:	8 kbs, 1400 kbs

Location: Shuttle cargo bay

Available: One carrier now available

Contact: NASA/Marshall Space Flight Center
Code JA41
Marshall Space Flight Center, AL 35812



MSL Experiment Apparatus Container (MSL EAC)

EACs are convenient, economical housings or covers for experiment apparatus and are integrated into the Materials Science Laboratory (MSL). The cargo bay EAC houses experiment apparatus with greater weight and power requirements than can be accommodated by the middeck EACs.

The EAC is a removable, bell-shaped containment shroud that can house a variety of experiment apparatus. The EAC has two sections: a tall shroud that encloses the experiment and a base ring section where the experiment attaches to the EAC. The cargo bay EAC is mounted on the MSF carrier and uses the carrier's host subsystems for control and support.

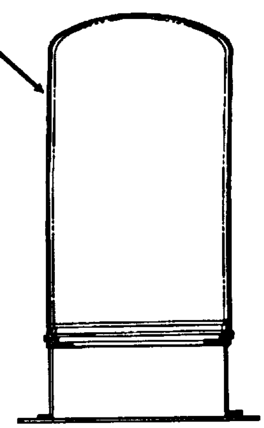
Operational Characteristics

Dimensions:	32.18 in H x 16.82 in diameter
Volume:	4.2 ft^3
Weight:	275 lbs
Power:	0.47 kW
Cooling:	0.8 kW Liquid, 0 kW Air
CMD & TLM:	TBD, 1,400 kbs max

Location: Materials Science Laboratory (MSL), Shuttle

Available: Now

Contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA81
Marshall Space Flight Center, AL 35812



Multi-Purpose Experiment Support Structure (MPESS)

The MPESS is a generic structure designed to be integrated into the Shuttle cargo bay in a cross-bay bridge configuration. Currently, the MPESS is being utilized with the MPESS-A, the Get-Away-Special Bridge, Spartan and the Hitchhiker-M carriers; it may be combined with MPESS-A to form the MPESS-B configuration for additional weight and area capability.

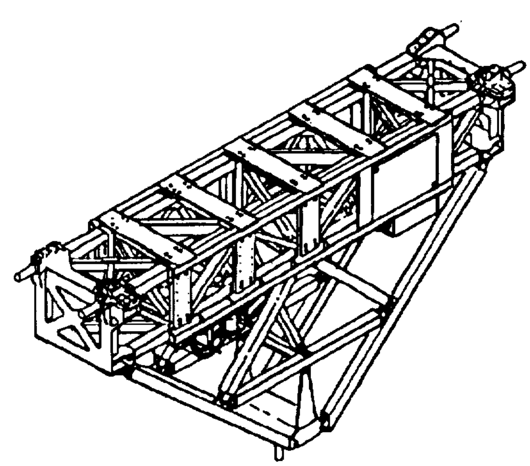
Operational Characteristics

Dimensions:	9.39 ft H x 2.79 ft W x 15.0 ft L
Mtg. area:	Mission dependent
User weight:	Up to 4,200 lbs
User power:	Not applicable
User cooling:	Mission dependent
CMD & TLM:	Mission dependent

Location: Shuttle cargo bay

Available: Seven structures are available (2 additional are under construction)

Contact: NASA/Marshall Space Flight Center
Spacelab Management Office, Code JA41
Marshall Space Flight Center, AL 35812



Retrievable Payload Carrier (RPC)

The RPC is a multi-mission payload carrier planned for launch and retrieval by the Shuttle on a regular basis. Customer payloads will fly 6-15 month missions, or longer, on the RPC for a nominal fee based on weight, volume and optional services. Industry, university and government payloads, both domestic and foreign, are accommodated by 28 pallets supporting 200-pound payloads distributed around the periphery and each face of the RPC. An extendible/retractable boom provides 40 feet of separation from the main bus of one payload. Flight kits providing unique payload support are available as an optional service.

The RPC configuration is derived from NASA's flight-proven Long Duration Exposure Facility. Its size provides more flexible Shuttle cargo manifesting capability, assuring better on-time launch and payload recovery. The RPC uses the full cross-section of the Shuttle carrier or, because of its volumetric efficiency, as an attached carrier that is not deployed. Shuttle recovery ensures low-g exposure for delicate payloads.

Operational Characteristics

Total Spacecraft weight:	8,043 lbs
Maximum payload weight:	5,600 lbs
Individual pallets support:	200-400 lbs
Mounting volume:	28 pallets, each @ 33.5 in L x 30.5 in W; depths are 3 to 40 inches
Power:	0.3-0.6 kW
CMD & TLM:	4.8 kbs (initial mission)

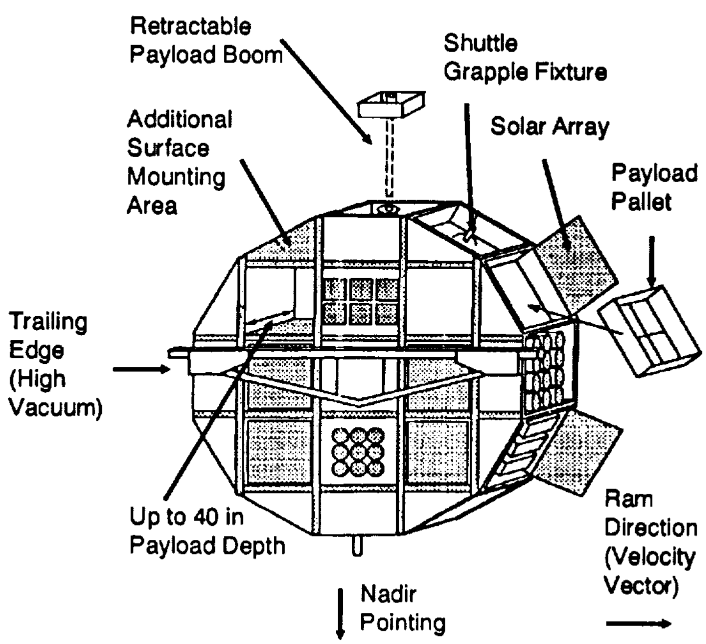
Vehicle oscillation

Roll:	1.3°	17,900 sec period
Pitch:	1.3°	30,100 sec period
Yaw:	6.8°	37,700 sec period

Carrier: Shuttle, on-orbit freeflyer

Available: 1992

Contact: Arthur T. Perry
American Space Technology, Inc.
2800 28th St., Suite 351
Santa Monica, CA 90405
(213) 450-7515



Shuttle Pallet

The Shuttle pallet is a U-shaped structure, 13 ft wide by 10 ft long. It consists of an aluminum frame covered by aluminum honeycomb skin panels. This type of construction governs the attachment provisions for experiment and subsystem equipment. Lightweight equipment and support brackets for Freon lines and cabling can be mounted directly to the inner surface skin panels. Threaded inserts arranged in a 5.5 inch square grid pattern provide the means for attachment. Each panel is capable of supporting a uniformly distributed total load of up to 1.02 lb/square foot. To mount large or heavy payloads, standard hard-point assemblies can be fastened to the intersection of the U-shaped cross members and longitudinal connecting members. Up to 24 of these hardpoints can be installed on a pallet. The pallet is directly exposed to space with the Shuttle cargo doors opened.

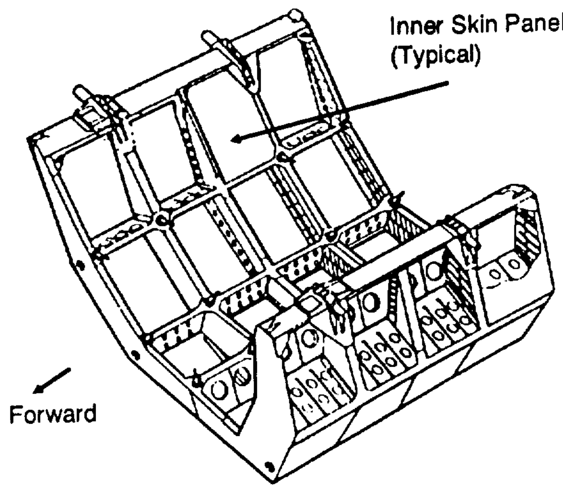
Operational Characteristics

Dimensions:	9.43 ft L x 13.12 ft W, U-shaped
User Mtg. area:	122 ft^2 to 151 ft^2
User weight:	6,856 lbs maximum
User power:	4.4 kW (cont), 8.5 kW (peak)
User cooling:	7.0 kW Liquid, 0 kW Air
CMD & TLM:	2 kbps, 50 kbps

Location: Shuttle cargo bay

Available: Now

Contact: NASA/Marshall Space Flight Center
Spacelab Management Office, Code JA41
Marshall Space Flight Center, AL 35812



Spartan Flight Support Structure (SFSS)

The Spartan base structure is a Multi-Purpose Experiment Support Structure (MPESS) with a detachable upper structure which houses unique instruments for each mission. This structure is released and retrieved by the Shuttle during the course of the flight.

The complete Spartan freeflyer carrier system consists of the Service Module (SM), the Upper Structure (US) and the Instrument Canister (IC). The Spartan is a basic standardized assembly that contains many of the subsystems necessary to support a specific mission configuration and to satisfy its requirements. The US is unique to each Spartan mission and consists of the upper housing, the IC, the Altitude Control System (ACS), pneumatics system with cold gas supply and support for the Remote Manipulator System (RMS) grapple fixture. The IC is the most common configuration for housing Spartan scientific experiments. Current configurations are cylindrical and are 17 and 22 inches in diameter. Lengths are experiment-dependent but are limited by the Shuttle cargo bay envelope to approximately 120 inches. ACS sensors required for instrument pointing may be mounted externally, on the end of the IC, or internally, co-aligned with the instrument.

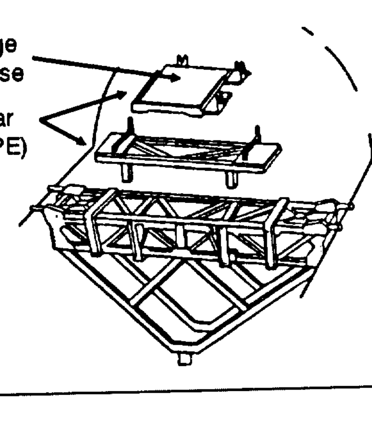
Operational Characteristics

Dimensions:	9.38 ft H x 22.79 ft W x 14.24 ft L
Mtg. area:	TBD
Weight:	5,000 lbs to users
Power:	0.28 kW
Cooling:	TBD
CMD & TLM:	TBD

Location: Shuttle cargo bay

Available: Two carriers are available

Contact: NASA/Goddard Space Flight Center
Spartan Project
Special Payloads Division, Code 740
Greenbelt, MD 20771



Standardized Experiment Module (ISEM-G)

The ITA ISEM-G consists of an aluminum aerospace structure with mounting hard points, support avionics and "housekeeping" instrumentation for experiment/payloads. The ISEM-G is designed to fit within and interface with the standard NASA 2.5 cubic feet and 5.0 cubic feet Get-Away-Special (GAS) canisters. Centrifuge tests have validated both the ISEM structure and avionics design to steady state acceleration profiles, simulating powered flight and reentry of the Shuttle and expendable launch vehicles with recovery capsules. The standard support equipment in the lower avionics section of the ISEM-G consists of a power supply, recorder, programmer-sequencer, temperature, pressure and microgravity accelerometer instrumentation. The upper section provides several mounting structure options for the experiment/payload. Current ISEM-Gs can accommodate from 3 to 10 experiments.

Operational Characteristics

5.0 ft^3 ISEM-G

Mechanical interface:	Standard NASA GAS can
ISEM-G structure weight:	39.4 lbs
Avionics Weight:	59.9 lbs
Expt. weight capability:	108.97 lbs
Expt. volume capability:	3.5 ft^3
Dimensions:	19.75 in D x 28.25 in H
Standard battery capacity:	1.2 kWh (lead acid cells)
Standard voltage:	5, 16, 24 V
Instrumentation:	Accelerometers, pressure and temperature sensors

2.5 ft^3 ISEM-G

Mechanical interface:	Standard NASA Gas can
ISEM-G structure weight:	19.5 lbs
Avionics Weight:	30 lbs
Expt. weight capability:	50.5 lbs
Expt. volume capability:	1.3 ft^3
Dimensions:	19.75 in D x 14.25 in H
Standard battery capacity:	0.6 kWh (lead acid cells)
Standard voltage:	5. 16, 24 V
Instrumentation:	Accelerometers, pressure and temperature sensors

Carrier: Get-Away-Special canisters

Available: Now

Contact: John M. Cassanto
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-3869

Standardized Experiment Module (ISEM-H)

The ITA Standardized Experiment Module is designed to be compatible with NASA's Hitchhiker-M across-the-bay carrier. The ISEM-H consists of three basic elements: an outer shell pressure vessel, an interior shelf structure for mounting experiments, and interface avionics which tap into the Shuttle's resources and distribute them to user experiments. One large payload or smaller multiple payloads can be flown in the ISEM-H. The internal environment can be maintained at one atmosphere or can be vented to the vacuum of space.

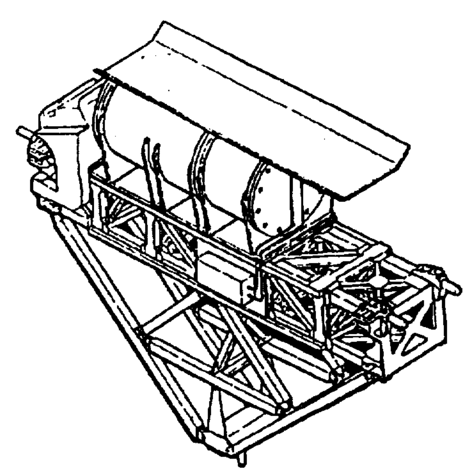
Operational Characteristics

Payload:	850 lbs
Volume:	To 50 cubic feet
Power:	1300 W
Energy:	5 kWh to 13.5 kWh/day
Heat rejection:	approximately 900 W

Carrier: Hitchhiker-M

Available: Now

Contact: John M. Cassanto
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569



Wake Shield Facility (WSF)

The WSF is designed to utilize the ultravacuum (10^{-14} torr on the wake side) of space to produce new electronic and superconductivity thin film materials and devices.

The principal experiment/support systems include:

- Wake Shield
- Shuttle cross-bay carrier
- Experiment attachment system
- Data acquisition and process control system
- Electrical power system

In addition, four payload containers (canisters) will be mounted on the WSF carrier for additional payload capabilities with power, command and data resources. This additional payload capability is available for microgravity, space exposure and space vacuum experiments. As a freeflyer, the Wake Shield Facility also can accommodate additional microgravity and space exposure payloads.

Operational Characteristics (as deployed)

Size:	12 ft diameter
Weight:	Up to 6,000 lbs
Power:	28 Vdc-42 kW-Hrs (batteries)
Vacuum:	10^{-14} torr behind Wake Shield
CMD & TLM:	S-band, 16 kbps (includes video)

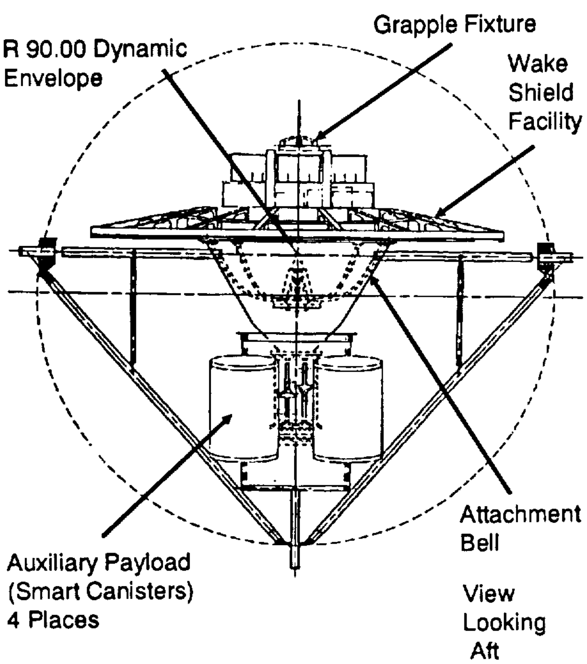
WSF Carrier Operational Characteristics

Dimensions:	9.4 ft H x 3.0 ft W x 15.0 ft L
Weight:	up to 4,600 lbs
Mounting Area:	Mission dependent
Power:	28 Vdc-1,000 W
Cooling:	Passive radiation
CMD & TLM:	16 kbps (includes video)

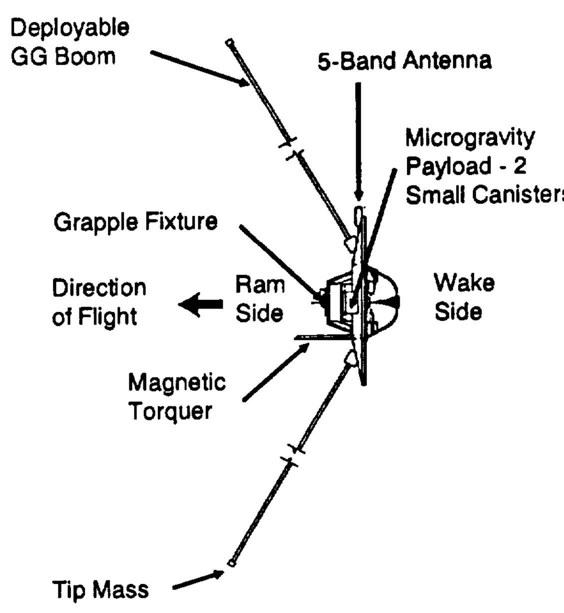
Carrier: Shuttle cargo bay

Available: Under construction by Space Industries, Inc., and CCDS members for flight as a freeflyer with the Shuttle in 1992.

Contact: Alex Ignatiev, Director
Space Vacuum Epitaxy Center
University of Houston
Science and Research, Building 1
Houston, TX 77204-5507
(713) 749-3701



WSF Carrier Assembly



WSF Free-Flyer

Chapter 13: Freeflyers and Satellites

Another opportunity for on-orbit experimentation lies in freeflyers and satellites that are launched into orbit by expendable launch vehicles. These cannot be man-tended and have limitations for control and data-gathering at present. However, with more experience in the design and operation of freeflyers, the conditions for experiments are likely to improve considerably.

Eyesat Miniature Communication Satellite

Originally developed by AMSAT, this small digital communications satellite technology now is available commercially. Four satellites were launched in January 1990 as secondary payloads on the Ariane IV vehicle. All are operating flawlessly in a 810 km sun-synchronous orbit. This low cost, high performance satellite is capable of digital voice, data, picture and fax message transmissions in a store-and-forward or transponder mode. Data rates of 4800 baud with 8 Megabytes of on-board computer memory permit a broad range of applications. Extra volume can accommodate a small, low power sensor or special communications package.

Operational Characteristics

Physical:	23 cm cube; 9.5 kg
Average power:	8 to 10 watts
Payload power:	4 W continuous; 50 W maximum
Stabilization:	Passive magnetic with solar spin
Operating Frequency:	UHF, VHF & S-Band downlink, VHF uplink
Available Channels:	5 Receivers

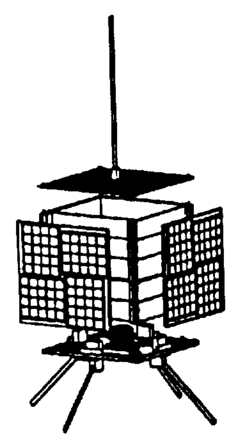
1200 to 9600 baud
15 kHz bandwidth, 20 kHz spacing
2 Transmitters
Binary PSK provides 19.2 kbits (omni)
56 kbits (gain antenna) @ 400 MHz

Power Requirements:	RF output: 2 to 4 W @ 75% eff. (300 to 1000 MHz)
CPU:	2 W peak
Receiver:	260 milliwatts
Computer:	NEC CMOS V-40 micro-processor 10 Mbytes RAM; 9.2 MHz oscillator 256K RAM EDAC memory Multi-tasking environment Direct Memory Access

Carrier: Expendable launch vehicles

Available: Now

Contact: Dino A. Lorenzini, V.P., Operations
Interferometrics, Inc.
8150 Leesburg Pike, Suite 1400
Vienna, VA 22182-2799
(703) 790-8500, Fax (703) 848-2492



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Multi-Use Lightsat Environment (MULE)

The Multi-Use Lightsat Environment (MULE) is a modular space vehicle that can handle all types of small payloads up to 250 pounds in mass, injected to orbits of up to 450 nautical miles. The system is compatible with launch on Pegasus or Taurus vehicles (see pages 207-210). The system concept is under development by Spectrum Research, Inc. and the Defense Advanced Research Projects Agency (DARPA).

Spectrum Research, Inc. specializes in the conceptualization, mission analysis, design, manufacture and test of sophisticated small space vehicles, including those in the low-cost, quick-reaction class. The vehicle depicted here is Spectrum's "Mini-Metsat" small weather satellite design, which incorporates the ITT Advanced Very High Resolution Radiometer (AVHRR) payload.

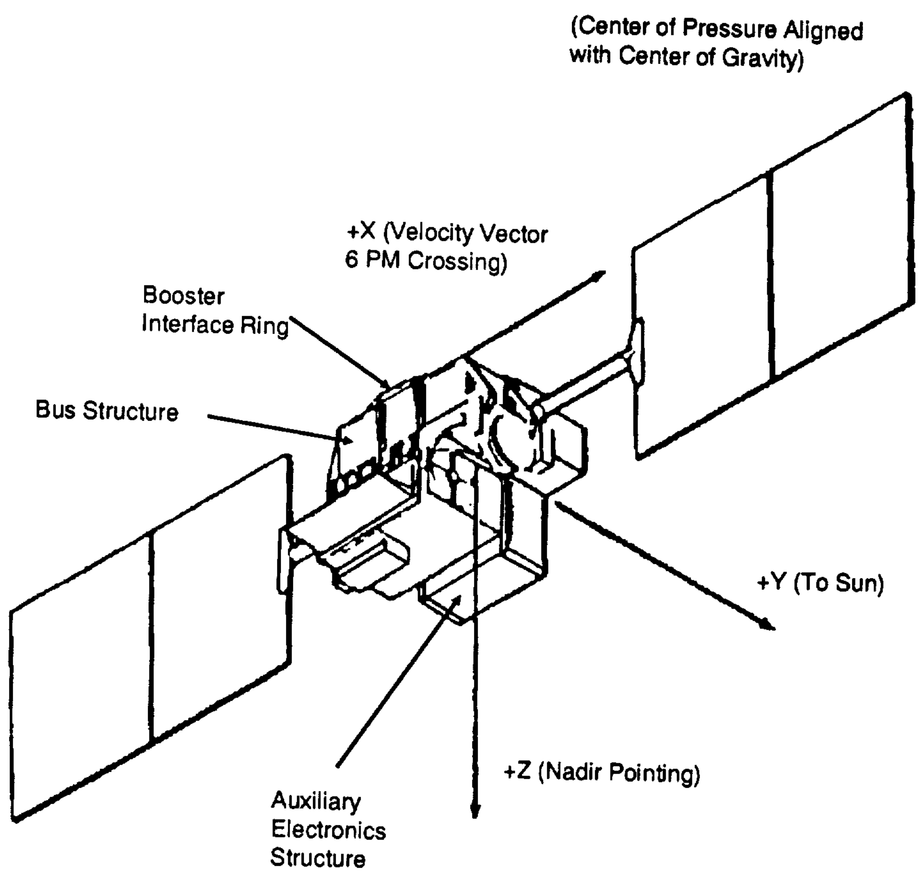
Operational Characteristics

Mass:	Approx. 500 lb total at insertion
Mission Duration:	Up to 3 years
Orbits:	LEO circular or elliptical
Payload Power:	180 W (typical)
Attitude Control:	3-Axis, .1 degrees

Carrier: Pegasus or Taurus launch vehicles

Available: Under development

Contact: W. David Thompson, President
Spectrum Research, Inc.
525 South Douglas Street
El Segundo, CA 90245
(213) 643-9303, Fax (213) 643-5369



PegaStar Low-Cost "Bus"

The PegaStar is being designed as a low cost multi-purpose spacecraft platform for use with Pegasus and Pegasus-derived launch vehicles (see page 207). Using many of the same systems that operate the Pegasus vehicle, PegaStar will be built around the third stage of Pegasus to provide the "housekeeping" services necessary to support customer-provided instruments, communications devices and other scientific equipment in orbit. Because the PegaStar platform will provide both the rocket and the payload with avionics and data systems, the need to duplicate these functions in a separate satellite is eliminated, thus improving overall performance. As a result, PegaStar will be able to accommodate heavier, more sophisticated payloads into orbit for the same, or lower, launch cost than otherwise would be required.

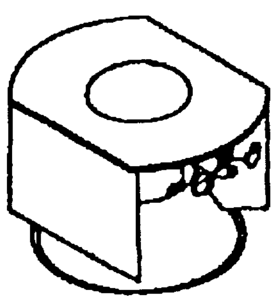
For example, a spacecraft in a 400 nautical mile, sun-synchronous orbit with an assumed typical payload/experiment mass fraction (25%) for the separable spacecraft, could be 43% heavier if orbited with a PegaStar bus. The actual percentage improvement for a given mission can be evaluated using customer specific mission requirements. Since the Pegasus Stage 3 and Taurus Stage 4 are almost identical, the PegaStar concept can be executed on either launch vehicle. This enables a wide range of payload weight and orbit capabilities to be supported by the PegaStar concept.

The actual configuration of a PegaStar for a specific mission develops as a function of meeting customer requirements. The flexible design depends on specific payload/experiment requirements such as orbit altitude and inclination; power; pointing accuracy and knowledge; telemetry (up and down), thermal; and on-orbit lifetime. Based on these requirements, the vehicle may be three-axis, spin or gravity-gradient stabilized. PegaStar can be configured with fixed or steerable solar arrays, with power levels to as much as one kilowatt.

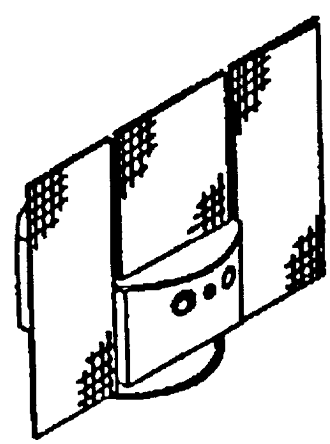
Carrier: Pegasus or Taurus launch vehicles

Available: Under development

Contact:
Robert E. Lindberg
Orbital Sciences Corporation
Space Systems Division
12500 Fair Lakes Circle
Fairfax, VA 22033
(703) 631-3600



Basic PegaStar Bus



3-Axis Sun Synchronous

Standard Affordable Small Spacecraft

The SCI Standard Affordable Small Spacecraft (SASS) is a highly adaptable spacecraft bus designed to accommodate a variety of payloads including: experimental, communications, remote sensing, reconnaissance and tactical missions for both government and commercial users.

SASS is compatible with Pegasus, Scout or other small expendable (soft or hard) launchers and readily provides three-axis, gravity gradient or spin-stabilized configurations.

The driving design criteria for SASS is user affordability while maintaining excellent reliability and performance characteristics. Depending on the mission requirements, power can be provided by body-mounted Silicon or Gallium Arsenide solar panels (providing extremely low atmospheric drag), or articulating sun-tracking arrays.

SASS can maintain a circular or elliptical Low Earth Orbit for various altitudes, inclinations and mission durations. The SCI spacecraft supports a wide variety of payload types and dimensions.

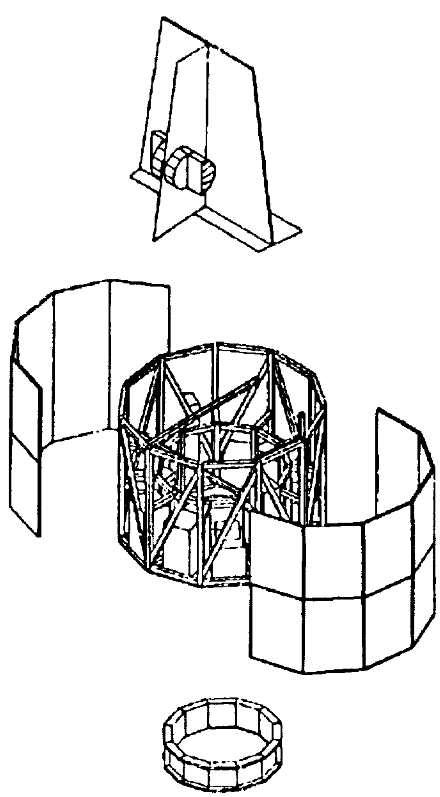
Operational Characteristics

Power consumed by spacecraft:	35 watts, 42 watts peak
Power to payload:	60 watts average, 106 watts peak with body mounted solar arrays. Available power can be increased using articulating arrays.
Basic spacecraft weight:	<226 lbs, >200 lbs available for payload with no modification. Can be expanded to accommodate heavier payloads with minor modification.

Carrier: SLV, ELV, Pegasus, Scout or equivalent vehicles

Available: Now

Contact: Ernie Blair
SCI Systems, Inc.
8600 South Memorial Parkway
Huntsville, AL 35802
(205) 882-4432



T-SAT

T-SAT is a generic, low-cost, 3-axis stabilized satellite designed to accommodate various scientific, commercial and military payloads. The same type of construction is used for four basic models, ranging from 18 inches long by 18 inches diameter for a Get-Away Special (GAS) to a 38 inch long by 36 inch diameter for a Scout or Pegasus launch vehicle; a commercial version is 48 inches long by 45 inches in diameter for an Atlas/Centaur secondary payload launch.

Payload capability is 50-250 pounds, depending on the T-SAT model selected. The form factor of each satellite is cylindrical monocoque structure. Power is supplied with body-mounted solar cells augmented by fixed deployable panels that provide 30-300 watts of orbit average power.

Operational Characteristics (T-36 model)

Dimensions:	38 in H x 36 in diameter
Volume:	24.94 ft^3
Weight:	470 lbs
Power:	115 watts average (EOL 3 years) 28 +/-4 Vdc
Payload temperature:	32-95° F
CMD and TLM:	1 kbps, 10.2 and 833 kbps
Control system:	Bias momentum
Pointing accuracy:	0.3°
Orbit change:	Thrust vector control (860 fps)

Carrier: Pegasus, Scout or equivalent

Available: Now

Contact: INTRASPACE Corporation
421 West 900 North
North Salt Lake City, UT 84054
(801) 292-0440, Fax (801) 292-6341

Chapter 14: External Tank Applications

The Shuttle's external tank (ET) carries the liquid fuels that power the main engines of the vehicle and serves as a "backbone" to support the solid fuel booster rockets as well as the Shuttle itself. Under current launch scenarios, when the Shuttle enters an orbit in space, its expended, external tank is jettisoned into the lower atmosphere, where it disintegrates into the ocean.

Each discarded tank weighs 34 tons and comprises 72,000 cubic feet of pressurized volume and up to 10 tons of residual hydrogen and oxygen fuel. During current Shuttle flights, the discarded tanks reach 99 percent of orbital velocity and remain in space for up to an hour before they fall.

