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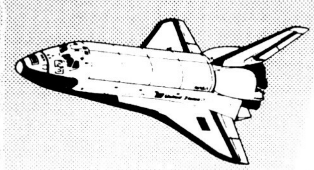
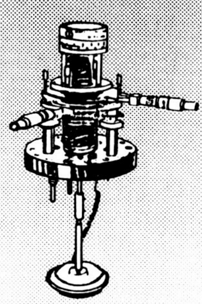
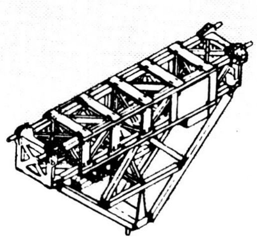
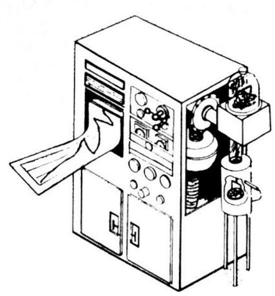
ACCESSING SPACE

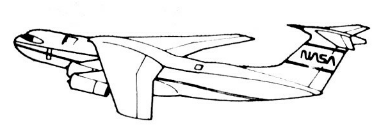
A CATALOGUE OF PROCESS, EQUIPMENT AND RESOURCES FOR COMMERCIAL USERS











ACCESSING SPACE: A Catalogue for Commercial Users 1988

ACCESSING SPACE:

A Catalogue of Process, Equipment and Resources For Commercial Users

NASA
National
Aeronautics and
Space
Administration

September 1988

ACCESSING SPACE: A CATALOGUE OF PROCESS, EQUIPMENT AND RESOURCES FOR COMMERCIAL USERS was prepared and published by the Commercial Development Division of the Office of Commercial Programs at the National Aeronautics and Space Administration.

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Commercial Users Catalogue

Commercial Development Division (Code CC)

Office of Commercial Programs

NASA Headquarters

Washington, DC 20546

September 1988
NASA NP-118

FOREWORD

A major part of the U.S. Space Program involves the commercial development of space. NASA realizes that American industry is interested in pursuing commercially-oriented, space-related activities, and to support that interest, NASA's Office of Commercial Programs provides a variety of guidelines and provisions that offer the private sector opportunities to expand corporate technology and create new markets. NASA facilitates the discovery of innovative processes and the development of new products at a cost and risk level commensurate with ground-based high technology business ventures.

NASA established the Office of Commercial Programs in 1984, to work with the business community, to educate, stimulate and, in many cases become a partner in joint ventures leading to commercial enterprise. Our office supports industry by providing access to NASA facilities and by promoting NASA/industry information exchanges. Government support of industry is designed to assure U.S. leadership in space endeavors and foster establishment of new industries, contributing to expanded employment and an enhanced U.S. competitive position.

The environment of space beckons human exploration and development. We welcome the commercial community with this publication, encourage investigation and offer a helping hand in bringing visions to reality. Your ingenuity, imagination and investment may reveal new ideas, new products, even new industries of the future. The horizons are limitless.

James T. Rose
Assistant Administrator for the Office of Commercial Programs
NASA Headquarters

INTRODUCTION

Our interest in accessing space grows consistently with evolving needs, developing technologies and new marketplaces. NASA's Office of Commercial Programs produced this catalogue to provide a broad source of information for the commercial developer of space who seeks knowledge and experience in the areas of microgravity research and remote sensing.

We are now sharing our inventory of projects and equipment to help reduce the cost of applied research for the commercial user. Some of this inventory has flown in space and can be re-used, revitalized or adapted for particular objectives. Other equipment is new or is being developed. Industry supplements this inventory with additional hardware.

As your ideas mature, this publication will serve as a guide and provide you with information about the equipment and facilities that are being used and developed for commercial space applications. If you find that this inventory does not answer your questions or meet the needs of your research endeavors, please let us know and we will help you obtain additional information.

We have attempted, in this one document, to provide a broad picture of resources for the commercial user. Even as we go to press, there are new pieces of equipment being tested, and new programs blossoming at NASA field centers and at the Centers for Commercial Development of Space. Commercial applications are rapidly becoming an active and vital facet of the space program at large.

This catalogue is a first edition. We expect to offer an update of all information-- including procedures, equipment, carriers, and resources-- on a regular basis. We welcome your comments, ideas and contributions.

Richard H. Ott

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

Raymond P. Whitten

Raymond P. Whitten
Deputy Director, Commercial Development Division
Office of Commercial Programs
NASA Headquarters

Ana M. Villamil

Ana M. Villamil
Venture Liaison, Commercial Development Division
Office of Commercial Programs
NASA Headquarters

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SECTION ONE: *process*

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introduction

Most commercially-oriented experiments in space are designed for testing materials or processes in the microgravity environment demonstrating characteristics of new technologies or observing natural phenomena and resources of the Earth.

The first step toward accessing space is the careful consideration of the objectives and parameters of a particular commercial research project. For example, can testing be achieved at a ground-based testing facility or does it require long-term exposure to the microgravity environment? In many cases, experiments evolve one step at a time, testing observational techniques and technologies, as well as results of data, before committing to more expensive and/or complex designs.