Between 1982 and 1987, a series of reports and recommendations by various government and nongovernment organizations advanced the concept of developing ET's for useful applications in space. In 1988, NASA published an announcement of opportunity that requested expressions of interest from the private sector for commercial and academic approaches for the use of expended ETs. Under the terms of each of the agreements, NASA will provide five ETs after studies and engineering designs are completed.

Global Outpost, Inc. of Alexandria, VA, and the University Corporation for Atmospheric Research (UCAR), of Boulder, CO, have signed separate agreements with NASA for the use of the expended ETs in orbit. Their plans and designs are included in this chapter.

OUTPOST Platform

GLOBAL OUTPOST, Inc. plans to put an External Tank (ET) in orbit with NASA's cooperation and salvage it with the OUTPOST Subsystems Package. The company is offering innovative research and testing opportunities as follows:

Large Space Structures Research, such as assembly development, long duration exposure materials testing, orbital latch and mechanism tests, EVA assembly tests and robotic assembly development. The existing assembly effort can be modified to produce a Large Space Structures Testbed. GLOBAL OUTPOST is proceeding to develop the truss, anticipate it will be compatible with the Space Station truss and will entertain cooperative ventures with entrepreneurial, commercial and government organizations.

Tether Research will include tether technology development and testing location in Low Earth Orbit. The platform is unpressurized and unmanned and includes the appropriate reduced safety restrictions. The attachment location offers tether technology development projects with an alternative to manned vehicle systems. The platform also can provide storage for research hardware.

Commercial materials processing development and testing of commercial production facilities will be possible on the OUTPOST Platform. The platform is expected to be revisited by the Shuttle on a non-priority basis and by other transportation vehicles. The return of product can be via the Shuttle, other vehicles or by reentry capsules.

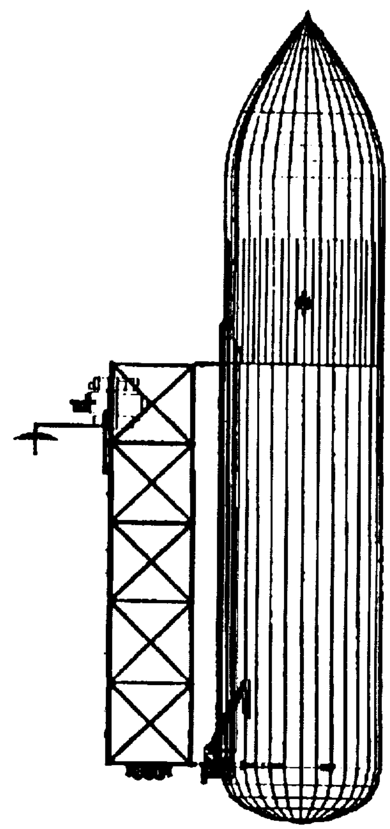
The structure will be available for the attachment of Earth viewing sensors with access to power and communications. It cannot provide fine pointing, therefore all sensors and cameras must provide required pointing capability. The attachment location for sensor research provides an unobstructed view below the platform in addition to the structural, electrical, communications, command and control and other services. Limited robotic services on an as-needed basis may be available for servicing of sensor, microgravity and life sciences payloads.

The OUTPOST Platform is an External Tank-derived commercial facility in Low Earth Orbit that will provide long duration flight testing services and development to commercial and government customers. GLOBAL OUTPOST is developing the platform under a signed NASA "Enabling Agreement." The 154-foot long platform will use the gravity-gradient stable platform to provide commercial services such as power, communications and other relatively simple services an order of magnitude less capable than the Space Station. Services will be offered in a phased manner as the market develops in orbit.

Location: On orbit

Available: 1993-1994

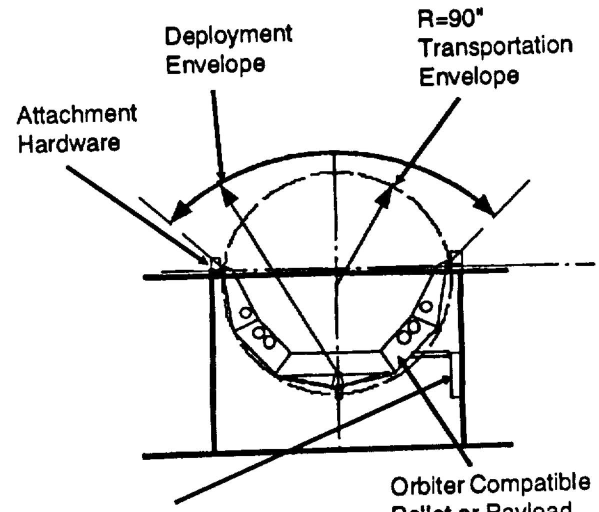
Contact: William A. Good
GLOBAL OUTPOST, Inc.
P.O. Box 4321
Highlands Ranch, CO 80126
(303) 791-6277



OUTPOST Platform (continued)

Orbital Pallet Attach Location

The OUTPOST Platform will offer a standard pallet attach location that will provide structural, electrical, thermal, communications, command and control and other services to hardware packages. The attached hardware on the truss is expected to be compatible with the Space Station attachment hardware and will offer access through a standard interface to the commercial services available from the platform. The pallets will be available in quarter, half and full Spacelab pallet sizes. The deployment of payloads from the 90 inch radius transportation envelope is possible.

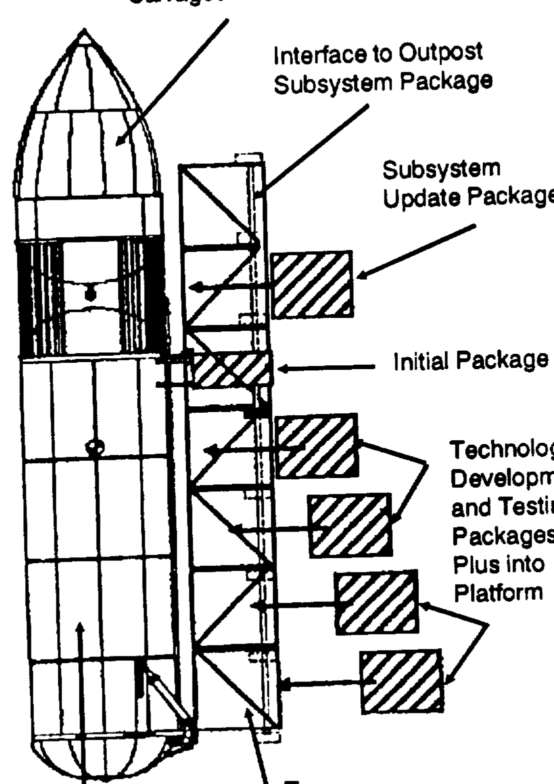


Orbital Space Effects and Materials Exposure Facility

The OUTPOST Platform will offer a long duration exposure tray attach location. The commercial service tray is similar to and will accommodate existing Long Duration Exposure Facility (LDEF) Tray experiments. It also will permit periodic monitoring of long duration flight testing of materials through the communications subsystem and the development of other activities contained in the tray.

Technology Development and Testing Location

The OUTPOST Platform will offer a "plug in" location for technology development and testing packages. The attachment location provides structural, electrical, thermal, communications, command and control and other services to hardware packages designed by other developers. The attached hardware can be installed via the remote manipulator system (RMS), or by other methods, and plugs into the commercial services available from the subsystem package. The services will be available on an "as required basis" and can flow potentially in either direction. The "plug in" service offers technology development projects an alternative to creating a separate satellite for long duration space testing.



Space Phoenix Program

Space Phoenix is a university-based, national program of the University Corporation for Atmospheric Research (UCAR) that was established for scientific and commercial use of the Shuttle's expended external tanks. The program manager, External Tanks Corporation, of Boulder, CO, is conducting studies for both suborbital and orbital use, following agreements with NASA whereby used tanks will be available for retrofitting as productive spacecraft.

Initial studies to provide an enclosure for payloads in the unpressurized Intertank section of the external tank have been completed, with NASA oversight. Studies for pressurized environments, including the addition of life support and other systems required for habitation on-orbit, are ongoing.

The Company's planned development and use of the tanks includes phased flight sequences between 1992 and 1996, based on four levels of progressively increasing capability. Phases 1 and 2, for payload module testing, will include five suborbital flights. Phase 3 will test the capability to place the unpressurized external tank into orbit; stabilize, control and use it effectively; and safely dispose of it. Phase 4 will incorporate the systems required to provide a pressurized habitable environment in one or both of the propellant tanks. Each of the four phases will be initiated with a flight that incorporates sufficient instrumentation to evaluate system performance and obtain environmental and flight dynamics data. Analysis of the information obtained will be used to verify the design and fabrication of both external tank systems and equipment to be used on each subsequent flight.

External tank suborbital uses include: measurement of lower temperature density, chemical release, recoverable reentry body research and deployment of small, freeflying spacecraft.

External tank orbital uses include: storage facilities in support of Space Station Freedom, platforms for hazardous operations or experiments, propellant depots, mother spacecraft for tether operations, variable-g test facilities, power facilities and bioregenerative facilities.

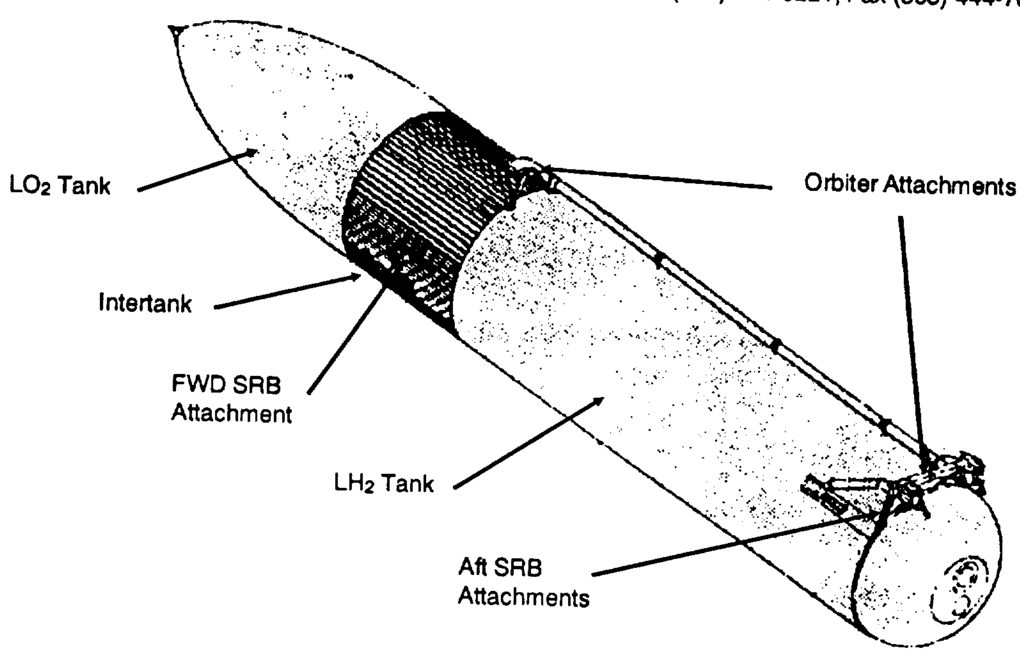
External Tank Characteristics

Dimensions:	153.8 ft long 27.6 ft in diameter
Volume:	74,000 cubic feet
Weight:	69,000 lbs empty; 1,660,000 lbs with propellants
Residual Fuel:	8,000 to 20,000 lbs of cryogenic and gaseous hydrogen and oxygen
Suborbital:	70 minutes of near-zero gravity and 17,000 mile trajectory after separation from the Shuttle
Orbital:	Altitudes between 300 and 500 km at Shuttle-compatible inclinations

Location: On orbit

Available: Under development

Contact: Randolph H. Ware, President
External Tanks Corporation (ETCO)
1877 Broadway
Boulder, CO 80302
(303) 444-6221, Fax (303) 444-7047



Chapter 15: Support Hardware

Development of the numerous carrier and mounting structures for payloads carried on the Shuttle, expendable launch vehicles, sounding rockets, aircraft and balloons has served as a catalyst for the design and manufacture of various pieces of connectors and support hardware. Many of these devices may be applicable to equipment functions on Earth and, as such, are space-derived products in their own right.

Fasteners for Use in Space

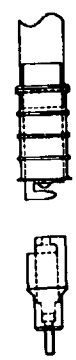
TRUSS-LOK (56547)
The TRUSS-LOK is a unique mechanical joint used to assemble erectable space structures such as Space Station truss-work. It can be operated quickly and efficiently even with large astronaut gloves used during EVA. Parts have been thoroughly tested to insure easy operation in space.

Quick Release Fasteners (53952)
BALL-LOK quick release pins are used to attach portable foot restraints to any structure during EVA. The positive locking pins can be removed easily, even while wearing astronaut gloves. Over 10,000 special designs are available. Custom designs can be ordered as required.

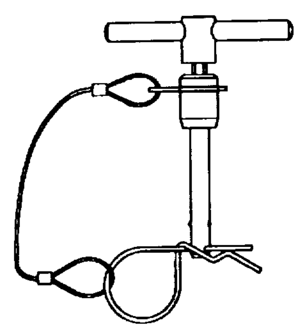
Adjustable Diameter Pins (ADP223)
Expanding diameter pins are used in the Shuttle bay to provide restraints on all cargo. They can be released easily by lifting the cam handle. Expanding segments fill the hole completely, thereby eliminating any vibration. They also can be used to align parts during assembly. These are the same type of adjustable fasteners that hold the rotor blades on military aircraft.

Available: Now

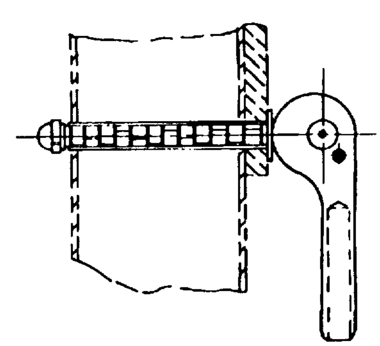
Contact: David Ladin
Avibank Manufacturing, Inc.
210 South Victory Boulevard, Box 391
Burbank, CA 91503-0391
(818) 843-4330



TRUSS-LOK



Quick Release Fasteners



Adjustable Diameter Pins

Interconnecting Devices

Interconnecting devices or connectors provide the mechanical operation for coupling and decoupling circuit elements. As connectors will be used by astronauts in extra vehicular activity, in a shirt-sleeve environment and, possibly, with remote manipulators, they must be easy to use and have mechanism commonality.

The 882 Series of Space Related Connectors
Engagement on the 882 family of connectors can be accomplished with angular misalignment up to +/-10 degrees and lateral misalignment up to +/-12 inch. The scoop-proof feature prevents inadvertent damage to contacts. The patented anti-bind roll-off feature prevents shell binding caused by side loads during separation. Connector materials are qualified to the stringent requirements of ASTM E 595-84 and the NASA Vacuum Stability requirements of SP-R-0022. Mater connectors with backshells exhibit a leakage attenuation of 60 db minimum over the frequency range from 10 kHz to 100 MHz and 40 db minimum over the frequency range from 100 MHz to 10 GHz. This connector allows the general shielding requirements necessary for the design of electroexplosive subsystems per MIL-STD-1512.

Operational Characteristics
Qualified to NASA/GSFC Specification S-700-42

Insulation Resistance:	5,000 Megohms minimum contact to contact or contact shell
Dielectric Withstanding Voltage:	1,000 VAC at sea level contact to contact or contact to shell
Vibration:	20 g's from 10 Hz to 2 kHz per MIL-STD-202, method 204
Physical Shock:	Per MIL-STD-202, method 213, condition G
Temperature Range:	-65° C to +125° C operating range
Thermal Shock:	Per MIL-STD-1344, method 1003.1, Condition A
Salt Spray:	Per MIL-STD-202, method 101, Condition B
Moisture Resistance:	Per MIL-STD-202, method 106
Durability:	250 mate and demate cycles

Robocon Series
This series of subminiature connectors has been designed for robotic/manipulator hand, EVA glove and blind-mate modes of operation for serviceable spacecraft, payloads and instrumentation applications. The connector incorporates the scoop-proof, EMI, backshell and other features of the MMS S-700-42 blind-mate connector technology and includes the use of long-lasting, low-insertion/low-withdrawal force, low-resistance contacts. For the manipulator, hand and EVA glove modes, the connectors are equipped with an automatic latching mechanism which retains the mated connector until the release mechanism is pressed, permitting easy release of the mated pairs. For blind-mate applications, one of the connector halves is firmly mounted with the opposite half float-mounted to provide a +/- 10 degree and +/-0.12 inch translational error without bonding contacts. There are plans for 30, 60 and 90 contact versions, as well as provision for coaxial, twinaxial, triaxial and optical couplers. Models have been made of a larger version for Space Station power distribution use employing a flat ribbon form of interconnection.

Operational Characteristics

Insulation Resistance:	5,000 Megohms minimum contact to contact to shell
Dielectric Withstanding Voltage:	1,000 VAC at sea level contact to contact to shell
Vibration:	20 G's from 10 Hz to 2 kHz per MIL-STD-202, method 204
Physical Shock:	Per MIL-STD-202, method 213, condition G
Temperature Range:	-65° C to +125° C operating range
Thermal Shock:	Per MIL-STD-1344, method 1003.1, condition A
Salt Spray:	Per MIL-STD-202, method 101, condition B
Moisture Resistance:	Per MIL-STD-202, method 106
Durability:	500 mate and demate cycles

Available: Concept models of the subminiature and power type of Robocons have been designed, produced and given preliminary tests.

Contact: G & H Technology, Inc.
Special Products Division
1649 17th Street
Santa Monica, CA 90404
(213) 450-0561, Fax (213) 452-5478

Motorized Door Assembly (MDA)

The MDA is designed to cover the aperture of a Get-Away-Special (GAS) Can during flight on the Shuttle. It operates from internal power in the same or another can or from Shuttle power. Commands to open and shut the door are from the Shuttle cabin. The MDA simply can cover the can aperture or it can serve as a hermetic seal if vacuum or pressurization by a gas is needed. The mechanical mechanism keeps pressure on an "O" ring seal until the opening command is activated, in space, in the sealed model. Optical components, such as mirrors, can be mounted to the inside of the door to provide a method for directing the viewing path of optical or microwave sensors.

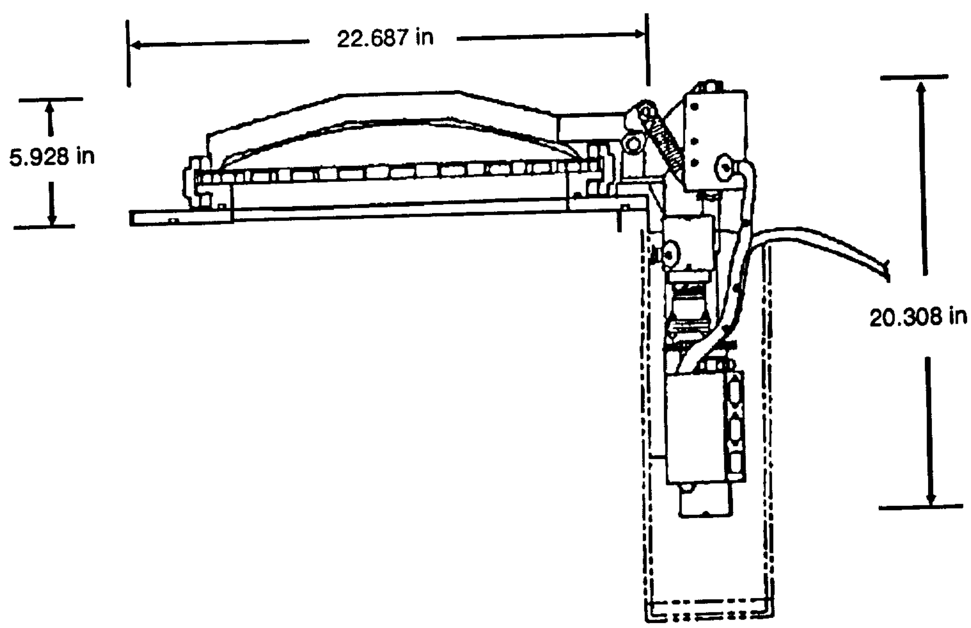
Operational Characteristics

Weight:	85 pounds in the nominal configuration, varies with mode, e.g. pressure sealed, optics mounted
Power:	200 W maximum during opening and closing
Dimensions:	As shown in drawing

Location: GAS Cans on Shuttle cargo bay

Available: Now, 4 months after receipt of order

Contact: Harvey E. Rice, Jr., Vice President
International Development &
Energy Associates, Inc.
14440 Cherry Lane Court, Suite 100
Laurel, MD 20707
(301) 369-9422



Section Five: Processing & Integration

Payload processing involves the ground-based operations required to prepare payloads, including integration with launch vehicles, for launch into space. A variety of facilities, equipment and expertise is required to meet payload processing requirements.

Typical launch site operations for large, deployable spacecraft include post-shipment assembly and checkout of the spacecraft; installation of hazardous elements, such as solid and liquid propellants; post-shipment inspection and assembly of the perigee stage; mating of the spacecraft and the perigee stage; and delivery of the payload assembly to the launch facility. Smaller payloads, such as those prepared by commercial developers for launch on the Shuttle, smaller expendable launch vehicles or sounding rockets, require similar checkout and integration, but on a lesser scale.

Chapter 16: Government Services

NASA handles most payload processing and integration activities for launches at Kennedy Space Center. Payload processing and integration services also are provided at other major launch sites, including Wallops Flight Facility, Vandenberg Air Force Base and White Sands Missile Range.

NASA/Kennedy Space Center(KSC)

KSC is responsible for the management and direction of:

- Shuttle and NASA ELV launch preparation, integration and checkout
- Integration and checkout of payloads flying on these vehicles, including Spacelab, Space Station, upper stages and other attached or deployable payloads
- Shuttle launch and landing operations and NASA ELV operations
- Design, development, construction, operations and maintenance of launch, recovery and landing facilities and ground support equipment

NASA encourages commercial payload developers to contact the KSC payload organization for technical assistance early in the planning stages. This assistance is important in factoring ground operations considerations into payload design and support requirements planning.

Payload developers planning a launch on an ELV should communicate directly with the launch vehicle provider, who then will coordinate payload and vehicle support requirements with KSC. Developers planning a launch on the Shuttle, should contact Flight Requirements and Manifesting Management at NASA Headquarters, Office of Commercial Programs, 703-557-5328.

The KSC payload organization appoints a Launch Site Support Manager (LSSM) when a NASA-managed payload element is assigned to fly on either a Shuttle or an ELV. The LSSM produces the KSC Launch Site Support Plan (LSSP), which compiles the processing scenario, the payload test and support requirements, together with the KSC requirements on the payload, into one plan for payload launch and landing site activities.

The LSSM is the primary contact for project planning and provides support to the payload owner during the ground processing at KSC. In this capacity, the LSSM coordinates planning activity between the customer and supporting elements within KSC, NASA Headquarters and other NASA Centers. This coordination assures that payload requirements and operational plans are feasible with KSC and Agency capability and plans.

KSC has entered into agreements with three major commercial ELV operators, McDonnell Douglas, for the Delta; General Dynamics for the Atlas/Centaur; and Martin Marietta for the Titan.

Contact: JoAnn H. Morgan
Payload Projects Management
NASA/Kennedy Space Center
Mail Code CP-APO
Kennedy Space Center, FL 32899
(407) 867-3374

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NASA/Wallops Flight Facility

Principal facilities on the Wallops launch range in Virginia are those required to process, checkout and launch solid rocket boosters carrying payloads on suborbital or Low Earth Orbit trajectories. Included are launch pads, launchers, blockhouses, booster preparation and payload checkout buildings, dynamic balance equipment, wind measuring devices, communications and control instrumentation, TV and optical tracking stations, surveillance and tracking radar units and other supporting facilities.

Wallops requires program interface with commercial developers for launching from its Wallops Island site.

The facility furnishes range operational planning, analytical feasibility and design studies; payload, vehicle and recovery system engineering; payloads construction and integration; test evaluation; and data analysis and reporting. Field support is provided as needed for launch operations.

Contact: Donald Friedman
NASA/Goddard Space Flight Center
Mail Code 702.0
Greenbelt, MD 20771
(301) 286-6242

Western Space and Missiles Center (Vandenberg)

NASA/Kennedy Space Center is responsible for the operation of the KSC Vandenberg Launch Site Resident Office in California. This office serves as the interface with the U.S. Air Force to arrange for base support for all NASA elements at Vandenberg. It supports spacecraft requirements of other NASA centers, commercial and government agencies not affiliated with DOD by providing operational and administrative support.

Contact: Robert Butterfield
NASA/Kennedy Space Center
Mail Code CP-APO
Kennedy Space Center, FL 32988
(407) 867-2217

White Sands Missile Range

Use of NASA-owned equipment and facilities are required for launches at White Sands in New Mexico. These include an assembly building and associated payload integration equipment. Approval from NASA, usually in the form of a Memorandum of Agreement (MOA), is required. Range support, including radar, telemetry, optical coverage, payload vibration, flight safety and other normally provided test range support and facilities, must be negotiated with the White Sands Missile Range.

Contact: U.S. Army White Sands Missile Range
Attention: STEWS-NR-PR
(Future Programs Team)
White Sands Missile Range, NM 88002
(505) 678-1134

Chapter 17: Commercial Services

Astrotech Space Operations (see below) is the only U.S. company that operates a commercial processing facility for large payloads.

Other companies offer payload processing as a third-party contractor, liaison or leasing agent. These firms can work with the commercial developer to design the experiment, the hardware and the planning scenario for launches on the Shuttle and on expendable launch vehicles.

Astrotech Space Operations, L.P.

Astrotech owns and operates the only U.S. commercial payload processing facility, located in Titusville, FL, adjacent to the Kennedy Space Center. Its capabilities include:

- Non-hazardous processing buildings; clean room high bay complexes (4);
- Hazardous processing building; clean room high bays (4)
- Payload storage building
- Customer office building
- Warehouse storage building (6,250 square ft)

Contact: George D. Baker
Astrotech Space Operations, L.P.
12510 Prosperity Drive
Silver Spring, MD 20904
(301) 622-5804, Fax (301) 622-2937

The Bionetics Corporation

The Bionetics Corporation provides life sciences payload development, integration and technical support for Shuttle middeck experiments, Spacelab racks and freeflyers; and ground support for animal, plant and cell biology experiments.

Services Include:

- Planning and schedules
- Complete documentation
- Hardware design
- Instrumentation
- Complete processing services
- Microbiological services

Contact: Chris Schatte
The Bionetics Corporation
2 Eaton St., Suite 1000
Hampton, VA 23669
(804) 722-0330

Eclipse Industries, Inc.

Eclipse Industries Inc. provides payload advance planning and microgravity testing on board the KC-135 aircraft.

Services include:

- Payload program and project evaluation, feasibility, testing
- Requirements
- Public affairs
- Staffing
- Resource planning
- Long-range forecasting

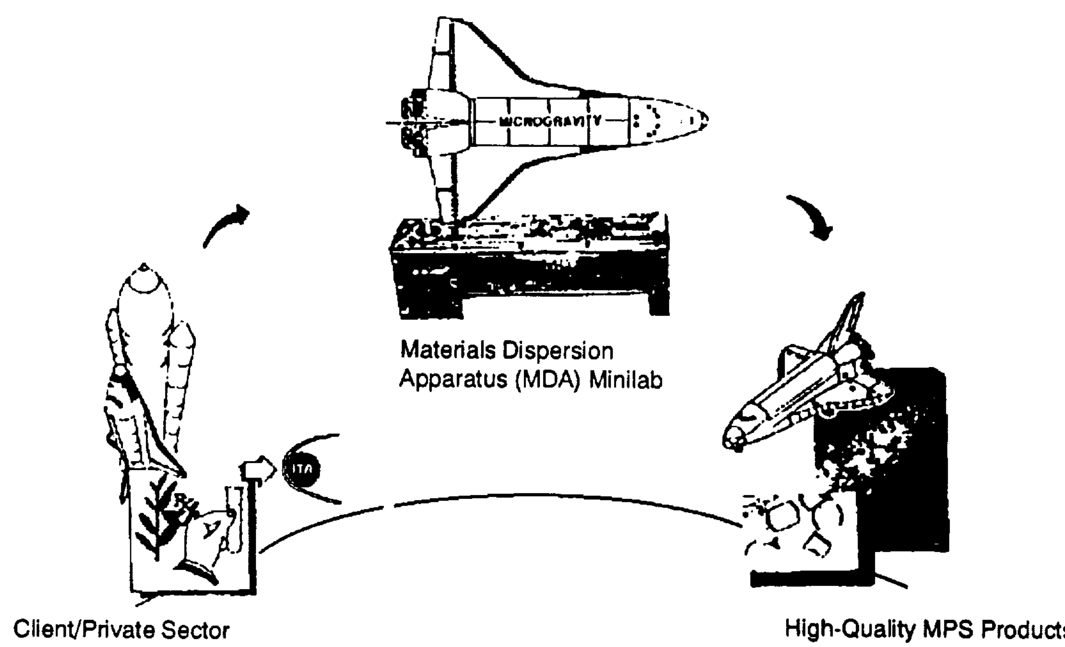
Contact: Rick Thienes
Eclipse Industries, Inc.
2719 W. Division St.
St. Cloud, MN 56301
(612) 259-4841, Fax (612) 654-8929

Instrumentation Technology Associates, Inc.

Turnkey access to space, generic experiment hardware payload integration, experiment carriers and payload integration for secondary payloads, including:

- Middeck lockers
- Get-Away-Special canisters
- Hitchhiker-M
- Hitchhiker-G
- OCP COMET recovery capsule
- Experiment apparatus containers
- Multi-Purpose Experiment Support Structure
- Experiment design validation includes a centrifuge to simulate Shuttle and ELV ascent and reentry

Contact: John M. Cassanto
Instrumentation Technology Assoc., Inc.
35 East Uwchlan Ave., Suite 300
Exton, PA 19341
(215) 363-8343, Fax (215) 363-8569



Integration, Assembly and Checkout Facility

This facility is adjacent to Ellington Field, Houston, and is near the NASA/Johnson Space Center and includes:

- Certified class 1,000 clean room
- High Bay integration area
- Bonded storage

Contact: Douglas S. Lilly
Space Industries, Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX 77598-4001
(713) 338-2676

Orbital Sciences Corporation

Orbital Sciences Corporation provides commercial space support services including commercial space operations licensing and coordination.

Mission Operations Services

- Mission planning and analysis studies
- Mission pre-launch and on-orbit operations
- Pre-launch ground operations
- Carrier aircraft flight operation

Payload Services

- Payload design and development
- Ground processing and logistics planning
- Payload integration
- Systems integration
- Spacecraft checkout

Range Services

- Range support planning and coordination
- Launch site selection
- Tracking and data reduction

Contact: Bruce A. Biehler
Orbital Sciences Corporation
12500 Fair Lakes Circle, Suite 350
Fairfax, VA 22033
(703) 631-3600

Orbital Systems, Ltd.

Aerospace engineering and consulting services include:

- Spacecraft system and system design and analysis
- Spacecraft integration with launch vehicles
- Launch vehicle assessment
- Environmental measuring systems
- Artificial intelligence
- Technical program management support

Contact: Roxanne B. Andrieux, Vice President for Computer Operations
Orbital Systems, Ltd.
1925 N. Lynn Street, Suite 301
Arlington, VA 22209
(703) 841-4394, Fax (703) 841-5196

Payload Systems Inc.

Payload Systems was founded in 1984 to provide science and engineering services to researchers undertaking experiments in space, ranging from Get-Away Specials (GAS), to middeck lockers to Spacelab programs. Project scientists and integration managers support payload design and development to assure that it meets all NASA safety and integration requirements and offers a valuable scientific return from space in a cost-effective manner. A typical Experiment Support team consists of a project scientist, project engineer and integration manager.

Services feature

- Payload integration and certification management for compliance with all NASA procedures and requirements, such as preparation and submission of all documents; project scheduling and budget; safety, acceptance and readiness reviews
- Experiment design to assure minimum scientific compromises due to Shuttle environment limitations such as power, weight, volume data storage and time
- Scientific expertise in materials processing, biomedical and human adaptation, large space structure and active control
- Crew training program to familiarize Shuttle crew with experiment operations
- Ground processing, flight support and post-analysis provided at Kennedy Space Center, Johnson Space Center and Edwards Air Force Base to accommodate all stages of flight

Contact: Michael D. Barg
Payload Systems Inc.
276 Third Street
Cambridge, MA 02142
(617) 868-8086, Fax (617) 868-6682

Space Hardware Optimization Technology, Inc. (SHOT)

This consulting engineering firm specializes in the design, fabrication and integration of spacecraft components and equipment. The firm has experience in life sciences and materials processing microgravity experiments. SHOT's engineers designed, fabricated and qualified flight hardware for the Shuttle.

Contact: John C. Vellinger, Vice President
Space Hardware Optimization Technology Inc., (SHOT)
P.O. Box 351
Floyd Knobs, IN 47119
(812) 923-9591

SPACETEC Ventures, Inc.

SPACETEC provides a unique approach to end-to-end space services which ensures in-depth technical and documentation support during feasibility, pre-flight, flight and post-flight phases of experiment development and implementation.

Capabilities

- Systems engineering support services
- Mission integration services
- Testing and evaluation support services
- Data analysis services
- Project management support services

Expertise

- Experiment feasibility analysis
- Experiment definition and development
- Mission integration, documentation and review assistance
- Systems checkout and verification
- Definition and implementation of physical integration requirements
- Mission planning and operations
- Recovery of experiment and data products

Contact: SPACETEC Ventures, Inc.
P.O. Drawer Y
Hampton, VA 23666
(804) 865-0900

SpaceTech, Inc.

A subsidiary of the Center for Space and Advanced Technology, SpaceTech is a science and engineering corporation specializing in development, analytical and physical integration, command and control, and data analysis of small payloads. The firm also offers associated training for users.

Contact: John R. Williams or Kim Ellsworth
SpaceTech Inc.
The James Burr House
58 Charles Town Road
Kearneysville, WV 25430
(304) 728-7288 or (703) 385-4355

Wyle Laboratories

Wyle offers a full range of payload engineering services, design, fabrication/assembly, testing, analysis, flight operations support, and program planning and control. The customer can enter anywhere in the process or contract for specific activities.

The firm also offers utilization and logistics support, as well as manifesting software. The software operates on Wyle's Space Station payload database which contains payload operational and logistics data throughout the 5 phases of a Space Station payload life cycle:

- Prelaunch ground operations
- Transfers-to-orbit
- On-orbit operations
- Transfer-from-orbit
- Post landing ground operations

Contact: Ronald E. Giuntini
Manager of Space Engineering
Wyle Laboratories
7800 Governors Drive West
Huntsville, AL 35807
(205) 837-4411

Section Six: Space Transportation

Routine, affordable, reliable access to space is the foundation on which many other commercial applications of space technology, such as for microgravity processing and remote sensing, are based. NASA operates the Shuttle, a reusable spacecraft that can launch satellites from its cargo bay, as well as carry payloads aboard the bay and the pressurized middeck area. Three major American transportation launch providers, McDonnell Douglas, Martin Marietta and General Dynamics, offer services for multi-stage vehicles that carry heavy payloads, such as communications satellites and other large payloads, into Low Earth Orbit and beyond. Other companies offer smaller vehicles and related support services. Still others, offer sounding rocket vehicles, launching payloads to near-space, but not in orbit.

There is a competitive international market that involves U.S. commercial launch-service providers and entities from a growing number of industrialized nations. In addition, support services and commercially operated spaceports are being planned in the United States and abroad.

Chapter 18: Regulations

Other than for the smaller capacity launch vehicles, alternatives to government ranges for launch operations do not exist at the present time – although several interest groups, notably Spaceport Florida and the states of Hawaii and Virginia, are moving in the direction of establishing private, commercial launch sites. Until that time, major launch service providers (e.g., McDonnell Douglas, General Dynamics, Martin Marietta) must abide by the Air Force's Model Range Use Agreement. This agreement sets forth the terms and conditions under which the Air Force will permit use of ranges, facilities and associated goods and services to commercial entities in support of production and/or launching of commercial expendable launch vehicles on a cost-reimbursable basis.

The major issues in these provisions include terms and conditions of the U.S. Government's ability to preempt commercial launches; defer establishment of firm prices for range use to subsequent agreements; and specify the degree of liability placed on the commercial launch service provider, subcontractors and customers.

Commercial space launch activities are defined to include launches, launch site operations and certain mission-related activities. In 1984, the Commercial Space Launch Act gave the Department of Transportation the authority to regulate these activities.

Licensing Procedures and Regulations

Launch service providers negotiate launch licenses through the U.S. Department of Transportation's Office of Commercial Space Transportation, which is responsible for licensing and regulating U.S. commercial space launch activities in a manner intended to protect both public safety and government interests, and to encourage the development of commercial launch capabilities. Among the regulatory functions of this office are:

- Development of Safety Requirements and Standards
- Financial Responsibility Requirements
- Review and Approval Criteria
- Monitoring Licensee Activities

Licensing procedures ensure the protection of interests stated explicitly in the Commercial Space Launch Act: public health and safety, the safety of property, and the national security and foreign policy interests of the United States.

The fundamental requirement is that the launch company proposing to conduct commercial space transportation activities demonstrate, through the application process, the capability to assure its operations will be conducted safely and responsibly. The Commercial Space Transportation Licensing Regulations (Final Rule 1988) constitutes the procedural framework for reviewing and authorizing all proposals for conducting commercial space transportation activities.

In order to encourage innovation, and recognizing the diversity of launch vehicles, missions and applicant circumstances, the Licensing Programs Division makes an effort to offer flexibility with regard to the form in which information may be submitted.

Assessment of a launch license application includes a Mission Review and a Safety Review. The Mission Review is general in nature and provides an early warning mechanism to identify policy questions that are germane to the application. The Safety Review is devoted to the applicant's operational capabilities, focusing on safety procedures and personnel equipment.

Licensing Procedures and Regulations (continued)

There are similar assessments of license applications for other commercial space activities, such as reentry operations. In conjunction with the two reviews, DOT sets insurance requirements for the launch or activity, as required by the Commercial Space Launch Act. Insurance requirements are based on a practical understanding of the elements comprising exposure, the factors affecting risks and a review of any failure history data.

Contact: Licensing Programs Division
U.S. Office of Commercial Space Transportation
Department of Transportation
400 Seventh Street SW
Washington, DC 20590
(202) 366-5770

Documentation

The commercial developer is referred to the following related documents for more in-depth information:

- Commercial Space Launch Act of 1984, 14 U.S.C. App. 2601
- Commercial Space Transportation Licensing Regulations, 14 CFR Part 400
- Requirements for Launch License Applications
- Requirements for Launch Site Operators License Applications
- Guidelines for Environmental Impact Statements for the Development of Commercial Space Launch Facilities

Chapter 19: Launch Ranges

At least ten countries and groups of countries have established facilities for space launches. The United States and the Soviet Union, member countries of the European Space Agency, Japan and China each have launch ranges to meet their particular range of launch requirements. Brazil has facilities for small capacity operations and is constructing new facilities to meet a wider range of requirements. Italy, India, Australia and Sweden also have facilities for small capacity launch operations. A number of these countries, as well as private entities, are studying the feasibility of establishing commercial space launch facilities to support the market of launch service providers worldwide.

Factors for consideration in selecting a launch site include: location, existing infrastructure and accessibility. Location is critical for economic and safety reasons. Regardless of whether the payload is intended for polar or equatorial orbit, the most efficient insertion is with a trajectory that requires little or no course correction. For equatorial orbits, the most practical launch is one that originates from the equator with an eastward trajectory, taking advantage of the Earth's rotation. Safety considerations restrict trajectories, though potentially optimal, over populated areas or regions of industry, agriculture or fishing activities.

Conducting launch operations requires a variety of services and facilities, such as a complete telecommunications system of tracking, telemetry and control; high-quality, high-output power supplies; integration and processing buildings; launch pads; and highly trained personnel.

There are two major range areas in the United States capable of supporting launch operations for the Delta, Atlas and Titan expendable launch vehicles (ELV's). Kennedy Space Center serves as the primary center within NASA for the test, checkout and launch of manned and unmanned space vehicles; it is the only launch site for the Shuttle. NASA and the Air Force have developed Model Range Use Agreements governing commercial use of other government-owned facilities such as Cape Canaveral Air Force Station in Florida and Vandenberg Air Force Base in California.

Small capacity ELVs have greater options for launch facilities. In addition to Cape Canaveral and Vandenberg, the NASA/Wallops Flight Facility in Virginia can accommodate sounding rockets and small orbital vehicles. Other ranges in the United States that can support sounding rockets include Barking Sands, HI; Eglin Air Force Base, FL; Greenriver, UT; Kwajalein, Marshall Islands; Tonapah, NV; White Sands, NM; and Poker Flat Research Range, AK. All of these are federally owned except for Poker Flat, which is owned by the University of Alaska.

There is considerable interest in the development of privately owned commercial launch facilities, notably Spaceport Florida at Cape Canaveral and/or Cape San Blas; Palima Point on the southeast coastline of the Island of Hawaii; and Wallops Island, VA. In 1990, plans were underway by the Spaceport Florida Authority to refurbish the Cape San Blas facility to accommodate a suborbital launch by the end of the year.

Global Launch Activity

Nation	Location	Latitude
United States	Kennedy Space Center, Cape Canaveral, FL	28.5° N
	Spaceport Florida (commercial site-under study)	28.5° N
	Vandenberg Air Force Base, CA	34.7° N
	Wallops Flight Facility, Wallops Island, VA	37.9° N
	Palima Point/Kahilipali Point, HI (under study)	19.0° N
Soviet Union	Baykonur Cosmodrome, Tyuratam	45.6° N
	Plesetsk	62.8° N
	Kapustin Yar	48.4° N
ESA/France	Guiana Space Center, Kourou, French Guiana	5.2° N
Italy	San Marco (platforms, off the coast of Kenya, Africa)	2.9° S
Sweden	Esrange, Kiruna	68.0° N
Japan	Tanegashima Space Center	30.4° N
	Kagoshima Space Center	31.2° N
	Hokkaido Space Center (under study)	0.0°
	Uchi Noura	—
China	Xi Chang, Sichuan Province	28.1° N
	Shuang-cheng Tzu (Jiquan), Gansu Province	40.6° N
	Jiuquan (west of Beijing)	—
	Hainan (under study)	—
Australia	Cape York, Queensland (under study)	11.0° N
	Woomera	31.1° S
India	Sriharikota Launching Range, Sriharikota Island	13.9° N
	Thumba Equatorial Rocket Launching Station	8.0° N
Brazil	Barraira Do Inferno	4.0° S
	Alcantara, St. Louis Bay	2.0° S
Canada	Churchill Research Range	—

Churchill Research Range

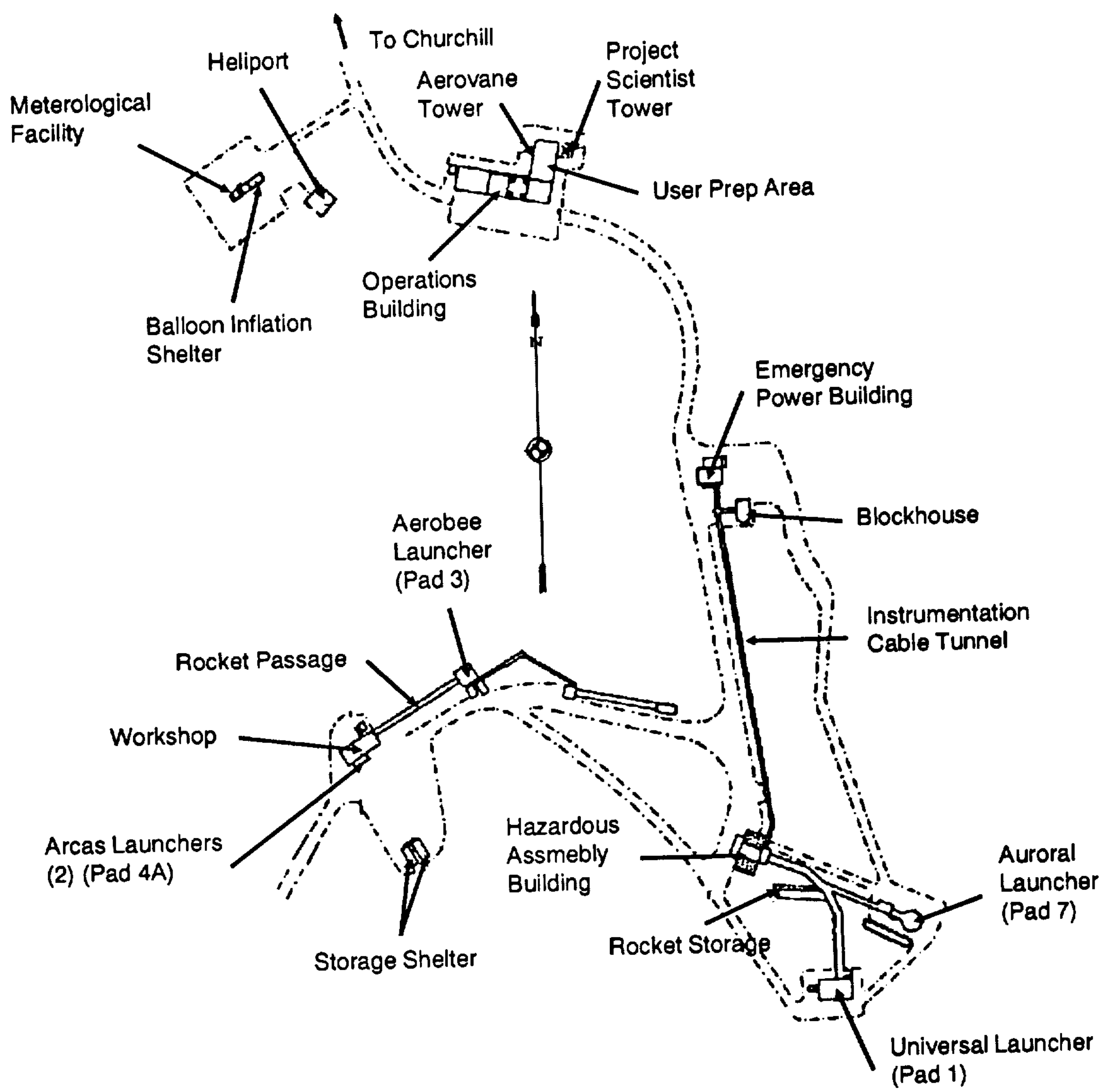
Churchill Research Range is located on the northeastern tip of Manitoba, Canada, with an impact area of back land and water extending 840 kilometers in an east-west direction and 800 kilometers in a north-south direction. The launch site includes four launch complexes, a hazardous assembly area, an explosive storage area, a blockhouse, an operations building and a meteorology building.

The rocket launching facilities include the Aerobee Tower, the Auroral Launcher, The Universal Launcher and an Arcas Launcher. The launch complexes share a common blockhouse which serves as the control center during launch operations. The operations building houses the telemetry, communications, tracking equipment, range user payload preparations area, administration offices, supply warehouse, motor vehicle workshop and an observation dome. An Auroral Observatory is located 13 km east of town to accommodate users' instruments for ground-based observations.

Facilities Include

- Launch site operations
- Launch in an auroral oval
- Excellent payload recovery
- Large impact area
- Temperature controlled launch bays
- Rocketry manufactured in Manitoba
- Shipping access by air, rail or sea

Contact: Les Tough, Manager
Aerospace Technology Program
430-155 Carlton Street
Winnipeg, Manitoba, Canada R3C 3H8
(204) 945-2030, Fax (204) 945-1354



NASA/Kennedy Space Center

Kennedy Space Center, immediately north and west of Cape Canaveral, is about 34 miles long and varies in width from 5 to 10 miles. The Center was created in the early 1960s to serve originally as the launch site for the Apollo lunar landing missions. After the Apollo program ended in 1972, KSC's Complex 39 was used for the launch of the Skylab spacecraft.

KSC is located at 28.5 degrees North Latitude. Because of their location on Florida's East Coast, the facilities at KSC permit a trajectory to equatorial and other low inclination orbits, entirely over the Atlantic Ocean. However, polar and other high inclination orbits are not practical from this location because of the costs that would be incurred in avoiding the land mass and population centers north or south of the Cape during insertion to orbit.

Today, KSC is responsible for the management and direction of the Shuttle and NASA's expendable launch vehicles (ELVs), including preparation, integration and checkout; integration and checkout of payloads flying on these vehicles, such as Spacelab, upper stages and other attached or deployable payloads, including commercial experiments; Shuttle launch and landing operations and NASA's ELV launch operations; and design, development, construction, operations and maintenance of launch, recovery and landing facilities and ground support equipment. The Center also conducts research programs in areas of life sciences related to human spaceflight. In the future, scientists and engineers at KSC will be responsible for the preflight and launch operations of the Space Station Freedom and will be involved in all phases of its logistics support activities.

The State of Florida has plans for developing a commercial spaceport at Cape Canaveral, adjacent to KSC (see page 195). The project includes refurbishing some of the launch sites that no longer are used by the Air Force or NASA. A commercial spaceport could support the entire range of U.S. commercial ELV's. It also could take advantage of the complete infrastructure, from payload processing facilities to down-range tracking equipment, already in place and operational, that is used to support NASA and Air Force space launch operations.

Contact: George Mosakowski
NASA/Kennedy Space Center
Mail Code PT-PMO
Kennedy Space Center, FL 32899
(407) 867-3494

NASA/Wallops Flight Facility

Wallops Flight Facility is one of the oldest launch sites in the world. Established in 1945, the facility manages and implements NASA's extensive sounding rocket projects, using suborbital rocket vehicles to accommodate about 50 scientific missions a year – almost half of all the rockets that are launched at Wallops. The first rocket, a Tiamat, was launched on July 4, 1945, and since that time about 13,000 rockets have been launched from Wallops Island.

Situated on the Delmarva Peninsula, on Virginia's coast, the Facility is located at 37.9 degrees North latitude. In addition to balloons and sounding rockets, Wallops also can support small orbital vehicles, such as LTV's Scout and SSI's Conestoga. The launch site includes five launch pads, two launch blockhouses and fifteen assembly bays. In addition to its launch capabilities, Wallops also plans and conducts Earth and ocean physics; ocean biological and atmospheric field experiments; satellite correlative measurements; and developmental projects for new remote sensor systems.

The state of Virginia has plans to develop a commercial launch site at Wallops Island, through its Center for Innovative Technology. The proposal would include refurbishing abandoned launch pads and/or constructing new ones to accommodate commercial scouts and smaller class ELVs. The project also considers refurbishment of an aircraft runway at Wallops to accommodate the Pegasus launch system.

Contact: Donald Friedman
NASA/Goddard Space Flight Center
Mail Code 702.0
Greenbelt, MD 20771
(301) 286-6242

Spaceport Florida

The concept of creating a commercial spaceport in Florida was developed by the Governor's Commission on Space in 1988. As a result, the Office of Space Programs was created within the Florida Department of Commerce. A feasibility study determined the Spaceport Florida concept to be financially, economically and operationally feasible.

The Spaceport Florida Authority was created by the 1989 Florida Legislature to develop commercial launch centers at deactivated Air Force launch sites at Cape Canaveral in Brevard County, and Cape San Blas in Gulf County. It also was charged with statewide responsibility for stimulating space-related industry, education, research and tourism development.

The Authority intends to attract high tech, space-related manufacturing industries and research and development projects to Florida by establishing the state as the premier location for access to space (commercial, NASA, military), and by extending other business incentives (sales-and-use tax exemptions, bonding capabilities, government support) to space-related industries.

Contact: Edward O'Connor, Executive Director
Spaceport Florida Authority/State of Florida
305 Cocoa Isles Boulevard, Suite 401
Cocoa Beach, FL 32931
(407) 868-6983

Western Space and Missile Center (Vandenberg)

The Western Space and Missiles Center (WSMC) is an operational component of the Air Force Space Command and is located at Vandenberg Air Force Base in Santa Barbara County, on the California central coast. Located at 34.7 degrees North Latitude, the Vandenberg launch facilities are used for polar and other high inclination orbits because the launches can be directed south or southwest, out over the Pacific Ocean.

As may be expected, programs of a wide variety are brought to WSMC, varying in magnitude from small, short-duration tests, to continuing programs involving developmental and operational testing of complex weapons systems. The requirement for assembly buildings, launch complexes and other technical support facilities at Vandenberg Air Force Base normally is presented to WSMC early in the planning stage. The Center provides support for programs that are approved and assigned, and attempts to meet user needs from the available inventory.

Commercial range users (i.e., non-DOD) should contact the responsible System Test Manager to determine the funding policy in effect for individual programs. The System Test Manager (STM) is the individual assigned to the Center through whom the user and the Test Center conduct business. The STM coordinates user requirements with other elements of WSMC, including test operations, comptroller, flight and ground safety, and performs a host of other functions in obtaining support for the program. The STM may provide assistance to the user in preparation of the Program Introduction, Program Requirements Document and other associated requirements documentation. Early initial contact with the WSMC should be established before any documents are generated or submitted.

Contact: Western Test Range
Directorate of Test Operations, WTR/DO
Vandenberg Air Force Base, CA 93437

White Sands Missile Range

White Sands Missile Range (WSMR) has the capability to launch suborbital sounding rocket vehicles. These are launched by, and using the facilities of, the Naval Ordnance Missile Test Station, (NOMTS) at WSMR. The NOMTS has the facilities and support capability to launch a variety of sounding rockets, such as the Black Brant V, Nike Black Brant V, Terrier Black Brant, Orion, Nike Orion, Taurus Orion and Aries, some of which may be suitable for commercial use.

The range, located in New Mexico, is approximately 100 miles long (north to south) by 40 miles wide (east to west), so the latitude and longitude represents a broad area. The launch facilities supporting the rockets listed above are at about 32 degrees, 25 min, 4 sec; 106 degrees, 19 min, 15 secs. The base of the launcher is at an altitude of some 4,000 feet.

Depending on the type of operation, approximately one launch every two weeks (25 or 30 per year) can be supported with current facilities and capabilities. The facility is very committed, with projected workload remaining stable. Launch support, or the use of launch facilities and equipment, must be negotiated separately with NOMTS and requires a Memorandum of Agreement (MOA) with the Naval Sea Systems Command. Availability of NOMTS facilities, equipment and services is dependent on projected workload. NASA/Johnson Space Center is responsible for the direction of operations at the White Sands Test Facility (WSTF), which is located on the western edge of the range. This facility supports the Shuttle propulsion system, power system and materials testing.

Three CONSORT missions were launched from White Sands in 1989-90, all part of a program of the Consortium for Materials Development in Space, a Center for the Commercial Development of Space at the University of Alabama in Huntsville. These commercial missions flew on Starfire rockets provided by Space Services, Inc., of Houston, TX.

Contact: U.S. Army White Sands Missile Range
Attention: STEWS-NR-PR
(Future Programs Team)
White Sands Missile Range, NM 88002
(505) 678-1134

Chapter 20: Launch Vehicles

The U.S. firms that provide expendable launch vehicle services include large, established government contractors and small entrepreneurial companies. They base their services on a variety of vehicles, ranging from existing rockets developed to meet U.S. Government requirements, to new ones being developed commercially, often with innovative technology and propulsion systems. In most cases, these companies sell space transportation services, rather than the hardware itself, so that title to the launch vehicle and associated hardware remains with the launch service provider. This chapter divides ELVs into orbital and suborbital capabilities. It also describes the Space Transportation System (Shuttle) and includes Reentry Vehicles and Orbital Transfer Vehicles.

Global Launch Activity

U.S. Launch Vehicles

Orbital		Suborbital	
Space Shuttle	NASA/Rockwell	Cygnus series	Conatec, Inc.
Titan series	Martin Marietta	Starfire	Space Services,Inc.
Delta II series	McDonnell Douglas	Javelin, Hydac, etc.	Orbital Sciences Corporation
Atlas series	General Dynamics		
Pegasus, Taurus	Orbital Sciences Corporation		
Scout series	LTV		
Conestoga series	Space Services, Inc.		
EPAC S-series	E'Prime		
Industrial Launch Vehicle	American Rocket Company		

Foreign Launch Vehicles

Orbital		Suborbital	
Ariane series	Arianespace (France)	Black Brant series	Bristol Aerospace (Canada)
H-2	Japan	Sonda	Brazil
Long March series	China	Condor	Argentina
Proton series, Soyuz Energia, Buran Shuttle	Soviet Union	MASER-1	Sweden
SLV-3, ASLV	India	Skylark series	Great Britain
Mariane	Sweden		

Suborbital Vehicles

High altitude, suborbital launch vehicles offer critical opportunities for scientific and industrial research into microgravity, astrophysics, plasma and solar physics. Several companies provide suborbital launch services of various capabilities, accommodating payloads from 300-1000 pounds to altitudes as high as about 100 miles. These vehicles are gaining in demand as microgravity research evolves and the need for testing increases. Sounding rockets can provide sustained microgravity levels of 10^{-4}g-10^{-5}g for periods of about 5-15 minutes, depending on the operational characteristics of the vehicle. Many payloads can be recovered by parachute.

Ballistic Sounding Rockets and Services

Orbital Sciences' suborbital launch products and services include suborbital vehicles and their principal subsystems, payloads carried by such vehicles, and related launch support installations and systems used in their assembly and operation. OSC offers customized vehicle and payload design, manufacturing and integration, launch and mission support, and tracking and recovery services, as well as construction and activation of launch pads and other infrastructure elements. It also designs and builds scientific experiments and other payloads for launch and deployment on its suborbital boosters.

OSC's Space Data Division has produced and launched over 600 suborbital vehicles in configurations weighing up to 70,000 pounds and reaching altitudes of up to 550 miles. Boosters and sounding rockets are frequently configured using combinations and/or multiples of Javelin, Hydac, Nike, Improved Honest John, Sergeant, Talos, Castor, Terrier, Malemute and Minuteman I second-stage motors. Both the Javelin and Hydac suborbital boosters are OSC commercially-developed motors. Standardized fins, interstages and other vehicle hardware have been developed for cost effectiveness and responsive delivery.

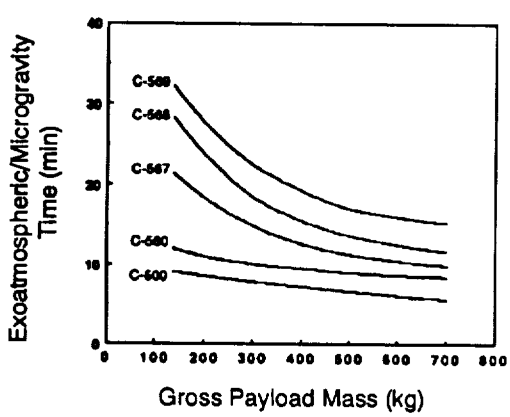
OSC also has established or supported suborbital rocket launch facilities at eleven locations including bases at South Point, HI; Kwajalein Atoll; Poker Flat, AK; Eglin AFB, FL; and Cape Cod, MA; as well as locations in Greenland, Indonesia, Puerto Rico and Brazil. It is installing two launch pad complexes (one at Wake Island in the Pacific and one at Cape Canaveral, FL) pursuant to launch of Starbird suborbital vehicles.

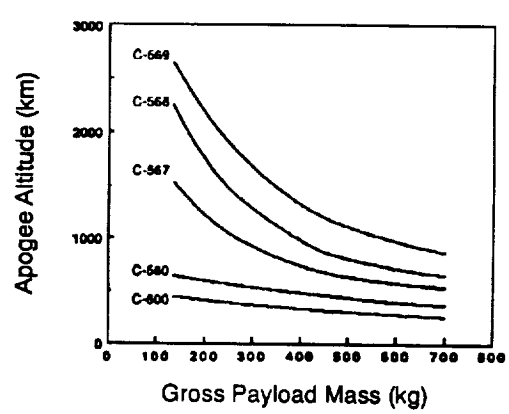
Available: Now

Contact: Scott Webster
Orbital Sciences Corporation
Space Data Division
3380 South Price Road
Chandler, AZ 85248
(602) 899-6000

Cygnus Series

The Cygnus series of suborbital launch vehicles is designed to accommodate typical research sounding rocket missions requirements while offering performance capabilities which exceed current operational sounding rocket systems. The Cygnus series consists of single-stage, two-stage and three-stage vehicle configurations employing solid propellant rocket motors. Performance in terms of experiment time versus payload mass, and apogee altitude versus payload mass are presented below.





Cygnus Series (continued)

The high reliability of the Cygnus series is based on the demonstrated reliability of a common stage motor (99.8% in over 570 flight applications), and augmented by the demonstrated reliability of the booster and upper stage motors (94 to 100% in 10 to over 100 flight applications respectively). The two-stage configuration (C-560) has a demonstrated reliability of 100% based on 20 flights.

The Cygnus vehicles are compatible with existing launchers and facilities at Wallops Flight Facility, White Sands Missile Range, Pacific Missile Range Facility, Poker Flat Research Range and Esrange. They also are compatible with range safety requirements at these ranges; i.e., three sigma dispersion areas within range boundaries and flight termination capability. Impact dispersions are contained within range safety acceptability, limited by use of a Boost Guidance System for two- and three-stage configurations, and the addition of a Guidance and Control System for three-stage configurations.

The Cygnus series employs a standard 31.0 inch diameter payload housing with an ogive and/or conical fairing. Accommodations for larger diameters (up to 40.00 inches) and small diameters (=17.26 inches) also are available. In addition, a full compliment of mission-unique support hardware is available, including telemetry systems, reentry/recovery systems, attitude and rate control systems and microgravity experiment modules.

Available: All systems are available for launch within 18 months of request.