The commercial researcher should evaluate the following factors: time, budget, environment, safety, technology and equipment, flight qualification (if applicable), available and appropriate testing facilities, procedural specifications and data retrieval and interpretation. It is important that you understand your responsibilities and your role in the process before committing your plan to action.

This catalogue is intended for commercial users who are considering, or who have in process, a research project involving characteristics of the microgravity environment of space or remote sensing of the earth. A review of the publication should give the reader both an orientation to commercial space research and a current national inventory of equipment, apparatus, carriers, vehicles, resources and services available from NASA and from U.S. industry for such research. Other countries also have such hardware and vehicles; however, this catalogue is limited to those available in the U.S.

In this first section, we will review the diverse methods of accessing space for research, including the shuttle, expendable launch vehicles, suborbital sounding rockets, experimental aircraft, drop towers and drop tubes and other ground-based facilities and laboratories. We also will discuss procedures for using these vehicles and facilities as well as funding options to pay for their use. Finally, we will consider operations, from the complex pre- and post-flight process of the shuttle, to the more simplified aspects of a laboratory.

CHAPTER 1

accessing space

As we have noted, there are several ways for commercial users to access space, each with variable capabilities to accommodate experimentation. Selection of a vehicle or a facility depends on those capabilities and the requirements of the project.

Research and technology accommodation needs vary, not only from project to project, but also from phase to phase, as a research or development project evolves. Researchers are concerned with factors such as control, data handling, electrical power and pointing accuracy as well as such important considerations as the frequency of flight opportunities.

Chapter 1 will discuss the various vehicles and facilities that are available to the commercial researcher and the capabilities for meeting experiment requirements.

■ *space facilities*

space shuttle orbiter

The most sophisticated vehicle for microgravity and remote sensing research is the shuttle orbiter (also called STS, or Space Transportation System), where experiments may be conducted for a few hours or as long as several days. The need for earth observation, human intervention, space vacuum and a microgravity environment are all features that characterize the orbiter as a platform on which to develop research and technology projects.

The orbiter provides accommodations for a wide variety of experiments in two locations: the middeck and the payload bay. Advantages and operational restrictions are unique to each area and therefore influence experiment design, the choice of carrier and the means of interfacing experiment hardware to the shuttle.

middeck

The middeck is a confined space located directly below the flight deck and adjacent to the payload bay. Resources available on the middeck are limited in both power and heat-rejection 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, if required.

The middeck contains mounting space for 42 storage 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, there are other volumes that might be utilized for experiment equipment. These include the volume occupied by the galley, the volume above the forward locker matrix and the volumes within the starboard closeout sections.

payload bay

Larger experiments may be accommodated in the payload bay area, where power and heat-rejection capabilities are available. The payload bay is 15 feet in diameter and 60 feet in length, occupying the midsection of the orbiter between the flight deck and crew quarters in the front, and the engine assemblies in the rear. Once in orbit, the payload bay doors are opened, exposing the payloads to space.

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 payload bay also has provisions for small, self-contained payload carriers that can be rapidly integrated 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 free flyers 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.

expendable launch vehicles

Expendable Launch Vehicles (ELVs) are becoming 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 ELVs.

■ *ground-based facilities and aircraft*

microgravity research

For experiments requiring microgravity conditions, ground-based testing often precedes orbital research. For this purpose, facilities such as drop tubes, drop towers, aircraft capable of parabolic flight (KC-135, F-104 and the Learjet), sounding rockets for suborbital flights and dedicated research laboratories are employed to simulate a microgravity environment for periods from 2 seconds to several minutes. Experiments in these facilities, many of which are located at NASA Centers, stimulate ideas for research and serve as test beds for space 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 (LeRC) in Ohio is an example of such a facility.

remote sensing research

Test facilities are now available for remote sensing research and technology suited for commercial use. Commercial applications in this field are growing and equipment such as NASA's large format camera will become available for use by the commercial researcher. Remote sensing experiments may be conducted from free-flyers, aboard the shuttle, on selected aircraft and from specially equipped balloons.

In addition, major achievements have recently been made in computational research for gathering, integrating, reducing and value-adding data. One of the more advanced programs in this area is the Space Remote Sensing Center at the NASA Stennis Space Center in Mississippi, which has recently been designated as lead center for remote sensing operations.