Contact: Wayne H. Montag
CONATEC, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088

CYGNUS M-500

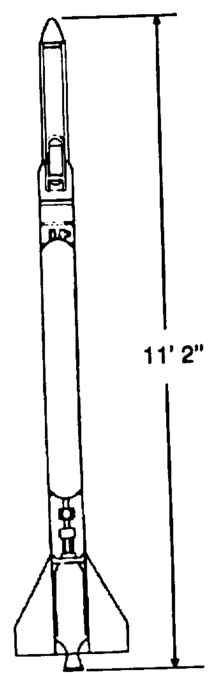
CYGNUS M-500 is a monopropellant rocket vehicle that incorporates light weight composite construction. The vehicle is provided as a compatible product with the SPACENESTS. A 500-pound thrust rocket motor will provide 30-40 seconds of propulsion for the CYGNUS/SPACENEST combination. Launch will be from a short mobile tower (production version), assisted by a solid fuel grain burned in the chamber prior to the ignition of the monopropellant. This integral solid grain concept is still experimental and may be replaced by a more conventional solid first stage booster.

Operational Characteristics

Dimensions:	134.0 in L, 6.5 in diameter
Weight:	40-45 lbs (empty)

Available: Now

Contact: Dean Oberg
Space Delivery Systems
P.O. Box 591
Buffalo, NY 14226
(716) 839-2158



SPACENEST-A

SPACENEST-A is a small, recoverable payload container. This near-space craft will be launched aboard a CYGNUS light-rocket to 40-50 mile altitudes. The craft will contain a standard-sized experiment rack (6 inches x 18 inches) which will have a variety of attachment and low voltage power supply options. The rack assembly will be provided to the client in advance. Experiment packages can be adapted to the rack and proprietary items added at the client's shop or laboratory. The rack is inserted into the container prior to the launch. Payload capacity using the CYGNUS launch vehicle will be 10 pounds.

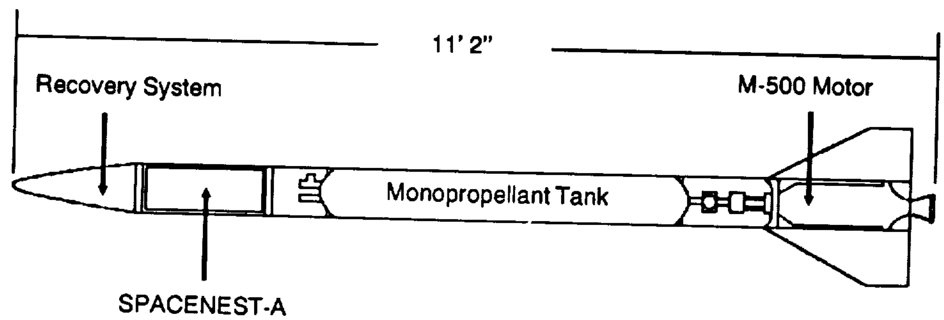
Operational Characteristics

Dimensions:	18.0 in L, 6.0 in diameter
Volume:	508.9 in^3
Weight:	10 lbs

Carrier: Cygnus Rocket

Available: 1991

Contact: Dean Oberg
Space Delivery Systems
P.O. Box 591
Buffalo, NY 14226
(716) 839-2158



SPACENEST-B

SPACENEST-B is a micro-spacecraft (4 in x 6 in) for launch to 150-200 miles. The micro-spacecraft also features a standard experiment rack, only smaller. It receives its initial boost via the CYGNUS MAX rocket with additional velocity imparted by a shaped charge or gas cannon mounted in the nose of the rocket. The mobility of the rocket-boosted-cannon (RBC) will provide flexibility not available with fixed base coil guns and cannons currently being proposed. Future enhancements to this system include the addition of four strap on boosters using the CYGNUS as a second stage and the SPACENEST-B cannon as the third stage. Orbital potential of this configuration is being assessed.

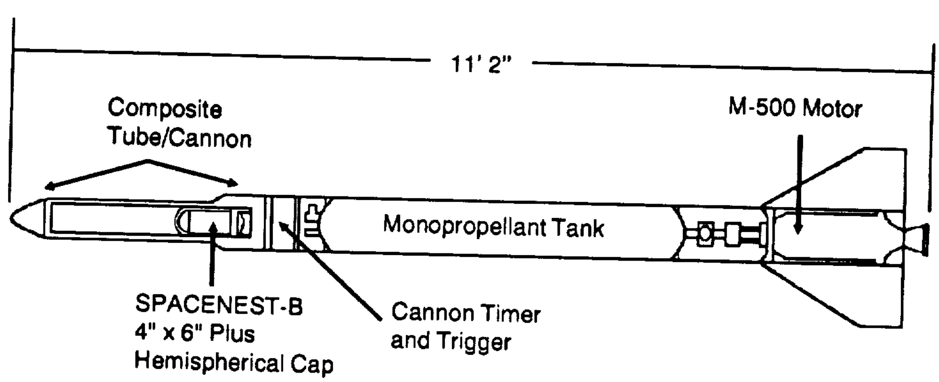
Operational Characteristics

Dimensions:	6.0 in Length, 4.0 in diameter
Volume:	75.4 cubic inches
Weight:	5-6 lbs

Carrier: CYGNUS MAX rocket

Available: 1992

Contact: Dean Oberg
Space Delivery Systems
P.O. Box 591
Buffalo, NY 14226
(716) 839-2158



Starfire Sounding Rockets

The Starfire series is a family of suborbital sounding rockets for microgravity or other scientific payloads. The Starfire I, IA, IV and V are based on various configurations employing TX 664-4 (Terrier upgrade) first stages and Black Brant 5 or Patriot second stages. The Starfire II and III employ a Castor IVB solid core motor with two Castor strap-ons for the Starfire III (the latter configuration is similar to the Conestoga 210 without an orbital insertion motor). These configurations offer a wide range of payload weight and microgravity time (up to 7,000 lbs for up to 20 minutes). Three Starfire I rockets were launched for the University of Alabama/Huntsville (the CONSORT program) as of July 1990. Space Services also has an agreement with NASA for launch from Wallops Island.

Operating Characteristics

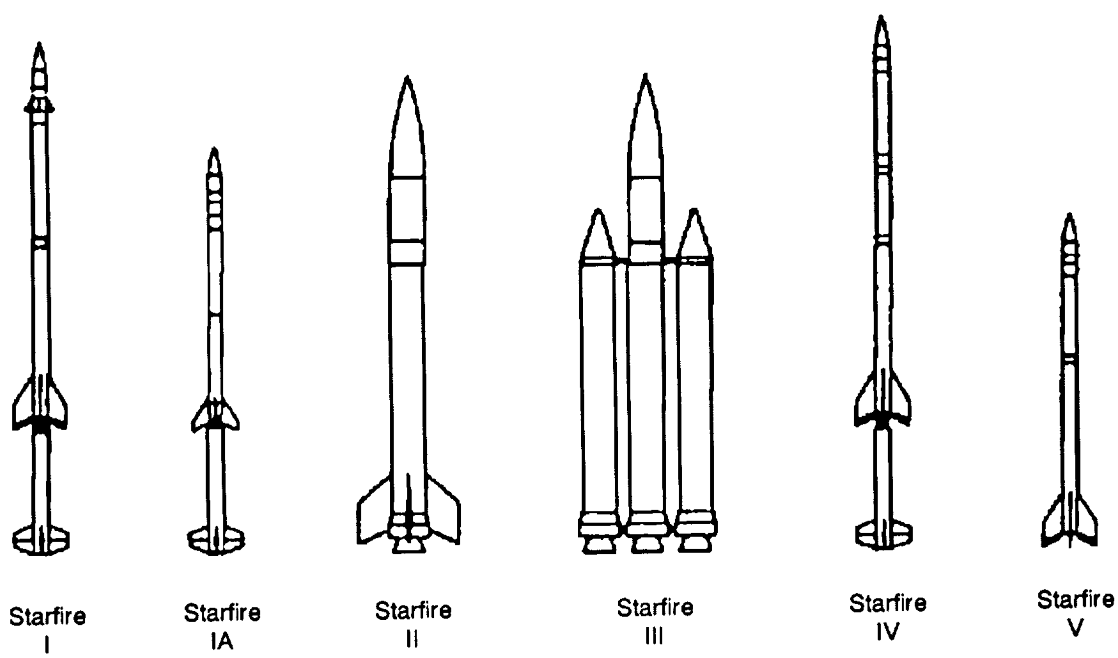
System height:	32 ft to 54 ft
Weight:	3,688 lbs to 82,000 lbs

Guidance: various, active boost guidance and spin stabilization; larger vehicles have thrust control

Payload Envelope: various, depending on configuration

Available: Now

Contact: Richard W. Scott, Jr.
Space Services Incorporated of America
7015 Gulf Freeway, Suite 140
Houston, TX 77087
(713) 649-1716, Fax (713) 649-3445



Starfire Sounding Rockets

Orbital Vehicles

Large capacity expendable launch vehicles (ELVs) are used for transporting satellites for communications, navigation, remote sensing and meteorology; facilities for materials processing, planetary missions and other scientific activities; and other types of spacecraft. Smaller ELVs carry research payloads, remote sensing and Low Earth Orbit (LEO) communications satellites.

The larger ELVs can lift payloads weighing more than 44,000 pounds to LEO, a circular orbit about 100-500 miles above the Earth. When ELV boosters are combined with upper stage motors, they can lift payloads weighing more than 11,000 pounds to Geosynchronous Transfer Orbit (GTO). GTO is a highly elliptical orbit required for placing communications satellites into their final position in Geostationary Orbit (GEO). GEO is a circular orbit at an altitude of 22,300 miles that allows a satellite to appear stationary at the same location over the Earth at all times.

As with many of the larger ELVs, the smaller class of ELVs often uses various configurations of the same vehicle design to accommodate payload requirements of weight and location. These vehicles generally can carry from 300 to 4,000 pounds to LEO and about 300-1200 pounds to GEO.

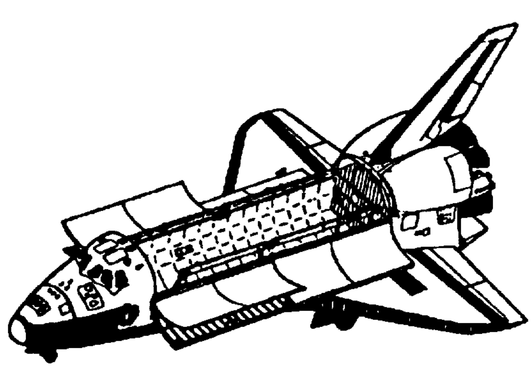
The Shuttle is an orbital vehicle that is reusable (hence, not an expendable vehicle). It is capable of accommodating not only humans, but also payloads that are large and small in both size (up to nearly 45 feet long, 15 feet wide) and weight (up to 55,000 pounds). The Shuttle is capable of traveling only to LEO (usually about 200 miles).

Space Shuttle

Orbiter

About the same size as a DC-9 aircraft (122.2 feet long, 78 feet wide at wing tips), the Shuttle contains the pressurized crew compartment, the unpressurized cargo bay and three main engines.

Orbiter Crew Compartment
The Orbiter pressurized crew compartment is comprised of three main areas, two of which are on an upper level called the flight deck. The Commander and Pilot's seats (stations) are in the forward part of the flight deck and look out the forward windshields. The aft flight deck (AFD) is the station for controlling and viewing orbital operations. The AFD is also the seat location for two mission specialists, and the two interdeck hatches that lead to the lower level ("the middeck").



Middeck
The middeck houses the one-to-three seats needed for the balance of the crew, the side hatch for crew entrance/exit, and the airlock for extravehicular activities. The middeck also houses Orbiter avionics and galley equipment, the waste management system, sleeping equipment, and lockers containing food, supplies, and other mission support equipment. Lockers (or their spaces) not needed for such purposes may be available for equipment to support experiments.

Cargo Bay
The Shuttle's unpressurized cargo bay is adaptable to hundreds of tasks. Large enough to accommodate a school bus (60 x 15 feet), the bay area carries satellites, spacecraft and pressurized Spacelab scientific laboratories to and from Low Earth Orbit. A wide range of equipment, described elsewhere in this catalogue, has been developed to accommodate flight activity in the cargo bay.

Remote Manipulator System
Mounted on the port side of the cargo bay is the remote manipulator system (RMS), developed and funded by the Canadian government. The RMS is a robot arm and hand with three joints analogous to those of the human shoulder, elbow and wrist. Two TV cameras mounted near its elbow and wrist provide visual ques to the crew member who operates it from the aft station of the flight deck. The RMS is about 50 feet in length and can move anything from satellites to astronauts to-and-from the cargo bay or to different points in nearby space, often deploying or retrieving satellites.

Space Shuttle (continued)

Thermal Protection System
Thermal tile insulation and blankets (known as the thermal protection system or TPS) covers the underside, bottom of the wings and other heat-bearing surfaces of the Shuttle and protects it during its reentry into the Earth's atmosphere. Some 24,000 individual tiles – no two alike – are installed by hand and are designed for reuse for 100 missions. The basic material of the tiles is pure-sand silicate fibers, mixed with a ceramic binder (see page 223).

Main Engines
The three main engines are clustered at the aft end of the Shuttle and have a combined thrust of nearly 1.2 million pounds at sea level. The high-performance, liquid-propellant rocket engines have a variable thrust ranging from 65 to 109 percent of their rated power level. The engines are 14 feet long and 8 feet in diameter at the nozzle exit. Designed for seven-and-a-half hours of operation, the engines fire for only eight minutes for each flight to orbit. As a result, the engines are expected to operate for 55 flights.

Orbital Maneuvering System
Once the main engines shut down as the Shuttle approaches orbital insertion, another propulsion system takes over. Two orbital maneuvering system (OMS) engines, mounted on either side of the aft fuselage, provide thrust for major orbital changes. For more exacting motions, the reaction control system comprising of 44 small rocket engines, clustered on the Orbiter's nose and on either side of the tail, are used in orbit.

External Tank

The external tank (ET), 154 feet long and 27.5 feet in diameter, is the largest single component of the Shuttle. In separate pressurized tank sections inside, the ET holds the liquid hydrogen fuel and liquid oxygen oxidizer for the Shuttle's main engines. During launch, the ET feeds the propellants under pressure through 17-inch ducts which branch off into smaller lines that feed directly into the main engines. Some 64,000 gallons of propellants are consumed by the main engines each minute. The tank also acts as a backbone for the Shuttle and the solid rocket boosters to which it is attached.

After orbital insertion, the external tank is jettisoned from the Shuttle. The discarded tank reaches 99 percent of orbital velocity and remains in space for up to an hour before it falls, re-enters the atmosphere and disintegrates. Machined from aluminum alloys, the ET is the only part of the system that is not currently reused.

In June 1988, NASA asked the private sector for expressions of interest in commercial and academic approaches for the use of ET's. Two organizations, GLOBAL OUTPOST, Inc. of Alexandria, VA (see page 170) and the Space Phoenix Program of Boulder, CO (see page 172), have signed separate agreements with NASA for the proposed use of expended ET's in orbit.

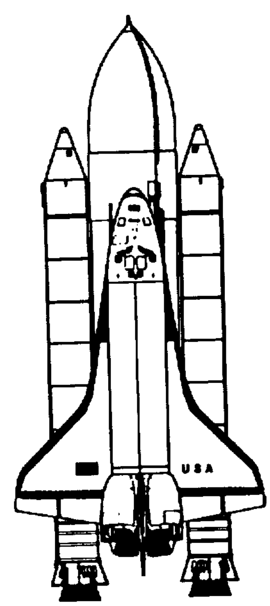
Solid Rocket Boosters

The Shuttle's two solid rocket boosters, designed for refurbishment and reuse, are the largest solids ever built (149.16 feet long, 12.16 feet in diameter) and the first to be flown on a manned spacecraft. Together, they provide the majority of thrust (5.8 million pounds) for the first two minutes of flight.

The solid propellant mix is composed of 16 percent aluminum powder (fuel) and almost 70 percent ammonium perchlorate (oxidizer), with the remainder consisting of a binder, a curing agent and a small amount of catalyst. A small rocket motor in each booster ignites the propellant at launch. During flight, the solid booster nozzles swivel up to 6 degrees, redirecting the thrust and steering the Shuttle toward orbit.

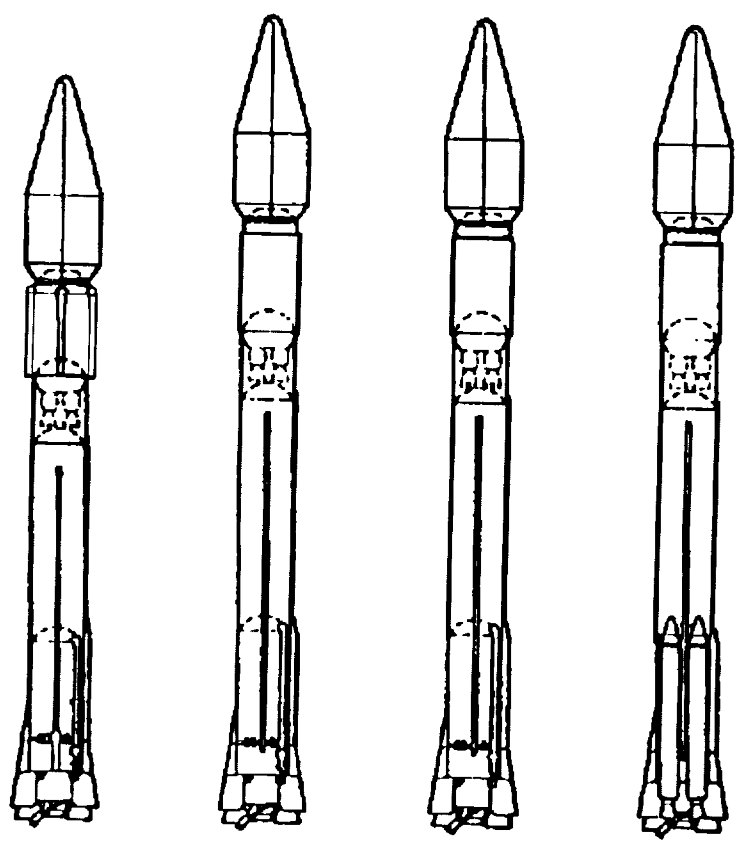
Available: Now operating with advanced scheduling

Contact: Richard N. Martucci
Customer Services Manager
Office of Space Flight
NASA Headquarters/Code MCI
Washington DC 20546
(202) 453-1921



ATLAS

The Atlas/Centaur, which is a combination booster and upper stage configuration, can carry up to 13,500 pounds in Low Earth Orbit (LEO) and over 5,000 pounds in Geostationary Transfer Orbit (GTO). An improved version of this vehicle is being developed to deliver 6,400 pounds to GTO. The Atlas is powered by a first-stage liquid engine burning kerosene (RP-1) and a second stage liquid hydrogen/liquid oxygen Centaur engine. Solid motor strap-on boosters provide extra lift. The first commercial Atlas launch carried a NASA scientific payload, the Combined Release and Radiation Effects Satellite (CRRES), in 1990.



ATLAS I ATLAS II ATLAS IIA ATLAS IIAS

Atlas (continued)

Atlas Launch Vehicle Specification Table

	Atlas I	Atlas II	Atlas IIA	Atlas IIAS
Overall Vehicle				
Length (Medium Fairing)	42.0 m/138 ft	45.6 m/150 ft	45.6 m/150 ft	45.6 m/150 ft
Length (Large Fairing)	43.9 m/144 ft	47.5 m/156 ft	47.5 m/156 ft	47.5 m/156 ft
Diameter	3.1 m/10 ft	3.1 m/10 ft	3.1 m/10 ft	
Gross Lift Off Weight (Med. Fairing)	163,900 kg/ 361,300 lbs	187,170 kg/ 413,500 lbs	187,310 kg/ 413,800 lbs	233,600 kg/ 515,900 lbs
(Large Fairing)	164,290 kg/ 362,200 lbs	187,560 kg/ 413,500 lbs	187,700 kg/ 413,800 lbs	234,010 kg 515,900 lbs
Centaur				
Length	9.1 m/ 30 ft	10.1 m/33 ft	10.1 m/33 ft	10.1 m/33 ft
Propellant	LH2 & LO2 (Liquid Hydrogen & Liquid Oxygen for all Atlas configurations)			
Propellant Weight	13,790 kg/ 30,400 lbs	16,780 kg/ 37,000 lbs	16,780 kg/ 37,000 lbs	16,780 kg/ 37,000 lbs
Total Thrust (Vacuum)	146.8 KN/ 33,000 lbs	148.1 KN/ 33,00 lbs	180.2 KN/ 40,500 lbs	180.2 KN/ 40,500 lbs
Specific Impulse Isp (Vacuum)	444.4 sec	442.3 sec	448.9 sec	448.9 sec
Atlas				
Length	22.2 m/73 ft	24.9 m/82 ft	24.9 m/82 ft	24.9 m/82 ft
Propellant	LO2 & RP-1 (Liquid Oxygen & Kerosene type fule for all Atlas configurations)			
Propellant Weight	137,530 kg/ 303,200 lbs	156,260 kg/ 344,500 lbs	156,260 kg/ 344,500 lbs	156,260 kg/ 344,500 lbs
Booster Engines Total Thrust (Sea Level)	1,679 KN/ 377,500 lbs	1,884 KN/ 423,500 lbs	1,884 KN/ 423,500 lbs	1,884 KN/ 423,500 lbs
Booster Engine Specific Impulse Isp (Sea Level)	259.1 sec	263.1 sec	263.1 sec	263.1 sec
Sustainer Engine Thrust (Sea Level)	269 KN/60,500 lbs for all Atlas configurations			
Sustainer Engine Specific Impulse Isp (Sea Level)	220.4 sec for all Atlas configurations			
Vernier Engine Total Thrust (Sea Level)	5,950 N/1,338 lbs	N/A	N/A	N/A
Vernier Engine Specific Impulse Isp (Sea Level)	186.7 sec	N/A	N/A	N/A
SRMs – 4 Used				
Propellant	N/A	N/A	N/A	HTPB
Propellant Weight per Motor	N/A	N/A	N/A	10,230 kg/22,560 lbs
Average Thrust per Motor	N/A	N/A	N/A	433 KN/97,520 lbs
Specific Impulse (Sea Level)	N/A	N/A	N/A	234 sec

Available: Now

Contact: Robert E. Dupuis, Director Business Development & Business Management
General Dynamics
Commercial Launch Services
P.O. Box 85911
San Diego, CA 92186-5911
(619) 496-4010

Conestoga Launch Vehicle

The Conestoga Launch Vehicle is a solid-motor, small payload expendable launcher based on the Castor IV-B motor (see page 215) in various parallel configurations. The Conestoga series employs a core motor with from two to six strap-ons, all Castor IV-Bs, and a Star 37 or 48 solid orbital insertion motor. The Conestoga series is designed for Low Earth Orbit payloads from 150 to 4,000 pounds, and geosynchronous payloads from 75 to 800 pounds, depending on mission requirements. Payload shrouds from 65 to 90 inches in diameter are available and payload reentry capsules up to 80 inches in diameter can be accommodated. The Conestoga requires minimal launch pad buildup and support. Utilizing modular telecommunication, command and control, it can be launched from any site world-wide offering approved range support. The period from go-ahead to launch can be as short as 14 months.

Operating Characteristics

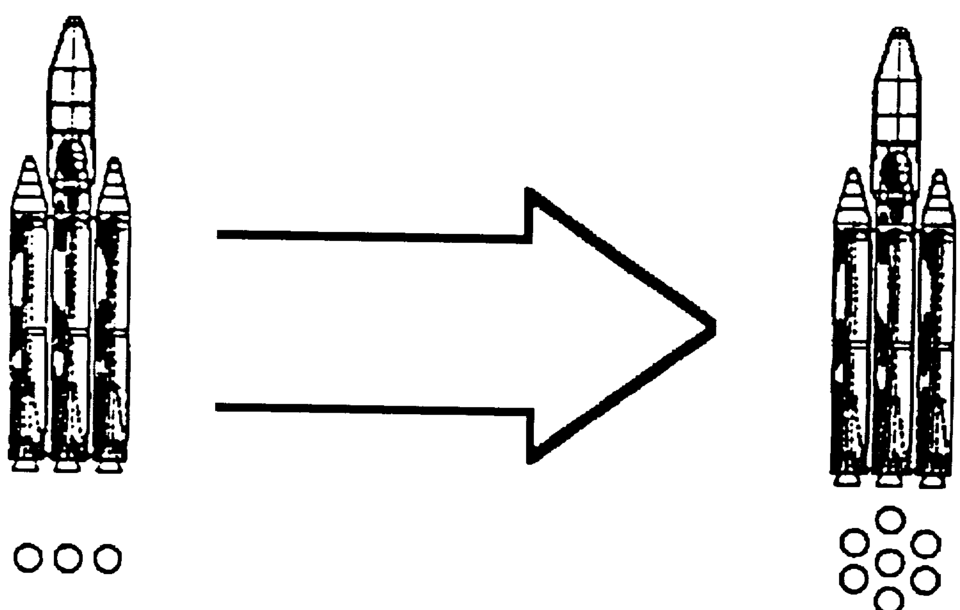
System height:	49.5 ft maximum
Weight:	84,000 to 188,000 lbs
Guidance:	Inertial with thrust vector control

Cold gas altitude control system on cone stage
Spin stabilized upper stage (active guidance available)

Payload envelope:	190 ft^3 to 260 ft^3

Available: Now

Contact: Richard W. Scott, Jr.
Space Services Incorporated of America
7015 Gulf Freeway, Suite 140
Houston, TX 77087
(713) 649-1716, Fax (713) 649-3445



Conestoga 210
400 lbs (181 kg) - 400 nm (742 km) Polar

Conestoga 421
1500 lbs (680 kg) - 400 nm (742 km) Polar

Delta II

The Delta II launch vehicle series can be configured as a two- or three-stage vehicle and equipped with either Castor IVA solid booster motors or Graphite Epoxy thrust augmenters. Launch can be from either Cape Canaveral (ESMC), FL or Vandenberg AFB (WSMC), CA. Orbit inclinations at Cape Canaveral are from 28.5° to 51° degrees and at Vandenberg are from 63° to 145°. Payload fairings for the various launch vehicles are shown in the accompanying chart.

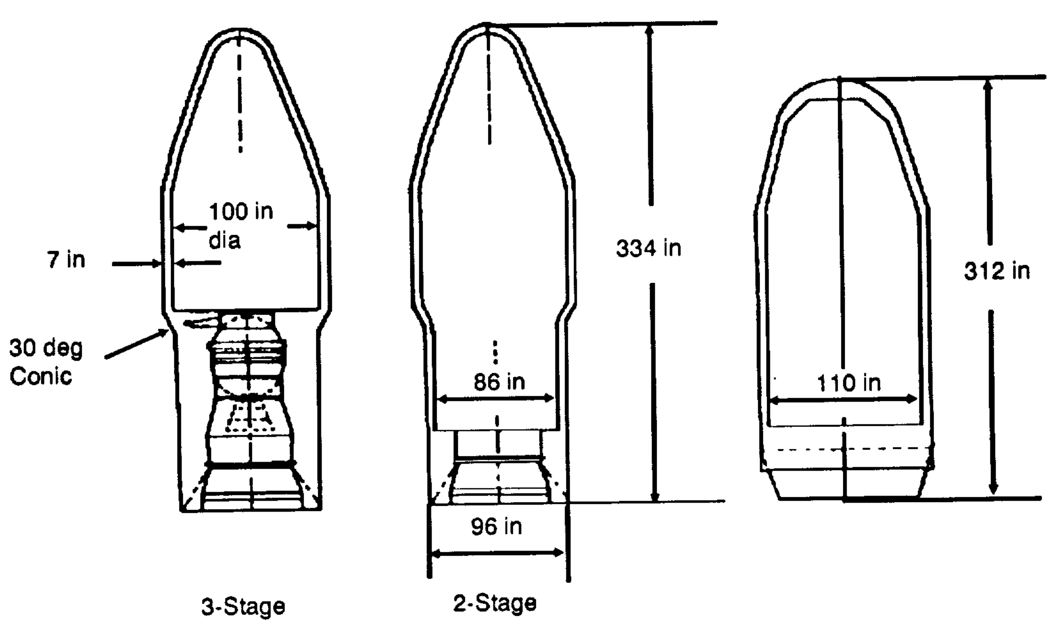
The Delta II series is capable of launching payloads into Geosynchronous Transfer Orbit (GTO), Low Earth Orbit (LEO), and the Global Positioning System Orbit (GPS) from Florida; and Sun Synchronous, Low Earth Orbit and a Highly Elliptical Orbit (HEO) from California.

Operating Characteristics Vehicles/Orbit[1]	**Spacecraft**	**Weight (lbs)**
Three-stage Vehicles	6925	7,925
GTO (100 x 19,323 nmi, i=28.7 deg) ESMC	3190	4,010
GPS (Hc=10,898 nmi, i=55 deg)		
(Launch AZ=50 deg)	1875*	2,500*
ESMC (Launch Az=112 deg)	1850*	2,350*
HEO (200 x 21,649 nmi,i=63.4 deg) WSMC	2120	2,810
Two-stage Vehicles	6920	7,920
Sun Synchronous		
(Hc=450 nmi, i=98.7 deg) WSMC	5660	7,000
LEO (Hc=100 nmi, i=28.7 deg) ESMC	8780	11,110
LEO (Hc=100nmi, i=90 deg) WSMC	6670	8,420

[1] 9-foot fairing
* Includes empty weight of the Star 37XFP AKM after circularizing burn

Available: Now

Contact: John Fredricks
McDonnell Douglas Space Systems
1735 Jefferson David Highway, Suite 1200
Arlington, VA 22202
(703) 553-3883



Pegasus Launch Vehicle

Orbital Sciences offers complete integrated space launch services using the advanced Pegasus launch vehicle, including the provision and operation of the vehicle as well as payload integration and mission support services.

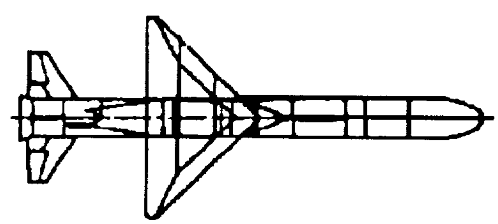
The Pegasus air-launched vehicle is a three-stage, winged, graphite composite launch vehicle that is approximately 50 feet long and 4.5 feet in diameter and weighs 42,000 pounds at launch. The vehicle uses an airborne launch from a jet aircraft to place small satellite payloads weighing up to 1,000 pounds into Low Earth Orbit. Because of its air-launched and aerodynamic lift-assisted feature, Pegasus achieves efficiency gains that enable it to lift approximately twice the payload that can be carried by comparable ground-launched vehicles. The air-launched feature also provides greater flexibility than traditional ground-launched vehicles by reducing launch site costs and geographic constraints, reducing vulnerability to weather conditions and offering a greater range of orbit inclinations.

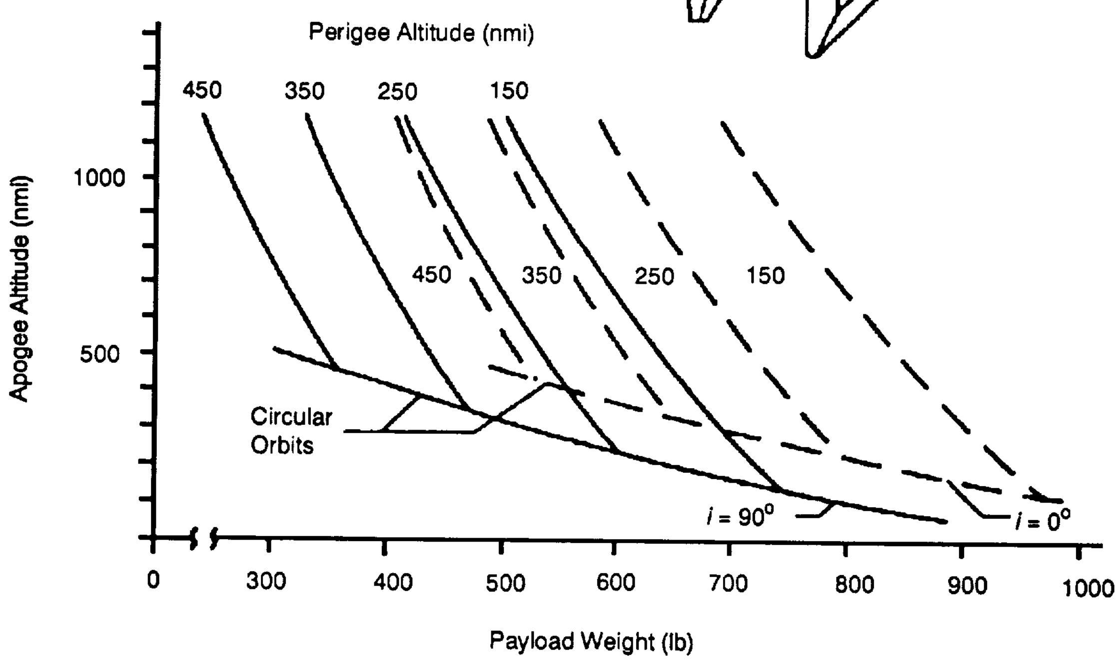
A Pegasus launch utilizes a wide-body commercial carrier aircraft or a NASA B-52 aircraft. The Pegasus launch vehicle is carried along the centerline of the commercial carrier aircraft or under the right wing of the NASA B-52. Following the drop, the first-stage motor ignites and Pegasus uses its wing to fly a shallow ascent trajectory to Mach 8.7 and 230,000 feet, where first-stage burnout and separation occur. The second- and third-stage rocket motors then function like more traditional launch vehicle upper stages to propel the vehicle's payload into orbit. The lift generated by the wing, combined with a launch initiated above 40,000 feet provides significant satellite payload-to-orbit weight benefits. Pegasus has the capability of placing 600-lb spacecraft into 250-nmi polar orbits and 900-lb payloads into 250-nmi equatorial orbits.

Pegasus has a large payload shroud with internal dimensions of 72 inches long by 46 inches wide. This large volume, combined with the 600 to 900-lb payload capability, can accommodate innovative satellite designs, including imaging spacecraft requiring large diameter optics.

Available: Now

Contact: Bruce A. Biehler
Orbital Sciences Corporation
Space Systems Division
12500 Fair Lakes Circle
Fairfax, VA 22033
(703) 631-3600





Pegasus Payload Performance

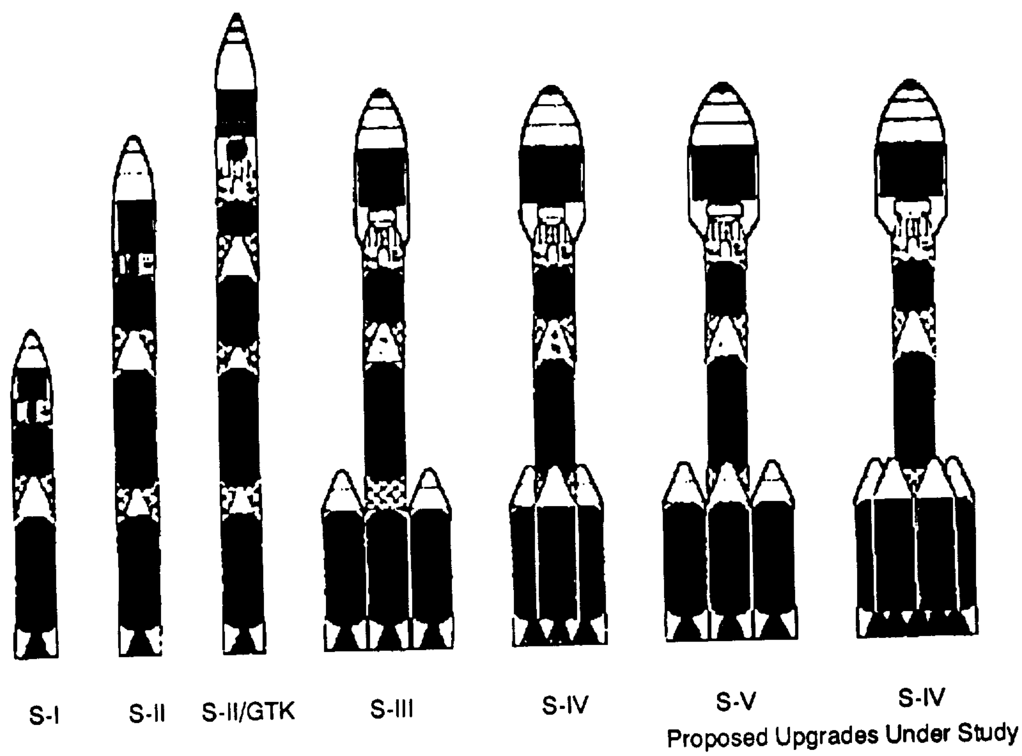
S-Series Medium Lift Launch Vehicles

The EPAC S-Series ELV has a three-stage solid rocket motor (SRM) core configuration. Performance capability in terms of payload weight is a function of both mission trajectory requirements and vehicle configuration (e.g., the basic core vehicle capacity can place payloads of up to 20,000 pounds into Low Earth Orbit, or payloads up to 7,800 pounds into Geosynchronous Transfer Orbit).

The S-Series is a five configuration family providing an efficient means of propelling a wide range of space payloads into planned trajectories. The SRMs are chosen to meet the propulsion requirements of the payload orbital position specifications. Two, three or four SRM stages are configured with or without SRM thrust augmentation motors. A storable liquid positioning module can be added to provide the remaining propulsion and accuracy for placing various payloads into Geostationary Transfer Orbit. These vehicles have 92-inch core diameter and range in height from 76 to 115 feet.

Available: Now

Contact: E'Prime Aerospace Corporation
P.O. Box 792
Titusville, FL 32781
(407) 269-0900



EPAC S-Series Launch Vehicles

Scout

The Scout is a four-stage solid rocket expendable launch vehicle manufactured and launched by LTV Missiles and Electronics Group. It is capable of providing orbital, reentry or probe missions. Scout has experienced a mission success ratio of 98.3 percent over the past 22 years.

Since the initial Scout launch, Scout's payload mass carrying capability has increased three to four times while increasing overall reliability. To further increase performance capability, LTV and BPD of Italy, have begun development of a more powerful version of the Scout; the Scout II. Scout II utilizes the Scout as the core vehicle and has two BPD-tailored Ariane-4 solid rocket motor strap-ons. The fourth-stage ALTAIR IIIA motor is replaced with the BPD Mage 2. Additionally, a third Scout configuration is under development; the Enhanced Scout. The Enhanced Scout is identical to the Scout II, except the Scout fourth-stage ALTAIR IIIA rocket motor is retained.

Scout has launch facilities at the Western Test Range, Vandenberg Air Force Base, CA; Wallops Flight Center, Wallops Island, VA; and San Marco Equatorial Mobile Range, located in Ngwana Bay of the Indian Ocean (off the east coast of Kenya, Africa).

Operational Capability

	Payload Wt. (kg)	Orbit (km)	Inclination Angle (Deg)
Scout	225	500x500	0-5
	170	500x500	90
	165	500x500	Sun-Synch
Enhanced Scout	400	500x500	0-5
	304	500x500	90
	295	500x500	Sun-Synch
Scout II	434	500x500	0-5
	334	500x500	90
	324	500x500	Sun-Synch

Available: Scout, immediately; Scout II and Enhanced Scout, 1993

Contact: W. R. Ray or H. E. Collins, MM-52
LTV Missiles and Electronics Group
P.O. Box 650003
Dallas, TX 75265-0003
(214) 266-7612

Taurus Launch Vehicle

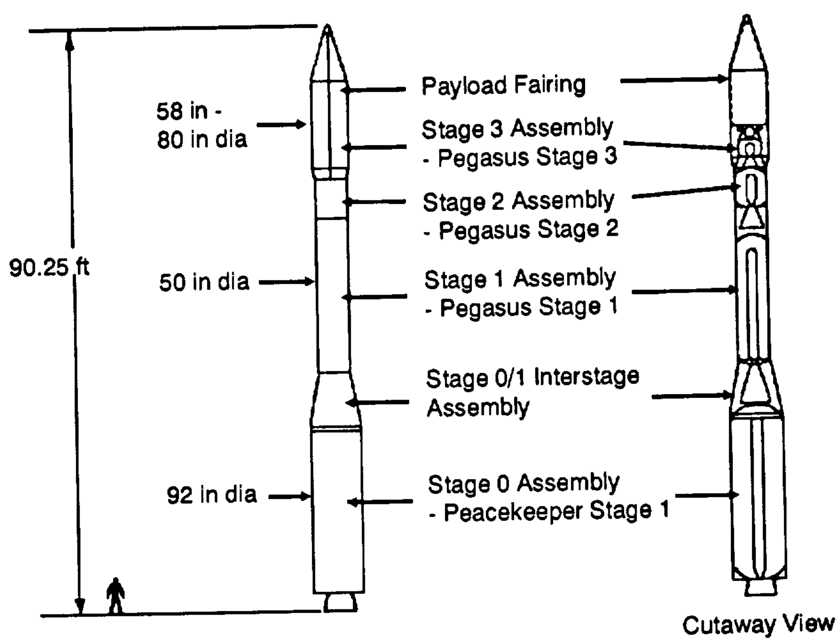
Orbital Sciences offers complete integrated space launch services using the advanced Taurus Launch Vehicle, including the provision and operation of the vehicle as well as payload integration and mission support services.

Currently under contract and development, Taurus is a four-stage, ground-launched vehicle derived from the flight-proven Pegasus vehicle (see page 208). The Taurus design provides for use of the Pegasus launch vehicle's avionics, control module and rocket motors, supplemented by a U.S. Air Force Peacekeeper or equivalent missile stage zero motor. The stage 0 motor design features an omni-axis movable carbon phenolic nozzle, with thrust vector control for pitch and yaw provided by a flex seal nozzle with turbo-hydraulic actuation. Taurus is approximately 90 feet long and 8 feet in diameter at its widest point and weighs about 175,000 pounds at launch. It is designed to be readily transported with a self-contained launch pad, including assembly and pre-flight testing equipment, so that launch from a variety of developed or remote locations can be achieved.

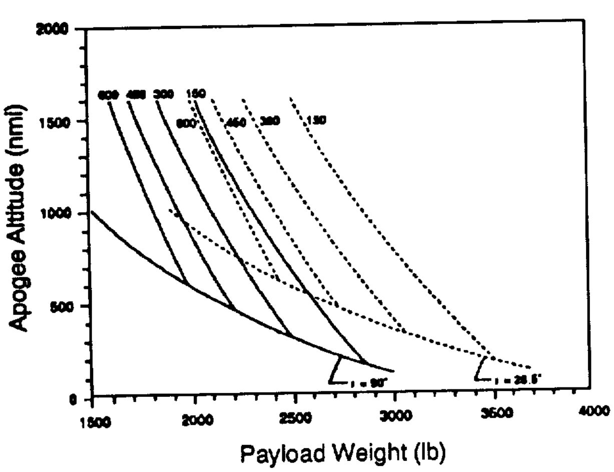
It is expected that Taurus will launch payloads weighing up to 3,500 pounds into Low Earth Orbit and up to 830 pounds into Geosynchronous Transfer Orbit. Injection accuracies to a 400 nm circular polar orbit are expected to be better than +/-20 nmi in altitude and +/-0.2 degrees in inclination.

Available: 1992

Contact: Bruce A. Biehler
Orbital Sciences Corporation
Space Systems Division
12500 Fair Lakes Circle
Fairfax, VA 22033
(703) 631-3600



Cutaway View



Taurus Payload Performance
(Enhanced Vehicle)

Titan III

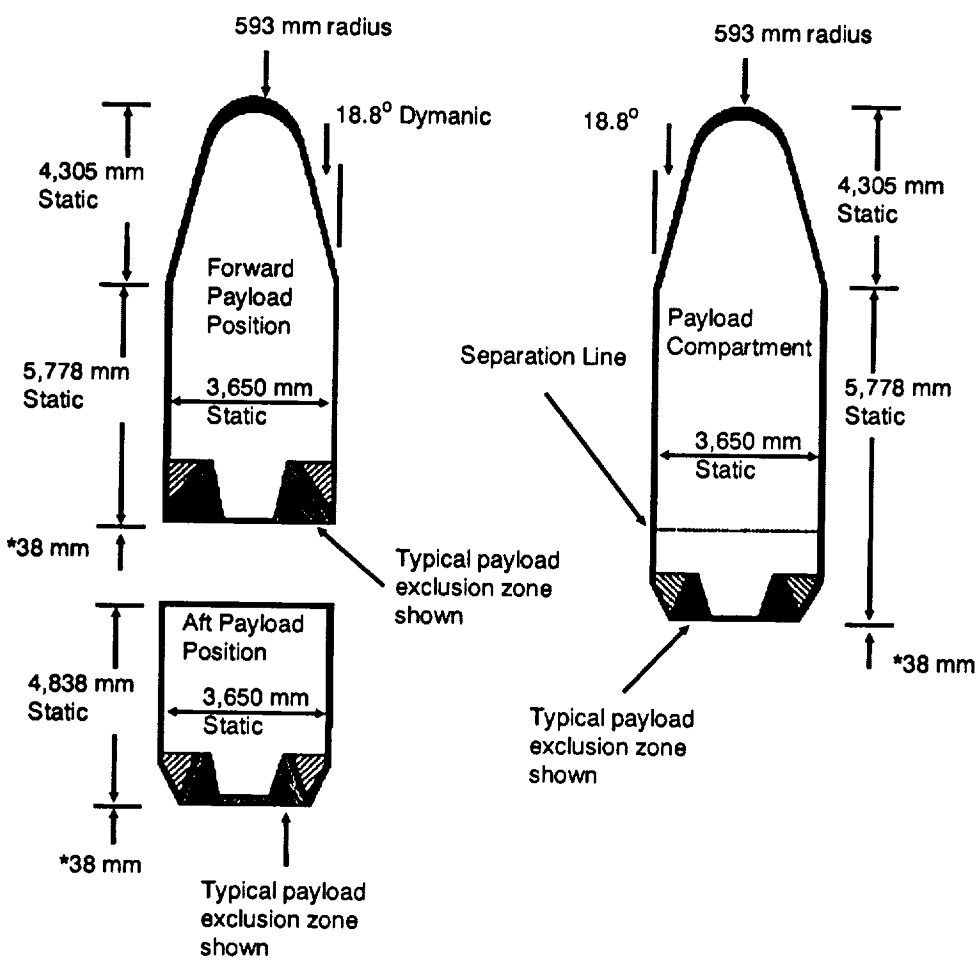
The baseline mission for the Titan III commercial launch vehicle is to insert payloads into Low Earth Orbit. Missions are flown into a park orbit of 80 x140 nmi at an inclination of 28.6°. The Titan III delivers 31,600 lbs into this LEO in the dual payload configuration or 32,500 lbs in the single payload configuration when launched from Cape Canaveral in Florida.

The Titan III system is capable of providing a full complement of payload accommodation services, including: payload integration analysis and verification, launch site payload processing facilities, mission safety verification, launch pad test and checkout support, airborne avionics integration and post flight data analysis. A standard set of services is included with each contract, with additional services provided depending on specific payload mission requirements. The initial launch of the Titan III commercial launch vehicle was December 1989.

Operating characteristics
System height: Up to 155.0 ft
Payload carrier length: Up to 52 ft
Payload carrier diameter: 13.1 ft

Available: Now

Contact: Timothy C. Abels
Manager, Government Systems
Martin Marietta Commercial Titan, Inc.
P.O. Box 179, MS DC1450
Denver, CO 80201
(303) 971-1586, Fax (303) 971-2390



*Dynamic exclusion zone

Dual Payload Carrier **Single Payload Carrier**

Reentry Vehicles

Reentry vehicles are designed to be launched into space with a payload module, remain (all or in part) with the payload during space exposure and then, usually upon command from ground-based operations, return to the atmosphere for recovery at a specified location. Reentry vehicles initially were designed with the first manned space flights in the 1960s, when an astronaut was launched into orbit by an expendable launch vehicle and returned safely to Earth. American astronauts traditionally floated through the atmosphere with parachutes attached to their spacecraft, landing in the water for recovery by the Navy.

As research programs in space mature and require more sophisticated data results and testing, the need for recoverable payloads increases. As a result, considerable research and development is underway, both by NASA and the private sector, to make these essential vehicles available.

COMmercial Experiment Transporter Program (COMET)

In 1990, NASA's Centers for the Commercial Development of Space jointly established a new initiative, the COMmercial Experiment Transporter Program (COMET), for launching and recovering commercial spaceborne experiments. The objective of the program is to develop both the hardware and infrastructure essential to facilitate innovative U.S. efforts to commercially develop space. With NASA's support, the CCDS's will be responsible for system design, fabrication, testing and operations.

The Center for Advanced Space Propulsion (CASP) at the University of Tennessee is responsible for program management and systems engineering. The six major elements of the COMET program include: launch vehicle and services, payload integration, service module, orbital operations, recovery system and services and systems engineering. Contractors are providing key hardware and services for each segment of COMET development and operations.

An expendable launch vehicle (ELV) will launch the COMET freeflyer, which will contain both a service module and a recovery system. The components will separate prior to reentering the atmosphere, allowing many of the experiments to return to Earth in the recovery system, while others, not requiring retrieval, can continue their mission aboard the service module. Launching on ELVs will give commercial developers the flexibility of orbital parameters that is not available with the Shuttle.

Present plans call for the first launch in mid-1992. The freeflyer, weighing up to 1800 pounds, will be placed into equatorial orbit with an inclination of about 40 degrees. Recoverable payloads nominally will have a 30-day mission, while non-recoverable payloads can remain on orbit in the service module for a year or longer. Specific launch and recovery sites will be selected through industry's proposals for the most optimal way to meet mission requirements.

In addition to CASP, other CCDS participants include:

- Payload Integration; Center for Macromolecular Crystallography, University of Alabama/Birmingham
- Recovery System; BioServe Space Technologies, University of Colorado/Boulder
- Service Module; Center for Space Power, Texas A&M University/College Station
- Expendable Launch Vehicle; Consortium for Materials Development in Space, University of Alabama at Huntsville
- Orbital Operations; Space Vacuum Epitaxy Center, University of Houston

The experimental payloads will be selected from the CCDS's and their industrial partners. The launch vehicle, recovery and reentry systems, and associated on-orbit and ground-support services are being purchased by competitive bid from private industry.

Contact: Joseph F. Pawlick, Jr.
COMET Program Manager
University of Tennessee Space Institute
UT-Calspan Center for Aerospace Research
P.O. Box 1385
Tullahoma TN 37388
(615) 454-9294

Orbital Payload Recovery Systems

The Reentry/Recovery Vehicle Division of COR Aerospace Corporation is dedicated to the design and development of vehicle systems for the autonomous recovery, from orbit, of a broad spectrum of commercial and scientific payloads. Orbital Payload Recovery System designs employ two basic vehicle types. Both are readily scalable to accommodate diverse payload requirements and a broad spectrum of launch system capabilities. The systems illustrated are representative of a number of vehicles of specific, prospective applications.

The "CHEOPS" concept is fully autonomous in operation. Following deployment and an orbital dwell period as dictated by payload requirements, it reenters on command and is recovered fully intact. This ensures against debris impact in the recovery area and facilitates the economy of refurbishment and reutilization of the total vehicle.

The spherical "Deliverer" vehicles are generally smaller, highly simplistic systems, which deploy in orbit from a companion satellite. The satellite provides gravity-gradient stabilization, power for payload functions and up-and-down link communication, prior to separation for vehicle reentry. This system discards its deorbit module (spent retrorocket and spin system) after initiation of reentry but allows for reuse of the remaining reentry vehicle.

CHEOPS "64" Operational Characteristics

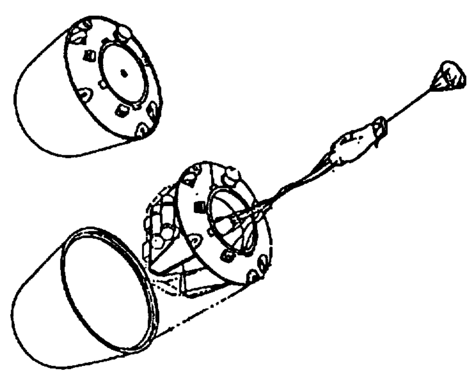
Shape:	Blunt Sphere/Cone
Size:	64 inch Base diameter
Total weight:	2600 lbs/2175 lbs
Total R/V Sys. Wt:	2600 lbs/2175 lbs
Reentry weight:	2350 lbs/1968 lbs
Payload volume:	19.0 cubic ft
Payload weight:	1575 lbs/1159 lbs
P/L mass fract:	0.61/0.53
Ballistic coeff. (B):	165 psf/138 psf
Autonomy:	Full
% Reuse:	85% estimated
Debris:	None
Term. descent:	Controlled Chute
Pref. recov. site:	Land

Deliverer "24" Operational Characteristics

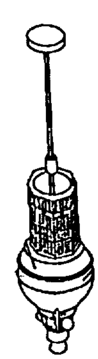
Shape:	Spherical
Size:	24 inch diameter
Total weight:	685 lbs
Total R/V Sys. Wt:	446 lbs
Reentry weight:	380 lbs
Payload volume:	2.0 cubic ft
Payload weight:	250 lbs
P/L mass fact:	0.36
Ballistic coeff. (B):	121 psf
Autonomy:	Requires companion satellite
% Reuse:	40% estimated
Debris:	Deorbit Module Remains
Term. descent:	Controlled Chute
Pref. recov. site:	Land

Available: Under development

Contact: Roland T. Mayer
Reentry/Recovery Vehicle Division
COR Aerospace Corporation
1495 Anthony Wayne Dr.
Wayne, PA 19087
(215) 964-9665



™CHEOPS-64



™Deliverer "24"

Orbital Transfer Vehicles

Orbital transfer vehicles carry satellite payloads from locations between Low Earth Orbit (200 miles) and Geostationary Orbit (22,300 miles) or to planetary trajectories. The vehicle and its attached payload typically are carried by the Shuttle or expendable launch vehicle into a low-altitude "parking" orbit, usually 150 to 200 miles above the Earth. The transfer vehicle then lifts its payload into an operational orbit, or a trajectory. Once properly situated, the vehicle separates from the payload.

The applications for orbital transfer vehicles are many, but the development of such vehicles has been limited. NASA has developed plans for an Orbital Maneuvering Vehicle (OMV) and studies have suggested that reusable rocket stages or discrete vehicles, that could be refueled in orbit, could provide the energy increment to raise and lower satellites or platforms between a servicing altitude and an operational altitude. In the future, other scientific or commercial missions may require a change of orbital plane to observe targets of opportunity or to optimize the scientific or application return. Transfer vehicles will be needed for manned and unmanned operation as missions dictate. With the development of Space Station Freedom, the need for on-orbit, or inter-orbital transportation will become even more essential. Orbital transfer vehicles will be an indispensable tool for operations at stations, platforms, satellites and other facilities in Earth, lunar and Martian orbits.

Transfer Orbit Stage (TOS)

The TOS vehicle is a single-stage solid-propellant rocket that measures approximately 7.5 feet in diameter and 10.5 feet in length and weighs up to 24,000 pounds. The TOS was engineered to be compatible with both the Shuttle and Titan ELV. TOS/STS performance is referenced for a 160 nm park orbit while TOS-on-Titan performance is referenced for a 90 nm park orbit perigee. TOS payloads typically consist of communications satellites, scientific probes or other commercial and defense spacecraft weighing between 3,000 and 7,000 pounds.

TOS propulsion consists of a main propulsion system and an attitude control system (ACS). Both systems have extensive hardware heritage with a large number of successful ground and flight tests on NASA and military space programs. Both combine selective redundancy with conservative design margins to assure high levels of safety and reliability. The ORBUS 21 solid rocket motor (see page 219) provides TOS main propulsion. The ORBUS 21's gimballed nozzle provides pitch and yaw control during motor firing. This motor's 50% propellant off-load capability accommodates a wide range of mission payload and energy requirements. A blow-down monopropellant hydrazine system produced by United Technology Corporation's Hamilton Standard Division provides ACS and velocity trim propulsion. Roll control during solid rocket motor firing and three-axis attitude control during coast is provided by 12 ACS thrusters.

TOS avionics hardware and software perform all functions involved in guidance and control, data management, event sequencing, telemetry and command and electrical power. Orbital Sciences Corporation has qualified an operationally simple but exceptionally powerful guidance, navigation and control capability using Honeywell's advanced laser inertial navigation system (LINS), enabling TOS to provide high injection accuracy and reliability at low cost. Under development by OSC and Honeywell since 1984, the LINS has pioneered the qualification of ring laser gyroscope avionics for space applications.

The TOS structural design provides uniformly-distributed load paths between the flight vehicle and ASE, allowing weight reductions not possible with discrete attachments. The tilt method of deployment and the Lockheed Super-Zip separation system both have extensive flight history.

Available: Now

Contact: Martin Deckett
Orbital Sciences Corporation
Space Systems Division
12500 Fair Lakes Circle
Fairfax, VA 22033
(703) 631-3600

Chapter 21: Ancillary Products and Services

A number of products and services are available to support the transportation industry, vehicles and systems. These include propellants, avionics, motors, parts and others. When on-orbit facilities become operational later in the decade, requirements for space-based transportation services will evolve, potentially stimulating a new sector of the industry. This chapter includes some of the products and services that are available and are being developed.

Brushless Space-Rated Motor

Thirteen of these motor/brake units were designed, built and qualified in four months. They were designed for deep space and use low outgassing components. The application requires six motor/brakes to deploy three masts on a satellite.

Operational Characteristics

Peak Torque:	25 in-oz @ 3.0 Amp
Maximum speed:	5,000 rpm @ 34 Vdc
Size:	2.50 in diameter x 6.80 in L
Weight:	3.0 lbs

Available: Now

Contact: Versatron Corporation
103 Plaza Street
Healdsburg, CA 95448
(707) 433-8244, Fax (707) 433-7110

Castor Launch Vehicle Propulsion

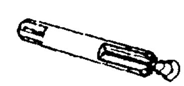
Castor rocket motors have been used as primary or augmenting propulsion for orbital and sub-orbital launch vehicles since the 1950s. As of 1990, more than 1,750 Castor motors have flown with a success record of 99.94 percent.

All Castor motors use a rugged, low-cost roll-and-welded steel motor case in diameters of 31 and 40 inches. Solid propellant weight ranges from 7,300 to over 22,000 pounds. Each motor has forward and aft attachment skirts, capable of supporting the full thrust load. Motors are available with straight, canted, sea level and altitude nozzles. The Castor IVB has a +/-6 degree omniaxial thrust vector control system with a hydraulic blow-down actuation system.

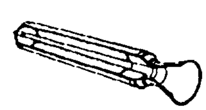
Optional accessories include a destruct system; shipping dollies; arm and fire device; clustering or strap-on hardware; ordnance, electrical or laser ignition; full length wiring tunnels; external cork or spray-on insulation; and nose cones.

Available: Delivery is nominally 12 to 16 months; Castor IVH and Castor V are under development.

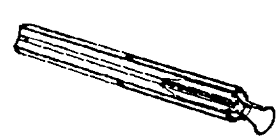
Contact: Donald G. Wilson
New Business
Development Manager
Thiokol Corporation
P.O. Box 400006
Huntsville, AL 35815-1506
(205) 882-8000



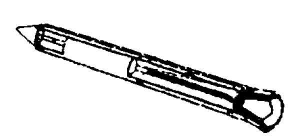
Castor I



Castor II



Castor IVA



Castor IVB

Cryogenic Propellants

Air Products and Chemicals produces cryogenic propellants, pressurants and purging agents for launches. Capabilities include the supply of propellant-grade liquid hydrogen, oxygen and methane, as well as nitrogen, argon and helium.

Contact: Air Products and Chemicals, Inc.
Government Systems
7201 Hamilton Boulevard
Allentown, PA 18195-1501
(215) 481-4911

Launch Vehicle Avionics

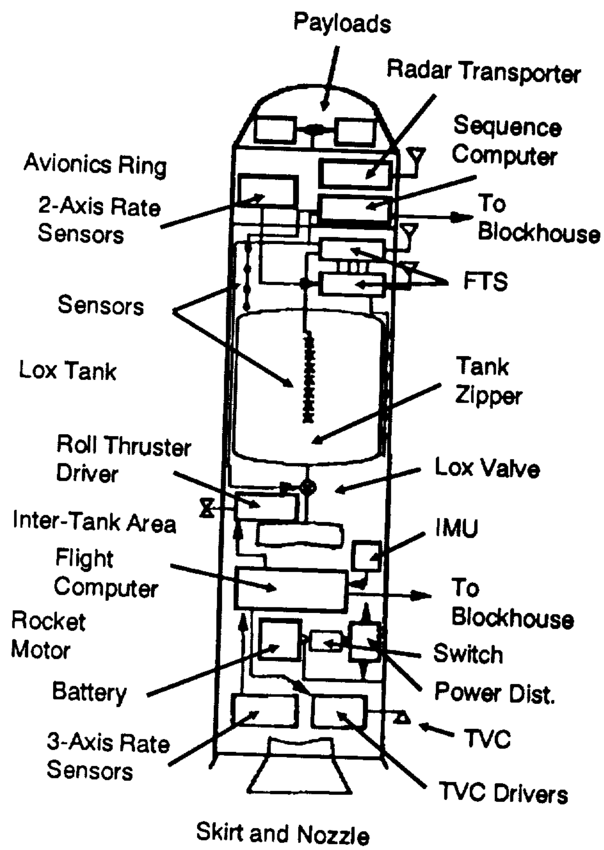
Interferometrics has built and flight-tested a complete set of low-cost avionics and electronic subsystems for commercial launch vehicles, using off-the-shelf components and custom microelectronics. These avionics, developed for the American Rocket Company's Industrial Launch Vehicle, are available as individual subsystems or as a complete integrated package. Engineering support includes mission planning and analysis, guidance and control system design and evaluation, system integration, test and operational support.