US MICROGRAVITY TEST TIME CAPABILITY

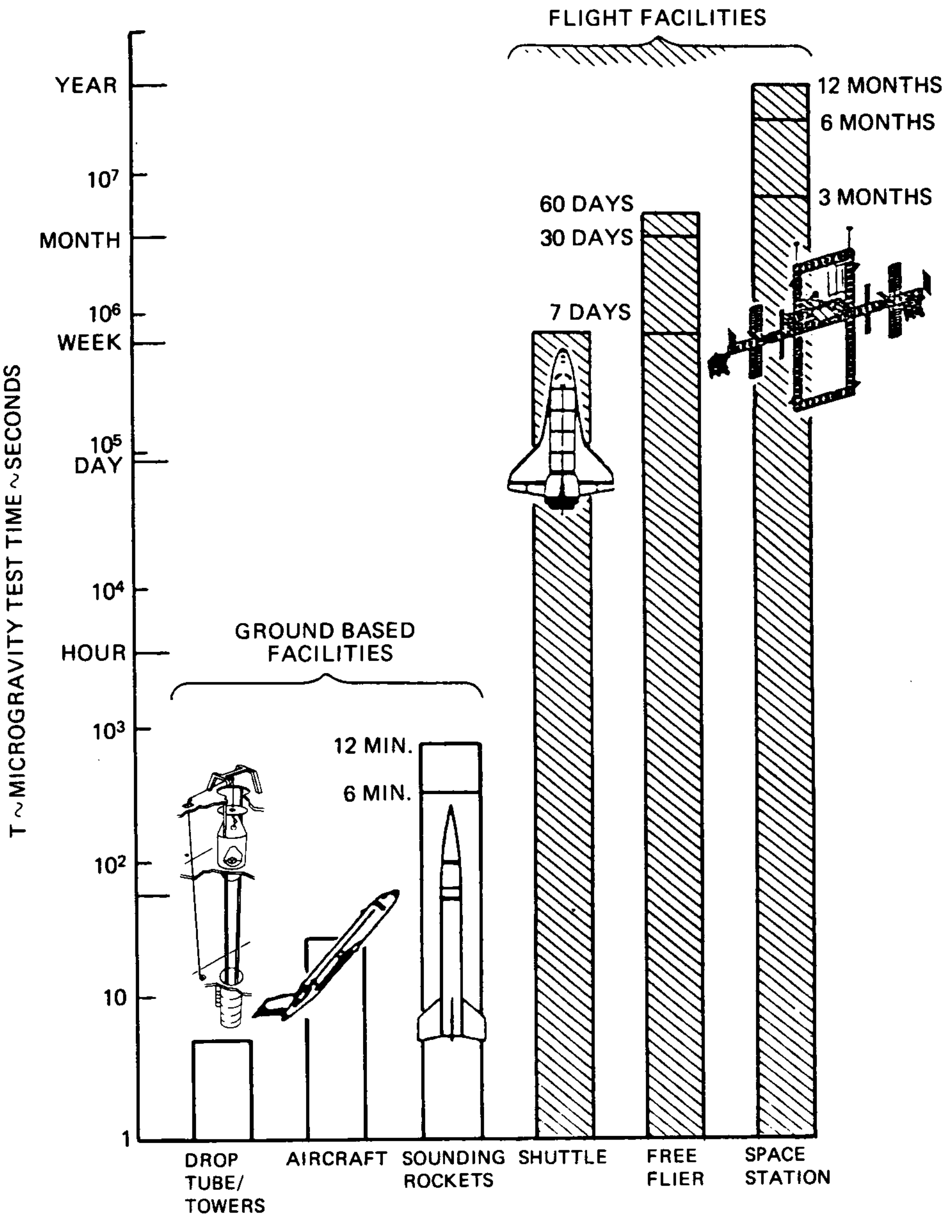


Illustration: Instrumentation Technology Associates, Inc.

CHAPTER 2

accessing the system

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 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 that is 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 orbiter (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), through commercial application working groups and by developing workshops that serve as an informational outreach activity 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 the researcher works with them to his advantage. This chapter also provides information about using hardware and carriers that either exist or are created/adapted by the researcher; scheduling a flight on the shuttle and scheduling ground-based facilities; and safety considerations.

■ *NASA-industry agreements*

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 has established several types of joint arrangements that offer some 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:

The 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.

The Industrial Guest Investigator (IGI) Agreement -- applicable to situations in which NASA and a company share a strong mutual interest in a shuttle flight experiment. The company appoints a scientist to participate as a member of the investigation team, at company expense, in a NASA-directed project.

The 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 agreement for organizations that are in the process of defining applied research goals and are not yet ready for the JEA.

The 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 worthwhile benefits.

Launch Services Agreement (LSA) -- Commercial developers who want to purchase shuttle launch services may enter into this agreement. Additional 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 scientist from industry and NASA are again encouraged. Bringing the unique capabilities and expertise of the 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.

As with most agreements using the shuttle, there is no exchange of funds between parties of collaborative efforts. Each party funds its own work. 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 commercial development of space (CCDS)

A company may develop an experiment and handle all integration and scheduling processes directly through NASA or its field centers. A company may also choose to work with one of NASA's Centers for the Commercial Development of Space (CCDSs). There are presently more than 100 U.S. firms associated with the 16 CCDSs now operating in locations throughout the nation. Each center focuses 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. At present, these centers represent disciplines in the following areas:

automation and robotics

life sciences

remote sensing

space power

space propulsion

space structures and materials

Please refer to Chapter 11 of this catalogue for a listing of all CCDSs and their corresponding points of contact.