Hardware Includes:

- Flight Computer (FC)
- Flight Termination System (FTS)
- Batteries & Power Conditioning Units
- Telemetry & Tracking System (TTS)
- Flight Data Acquisition & Multiplexer
- Payload Activation System
- Launch Sequence Computer System
- Thrust Vector Control System (TVC)
- Inertial Measurement Unit (IMU)
- Vehicle Instrumentation Sensors
- Altitude Control System (ACS)

Software Includes:

- Guidance & Control Programs
- Launch Control Software
- Critical Flight Code
- Six-DOF Simulator
- Mission Planning Software
- Structural Mode Analysis



Available: Now

Contact: Dino A. Lorenzini
Vice President, Operations,
Interferometrics, Inc.
8150 Leesburg Pike Suite 1400
Vienna, VA 22182-2799
(703) 790-8500, Fax (703) 848-2492

On-Orbit Transportation Services

GLOBAL OUTPOST, Inc. plans to offer transportation-related services beginning in 1993-94. The company is developing a fluid transfer location on the initial OUTPOST Subsystem package (see pages 170-171) which will have limited storage tanks. Couplings from third-party developers will provide on-orbit storage and transfer of fluids in both directions. A passive platform interface location will provide structural attachment, electrical, thermal, communications, command and control, storage and other services to freeflyers and expendable launch vehicles having an ability to rendezvous and dock, and requiring some or all of these services.

The company anticipates a limited capability to unload vehicles using robotic hardware and /or dispose of vehicle hardware.

Location: OUTPOST Platform (Low Earth Orbit)

Available: 1993-94

Contact: William A. Good
GLOBAL OUTPOST, Inc.
P.O. Box 4321
Highlands Ranch, CO 80126
(303) 791-6277

ORBUS Space Motors

The ORBUS series of space motors was developed to satisfy specific space requirements and have supported the following applications:

ORBUS 6
Shuttle payloads, Titan 34D payloads

ORBUS 6E
Shuttle payloads

ORBUS 6S
Titan 34D Inertial Upper Stage apogee motor, Shuttle Inertial Upper Stage apogee motor

ORBUS 7S
Perigee motor for Hughes HS-393 series communication satellites

ORBUS 21
Titan 34D Inertial Upper Stage, Shuttle Upper Stage

ORBUS 21S
Perigee motor for INTELSAT-VI satellites

Available: Now

Contact: Larry Ross, Marketing Manager
Chemical Systems Division
United Technologies Corporation
P.O. Box 49028
San Jose, CA 95161-9028

Proximity Switch System

The ELDEC Proximity Switch System provides door and landing gear position indication for the Shuttle. The system is comprised of two 10-channel electronics packages, remotely located proximity sensors (up to 10 per electronics package) and a target for each sensor. When a target is brought within a specified actuation envelope of a proximity sensor, the electronics package will provide a discrete output for that channel.

Typical Indication Includes:

- Nose Landing Gear Weight on Wheels
- Main Gear Downlocked (R&L)
- Main Gear Uplocked (R&L)
- Main Gear Door Uplocked (R&L)
- Nose Landing Gear Door Uplocked (R&L)
- Main Gear Weight on Wheels

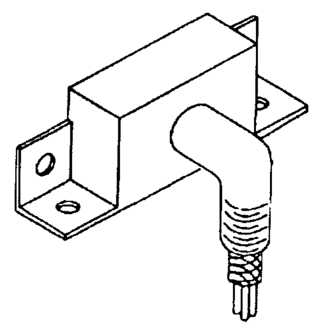
Operational Characteristics

Electronics Package	
Size:	3.72 in x 4.10 in x 8.00 in
Input power:	115 Vac, 400Hz
Proximity Sensor	
Size (typ):	0.50 in x 0.90 in x 1.20 in

Locations: Shuttle cargo bay and landing gear

Available: Now

Contact: ELDEC Corporation
Monitor and Control Division
16700 13th Avenue West
Lynnwood, WA 98037-8503
(206) 743-1313



RL10-A-3-3A Space Engine

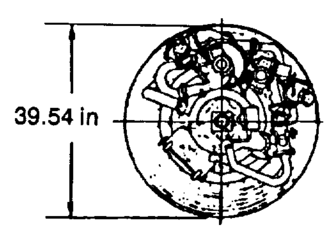
The RL10-A-3-3A is a liquid hydrogen-fueled engine with a highly-efficient expander cycle, ideally suited for applications requiring restart capability, with large variations in coast periods between firings. The engine can be modified for lower (down to 7,500 lbs) or higher (up to 22,000 lbs) thrust ratings to adapt to future needs. The mixture ratio is variable from 4:1 to 7:1. The nozzle area ratio also can be tailored to specific vehicles and two-position nozzle extensions are under development.

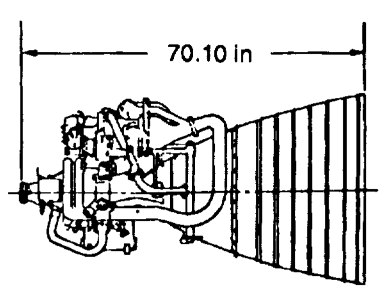
Operational Characteristics

Thrust vacuum:	16,500 lbsWeight: 305 lb
Mixture ratio (lb O2/lb H2):	5:1
Specific impulse vacuum:	444.4 sec
Chamber pressure, psia:	475 (327 bar)
Area ratio:	61:1
Qual life, firings/hr:	20/1.25

Available: Now

Contact: James R. Brown
RL10 Engine Program Manager
United Technologies/Pratt & Whitney
P.O. Box 109600
West Palm Beach, FL 33400-9600
(407) 796-3371





STAR Space Motors

Thiokol's STAR family of space motors provides reliable propulsion for spacecraft and launch vehicle upper stages. Designed to provide maximum payload capability by using high-specific-impulse propellants and advanced materials, more than 60 different STAR motors have been developed and qualified (see listing). The STAR number for each motor indicates its approximate principal diameter in inches, while the letter designations are used to denote configurations tailored to a particular set of requirements.

Performance is tailored within our family of existing qualified motors either by decreasing the propellant weight loaded into the motor, or by increasing motor case length to increase motor volume, thereby permitting increases in propellant loading. These approaches permit a wide range of performance to be achieved for specific missions without changing the basic motor configuration.

Another characteristic of the STAR motor family is the delivery of total impulse in vacuum, predictable within 0.5% and reproducible within 0.6R over a 30° to 100°F temperature range.

Motor Characteristics

Name	Star No.	Motor Weight (kg)	Tested	Flown as of April 23, 1990
Perigee Kick Motor	75	7,938	1	–
AUSSAT	63F	4,644	4	–
PAM-DII	63D	3,498	5	3
Perigee Kick Motor	48A	2,420	1	–
Shuttle & Delta Payload Assist Module	48B	2,135	3	17
Shuttle & Delta Payload Assist Module	48	2,107	18	31
Antares III, Scout Third Stage	31	1,393	6	11
Improved Performance Space Motor	37Y	1151	2	–
Improved Performance Space Motor	37X	1151	1	–
FLTSATCOM (EHF) Apogee	37FM	1145	4	2
Improved Extended Delta	37G	1141	4	–
Delta 2914/3914, Atlas-Centaur	37E	1122	13	78
Titan-Centaur GPS, Block 5D and Japanese N-2 Upper Stage Delta 2914 Third Stage	37C	1047	1	8
GPS, KuBAND Apogee	37XFP	656	3	10
Improved Intelsat V, GPS Phase III Apogee	37XF	942	9	10
FLTSATCOM, Intelsat V Apogee	37F	933	8	11
Star 37B Burner II, 37D Delta, 37N Japanese N-1 Upper Stage Motors, 37S Block 5-D, and TIROS-N Orbit Insertion	37B,D,N,S	718	18	69
Surveyor Main Retro	37	621	50	7
Skynet 4 Apogee	30E	660	3	2
GSTAR, ASC, and DBS Apogee	30C	621	4	5
Space, GSTAR, MORELOS, TELSTAR and AUSSAT Apogee	30BP	543	5	16
SBS, SATCOM, WESTAR, ANIK, PALAPA, Galaxy, TELESTAR, Spacenet and BRASILSAT Apogee	30B	537	14	30
Apogee Motor	30,30A	492	4	–
CTS, GMS I/II, BSE and BS II, GPS I/II, NTS, P78-1, GOES D, E, and F, CS-2 SANDIA LABS, NATO III Apogee	27	363	16	31
Advanced Altair	20A	314	2	–
ASAT	20B	306	6	5
Altair III, Scout Fourth Stage	20	301	9	28
Viking, Dot and STRYPI Upper-stage	26C	263	4	14
Burner IIA Apogee	28B	261	1	8

STAR Space Motors (continued)

Motor Characteristics (continued)

Name	Star No.	Motor Weight (kg)	Tested	Flown as of April 23, 1990
IUE Apogee	24C	239	1	1
Pioneer Venus, Timation III (STP-73-3), LAGEOS and SKYNET II Apogee	24	218	8	5
IMP H & J Apogee	17A	126	3	2
SOLRAD, STP 72-2, S-3, SKYNET I and NATO I Apogee	17A	126	7	7
Radio Astronomy Explorer (RAE), S-3 and Solrad Apogee	17	79	6	4
AMPTE Apogee	13B	47	1	2
SESP, LES, AND S-3 Apogee	13A/F	38	5	8
Interplanetary Monitoring Platform (IMP D & E) Orbit Insertion	13	36	7	2
Super SARV Retro	12A	33	6	
SARV Retro	12	28	160	350
Re-entry Control	6B	10.3	8	14
Drag Make-up	6	6.1	47	247
	6A	4.7	47	247
Orbit InsertioN	5A	4.6	5	2
Titan Retro	5C	4.5	226	674
Trailblazer			4	11

Available: Now

Contact: Thiokol Corporation
Tactical Operations, Elkton Division
P.O. Box 241
55 Thiokol Road
Elkton, MD 21921-0241
(301) 392-1111

Thermal Protection

Exterior temperature-resistant components used in the Shuttle program protect the orbiter's aircraft-like structure from surface temperatures to 2200°F. Interior thermal components provide stable temperature environments for personnel and electronic equipment during the various mission phases.

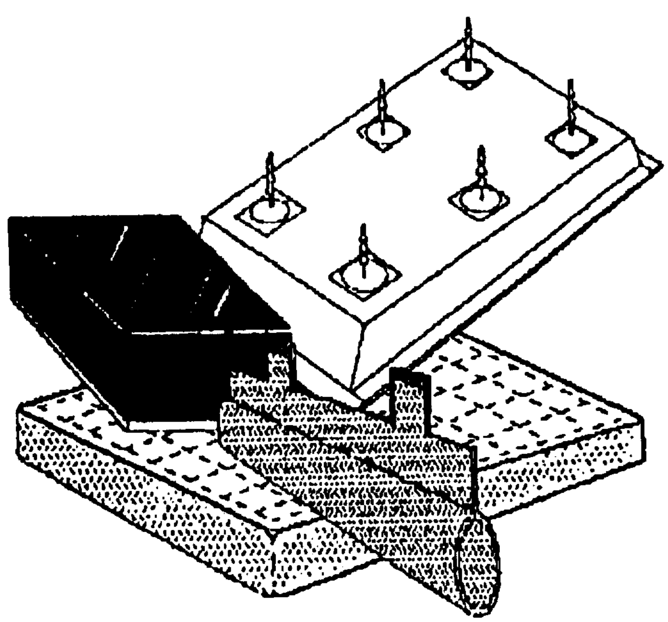
The Thermal Protection System (TPS), designed for 100 Shuttle missions, is comprised of ceramic tile; quilted flexible quartz and aramid felt insulating blankets; alumina-boria-silica fabric thermal barriers; and special coated fabrics. The over 24,000 rigid, low density fibrous silica tiles used on each Shuttle are machined to various geometries using numerically-controlled mills. The tile dimensions are held to exacting tolerances to maintain minimum weight/maximum heat protection. The tiles are covered with a thin glass ceramic, optical coating to achieve necessary on-orbit and reentry heat protection and to prevent surface erosion. The quilted blankets, coated with a silica ceramic slurry, have a service temperature of 1500° F. Aromatic nylon felt blankets, coated with silicone paint, are used in areas less than 700° F. Thermal barriers are made of various types of high temperature fabrics, battings and specialized internal details for use with dynamic structure penetrations. Other fabric materials have ceramic and silicone rubber impregnated coatings.

The Thermal Control System (TCS) uses blankets fabricated from aluminized polyamide film and teflon-coated fiberglass materials. The insulating properties are achieved by multi-layering the film with dacron net separators or filling with fibrous batting. Fabrication capabilities include numerical control programming, NC and duplicating mills, various types of instrumentation, laser part digitizing, unique machine stitching, high-temperature glazing, vapor phase waterproofing and rubber transfer coating. Installation of TPS/TCS components uses various room temperature vulcanizing (RTV) silicone rubber adhesives and mechanical attachment methods, along with time proven techniques. Statistical process controls are employed to assure consistent product conformity.

Location: Shuttle (other applications possible)

Available: Now

Contact: Richard E. Hammons, Manager
Space Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
MS/PL29, Department 188
Downey, CA 90241
(805) 272-4262



Section Seven: Resources & Services

In addition to the scientific, engineering and technical support services and equipment described in this catalogue, there are many other resources available to commercial developers from NASA, other federal and state agencies, organizations and commercial firms. Whole new segments of the "commercial space community" have developed with these emerging activities, such as space law, intellectual property, insurance, management consulting, project assessment and scheduling, investment research and counseling, payload testing and processing as well as creative support services. The entries included in this section represent but a small sampling of the spectrum.

Chapter 22: Industry

Industry offers products and services to commercial space developers, from cryogenic propellents to creative consulting, from operations management to flight simulation, from neural networks to liability insurance. As in any growing business, the very nature of the challenge draws enterprising supporters.

Air Products and Chemicals, Inc.

Air Products and Chemicals, Inc. provides ground-based services ranging from the supply of cryogens to designing, engineering, installing and operating custom-tailored systems to meet the requirements for propellant production, storage, distribution and application at both test and launch sites.

Contact: Larry Belnoski, Manager
Cryogenic Propellants and Systems
Government Systems
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
(215) 481-4911
(Locations also available in England and France.)

American Institute of Aeronautics and Astronautics (AIAA)

The American Institute of Aeronautics and Astronautics provides technical information services and an aerospace database. Information products include:

The Aerospace Database (file 108 on DIALOG)
The electronic version of International Aerospace Abstracts (IAA) and Scientific and Technical Aerospace Reports (STAR).

Aerospace Database OnDisc
The CDROM version of the online database. Available either: current year + 1 year backfile or current year + 4 years backfile.

International Aerospace Abstracts
Abstracting, indexing and bibliographic information on international research in the aerospace field and related fields.

Aerospace Research Bulletins
Current awareness bibliographies covering contemporary aerospace research.

Finding Guide to AIAA Meeting Papers
Published yearly.

Contact: Technical Information Service
American Institute of Aeronautics and Astronautics
555 West 57th Street
New York, NY 10019
(212) 247-6500

American Space Technology, Inc. (AmSpace)

AmSpace provides technical services including:

- Microgravity experiment design, analyses, fabrication and testing in the areas of combustion, materials and life sciences
- Space systems studies, design, analyses, traceable requirements definitions for mission, functional, interface and verification
- Attached and freeflyer spacecraft systems design support for Low Earth Orbit, Geosynchronous Orbit and planetary spacecraft
- Payload integration studies for Shuttle, Space Station, booster stages, spacecraft and Get-Away-Specials
- Detailed design and analyses for electronics, software structures, heat transfer, propulsion and materials
- Program management, costing, critical path network development/analysis and related scheduling

Contact: Arthur T. Perry
American Space Technology, Inc.
(AmSpace)
2800 28th Street, Suite 351
Santa Monica, CA 90405-2936
(213) 450-7515

Arthur D. Little, Inc.

Arthur D. Little, Inc. designs and assembles various space based experiments and space hardware including:

- Blood storage experiment flown on Shuttle
- Passive radiative cooler
- Heat transfer pump/thermal control system
- Lunar heat flow probes
- Lunar Gravimeter
- Laser ranging retro-reflector for measurement of to-moon distances

Contact: Peter Glaser, Vice President
Arthur D. Little, Inc.
20 Acorn Park
Cambridge, MA 02140
(800) 677-3000

Booz-Allen & Hamilton, Inc.

The Space Systems and Technology Division of Booz-Allen & Hamilton is a technical consulting organization specializing in space systems development and operations management. It has locations in Washington (DC), Houston, Huntsville, Cocoa Beach, Colorado Springs and Los Angeles.

Services include:

- Commercial market-driven space systems configuration analysis
- Requirements analysis and payload concept definition
- Project and design feasibility studies
- Space systems life-cycle cost analysis
- Space systems logistics planning and supportability analysis
- Space and ground systems operations capability development and management

Contact: Henry J. Pierce, Senior Associate
Space Systems Division
Booz-Allen & Hamilton, Inc.
4330 East West Highway
Bethesda, MD 20824
(301) 951-2940

Business Communications Company, Inc.

Business Communications Company, Inc. is a full-service technical market research firm that specializes in advanced technology areas including aerospace materials (metals, intermetallics, ceramics, polymers, carbon and composites), advanced optics, sensors, detectors, lasers, electronics, advanced membranes, biotechnology and related industries. BCC provides off-the-shelf multi-client technical/economic studies, as well as custom-designed studies.

Contact: Robert Butler, Director of Operations
Business Communications Company, Inc.
25 Van Zant Street
Norwalk, CT 06855
(203) 853-4266, Fax (203) 853-0348

The Center for Space and Advanced Technology (CSAT)

CSAT was founded to "promote U.S. and Free World leadership in the development and application of advanced technology."

The organization is divided into two principal divisions. CSAT's Strategic, Technical and Business Development Division supports a variety of government, university and commercial clients. CSAT's Engineering and Science Services Division provides technical support services.

Commercial space services include:

- Policy analysis
- Business planning
- Technologies evaluation
- Financial and market analysis
- Strategic programs and advanced planning
- Program management and analysis support

Discipline areas include:

- Engineering
- Life sciences
- Microgravity sciences
- Earth sciences
- Physical sciences
- Information sciences

Contact: Richard Sade or Kim Ellsworth
The Center for Space and Advanced Technology
9302 Lee Highway, Suite 1200
Fairfax, VA 22031
(703) 385-1660

Commercial Space Archives

The Commercial Space Archives is a Space Foundation project established to develop and operate a library of key documents relevant to the development and progression of the commercial space industry, across a broad range of markets. Housed at Virginia's Center for Innovative Technology, the public may access the archival collection of business plans, market reports, congressional hearings, policy statements and corporate reports that have had an impact on the industry.

The Space Foundation is a non-profit corporation headquartered in Washington, DC, that serves a forum through which the business, aerospace industry, government and academic communities meet to discuss the development of commercial space enterprises. The Foundation is the parent organization of the worldwide network of space business roundtables.

Contact: Jeffrey Manber, Executive Director
The Space Foundation
P.O. Box 27017
Washington, DC 20038
(202) 347-2414

Commercial Space Group of KPMG Peat Marwick

The Commercial Space Group supports U.S. and international commercial and government clients with business and financial consulting services. The consulting practice is based on an understanding of the technologies and issues facing each of the primary space technology areas: materials processing, communications, transportation, life sciences, remote sensing and space infrastructure. Services range from strategic planning, operations management and market research to financial analysis, cost management and price analysis.

Located in Washington, DC and Houston, TX, the Commercial Space Group assists federal institutions, academia and industry including emerging entrepreneurial companies and members of the Fortune 500.

Contact: Frank DiBello
KPMG Peat Marwick
2001 M Street, NW
Washington, DC 20036
(202) 467-3098

Conatec, Inc.

Conatec, Inc. provides launch vehicle technical services.

Launch Vehicle/Operations Engineering:

- Mission planning
- Mission integration
- Mission analyses
- Configuration management
- Design and design assessment
- Trajectory and performance analyses
- Aerodynamic analyses
- Thermal analyses
- Safety analysis
- Risk assessment
- Reliability analysis
- Flight and test data evaluation

Launch Vehicle/Operations Technical Services:

- Specifications preparation
- Interface requirements/control documents
- Procedures assurance/quality control
- Assembly
- Integration
- Test coordination
- Flight safety documentation (for expendable launch vehicles and Shuttle)
- Launch operations
- Cost estimating

Contact: Wayne H. Montag
Conatec, Inc.
5900 Princess Garden Parkway, Suite 105
Lanham, MD 20706
(301) 552-1088

Cost, Inc.

Cost, Inc. provides independent cost estimates and cost model development. These include proprietary space system cost models for instruments, spacecraft platforms/buses and mission integration. Models are based on many data points and include independent and objective resource analysis. Parametric models provide fast response.

Consulting services include:

- Cost estimation
- Cost model development
- Cost-engineering trades
- Cost-effectiveness analysis
- Design-to-cost analysis
- Program analyses
- Survey research
- Proposal preparation
- Budget preparation
- Cost analysis training

Contact: Don Strope, President
Cost, Inc.
10630 Little Patuxent Parkway, Suite 329
Columbia, MD 21044
(301) 997-0483

Creative Consulting for the Space Program

Creative Consulting offers a creative approach to technical and scientific information issues and projects.

Services Include:

- Strategic planning for information packages and programs
- Research studies on issues related to space policy, commercial space development, space sciences, technology and international commercial space activities
- Marketing communications – strategic planning and development
- Liaison/coordination – for NASA, industry and academia
- Publication management – form, design and content development; writing, editing and production for publications, reports and brochures
- Conference management and design

Contact: Paula Korn, Principal
Creative Consulting for the Space Program
490 M Street SW, W305
Washington, DC 20024
(202) 479-0025

Early Signals

Commercial Space Services Include:

- Strategic management
- Trend analysis
- Management training workshops
- Research on aerospace issues

Contact: Lena Lupica, President
Early Signals
214 9th Street, NE
Washington, DC 20002-6216
(202) 547-5751

The Egan Group

Commercial Space Services Include:

- Liaison/coordination
- Business planning
- Financial analysis/marketing
- Market study and analysis
- Policy formulation
- International activities

Contact: John J. Egan, President
The Egan Group
1701 K Street, NW, 12th Floor
Washington, DC 20006
(202) 775-0720, Fax (202) 293-1408

E'Prime Aerospace Corporation

Launch Vehicle Services:

- Launch vehicle selection and integration
- Operations planning
- Mission/orbit/trajectory analysis and reviews

Payload Services:

- Payload integration and spacecraft checkout
- Ground support equipment

Range Services:

- Range support planning and coordination
- Data reduction

Other Services:

- Payload/launch vehicle cost studies
- Site selection studies

Contact: E'Prime
P.O. Box 792
Titusville, FL 32781
(407) 269-0900

Futron Corporation

Futron is a diversified technology and management services company, supporting government and industry with a variety of services related to the planning, development and implementation of space flight systems. The professionals at Futron have extensive experience with the commercial space program and NASA's supporting infrastructure.

Space systems engineering and commercial development services include:

- Strategic and program planning
- Mission planning and development
- Technology cost assessments
- Systems engineering and integration
- Policy studies
- Project management training
- Organizational development

Contact: Joseph Fuller, Jr., President
Futron Corporation
7315 Wisconsin Avenue, Suite 400W
Bethesda, MD 20814-3202
(301) 657-7732

Geostar Corporation

The Geostar Corporation is a mobile satellite communications company which provides radiodetermination satellite service (RDSS), a position location and two-way messaging service. These services are provided primarily to mobile vehicles, such as trucks, aircraft and boats, but also can be used in fixed site applications as well. This service allows the headquarters of a fleet of vehicles to monitor the position of its fleet and to communicate with it. The system consists of vehicle-mounted equipment, satellite relays, a central ground station and terrestrial telecom links connecting Geostar to a customer's headquarters. It is being used for both commercial and governmental transportation needs.

Operational Characteristics

Ground station uplink frequency:	6 GHz
Ground station downlink frequency:	4.2 GHz
User uplink:	1610-1626.6 MHz
User downlink:	2483.5-2500 MHz
Information rate:	1.2 kb/sec
Modulation:	BPSK/Spread Spectrum
Spread Ratio:	30 dB
Message unit:	100 alphanumeric characters
Message time:	10-15 seconds

Contact: Geostar Corporation
1001 22nd Street, NW, Suite 500
Washington, DC 20037
(202) 887-0870

Gulton Data Systems

Gulton Data Systems provides space flight electronics including command decoding, data acquisition, timing systems, power conditioning and special processing. Available systems include both standard and custom designs for satellites, spacecraft, experiments and launch vehicles.

Gulton's engineering and manufacturing capabilities are available on a subcontract basis, including:

- Electrical design and analysis
- Mechanical design and analysis
- Redundant systems
- Radiation hard systems
- Electronic assembly
- Printed circuit board manufacture (MIL-P-55110)
- Machining
- Electronic parts testing and screening

Contact: Tim Turner, Director of Program Development, Gulton Data Systems
6600 Gulton Court, NE
Albuquerque, NM 87109
(505) 345-9031

Horizon Aerospace

Horizon Aerospace offers aerospace engineering and contract management services to NASA and prime contractors, with facilities in the immediate area of NASA's Johnson Space Center. Horizon capabilities cover program/project management, systems engineering and integration, flight and ground operations, simulations and training, and research and technology assessment. Horizon manages and conducts trade and analytical studies, and is expert at forming and leading teams and subcontractors to bring recognized expertise to bear on projects and programs.

Horizon's services include:

- Aerospace management services
- Systems engineering and integration
- Flight and ground operations
- Simulation and training
- Research and technology

In addition, Horizon provides computer system and software services, Computer Aided Logistics Systems (CALS), marketing services, visuals/graphics, and safety and quality assurance.

Contact: Neal Jackson
Horizon Aerospace
18333 Egret Bay Blvd., Suite 300
Houston, TX 77058
(713) 333-5944, Fax (713) 333-5949

Information Universe

Space Information Services include:

- Research capabilities
- Custom PC databases
- Information summaries and indexes
- PC information systems
- Editorial assistance for manuscripts and publications

Small and medium size companies that do not have library or information center staff will find these services very useful. Start-up companies also will find business and technical research services available. Indexes can be produced for a variety of publication types including book indexes, newsletters, magazines, document databases, reference databases and proceedings.

Contact: Linda Kenny-Sloan, President
Information Universe
300 Carlyle Ave.
Belleville, IL 62221
(618) 233-4659

Infospace, Inc.

Infospace provides marketing support, research and weekly and quarterly publications that provide insight into procurement opportunities and activities at NASA/Johnson Space Center.

Contact: Walter Salyer, President
Infospace, Inc.
P.O. Box 58564
1199 NASA Road One, Suite 210
Houston, TX 77258
(713) 480-8849

Integrated SpaceSystems

Integrated SpaceSystems specializes in manned space systems R&D and offers consulting services which include human factors engineering, crew quarters and habitat design and EVA/IVA operations analysis and planning. Our Model and Mockup Group specializes in the design and fabrication of high fidelity representations of aerospace technology, lunar surface topographic models, crew quarters and workstation mockups, and neutral buoyancy mockups. We also provide end-to-end planning and arrangements for spacesuited neutral buoyancy simulations.

Services include:

- Outfitting of spacecraft interiors
- Space human factors environmental design and engineering
- Space construction operations research and technology R&D
- Zero-G and partial-G anthropometric studies
- Manned space systems technology R&D
- EVA and IVA operations research and planning
- Design and fabrication of aerospace models and mockups
- Neutral buoyancy mockups/trainers and simulations

Contact: Andrew W. Daga, President
Integrated SpaceSystems
P.O. Box 156
Collegeville, PA 19426-2904
(215) 489-7282, Fax (215) 489-4766

International Technology Underwriters (INTEC)

Space and other space-related insurance coverage includes:

- Large and small ELV and Shuttle launch coverage
- Spacecraft initial operations coverage
- Spacecraft on-orbit life coverage
- DOT-required third-party liability and government property damage coverages
- NASA-required Shuttle third-party liability coverage
- NASA-required KC-135 flight program coverages

Contact: Peter M. Stark
Director, Advanced Space Programs
International Technology Underwriters
4800 Montgomery Lane, 11th Floor
Bethesda, MD 20814
(301) 654-8585, Fax (301) 654-7568

Interstel Inc.

Interstel Inc. provides Payload Integration and Engineering Support Services, including:

- Project plans and work breakdown structures
- Flight readiness verification plans and procedures
- Payload integration plans
- Instrument integration plans
- Interface control documents
- Flight ground safety data packages
- Interface requirements definition
- Ground operations and servicing requirements documents
- Configuration management
- Schedule and cost control
- Mechanical design and analysis

Contact: John Ralph, Program Manager
Interstel Inc.
9470 Annapolis Road Suite 401
Lanham MD 20706
(301) 459-7088, Fax (301) 459-1599

Johnson Engineering Corporation

Johnson Engineering Corporation provides Computer Illustrated Drawing (CID) software used to prepare the Crew Compartment Configuration Drawing (CCCD) for each Shuttle and Spacelab launch. All loose provisions stowed in the middeck or flight deck are listed in a bill of materials illustrated in three-dimensional pictorial views showing where they are stowed with callouts. The CAD workstation operator can create and update the drawings, DCN's and bill of materials using this CAD software and large database management system. User licenses and support services are available to commercial researchers needing to optimize the stowage of supplies in limited volumes. CID software can be used with VMS operating systems on DEC mini or microVAX computer equipment. Graphic terminals are either Megatek or Evans and Sutherland.

Habitability design services also are available, including studies and/or designs of crew cabins for people to live and work effectively in partial gravity environments. The technical approach is used to prepare concept sketches, color renderings, scale models and full-scale mockups until the design is mature. Trainers are provided for crew training in one-gravity, KC-135 aircraft and underwater neutral buoyancy. The habitability features usually include the general arrangement, workstations, sleep compartments, galley, personal hygiene, waste management, ward room, health maintenance equipment, exercise equipment, personal provisions, entertainment and stowage compartments. The same CAD software (named DASH) as above is used to optimize the stowage of loose crew provisions in stowage compartments.

Contact: Johnson Engineering Corporation
3055 Center Green Drive
Boulder, CO 80301-5406
(303) 449-8152

MARCOR

MARCOR is a multi-disciplinary space technology commercialization and applications firm specializing in analysis, planning and start-up financing of new space ventures. Clients include private firms (including aerospace firms) and government agencies.

MARCOR is pursuing new ventures in satellite communications, remote sensing and digital mapping. The company is working in the area of satellite sound broadcasting where it holds a 50% interest in the newly formed Satellite CD Radio, Inc., a company dedicated to flying the first commercial satellite dedicated to providing CD-Quality radio on a nationwide basis.

MARCOR services include:

- Market assessment and development
- Regulator analysis
- System design and project management
- Business plan development and financing
- Strategic planning

Contact: Martin Rothblatt, President
MARCOR
Techworld Plaza
800 K St. NW, Suite 750
Washington, DC 20001
(202) 408-0080, Fax (202) 408-0925

Netrologic, Inc.

Netrologic provides consulting and research on the application of neural networks to solving complex problems for government and industry. Projects for NASA mission management functions include neural networks trained on rocket engine data (Shuttle main engine) to perform engine health monitoring, RF measurements of cryogenic tanks to determine fuel mass and engine control valve time signatures to recognize faults and perform value identification.