■ *hardware accommodations and carriers*

An individual or a company may utilize either existing apparatus, or develop special equipment for an experiment. In the latter case, the investigator must work closely with NASA engineers during the design and construction of this equipment, to assure its safety, especially for use on aircraft or the shuttle.

existing hardware

Once the individual or the company (the researcher) has determined the nature of the experiment -- such as orbital, requiring shuttle flight; or ground-based, requiring drop tube facilities -- he must then select the type of hardware apparatus and carrier that will be required to accommodate the project. 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.

Apparatus and carriers developed by NASA are available at the field center that developed them. Refer to Chapter 11 for a listing of 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.

new developments

The challenge in developing experiment flight hardware is to package the basic science apparatus in a way that 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 often a team effort where the investigator works in close association with engineers and technicians experienced in hardware development. But often the task is one of finding suitable existing hardware from the growing inventories of NASA and industry. Equipment is often adaptable for various applications and should be carefully evaluated and modified to suit the requirements of a particular experiment. 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. carrier or satellite)

Cargo Integration (e.g. space shuttle)

Launch

Flight Operations

Reentry and Landing

Cargo and Payload Deintegration

Return Shipping

■ *scheduling*

scheduling -- shuttle

For scheduling a flight on the shuttle orbiter, the Commercial Development Division of the Office of Commercial Programs assigns compatible experiments. For equipment with modest resources demands and no special accommodation requirements, this may be a simple matter of adding the experiment to a queue. For larger, more complex missions, NASA Headquarters works with the field centers to establish the makeup of the payload group. Equipment combination is an important consideration in establishing payload groups, as they must be physically and operationally compatible with each other and with the shuttle and the carrier used. Descriptive data from proposals and other sources are used as a basis for mission feasibility studies.

To request a flight on the shuttle, the commercial researcher must obtain an OCP Flight Request form from the Commercial Development Division of NASA's Office of Commercial Programs. Contact NASA Headquarters, Office of Commercial Programs, Code CC, Washington, DC 20546.

A manager designated by the Office of Commercial Programs is the commercial researcher's principal point of contact for payload development and integration. This individual obtains a flight assignment, coordinates activity with the field centers involved, and works with the researcher to combine the experiment into an integrated payload ready for flight. Preparatory and operational phases of a shuttle mission normally require the researcher to participate in activities of his experiment at the field center(s) involved. In most cases, payload integration and check-out also require the researcher's presence at the Kennedy Space Center (KSC) in Florida.

scheduling -- other facilities

Use of facilities such as aircraft and drop tubes may be requested directly through NASA field centers (see points of contact in Chapter 11). Low-gravity flights of the KC-135, the F-104 and the Learjet 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. Typical experiment project documentation includes such items as:

Payload Integration Plan

Interface Control Document

Ground And Flight Safety Plans

Crew Timeline Plan

■ *miscellaneous*

safety

For the benefit of the flight crew as well as 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 Transportation 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.

other considerations

More specific information about the shuttle manifesting process or 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.

CHAPTER 3

operations

Operations during the experiment itself vary greatly with the nature of the event. For example, ground-based research may be tested in a matter of seconds, with data recorded and completed 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 analysis as appropriate.

The key points in developing research payloads are:

> *The smaller the payload and the fewer number of payload interfaces, the easier it is to manifest.*
>
> *The more complex the payload, the more time is required for payload integration.*

Chapter 3 addresses issues concerning the researcher's experiment during the actual operations of a shuttle flight or testing at a ground-based facility or laboratory. These issues focus on integration, pre-flight activities and post-flight activities.

■ *pre-flight - shuttle*

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

To facilitate mission planning, the researcher should describe the conduct of his on-board activity in terms of functional objectives. He also is 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.

■ *integration - shuttle*

The primary goal of any experiment process is to assemble a complement of apparatus on a carrier in a way that maximizes the return. Integration is accomplished in two major phases:

1. ***Analytical integration*** - involves the planning, analysis and preparatory tasks of payload hardware design

2. ***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 his operations requirements to his 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. The Payload Integration Plan is generated for concurrence by all parties, and flight preparations proceed. The researcher also may be required to develop flight procedures, assist with crew training, participate in simulations and in real-time operations.