Additional experience includes adaptive image compression on multi-spectral imagery (200 spectral bands); dynamic emitter recognition using neural networks; investigation of the application of genetic algorithms to specify topologies for neural networks from the parameters characterizing a problem; duplication of the performance of an air traffic controller (LAX TRACON); and development of an intelligent tutor for the Navy's sonar operators and image compression using Fractals and Group Representation Theory.

Contact: Dan Greenwood, President
Netrologic, Inc.
5080 Shoreham Place, Suite 201
San Diego, CA 92122
(619) 587-0970, Fax (619) 458-1624

Optical Research Institute, Inc.

Optical Research offers services in the design, construction, operation and consultation in and of advanced microgravity optical measurement systems, specializing in KC-135 low-gravity simulation measurements and experiments. Measurement techniques include Schlieren, shadowgraph, interferometric and holographic systems. Applications include space hardware development and basic research in microgravity processes.

Contact: Robert B. Owen, Chief Scientist
Optical Research Institute, Inc.,
P.O. Box 17382
Boulder, CO 80308-7382
(303) 441-9027

Precision Aerospace Marketing and Fabrication (PAMCO)

PAMCO, a division of Space Industries, Inc., provides state-of-the-art marketing and fabrication capabilities for spaceflight and prototype hardware.

Contact: Roger L. Pulley, Manager
PAMCO
12610 Old Galveston Road
Webster, TX 77598
(713) 488-4208

W.L. Pritchard & Co.

Planning, design and consulting services in satellite and telecommunications systems include:

- Systems design and engineering
- Economic analysis
- Market research
- Appraisals
- Demand forecasts
- Technology assessment
- Regulatory submissions

Contact: W.L. Pritchard
W. L. Pritchard & Co.
7315 Wisconsin Ave., Suite 520-E
Bethesda, MD 20814
(301) 907-7070

David L. Reed

Systems Engineering and Analysis services include:

- Space systems design and analysis
- Orbital mechanics
- Trajectory analysis
- Navigation location and analysis
- Missile dynamics

Contact: David L. Reed
14649 Stonewall Drive
Silver Spring, MD 20905
(301) 384-2419

Rizenthor

Rizenthor specializes in graphic design for the space industry. Workscope includes presentations, logos and symbolic representation of complex data, 35 mm photography using high color saturation techniques and backgrounds for home, office and laboratory environments.

Contact: Robert Anthony Foster
Rizenthor
721 North Alfred Street, Suite 108
Los Angeles, CA 90069
(213) 651-1024

SaraTech Finance, Inc.

A subsidiary of the Center for Space and Advanced Technology, SaraTech provides financial services and capitalization support to emerging growth ventures dedicated to the application of advanced technology.

Commercial Space Services include:

- Financing and capital sourcing
- Capital structure planning
- Business plan development
- Business valuation
- Organizational design
- Due diligence support

Contact: Jeff Struthers or Anne Renouf Headley
SaraTech Finance, Inc.
9302 Lee Highway, Suite 1200
Fairfax, VA 22031
(703) 385-1660

Satellite Mapping Corporation, Inc.

Satellite Mapping Corporation (SMC) specializes in the use of Landsat, SPOT and complementary data sources for a wide variety of geographic information products in both the domestic and international market. SMC has particular expertise in the use of commercially available, remotely sensed data for information collection and analysis in a wide variety of fields, from agricultural and urban development to military threat assessment and contingency planning. SMC provides not only studies and analyses of remote sensing data, but also develops custom-designed image analyses and mission rehearsal workstations to meet unique geographic database requirements.

Contact: Douglas N. Grize, President
Satellite Mapping Corporation, Inc.
8229 Boone Boulevard, Suite 800
Vienna, VA 22182
(703) 790-0893

W.J. Schafer Associates, Inc.

W.J. Schafer Associates, Inc. offers critical, decision-making information for making major commitments in the research, development and implementation of new technologies in defense, space, energy and the environment. The group's strong benefit is providing program managers with access to over 200 leading experts in a broad range of technical disciplines who provide an unequalled pool of talent to help manage and execute high technology programs. Key components of the firm's approach are concept development, technology assessment, systems analysis and programmatic support.

WJSA has tools to provide system and sub-system analysis to help clients meet performance and schedule requirements. These tools include modeling and simulation capabilities from small models to large, detailed Monte Carlo simulations, encompassing cost, risk, life cycle and schedule considerations. WJSA maintains a fully-equipped research laboratory where proof-of-principle experiments and hardware development activities are performed. Services also include verification of scientific concepts, investigation of technological potential, and design and construction of laboratory prototypes. WJSA has 14 offices nationwide.

Contact: Phil Mace
Director, New Business Development
W. J. Schafer Associates, Inc.
1901 North Ft. Myer Drive, Suite 800
Arlington, VA 22209
(703) 558-7900

Science Applications International Corporation (SAIC)

SAIC provides mission planning, science support, Systems Engineering & Integration, data management, sensor development, propulsion management, tracking, telemetry and command, and EVA/Servicing.

Contact: Ron G. Crawford
Manager, Space Programs
Science Applications International Corp.
1710 Goodridge Drive, Mail Stop 2-4-3
McLean, VA 22102
(703) 556-7019

Source Translation & Optimization (STO)

STO maintains a database of information on over 10,000 computer programs available to the public from the government. STO helps companies acquire and reuse software from various agencies, in particular, NASA, DOD and DOE. Software is available in Fortran, C and Ada for personal computers, workstations and mainframes.

Space technology related software available includes:

- Aeronautics
- Atmospheric
- Remote sensing
- Life support
- CAD/CAM/CAE
- Expert systems
- Propulsion
- Transportation
- Spacecraft and aircraft design
- Materials processing
- Fluid and structural mechanics

Contact: Gregory Aharonian
President
Source Translation & Optimization
P.O. Box 404
Belmont, MA 02178
(617) 489-3727

Space Business Research Center

Specializing in forecasts and issues management, Space Business Research Center presents seminars, workshops and conferences that are custom-tailored to the client's needs. The Center also provides:

- Primary, secondary and proprietary research
- Data services of analysis and interpretation
- Publications, including executive summaries and detailed industry and market reports
- Economic analysis and market forecasts

Contact: Space Business Research Center
University of Houston-Clear Lake
Houston, TX 77058-1090
(713) 283-3320, Fax (713) 283-3810

Space Industries, Inc.

Intelligent Systems provides consulting, software development, and basic research services to enhance the capabilities to access, manipulate and interpret information for aerospace and commercial applications. By applying extensive in-house expertise, understanding and insight into the problems and complications of space operations and logistics, Space Industries develops innovative approaches in areas such as:

- Decision support systems
- Scheduling systems
- Project management tools
- Expert systems
- Telescience applications
- Operations research
- Data acquisition, monitoring and control

In addition to development for space applications, Intelligent Systems also brings the high technology of space to the development of state-of-the-art approaches for customers with Earth-based uses.

Contact: Clifford R. Kurtzman, Ph.D.
Manager, Intelligent Systems
Space Industries, Inc.
711 W. Bay Area Blvd., Suite 320
Webster, TX 77598-4001

Spaceflight Insight Services

Consulting services include:

- Soviet space technology
- US/USSR interfacing
- Manned spaceflight operations
- Historical/archival data access
- Spaceflight and society issues
- Lecture programs

Contact: James Oberg
Route Two, Box 350
Dickinson, TX 77539
(713) 337-2838

Spire Corporation

Spire Corporation provides surface modification services for space materials including:

- Ion-assisted dielectric coating
- Beryllium and other metal coating
- Ion implantation
- Ion-assisted texturing

Applications:

- Ram oxygen protection
- Radiation resistance
- Optical baffles and mirrors
- Friction reduction and control
- Thermal control

Contact: Ward Halverson
Director/Thin Film Division (for space solar cells, contact Robert G. Wolfson)
Senior Vice President
Spire Corporation
Patriots Park
Bedford, MA 01730
(617) 275-6000

Technology Transfer Specialists, Inc.

Technology Transfer Specialists, Inc. processes commercial space information and creates paper (newsletters, brochures, manuals, tech notes, tech briefs, etc.) and paperless (linear videotape, computer-based training, computer simulation, computer-generated animation, laser video disc, interactive multimedia, etc.) mediums for transfer of commercial space information.

Contact: S. Carl Ahmed, CEO & President
Technology Transfer Specialists, Inc.
Highway A-1-A, Satellite Beach
P.O. Box 03-4075
Indialantic, FL, 32903-0975
(407) 777-6777

United States Aviation Underwriters, Inc.

Satellite and other space-related risks insurance coverage for owners, operators, users and manufacturers. Coverage areas include:

- Launch
- In-orbit
- Launch liability
- Products liability

Contact: C.T.W. Kunstadter, Senior Vice President
United States Aviation Underwriters, Inc.
One Seaport Plaza
199 Water Street
New York, NY 10038
(212) 952-0100, Fax (212) 747-0840

Walker Communications

International consulting in marketing and public relations for commercial space companies, ventures and products. Services include:

- Market research and analysis
- Marketing programs
- Public relations campaigns
- Media relations
- Article placement
- Press releases/newsletters
- Product introduction
- Special events and promotion

Contact: Pat Walker
Walker Communications
1150 Marina Village Parkway, Suite 104
Alameda, CA 94501-1043
(415) 865-5157, Fax (415) 386-8334

Wallwork-Warner

Wallwork-Warner provides commercial space, NASA and DOD space business development services including:

- Market entry strategy
- Program plans
- External environment/trends
- Strategic plans
- Proposal development
- Economic evaluation

Contact: David Wallwork, Partner
Wallwork-Warner
720 Creek Road
Downingtown, PA 19335
(215) 873-0669

Chapter 23: Government and Academia

In 1958, NASA was established as the primary agency for all civil research and development in space. Since then, with the emerging developments of commercialization, technology, disciplines and global change, there now are several federal and academic organizations that are active in, or supportive for, commercial activities in space. Many of these organizations offer technical assistance, equipment and facilities, technology transfer, policy and regulatory control, as appropriate.

This chapter surveys many of the various agencies, organizations and academic institutions that play an active role in the commercial development of space.

National Aeronautics and Space Administration (NASA)

Within NASA, the Office of Commercial Programs takes the lead role in developing and implementing programs that will stimulate and sustain U.S. commercial interest and investment in commercially oriented, space-related R&D activities. NASA has no responsibility or authority to regulate private commercial space activities. However, NASA does set the terms for all use of the Space Shuttle.

Whatever the market entity, private commercial customers must abide by NASA's rules and regulations regarding payment, scheduling, liability, insurance, safety and technical standards and policy. NASA also controls much of the equipment, technology and facilities that are important to the commercialization of space. NASA thereby dictates price, terms and conditions when making these available for use. The terms and conditions for sale and use of NASA-derived technology reflects official regulatory policy.

Opportunities to fly space experiments are arranged through the Office of Space Flight, where NASA has set aside flights on the Shuttle, expendable launch vehicles and sounding rockets to support private-sector research with the potential for commercial development. Shuttle flights are available primarily through Joint Endeavor Agreements and the Centers for the Commercial Development of Space. In an effort to stimulate and encourage the private sector to team with NASA for the purpose of commercial enterprise, its Office of Commercial Programs actively recruits researchers and entrepreneurs to participate in industry-government partnership agreements and industry-academic consortia.

The Commercial Programs Advisory Committee (CPAC) addresses critical policy issues and contributes in shaping NASA's commercial development strategic planning. In 1990, NASA Administrator Richard H. Truly established the Space Commerce Steering Group, to provide a high-level overview and coordinating mechanism for commercial applications of space technology throughout the Agency.

NASA Field Centers

NASA facilitates access to its resources, personnel and information through a representative contact for commercial space development in each of its eight field centers nationwide. The services available through these centers include information, transportation, payload processing and integration, program planning, experiment testing and equipment development.

Elizabeth A. Inadomi
Mail Code 223-3
NASA/Ames Research Center
Moffett Field, CA 94035
(415) 694-6472

Donald S. Friedman
Mail Code 702.0
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 286-6242

Mark Nolan
Mail Code EA-111
NASA/Johnson Space Center
Houston, TX 77058
(713) 283-5320

Robert L. Butterfield
Mail Stop PT-PMO-A
NASA/Kennedy Space Center
Kennedy Space Center, FL 32899
(407) 867-3017

Fred Allamby
Mail Stop 356
NASA/Langley Research Center
Hampton, VA 23665
(804) 864-3788

Harvey Schwartz
MS 3-17
NASA/Lewis Research Center
221000 Brookpark Road
Cleveland, OH 44135
(216) 433-2921

Kenneth Taylor
Mail Code PS05
NASA/Marshall Space Flight Center
Huntsville, AL 35812
(205) 544-0640

Chuck Hill
Mail Code HA31
Building 1100, Room 230
NASA/Stennis Space Center, MS 39529
(601) 688-2047

William T. Callaghan
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-0865

Centers for the Commercial Development of Space (CCDS's)

The Centers for the Commercial Development of Space (CCDS's) were initiated to stimulate high technology research which takes advantage of the characteristics of space; and to lead in the development of new products and services which have commercial potential or contribute to possible new commercial ventures. More than 175 U.S. firms are associated with the operating CCDS's as business incubator settings for new research. NASA funds initial start-up costs on a three-phase basis.

NASA presently sponsors sixteen CCDS's, which have grown as unique sources for partnerships in technology development, experiment design, business planning and basic research in seven discrete discipline areas. The centers represent consortia of university, industry and government involved in early research and testing stages of potentially viable products or services. A CCDS Management Operations Working Group serves as a coordinating body for collaborative efforts and program planning. (For an in-depth description of each CCDS, refer to Chapter 5.)

Ramesh Jain, Director
Space Automation and Robotics Center (SPARC)
P.O. Box 8618
Ann Arbor, MI 48107
(313) 994-1200 x2457

John Bollinger, Director
Wisconsin Center for Space Automation & Robotics (WCSAR)
University of Wisconsin/Madison
1357 University Ave.
Madison, WI 53715
(608) 262-5524

John Bossler, Director
Center for Mapping
Ohio State University
1216 Kinnear Road
Columbus, OH 43212
(614) 292-6642

Centers for the Commercial Development of Space (continued)

George May, Director
Space Remote Sensing Center
Bldg. 1103 - Suite 118
NASA/Stennis Space Center, MS 39529
(601) 688-2509

Marvin Luttges, Director
BioServe Space Technologies
University of Colorado/Boulder
Campus Box 429
Boulder, CO 80309
(303) 492-7613

Wesley Hymer, Director
Center for Cell Research (CCR)
Pennsylvania State University
204 S. Frear Laboratory
University Park, PA 16802
(814) 865-2407

Charles Bugg, Director
Center for Macromolecular Crystallography (CMC)
University of Alabama/Birmingham
THT-Box 79, University Station
Birmingham, AL 35294
(205) 934-5329

Frank Jelinek, Director
Advanced Materials Center/Battelle
505 King Ave.
Columbus, OH 43201
(614) 424-6376

William Wilcox, Director
Center for Commercial Crystal Growth in Space
Clarkson University
Old Main, Room 126
Potsdam, NY 13676
(315) 268-2336

Charles Lundquist, Director
Consortium for Materials Development in Space (CMDS)
University of Alabama/Huntsville
Research Institute Building
4701 University Drive
Huntsville, AL 35899
(205) 895-6620

Tony Overfelt, Director
Center for Space Processing of Engineering Materials
Vanderbilt University
Box 6309, Station B
Nashville, TN 37235
(615) 322-7054

Alex Ignatiev, Director
Space Vacuum Epitaxy Center (SVEC)
University of Houston
Science & Research Bldg. 1
4800 Calhoun Road
Houston, TX 77204
(713) 749-3701

Alton Patton, Director
Center for Space Power (CSP)
Wisenbaker Engineering Research Center
Room 223
Texas A&M University
College Station, TX 77843
(409) 845-8768

Raymond Askew, Director
Center for the Commercial Development of Space
Power & Advanced Electronics
Space Power Institute
Auburn University
231 Leach Center
Auburn, AL 36849
(205) 844-5894

George Garrison, Director
Center for Advanced Space Propulsion (CASP)
University of Tennessee Space Institute
UT-Calspan Center for Aerospace Research
P.O. Box 850
Tullahoma, TN 37388
(615) 454-9294

Eric Baer, Director
Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Ave.
Cleveland, OH 44106
(216) 368-4203

Small Business Innovation Research Program

The Small Business Innovation Research (SBIR) Program enhances the role of small businesses in meeting NASA's requirements for aerospace technology while stimulating innovation and commercialization in the private sector. In accordance with the Small Business Development Act of 1982, NASA allocates 1.5% of its R&D budget for SBIR. To participate, small businesses must be independently owned and organized for profit, be located principally in the U.S., be owned at least 51% by U.S. citizens or permanent resident aliens, and employ not more than 500 persons. Each year, NASA solicits proposals for innovations in selected technical areas. Highly rated proposals receive six-month, Phase I contracts for about $50,000. Successful projects can receive Phase II contracts with funding up to $500,000. Phase III, commercialization and end-use development of SBIR products, is funded by the private sector or other non-SBIR sources. The program is managed through the headquarters SBIR office and SBIR representatives at each of the NASA field centers.

Contact: SBIR Program Manager
NASA Headquarters/Code CR
Washington DC 20546

Technology Transfer and Utilization

By participating in a number of new cooperative ventures and implementing new initiatives, NASA's nationwide technology transfer network is growing, bringing NASA-developed and space-derived technologies to the public and private sectors, particularly for the development of new products, processes and services. With the addition of seven new affiliates, this network now extends into 40 states across the country. Spinoffs, in such diverse areas as transportation and medicine, have generated far-reaching social and economic benefits for the nation. NASA also supports strong technology utilization and application programs. These include:

- Field Center Technology Utilization officers, who manage center participants in regional technology utilization activities.
- Industrial Applications Centers (IAC's), which provide information retrieval services and assistance in applying technical information relevant to user needs.
- Industrial Applications Centers Affiliates, which are state-sponsored business or technical assistance centers, providing access to NASA's technology transfer network.
- Computer Software Management and Information Center (COSMIC), which offers government-developed computer programs adaptable to secondary use (see page 251).
- Technology Application Teams, which work with public agencies and private institutions in applying aerospace technology to solution of public problems.

Industrial Application Centers (IAC's)

F. Timothy Janis, Director
Aerospace Research Applications Center
Indianapolis Center for Advanced Research
611 N. Capitol Ave.
Indianapolis, IN 46204
(317) 262-5036

Dickie Deel, Director
Central Industrial Applications Center
Rural Enterprises, Inc.
P.O. Box 1335
Durant, OK 74702
(405) 924-6822

Paul A. McWilliams, Executive Director
NASA/Industrial Applications Center
823 William Pitt Union
Pittsburgh, PA 15260
(412) 648-7000

Radford G. King, Director
NASA/Industrial Applications Center
Research Annex, Room 200
University of Southern California/Los Angeles
3716 South Hope Street
Los Angeles, CA 90007
(213) 743-6132

Daniel Wilde, President
NERAC, Inc.
One Technology Drive
Tolland, CT 06084
(203) 872-7000

H. Lynne Reese, Director
Science and Technology Research Center
P.O. Box 12235
Research Triangle Park, NC 27709
(919) 549-0671

Stanley A. Morain, Director
Technology Applications Center
University of New Mexico
2808 Central, S.E.
Albuquerque, NM 87131
(505) 277-3622

Technology Transfer and Utilization (continued)

Industrial Application Centers (IAC's) (continued)

J. Ronald Thornton, Director
NASA/Southern Technology Applications Center
Progress Center, Box 24
One Progress Blvd.
Alachua, FL 32615
(904) 462-3913

William R. Strong, Director
NASA/UK Technology Applications Program
10 Kinkead Hall
University of Kentucky
Lexington, KY 40506
(606) 257-6322

John Hubbell, Director
NASA/SU Industrial Applications Center
Southern University
P.O. Box 9737
Baton Rouge, LA 70813-9737
(504) 771-4950

Aerospace Research Applications Center

The Aerospace Research Applications Center provides Technology Transfer Surveys (TTS), involving the engineering/scientific application of existing technology (knowledge). TTS's are useful to ascertain the potential viability of novel/proposed commercial space projects. A typical study requires 10-12 weeks.

Contact: F. Timothy Janis, Director
Aerospace Research Applications Center
Indianapolis Center for Advanced Research
611 N Capitol
Indianapolis, IN 46204
(317) 262-5036

NERAC, Inc.

NERAC, Inc. is a not-for-profit service working in cooperation with NASA to promote the dissemination and utilization of global technologies. NERAC's resources include two mainframe computers, over 120 major databases in all technical and scientific disciplines, a large staff of technical experts, document retrieval services and liaison to the 400+ Federal Laboratories.

Contact: Nan R. Cooper
Manager, Communications
NERAC, Inc.,
One Technology Drive,
Tolland, CT 06084
(203) 872-7000

Science and Technology Research Center (STRC)

The Science and Technology Research Center (STRC) provides scientific and technical information services and engineering assistance to industry and university research programs throughout the southeastern United States. Utilizing a large number of remote online and locally maintained machine-readable databases, the Center's basic objective is to help industry upgrade products and improve processes through the application of new technology documented in worldwide published and unpublished literature from governmental sources. There is broad coverage in all fields of the social sciences, science, technology, engineering and business.

Machine-readable copies of the Institute of Textile Technology File and World Textile Abstracts are maintained. The Center also has access to over 500 available microfiche of NASA's Scientific and Technical Aerospace Reports (STAR). Databases accessed online by STRC include those carried by DIALOG Information Services, Inc., BRS Information Technologies, U.S. National Library of Medicine, NASA/RECON and others. Search services available include retrospective searches, current awareness and standard interest profiles, supplemented by manual searching and the provision of complete documents or pertinent citations.

Additional activities include in-depth studies, reference and referral, seminars, workshops and conferences. As part of the NASA Industrial Applications Centers' Network, the Research Center receives support from NASA's Technology Utilization Division. The Center also is part of the North Carolina Department of Economic and Community Development.

Contact: Tony Pollard, Marketing Manager
Science and Technology Research Center
P.O. Box 12235
Research Triangle Park, NC 27709-2235
(919) 549-0671

Southern University Industrial Applications Center

Information Services and Technical Assistance includes:

- Literature searches
- Marketing research
- Technical activities
- Demographic trends
- Patent information
- Government procurement
- NASA technology

Contact: John Hubbell, Director
NASA/Southern University Industrial Applications Center
P.O. Box 9737
Baton Rouge, LA 70813-9737
(504) 771-4950

Department of Transportation

Space activities of the Department of Transportation (DOT) are focused in the Office of Commercial Space Transportation, established to foster the creation and growth of the expendable launch vehicle (ELV) industry, issue launch licenses and administer required mission and safety reviews. Authorized by the Commercial Space Launch Act of 1984, this office is mandated to license and regulate U.S. commercial space launch activities in a manner which protects both public safety and government interests, and to encourage the development of commercial launch capabilities. Toward this end, the Office of Commercial Space Transportation acts as a regulator and a service provider for launch operators.

This office also supports the Commercial Space Transportation Advisory Committee, which assisted in negotiating a Model Launch Range Agreement for commercial launches from Air Force ranges in 1987, and continues to oversee issues of concern for the development of the commercial launch services industry at large.

The Office of Commercial Space Transportation is committed to the development of an efficient, safe, low-cost space launch industry. Low cost and reliable access to space is the foundation on which many other commercial applications of space technology, such as microgravity research and remote sensing, are based. Among its many responsibilities, this office:

- Provides a single point of contact for companies acquiring launch vehicles for commercial purposes
- Serves as a government focal point for the commercial ELV industry
- Establishes a manifest for payloads and vehicles

Licensing

The Office of Commercial Space Transportation provides a variety of services to anyone seeking a license or DOT approval, which is required if offering commercial services that include:

- Preparation and launch of a commercial launch vehicle on an orbital or suborbital trajectory
- Placement of a payload into space aboard an American launched, non-U.S, government vehicle (except for communications and remote sensing payloads, which are covered by FCC and NOAA regulations, respectively)
- Operation of a commercial reentry vehicle
- Operation of a commercial launch site

Consultation

DOT encourages applicants to consult with the Licensing Programs Division at the earliest possible stage of planning for a launch to address issues for preparation, submission and review of applications. The applicant should obtain written summaries of current requirements, DOT's role in determining insurance requirements and license compliance monitoring.

Sponsorship

Companies wishing to use the facilities and services of government launch centers, such as the Air Force Western Space and Missile Center (Vandenberg, CA), may require sponsorship by another government agency to obtain access. DOT provides this service and will assist in establishing points of contact between the company and the government operator.

Insurance

Although usually associated with an actual launch license, DOT offers advance determinations of financial responsibility requirements, if requested, concerning third-party and government property insurance levels. This information may be helpful in planning for future launches, prior to submitting an application.

Contact: Associate Director for Program Affairs
U.S. Office of Commercial Space Transportation
400 Seventh Street SW
Washington DC 20590
(202) 366-5770

Department of Commerce

In 1987, the Secretary of Commerce established the Office of Space Commerce to work with governmental and international organizations in formulating policies to support commercial space development and coordinate the activities of other Department of Commerce (DOC) bureaus affecting space business. This office also conducts outreach activities to keep U.S. companies informed of new prospects in commercial space development, issues of international trade and commerce, and statistics concerning the world market in space industry services and products.

Through the National Oceanographic and Atmospheric Agency (NOAA), the Department of Commerce operates the weather satellite system and oversees LANDSAT operations, managed by the EOSAT Company.

The National Institute of Standards and Technology (NIST) is a resource to industry in areas such as robotics development, which ultimately will be essential to the success of space-based processing, construction and operations.

Other offices active in commercial space developments include the Patent and Trademark Office, the International Trade Administration and the National Telecommunications and Information Administration (NTIA).

Office of Space Commerce

The Office of Space Commerce is the principal unit for the coordination of space-related issues, programs and initiatives within DOC. In this capacity, it promotes private sector investment in space activities by collecting, analyzing and disseminating information on space markets, and by conducting workshops and seminars to increase awareness of commercial space opportunities. It also supports the Secretary of Commerce's Commercial Space Advisory Committee.

The office assists commercial space companies in their efforts to do business with the U.S. Government. It also acts as industry's advocate with the Executive Branch to ensure the government meets its space-related requirements to the fullest extent possible with commercially available goods and services; and works to prevent action that may preclude or deter the commercial sector from conducting those activities, except for reasons of national security or public safety.

The Office of Space Commerce promotes the export of space-related goods and services and represents DOC in the development of U.S. policies and in negotiations with foreign countries, to ensure free and fair trade on the international space market. It also seeks the removal of legal, policy and institutional impediments to space commerce.

While the Office of Space Commerce is not responsible for regulating commercial launch and service providers (as is DOT), or for funding technical research programs (as is NASA), it does, however, represent a full range of business interests in space. For example, the satellite, remote sensing and satellite navigation industries; as well as mobile communications, space-based facilities and the commercial microgravity industries; are addressed in their entirety by either NASA or DOT programs. However, non-technical concerns; such as financing, tort liability, procurement reform, antitrust protection and tax reform; all are critical to emerging space industries and are areas of concern to DOC.

National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) establishes and maintains national standards of measurement. It also provides measurement services consisting of Calibration Services, Standard Reference Materials and Standard Reference Data that assure traceability to national and international standards. And it provides fundamental physical, chemical, engineering and material data to support national goals in civil, national security and commercial space activities.

NIST supports a wide variety of aeronautical and space programs in areas such as high performance airframe and propulsion materials evaluation, satellite and ground-based antenna calibration, time standards, image analysis methods and hardware, robotics and telerobotics development, high performance computing and networking, data transmission security and calibration of sensors.

As part of its new responsibilities assigned by the Omnibus Trade Act of 1988, NIST is increasing its activities that support transfer of government-developed technology to U.S. industry, and is providing assistance to small business.

NIST's most recent activities include work in the areas of Space Programs Support, High Performance Aerospace Materials, Space Sciences Research, Atmospheric Sciences Research, and Commercial Space Development and Technology Transfer.

Department of Commerce (continued)

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) conducts research; gathers, stores and analyzes data about the oceans, atmosphere, space and sun; and applies this knowledge in environmental forecasting and enhancement of knowledge of environmental processes.

These functions are performed by NOAA's National Weather Service, National Ocean Service, National Marine Fisheries Services and Environmental Research Laboratories. The satellite data that is obtained and utilized originates from NOAA's own polar-orbiting (NOAA) and geostationary spacecraft (GOES), which are operated by the National Environmental Satellite, Data and Information Service (NESDIS), and from the satellites of other agencies or governments.

Satellite Data Services Division – A prime source of remote sensing data is available from the Satellite Data Services Division (SDSD) at the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA).

NOAA's Satellite Data Services Division is a unique source of information gathered by a series of Earth-watching spacecraft that began in 1960. The Division receives data (e.g., negatives, film loops, digital data on magnetic tape) for quality control and archiving which are readily accessible for retrospective use. Over 8 million separate images and 100,000 computer compatible tapes are now in archives.

Environmental data files at the Satellite Data Services Division contain imagery from the current polar orbiting (NOAA Series) and Geostationary Satellites (GOES). The Division also maintains magnetic tapes containing digital data from these satellites, representing an important source of information that can be used quantitatively in computerized research and analysis programs. Other satellite digital data has been acquired by the Defense Meteorological Satellite, SEASAT, and the NIMBUS-7 Coastal Zone Color Scanner.

Contact: Satellite Data Services Division
5627 Allentown Road, Room 100
Princeton Executive Center
Camp Springs, MD 20746
(301) 763-8402

National Telecommunications and Information Administration

The National Telecommunications and Information Administration (NTIA) is the principal communications adviser to the President. This DOC bureau develops and coordinates Executive Branch policy in telecommunications and information. NTIA also is responsible for managing the radio spectrum assigned for Federal use and provides technical assistance to other Federal agencies. NTIA plays an important role in helping to develop U.S. policy in space communications.

Information

For information pertaining to any of the above described offices or functions of the Department of Commerce, contact the following individuals:

Office of Space Commerce
Laura Ayers, Associate Director for Special Programs, (202) 377-8125

National Institute of Standards and Technology
Dick Franzen, Chief of the Public Affairs Division, (301) 975-2759

National Oceanic and Atmospheric Administration
Reed Boatwright, Director of the Office of Public Affairs, (202) 377-4190

National Telecommunications and Information Administration
Eileen B. Doherty, Director of Media Relations, (202) 377-1551

Department of Defense

The Department of Defense (DOD) contributes to the development of commercial space technology in such areas as low-cost, lightweight satellites, space robotics, sensors, communications technology and new-technology launch vehicles. Organizations such as the Defense Advanced Research Projects Agency (DARPA) and the Strategic Defense Initiative Organization (SDIO) have become key customers for several space products and services in which many new start-up businesses and small space companies have participated.

DOD exercises authority over and provides invaluable support to many private space ventures. Through the interagency review process, DOD comments on the national security aspects of proposed private space activities and sometimes public safety aspects. The U.S. Air Force controls and operates most of the government launch ranges. In addition, the Air Force is responsible for space traffic and monitoring through the NORAD/Space Command.

Strategic Defense Initiative Organization

Research sponsored by the Strategic Defense Initiative serves as a catalyst for spinoffs in many scientific and technical fields. Spinoffs have been developed successfully in areas such as computer technology, materials science, optics, medicine, sensor technology, energy and semiconductor research and development.