post-flight - shuttle

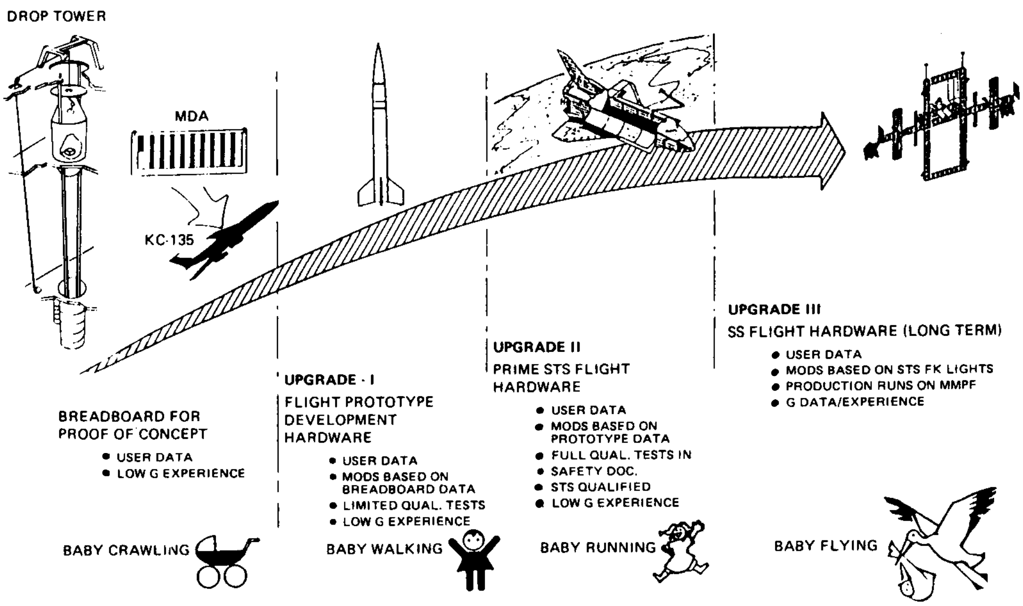
Once the orbiter has landed, the researcher has only to retrieve and analyze the data or other products generated during the flight.

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 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 procedures are as important to tests in laboratories and on drop towers, experimental aircraft and expendable launch vehicles as they are on the shuttle. However, as stated above, 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.

TRANSITION GROUND BASED RESEARCH TO SPACE



MESSAGE: USERS NEED TO LEARN TO WALK BEFORE THEY RUN

Illustration: Instrumentation Technology Associates, Inc.

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introduction

Microgravity research includes all work in which components are affected by gravity (or the lack of gravity), such as in the materials sciences and life sciences. One of the most developed areas is materials processing, where research has been conducted on metal alloys, pharmaceuticals and crystals, among others.

Most microgravity research and development in the U.S. is conducted on the shuttle, with additional work at ground-based laboratories, facilities such as drop tubes and towers, and on experimental aircraft such as the KC-135 and the Learjet, as mentioned previously. Private space platforms, such as the Industrial Space Facility (ISF) and the Space Phoenix Program, created to utilize the intertank section of expended external tanks, propose to provide commercial space facilities on which to conduct microgravity research in the interim period before the space station becomes operational.

The following section focuses on apparatus (Chapter 4) used to perform various kinds of microgravity experiments, the carriers (Chapter 5), including pressurized and non-pressurized carriers that are available, and developmental and testing facilities (Chapter 6), where experiments may be designed and/or performed.

CHAPTER 4

experiment apparatus

Experiment apparatus potentially available for commercial applications generally fall into one of the following categories:

- ***materials processing***
- ***combustion engineering***
- ***life sciences/biotechnology***
- ***ancillary equipment***

Many items of flight-qualified support hardware have been developed to help potential commercial users accomplish their space research. For identification, these items are called Ancillary Equipment in this publication.

Chapter 4 lists, by the areas mentioned above, all known experiment apparatus hardware either developed or being developed to date in the U.S. This includes space-based and ground-based apparatus, such as those used at the Microgravity Materials Science Laboratory (MMSL) at the NASA/Lewis Research Center. The apparatus is listed alphabetically in each area and is described as follows:

A drawing or photograph (if available) and: (a) a brief description of the apparatus, (b) pertinent operational characteristics, (c) a point of contact for further information, and (d) the present state of development. Also listed is the payload carrier for which the hardware was designed. The payload carriers are listed and described in Chapter 5.

Listed in Chapter 11 of this catalogue are the 16 Centers for the Commercial Development of Space. The appropriate center may be contacted if you need assistance in investigating an idea for a microgravity experiment.

materials processing

The major emphasis for commercial research in microgravity has been in the area of materials processing. Microgravity provides 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 promise because the microgravity of space eliminates the natural convection which occurs in normal gravity. This allows composite materials which are much more uniform in composition and microstructure to be produced.

The apparatus described in this chapter represents a variety of systems available or in the development stage. Any researcher interested in materials processing in space should consider the possibility and benefits of using existing equipment.

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.

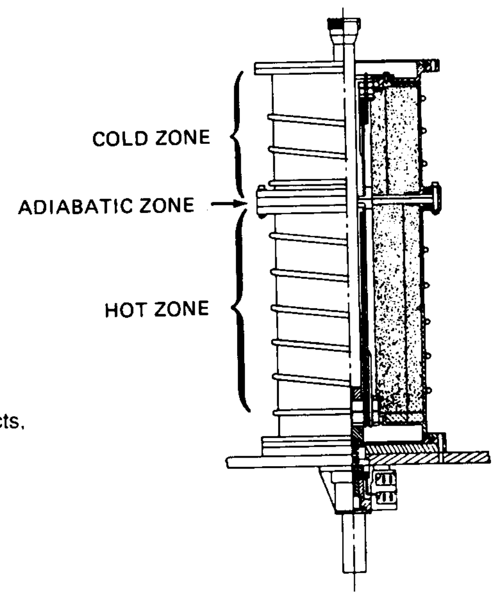
The apparatus contains a multi-zone furnace and mechanism that moves the sample through the furnace. The furnace may be configured to compensate for changes in temperature as a sample adjusts to its steady-state value, changes in thermal conductivity between solid and melt, and energy disposition. One sample per furnace of approximately 2.0 cm diameter by 25 cm in length is planned.

operational characteristics:

Temperature range:	200 to 1,620°C
Translation rate:	0.5 to 50.0 mm/hr
Furnace size:	130 cm H x 43 cm Dia
Furnace weight:	90 kg

carrier: Materials Science Laboratory (MSL)

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812. (205) 544-5423. Engineering prototype has been completed.



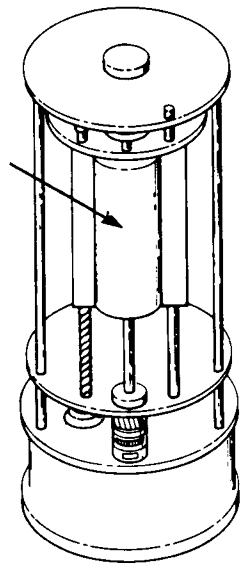
automated directional solidification furnace (ADSF-1)

The ADSF-1 is used to directionally solidify composite materials, called eutectics, to produce materials which exhibit greater strength along the axis or direction of solidification. This allows investigation into the anisotropic properties of metals and the unusual electrical, magnetic and optical properties of directionally solidified molecular structures.

The furnace can handle four samples of 4 mm in diameter and up to 135 mm in length each. Each furnace can be programmed for up to two cooling rate changes during sample processing. A heating unit translates along the long axis of the sample during the melt process, and then each sample is cooled at a controlled rate.

operational characteristics:

Temperature range:	200 to 500°C
Translation rate:	0.1 mm/hr to 500 mm/hr
Furnace size:	49.4 cm H x 44.9 cm diameter
Furnace weight:	36 kg



carrier: Orbiter middeck - 5 locker spaces

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812. This hardware is available.

bulk undercooling furnace (BUF)

The BUF is a three-zone furnace designed to study the effects of undercooling on the microstructure of metal alloys. The temperature of the sample is monitored and recorded with a thermocouple. The BUF uses larger samples than other undercooling furnaces. The BUF consists of three resistance heater zones with a water or gas cooling system at one end. The thermal profile in the sample can be adjusted by computer control of the three heating elements.

operating characteristics:

Operating temperature:	25 to 500°C
Maximum power per zone:	300 w
Gases (Standard Liters/minute):	Helium 0 to 320 SLM Nitrogen 0 to 100 SLM
Cooling system fluid flows:	Argon 0 to 100 SLM Helium 0 to 320 SLM Nitrogen 0 to 100 SLM Air 0 to 100 SLM Water 0 to 1.2 liters/minute
Sample shape:	Cylindrical
Sample size:	12 L x 3.5 cm Dia max

carrier: Designed for ground-based research only (MMSL). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

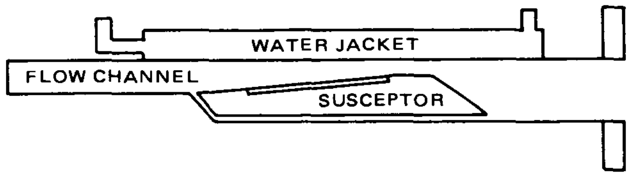
contact: NASA/Lewis Research Center, Code 105-1, MMSL, Cleveland OH 44135, (216) 433-5014.

chemical vapor deposition facility (CVDF)

The objective of this hardware is to develop a flight facility for flow characterization of chemical vapor deposition reactors in the microgravity environment of space. The plan is to demonstrate the CVDF for non-reacting flows and then determine the feasibility of fluorescent measurement techniques.

operational characteristics:

Sample size: 50 cm^3



carrier: Cross-bay carrier

contact: I.O. Clark, NASA/Langley Research Center, Hampton, VA 23665, (804) 865-3777.
This apparatus is proposed.
Ground-based facility (non-reacting flows) is available. A flight unit is proposed.

cosmic ray determination (Nuclear Track Detectors)

The hardware consists of a stack of plates 150 x 150 x 150 mm; typical thickness of a single plate is 1 to 2 mm. 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: 190 x 190 x 190 mm

Weight: Dependent on box contents

Power: Entirely passive

carrier: To be determined

contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space,
Research Institute Building, Huntsville, AL 35899,
(205) 895-6620.