Acting under the direction of Congress and the President, SDIO established its Office of Technology Applications in 1986 to implement a program that makes SDI technology available to other Federal agencies, qualified U.S. corporations, small businesses, entrepreneurs, universities, and state and local governments. These technologies are being licensed for use in products and R&D efforts. For additional information, call (202) 693-1556.

SDIO also developed a Technology Applications Information System that uses voluntary scientific and technical specialists from universities, national laboratories, private research institutes, corporations and professional associations throughout the country to help identify potential spinoffs of SDI technology. For additional information, call (202) 693-1563.

Other Space Activities

DOD's primary activity in space involves its military communications satellite capabilities, which are provided by several satellite systems, each tailored to a specific set of requirements. These systems include the Fleet Satellite Communications System (FLTSATCOM), Air Force Satellite Communications (AFTSATCOM), Defense Satellite Communications System (DSCS), Milstar Satellites and Satellite Laser Communications (SLC) System.

DOD also has programs in navigation and geodesy, notably the Global Positioning System (GPS); meteorology and oceanography; and surveillance and warning systems.

Department of Energy

The Department of Energy (DOE) is responsible for the oversight of several major multiprogram and single program research laboratories. These labs, commonly known as the National Laboratories, engage in ongoing research work for DOE and also represent valuable, often unique, resources for university and commercial developers in many important research fields. It is the policy of the DOE to make its laboratories and facilities available to qualified scientists who can make the best use of these capabilities.

The activities of the National Labs and the cooperation between foreign governments and their industries provide additional examples of government-industry cooperation. A number of the U.S. Labs that conduct research in many of the high-technology areas are owned by the government and operated by the private sector. Beginning in the 1980s, the labs have been placing more emphasis on the importance of technology transfer to the private sector. Some labs, such as Oak Ridge in Tennessee, have technology transfer departments which assist in the commercialization of technologies developed at the lab by offering businesses licensing agreements. In some instances, businesses with successful products must give some of their profits to the laboratories.

Department of Energy (continued)

Department of Energy – National Labs

Ames Laboratory
Iowa State University
Ames, Iowa 50011
(515) 294-2770

Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
(312) 972-5555

Bates Linear Accelerator Facility
Massachusetts Institute of Technology
P.O. Box 95
Middleton, MA 01949

Brookhaven National Laboratory
Upton, Long Island, NY 11973
(516) 282-3000

Component Development Integration Facility
P.O. Box 3767
Butte, MT 59702
(406) 494-7313

Energy Technology Engineering Center
P.O. Box 1449
Canoga Park, CA 93104
(213) 700-5326

Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, IL 60510
(312) 840-3000

Geothermal Test Facility
c/o WESTEC Services, Inc.
P.O. Box 791
Holtville, CA 92250

Grand Junction Facility
Grand Junction Area Office
P.O. Box 2567
Grand Junction, CO 81502
(303) 242-8621

Idaho National Engineering Laboratory
Idaho Falls, ID 83401
(208) 526-0111

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
(415) 486-4000

Los Alamos National Laboratory
University of California
P.O. Box 1663
Los Alamos, NM 87545
(505) 667-5061

Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830
(615) 576-5454

Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 375-2559

Sandia National Laboratories
Albuquerque, NM 87185
(505) 844-5678

Sandia National Laboratories
P.O.Box 969
Livermore, CA 94550
(415) 422-7011

Savannah River Laboratory
Aiken, SC 29801
(803) 725-2277

Savannah River Laboratory
Drawer E
Aiken, SC 29801
(803) 725-2472

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
(303) 231-7115

Stanford Linear Accelerator Center
Stanford University
P.O. Box 4349
Stanford, CA 94305
(415) 854-3300

Other Organizations

The government's role in nurturing an environment that will encourage U.S. private sector participation and investment in space includes creating opportunities through the development of new technology, infrastructure and favorable policies while concurrently minimizing bureaucratic obstacles; informing the public of opportunities, technology and policies; and stimulating private-sector investments by reducing business capital requirements and reducing both real and perceived risks.

In addition to the government agencies previously discussed in this section, the following organizations and entries also are involved in the commercial development of space.

COSMIC

COSMIC is the NASA/Computer Software Management and Information Center, a central office established to distribute software developed with NASA funding. Since its beginning in 1966, COSMIC has been operated by The University of Georgia.

COSMIC's role as part of the NASA Technology Transfer Network is to ensure that industry, other government agencies and academic institutions have access to the advanced computer software technology produced for NASA projects. COSMIC publishes an annual Software Catalog containing over 1100 computer programs available for use within the United States. An international catalog is published also. In addition to the annual catalogs, brochures and collections of program abstracts are available, covering specific subject areas:

- Artificial intelligence and expert systems
- CAD/CAM
- Composites
- Computational fluid dynamics
- Control systems and robotics
- DEC VAX Utilities
- Finite element analysis
- Heat transfer and fluid flow
- Image processing
- IBM mainframe utilities
- Microcomputers
- Optics and lens design
- Project management
- Reliability
- Satellite/communication
- Scientific visualization
- Trajectories and orbital mechanics
- Turbine engineering
- UNIX utilities

Program source code is provided to permit modification or enhancement for particular applications. The program documentation is sold separately to allow for the review of program capabilities in detail before an expensive purchase decision is made. Ongoing development of NASA software provides new programs for the COSMIC inventory throughout the year. The COSMIC Customer Support Staff offers information about recent additions or programs in progress.

Contact: Customer Support, COSMIC
University of Georgia
382 East Broad St.
Athens, GA 30602
(404) 542-3265, Fax (404) 542-4807

Federal Communications Commission

Satellite communications has been the most profitable and thriving space business for more than 25 years. The Federal Communications Commission (FCC) is responsible for assigning appropriate frequencies and orbital slots for satellite communications from the international agreements reached under the auspices of the International Telecommunication Union, and for issuing individual licenses for the construction and operation of each satellite. FCC review and approval has been the only significant regulatory restraint on the burgeoning space communications business.

Every space endeavor requires the use of radio frequencies at some point. For example, FCC approval is required for licensing a radio operator to control an object or payload in space and for assigning the necessary radio frequencies for a particular mission, such as data transmission to Earth for a remote sensing system.

NASA/Space Engineering Research Center for Very Large Scale Integration System (VLSI) Design

The objective of this center is to design high performance VLSI processors for space applications. Processors already designed or in the final design cycle include:

- High performance Reed Solomon CCSDS (Consultative Committee for Space Data Systems) chip(s) that perform in excess of 1 billion operations per second at data rates of 80 Mbits/second
- Space Qualified Reed Solomon encoder chip for CCSDS standard that operates at 200 Mbits/second
- Image compression/decompression chip set that operates at 10 Msamples/second
- Automatic centroid calculator for wide-angle field of view camera

The Center features a team of professional full-custom VSLI engineers capable of military and commercial quality design.

Contact: Gary K. Maki, Director
NASA/Space Engineering Research Center for VLSI Systems Design
Electrical Engineering Department
University of Idaho
Moscow, ID 83843
(208) 885-6500

National Space Council

The National Space Council, chaired by the Vice President, was created by the Congress to help the President in developing a National Space Policy and strategy and to monitor its implementation. One of the key goals of the Space Policy includes encouraging a self-sustaining, market-driven commercial space sector which will generate significant economic benefits for the nation, as well as supporting the government space sectors with an expanding range of goods and services.

The National Space Council coordinates several major interagency reviews to ensure that the National Space Policy is being implemented as effectively as possible. One of these reviews included a major assessment of commercial space policy in 1990. This effort reflected the President's commitment to exploring how the private and public sectors can best work together so that our space program uses its national assets in the most cost-effective way possible.

Contact: Courtney A. Stadd
Senior Director, Commercial Space
National Space Council
The White House
Washington, DC 20500
(202) 395-6175

State Organizations

A number of state governments are organizing to develop space business programs, facilities and industrial capabilities. Examples of interest include the following activities:

- Florida and Hawaii have active space development programs for establishing commercial spaceports and supporting related industry developments.
- Virginia's Center for Innovative Technology attracts and develops high-technology industry and incubator programs, among them, several space-related initiatives, and an effort to develop a commercial launch site at Wallops Island also is underway.
- West Virginia is engaged in attracting space industry by establishing research parks that offer special incentives to space industry.
- Texas has an active program to encourage private-sector research in fields such as space medical technology.
- Utah, Illinois, Colorado, California, Alabama, Ohio, New Mexico, Louisiana and Mississippi also are initiating commercial space activities at a state government level.

State Space Program Contacts

Alabama
Harry Atkins, Special Asst. for Aerospace Development
Department of Economic and Community Affairs
3465 Norman Bridge Road
P.O. Box 25034
Montgomery, AL 36125
(205) 284-8952

California
Thomas Walters
California Department of Commerce
Office of Innovative Technology
1121 L Street, Suite 600
Sacramento, CA 95814
(916) 322-1394

Colorado
John Darrah
Commission of Space Science and Industry
Air Force Space Command/CN
Peterson Air Force Base, CO 80914
(719) 554-3497

Florida
Edward O'Connor, Executive Director
Spaceport Florida Authority
150 Cocoa Isles Boulevard, Suite 401
Cocoa Beach, FL 32931
(407) 868-6983, Fax (407) 868-6987

Hawaii
George Mead, Executive Director
Office of Space Industry
Hawaii Space Development Authority
P.O. Box 2359
Honolulu, HI 96804
(808) 548-3451, Fax (808) 548-8156

New Mexico
Burton H. Lee, Consultant
Commercial Space Programs
Physical Science Laboratory
New Mexico State University
P.O. Box 30002
Las Cruces, NM 88003
(505) 522-9323, Fax (505) 522-9389

Ohio
Michael Salkind
Ohio Aerospace Institute
2001 Aerospace Parkway
Brook Park, OH 44142
(216) 891-2100, Fax (216) 891-2140

Texas
Oran W. Nicks
Texas Space Commission
223 WERC
Texas A&M University
College Station, TX 77843-3118
(409) 845-5293, Fax (409) 847-8857

Utah
Lt. Governor Val Oveson
State Capitol
Salt Lake City, UT 84114
(801) 538-1520

Virginia
Stephen L. Morgan, Director
Space Industry Development
Center for Innovative Technology
CIT Tower, Suite 600
2214 Rock Hill Road
Herndon, VA 22070
(703) 689-3024, Fax (703) 689-3041

West Virginia
Susan Shemenko
State Capitol Complex
Building 5, Room A-109
Charlestown, VA 25305
(304) 348-0444

Aerospace States Association (ASA)

The Aerospace States Association (ASA) is an organization that brings together representatives from states with interests in furthering their participation in the commercial space community. One of its central purposes is to ensure that states' interests are represented in the federal policy development process. The organization is being coordinated by Virginia's Center for Innovative Technology.

Contact: Stephen Morgan
Center for Innovative Technology
CIT Building, Suite 600
2214 Rock Hill Road
Herndon, VA 22070
(703) 689-3024, Fax (703) 689-3041

Section Eight: Information Sources

In addition to commercial services and products, agencies of the government and academic organizations, the commercial developer is referred to publications, directories and membership groups that also may serve as support sources. This section offers a sampling of these sources.

Chapter 24: Publications

The commercial space developer may keep advised of the latest information in the field by reviewing any of the following suggested publications on a daily, weekly, monthly or quarterly basis. All of these documents may be obtained on a subscription basis or may be found in libraries.

This chapter also includes a brief listing of recent reports and studies pertinent to issues concerning remote sensing, space commerce and ventures, space transportation systems, spacecraft servicing, legal policies and intellectual property.

Ad Astra (monthly)
Palmer Publications, Inc.
P.O. Box 296, 318 N. Main Street
Amherst, WI 54406
(715) 824-3214

Aerospace America (monthly)
American Institute of Aeronautics and Astronautics
370 L'Enfant Promenade SW
Washington, DC 20024
(202) 646-7471

Aerospace Daily (daily)
World Aviation
1156 15th Street NW
Washington, DC 20005
(202) 822-4600

Aviation Week and Space Technology (weekly)
McGraw-Hill Publications
1221 Avenue of the Americas
New York, NY 10020
(212) 512-2000

Commercial Space Developments (quarterly)
NASA/Office of Commercial Programs
NASA Headquarters/Code CC
Washington, DC 20546
(703) 557-4640

SPACE (bimonthly)
The Shephard Press Ltd.
111 High Street
Burnham, Bucks SL1 7JZ, England

Space Business News (biweekly)
Pasha Publications, Inc.
1401 N. Wilson Blvd., Suite 900
Arlington, VA 22209
(703) 528-1244

Space Calendar, (weekly)
75-5751 Kuakini Highway, Suite 209
Kailua-Kona, HI 96740
(808) 326-2014

Space Commerce (quarterly)
Harwood Academic Publishers GmbH
c/o STBS Ltd., P.O. Box 197
London, WC2E 9PX, England

Space Markets (bimonthly)
Interavia SA
20 route de Pre-Bois
P.O. Box 636
CH-1215, Geneva 15, Switzerland

Space News (weekly)
6883 Commercial Drive
Springfield, VA 22159
(703) 750-2000

Space Policy (quarterly)
Butterworth Scientific Ltd.
P.O. Box 63
Westbury House, Bury Street
Guildford, Surrey GU2 5BH, England

Space Station News (weekly)
1850 M Street NW
Washington, DC 20036
(202) 429-1888

The following reports on commercial applications of remote sensing are available from the NASA/Stennis Space Center. Call (601) 688-2042.

- *Commercial Earth Observation Payload Integration Into the Shuttle Orbiter Middeck*, LESC-27840
- *A Description of the Regulatory Process to Launch a Commercial Earth Observation Satellite on a Commercial Launch Vehicle*, LESC-27841
  – Volume I: Department of Transportation and National Launch Range Regulations
  – Volume II: Department of Commerce Regulations
- *Lightsat Technology Status Report*, LESC-28032
- *Planning For Large Format Camera Reflight Options*, LESC-27563
- *Payload Workstation Requirements Second Survey Results and Analysis*

The following reports on commercial space activities were published by the U.S. Office of Space Commerce, Department of Commerce.
Call (202) 377-8125.

- *COMMERCIAL SPACE VENTURES: A Financial Perspective* (1990)
- *SPACE COMMERCE: An Industry Assessment* (1988)

The following reports on space transportation systems and spacecraft alternatives are available from the U.S. Office of Technology Assessment. Call U.S. Government Printing Office, (202) 783-3238.

- *AFFORDABLE SPACECRAFT: Design & Launch Alternatives - Background Paper* (1990), GPO Stock #052-003-01174-3
- *ACCESS TO SPACE: The Future of U.S. Space Transportation Systems* (1990), GPO Stock #052-003-01177-8
- *ROUND TRIP TO ORBIT: Human Spaceflight Alternatives* (1989), GPO Stock #052-003-01155-7
- *REDUCING LAUNCH OPERATIONS COSTS: New Technologies and Practices* (1988), GPO Stock #052-003-01118-2
- *LAUNCH OPTIONS FOR THE FUTURE: A Buyer's Guide* (1988), GPO Stock #052-003-01117-4

The following reports were published by the National Legal Center. Call (202) 296-1683.

- *AMERICA ENTERPRISE, THE LAW, AND THE COMMERCIAL USE OF SPACE* (three volumes)
  - Vol. 1, An Analysis of Treaties, Legislation, Regulation and the Political Scenario (1986)
  - Vol. 2, Remote Sensing and Telecommunications: How Free? How Regulated? (1986)
  - Vol. 3, Jurisdiction, Tort Law, Intellectual Property, Communications, Taxation, Patents and Insurance (1987)

- *PROTECTING SCIENTIFIC IDEAS AND INVENTIONS* (1988), by R.D. Flotz and T.A. Penn. CRC Press, 2000 Corporation Blvd., Boca Raton, FL 33431

- *DISCOVER THE VALUE* (1990), a documentary about the Centers for the Commercial Development of Space, produced on videotape by NASA/Kennedy Space Center. Call (407) 867-3374.

This publication features information, guidelines and recommendations for designing spacecraft payloads and equipment for manual servicing (extravehicular activity (EVA) astronauts) and telerobotic servicing (remote manipulators). Contact Janice Nyman, ERIM, Space Automation and Robotics Center (SpARC), P.O. Box 8618, Ann Arbor, MI 48107-8618, (313) 994-1200, ext. 2469.

- *DESIGN FOR ON-ORBIT SPACECRAFT SERVICING, DFOSS Handbook* (1990)

This report is available from the Office of Commercial Space Transportation, Licensing Programs Division. Call (202) 366-5770.

- *HAZARD ANALYSIS OF COMMERCIAL SPACE TRANSPORTATION* (1988) (three volumes)
  - Vol. 1, Operations
  - Vol. 2, Hazards
  - Vol. 3, Risk Analysis

This report is available from the Center for Innovative Technology (CIT). Call (703) 689-3024.

- *AN ASSESSMENT OF POTENTIAL MARKETS FOR SMALL SATELLITES* (1989)

Chapter 25: Directories and Catalogues

Several organizations and businesses in the United States and Europe regularly issue catalogues and directories that may be used as references for a broad range of information that may be of interest to commercial space developers. What follows is a partial listing of these resource materials, which may be purchased or received upon request.

Accessing Space: A Catalogue of Process, Equipment and Resources for Commercial Users (biannual)
NASA/Office of Commercial Programs
NASA Headquarters/Code CC
Washington DC 20546
(703) 557-4626

European Space Directory (annual)
Sevig Press Publishing Company
331 W. Wilson Ave., Suite 101
Glendale, CA 91203
(818) 500-1930

Interavia Space Directory (annual)
Jane's Information Group
Department DSM
1340 Braddock Place, Suite 300
Alexandria, VA 22314

The International Space Directory (annual)
The Shephard Press Ltd.
111 High Street
Burnham, Buckinghamshire SL1 7JZ, England

The PROSPACE Catalog (4 volumes)
Prospace
2, place Maurice Quentin
75039 Paris cedex 01, France
– Vol. 1, Prospace Members
– Vol. 2, Onboard Equipment
– Vol. 3, Ground Equipment
– Vol. 4, Services

The Soviet Year in Space (annual)
Teledyne Brown Engineering
Colorado Springs Office
1250 Academy Park Loop, Suite 240
Colorado Springs, CO 80910
(303) 574-7270

Space Technology International (annual)
Cornhill Publications Ltd.
4-7 Nottingham Court
Short's Gardens
London WC2H 9AY, England

World Space Industry Survey (annual)
Euroconsult
71, bd Richard-Lenoir
F-75011 Paris, France

Chapter 26: Organizations

The number of active professional and advocacy membership organizations continues to grow and to expand in focus as space development activity moves through disciplines, regions and industries. This chapter includes a partial listing of such organizations and programs.

Aerospace Industries Association (AIA)
1250 Eye Street NW
Washington, DC 20005
(202) 371-8400

Aerospace States Association
c/o Center for Innovative Technology
CIT Building, Suite 600
2214 Rock Hill Road
Herndon, VA 22070
(703) 689-3024

American Astronautical Society (AAS)
6352 Rolling Mill Place, Suite 102
Springfield, VA 22152
(703) 886-0020

American Institute of Aeronautics and Astronautics
370 L'Enfant Promenade SW
Washington DC 20024
(202) 646-7400

Association of Space Explorers, ASE-USA
3263 Sacramento Street
San Francisco, CA
(415) 931-0585

California Space Grant Consortium
Code B-017
University of California/San Diego
La Jolla, CA 92093
(619) 534-7441

California Space Institute
CalSpace A-021
University of California/San Diego
La Jolla, CA 92093
(619) 534-2908

Center for Space and Geosciences Policy
Campus Box 361
University of Colorado/Boulder
Boulder, CO 80309
(303) 492-1171

Center for Innovative Technology (CIT)
CIT Tower, Suite 600
2214 Rock Hill Road
Herndon, VA 22070
(703) 689-3000

Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, GA 30332
(404) 894-3530

The Geosat Committee, Inc.
601 Elm Street, Room 438C
Norman, OK 73019
(405) 325-3329

Institute for Security and Cooperation in Outer Space
1336A Corcoran Street NW
Washington, DC 20009
(202) 462-8886

International Hypersonic Research Institute
University of Central Florida
Political Science Dept.
P.O. Box 25000
Orlando, FL 32816
(407)366-1764

International Space University
955 Massachusetts Avenue
Cambridge, MA 02139,
(617) 354-1987

International Space Year Association (US-ISY)
600 Maryland Ave. SW
Washington, DC 20024
(202) 863-1734

Lunar and Planetary Institute
3303 NASA Road One
Houston, TX 77098
(713) 486-2196

National Space Club
655 15th Street NW
Washington, DC 20005
(202) 639-4210

National Space Society (NSS)
922 Pennsylvania Ave. SE
Washington, DC 20024
(202) 543-1900

The Planetary Society
65 N. Catalina Ave.
Pasadena, CA 91106
(818) 793-5100

The Space Foundation
P.O. Box 27017
Washington, DC 20038
(202) 347-2414

Space Studies Institute (SSI)
P.O. Box 82
Princeton, NJ 08540
(609) 921-0377

Spaceweek National Headquarters
P.O. Box 58172
Houston TX 77258
(713) 480-0007

Universities Space Research Association (USRA)
600 Maryland Ave. SW
Washington, DC 20024
(202) 547-2506

U.S. Space Foundation
P.O. Box 1838
Colorado Springs, CO 80916
(719) 550-1000

Woman in Aerospace (WIA)
6352 Rolling Mill Place, Suite 102
Springfield, VA 22152
(703) 886-0020

World Space Foundation (WSF)
P.O. Box Y
S. Pasadena, CA 91030
(818) 357-2878

Appendix

Included in this section is a cross-referenced index to all entries in this catalogue, a listing of commonly used acronyms and a page for submissions to the next edition of **Accessing Space** (planned for 1992). In addition to updated and new information, the editors and publishers of this document appreciate and welcome all comments and suggestions.

Acronyms

As with many populations of profession and discipline, the space community is renowned for its capacity to create acronyms at every opportunity. The following listing was compiled explicitly with the commercial space developer in mind, in an effort to translate some of the "alphabet soup" into meaningful language.

ac	Alternating current
A&I	Assembly and Installation
ACS	Attitude Control System
AFD	Aft Flight Deck
ALS	Advanced Launch System
AO	Announcement of Opportunity
APC	Autonomous Payload Controller
ARC	Ames Research Center
AR/IRR	Acceptance Review/Integration Readiness Review
ARS	Air Revitalization System
CCAFS	Cape Canaveral Air Force Station
CCAP	Commercial Development Payload
CCDS	Center for the Commercial Development of Space
CCTV	Closed Circuit Television
CDMS	Command and Data Management Subsystem
CDR	Critical Design Review
CDSF	Commercially Developed Space Facility
CELSS	Closed Environmental Life Support System
CERV	Crew Emergency Return Vehicle
CIFS	Critical Initial Flaw Size
cm	Centimeter
CMC	Center for Macromolecular Crystallography
CMD	Command
COMET	COMmercial Experiment Transporter Program
cont	Continuous
CPAC	Commercial Programs Advisory Committee
CRT	Cathode Ray Tube
cu^3	Cubic meters
DARPA	Defense Advanced Research Project Agency
dc	Direct current
DDL	Dedicated Discipline Laboratory
DDS	Data Display System
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DOMSAT	Domestic Satellite
DR	Double Rack
EAC	Experiment Apparatus Container
EC	Experiment Computer
ECAS	Experiment Computer Application Software
ECE	Experiment Checkout Equipment
ECIO	Experiment Computer I/O
ECOS	Experiment Computer Operating System
ECS	Environment Control System
EGF	Electrical Grapple Fixture
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMP	Enhanced MDM Pallet
EOCAP	Earth Observations Commercialization Applications Program
EOS	Electrophoresis Operations in Space
EPSP	Experiment Power Switching Panel
ERD	Experiment Requirements Document

PRECEDING PAGE BLANK NOT FILMED

ESMC	Eastern Space and Missile Center
ETR	Experiment Tape Recorder
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FEO	Flight Experiment Opportunity
FDD	Flight Definition Document
FM	Frequency Modulation
FMDM	Flexible Multiplexer/Demultiplexer
FO	Functional Objective
ft	Feet
ft^2	Square feet
ft^3	Cubic feet
fwd	Forward
g	Acceleration due to gravity
GAS	Get-Away-Special
GBA	GAS Bride Assembly
GBS	GAS Bridge System
Gbyte	Gigabyte
GIRD	Ground Integration Requirements Document
GMT	Greenwich Mean Time
GN&C	Guidance, Navigation and Control
GPC	General Purpose Computer
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
H	Height
HDRR	High Data Rate Recorder
HH-G	Hitchhiker-G
HH-M	Hitchhiker-M
HRM	High Rate Multiplexer
IAC	Industrial Applications Center
ICD	Interface Control Document
IECM	Induced Environment Contamination Monitor
IGI	Industrial Guest Investigator
IIA	Instrument Interface Agreement
IMU	Inertial Measurement Unit
In	Inch
I/O	Input/Output
IPL	Integrated Payload
IPMP	Investigations into Polymer Membrane Processing
IPOTP	Integrated Payload Operations Training Plan
IPRD	Integrated Payload Requirements Document
IPS	Instrument Pointing Subsystem
ISF	Industrial Space Facility
IVA	Intravehicular Activity
IWG	Investigator Working Group
JEA	Joint Endeavor Agreement
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
kbps	Kilobits per second
kbytes	Kilobytes
kg	Kilogram
kHz	Kilohertz
KSC	Kennedy Space Center
KuSP	Ku-Band Signal Processor
kW	KiloWatt
L	Length
LaRC	Langley Research Center
lbs	Pounds
LDEF	Long Duration Exposure Facility
LeRC	Lewis Research Center
liq.	Liquid
LOX	Liquid oxygen
LM	Long Module
LSA	Launch Services Agreement
LTA	Linear Tri-Axial Accelerometer
m	Meter
m^2	Square meters
MAR	Middeck Accommodations Rack
max	Maximum
Mbps	Megabits per second
Mbytes	Megabytes
MC	Modular Container
MCC	Mission Control Center

MCDS	Multifunctional CRT Display System
MD	Middeck
MDL	Middeck Locker
MDM	Multiplexer/Demultiplexer
MET	Mission Elapsed Time
MFCC	Missile Flight Control Center
MHz	MegaHertz
min	Minimum
MIUL	Materials Identification and Usage List
mm	Millimeter
MMSL	Microgravity Materials Science Laboratory
MMU	Manned Maneuvering Unit (or Mass Memory Unit)
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPE	Mission Peculiar Equipment
MPESS	Multi-Purpose Experiment Support Structure
MSFC	Marshall Space Flight Center
MSL	Materials Science Laboratory
MTU	Master Timing Unit
MUA	Materials Usage Agreement
N/A	Non Applicable
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASP	National Aerospace Place
NRT	Near real time
NSP	Network Signal Processor
O&C	Operations and Checkout
O&IA	Operations and Integration Agreement
OCP	Office of Commercial Programs (NASA)
OCST	Office of Commercial Space Transportation
OFT	Orbital Flight Test
OPF	Orbital Processing Facility
OR	Operational Recorder
OSTP	Office of Science and Advanced Technology
OTA	Office of Technology Assessment
PATH	Postflight Attitude and Trajectory History
PCB	Power Control Box
PCG	Protein Crystal Growth
PCMMU	Pulse Code Modulation Master Unit
PDI	Payload Data Interleaver
PDP	Plasma Diagnostic Package
PDR	Preliminary Design Review
PED	Payload Element Developer
PI	Payload Interrogator (or Principal Investigator)
PIP	Payload Integration Plan
PMM	Payload Mission Manager
POCC	Payload Operations Control Center
POD	Payload Operation Director
PR	Payload Recorder
PRR	Preliminary Requirements Review
PSP	Payload Signal Processor
PTO	(U.S.) Patent and Trade Office
RAU	Remote Acquisition Unit
R&D	Research and Development
REM	Release and Engage Mechanism
RF	Radio frequency
RFP	Request for Proposal
RMS	Remote Manipulator System
SAL	Scientific Airlock
SANC	Spacelab Ancillary Data Tape
SC	Subsystem Computer
SCU	Systems Control Unit
SDIO	Strategic Defense Initiative Organization
SDMU	Serial Data Management Unit
sec	Second
SEDT	Spacelab Experiment Data Tape
SFMDM	Smart FMDM
SFSS	Spartan Flight Support Structure
SIDT	Spacelab I/O Data Tape
SII	Space Industries Incorporated
SL	Spacelab
SLDPF	Spacelab Data Processing Facility

SLLM	Spacelab Long Module
SLS	Space Life Sciences
SLSM	Spacelab Short Module
SM	Short Module
SMCH	Standard Mixed Cargo Harness
SMIDEX	Spacelab Middeck Experiment
SPAH	Spacelab Payload Accommodations Handbook
SR	Single Rack
SRM	Solid Rocket Motor
SS	Space Station
SSC	Stennis Space Center
SSDA	Space Systems Development Agreement
SSP	Standard Switch Panel
STEP	Space Technology Experiments Platform
STS	Space Transportation System
SWAA	Spacelab Window Adapter Assembly
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TEA	Technical Exchange Agreement
TLM	Telemetry
USL	United States Laboratory
V	Volt
VAA	Viewport Adapter Assembly
VAFB	Vandenberg Air Force Base
VPF	Vertical Processing Facility
W	Width (or Watt)
WFF	Wallops Flight Facility
w/o	With out
WSF	Wake Shield Facility
WSMC	Western Space and Missile Center
WSTF	White Sands Test Facility
Y/N	Yes/No

Accessing Space – Submission Instructions

If you believe your company or organization should be included in this catalogue, we are interested in considering your entry for the next edition. Please note that NASA reserves editorial and acceptance rights on all submissions for this document and is not accountable for the return of any materials submitted. To assure consideration for inclusion in the next edition, please include your name, title, address and telephone/fax numbers on business letterhead, along with a brief description of the entry you propose to include to the following:

Accessing Space Catalogue
Office of Commercial Programs
NASA Headquarters Code CCL
Washington, DC 20546

We also are interested to know if your current entry has changed sufficiently to warrant a significant revision. Plans call for the next edition of **Accessing Space** to be issued in late 1992. However, those plans are subject to change (earlier or later) depending upon a number of factors, including the number of possible new entries and revisions. When activities begin on the next edition, or its equivalent, you will be contacted regarding how and when to provide your submission. For your information, instructions for submissions for this edition of **Accessing Space** are as follows:

- Name of product, service or resource (with acronym, if appropriate)
- A brief description (500 words or less) with enough information to enable readers to know what it is, does and who might use it.
- List important characteristics; such as dimensions, weight, carrier, other requirements and/or limitations.
- Is your product, service, etc. currently available, tested or under development?
- Please provide a contact, someone familiar with this product who will be able to answer questions or assist others with it. Make sure to include the contact's name, title, the company name, address, city, state, zip code, telephone number and fax number as available.
- Please suggest the category most appropriate for your entry. (Use the Table of Contents as a guide.)
- Provide, as appropriate, a camera-ready line drawing (photographs or tone drawings are not acceptable).

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