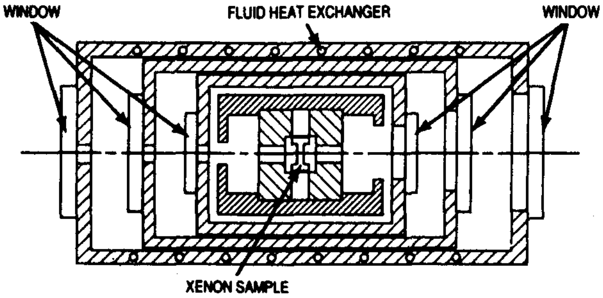
critical fluid light scattering experiment apparatus (CFLSE)

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 will measure the decay rates and correlation lengths of critical density fluctuations in Xenon, a nearly ideal model fluid, very near its liquid-vapor critical point using laser light scattering and photon correlation spectroscopy. The fully automated system will permit 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 L x 0.6 W x 0.45 m H 0.3 L x 0.6 W x 0.6 m H
Apparatus weight:	247.5 kg overall



carrier: Materials Science Laboratory (MSL)

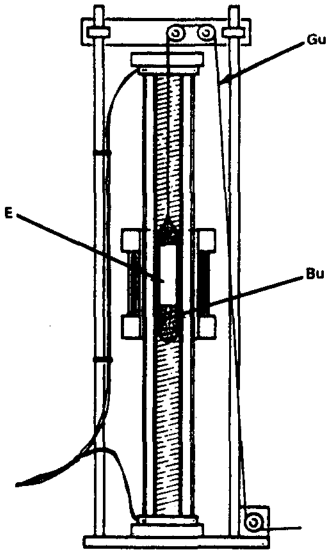
contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland OH 44135.
This apparatus is being developed.

crystal growth apparatus

The Physical Vapor Transport Crystal Growth Furnace is a transparent two-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 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:	50nm/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). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

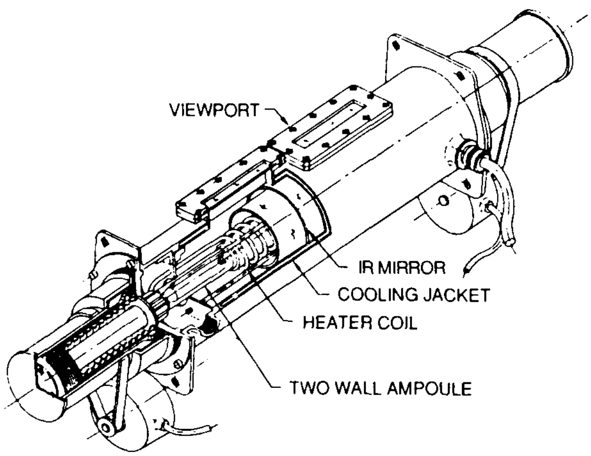
contact: NASA/Lewis Research Center, Code 105-1, MMSL, Cleveland OH 44135, (216) 433-5014.

crystals by vapor transport (CVT) furnace

Each CVT 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 does provide 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 will be processed in a two-walled ampoule with an inner diameter of up to 25mm.

operational characteristics:

Operating temperature:	Up to 1,100°C
Furnace size:	7 x 7 x 40 in (holds 2 samples)
3-Furnace system size	20 x 70 x 16 in (fits in single standard rack)
Weight:	160 kg
Power requirement:	Up To 1 kw (for current systems)



carrier: Orbiter: middeck accommodation rack (current)
Orbiter: payload bay (minor modification);
Free flyer/space station (minor modification)

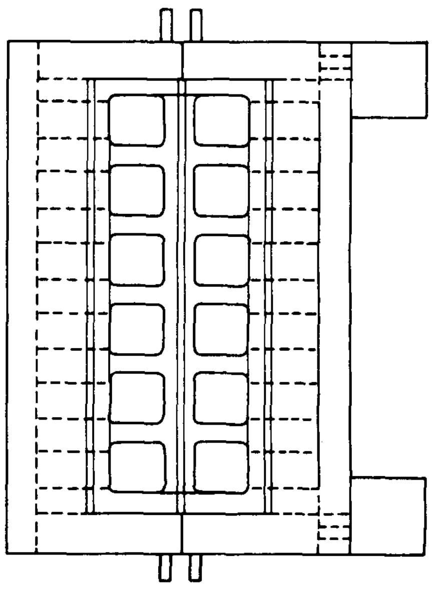
contact: V.A. Sweberg or D.M. Garman, Boeing Commercial Space Development Company, P.O. Box 3707, M/S 8R-30, Seattle, WA 98124-2707, (206) 773-6017.

demixing of immiscible polymers

The apparatus consists basically of several glass cuvettes (1.5 ml) containing immiscible liquids and stirring bars which are spun by small motors. 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 approximately 100 ma. each. Heater requires approximately 5 watts. Power needed to operate camera and flash.



carrier: Shuttle, Get-Away-Special canister, sounding rockets, KC-135 parabolic flights

contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space, Research Building, Huntsville, AL 35899, (205) 895-6620.

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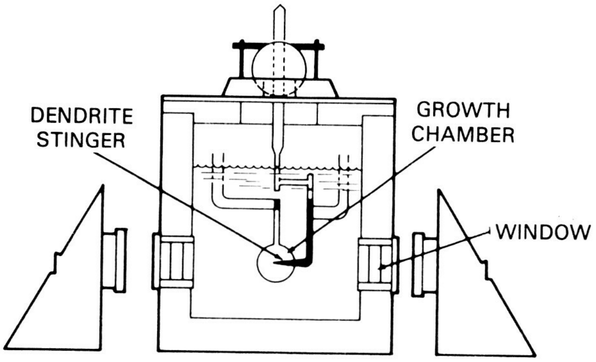
dendrite growth apparatus

The 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 $\pm 0.002^{\circ}C$.

operational characteristics:

Operating temperature:	40 to 80°C
Temperature accuracy:	±0.002°C
Photogenic resolution:	+5 micrometers
Sample capacity:	One growth chamber
Sample chamber size:	1 to 8 cm diameter



carrier: Designed for ground-based research only (MMSL). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

contact: Leslie Greenbauer-Seng, NASA/Lewis Research Center (MMSL), Cleveland, OH 44135, (216) 433-5013.

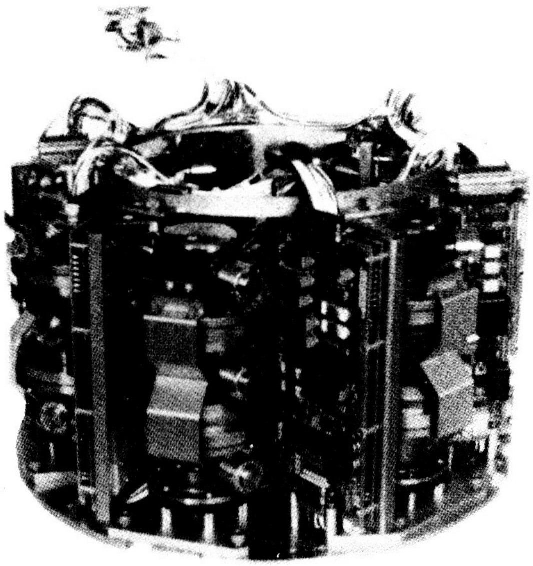
diffusive mixing of organic solutions (DMOS) apparatus

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

operational characteristics:

Operating temperature:	Ambient to 45°C (higher temperatures possible with modifications)
Modular cell size:	13.7 x 17.3 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: See text

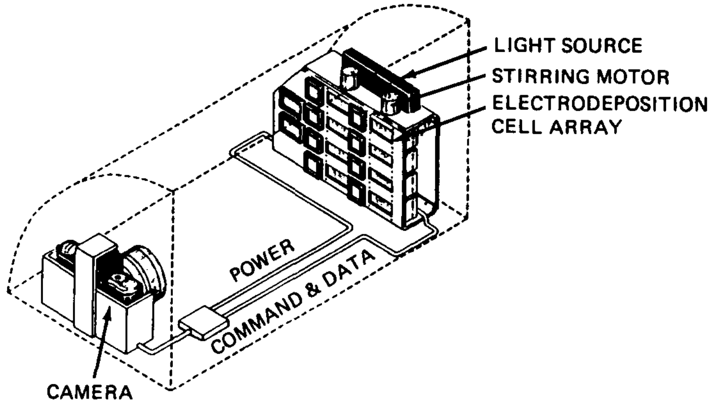
contact: J.R. Reinhardt, 3M/Central Research, 3M Center, Bldg 201-25-05, St. Paul MN 55144, (612) 736-6351. Apparatus is available.

electrodeposition and codeposition apparatus

Eight electrodeposition cells are arranged in a bank. Each cell can contain a chemical solution to sustain an electrodeposition process. The process is driven by power from a battery regulated to 1 volt. Two of the cells are equipped with tiny stirring motors to agitate inert particles placed in solution to obtain codeposits. Voltage for one cell and temperature measurements for the whole bank are digitally displayed. Thermal control of the cell bank is maintained by battery-powered strip heaters and insulation. An overtemperature cut-off sensor is employed as a means to prevent thermal runaway in the event of controller failure.

operational characteristics:

Size:	700 x 200 x 230 mm
Weight:	8 kg
Power:	Approximately 20 watts to drive motors, cells, camera and flash.



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

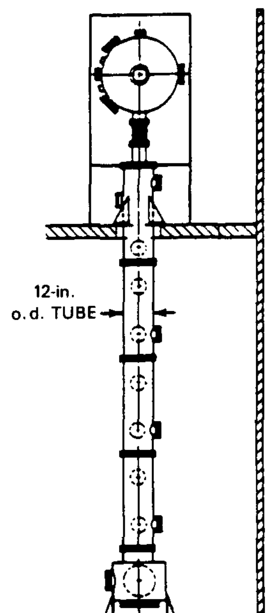
contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space, Research Institute Bldg, Huntsville, AL 35899, (205) 895-6620.

electromagnetic levitating furnace (EML)

This facility uses an induction furnace to levitate and melt metal alloy samples. The EML is mounted on a 1-second drop tube for microgravity solidification. This furnace can maintain a vacuum or inert gas atmosphere.

operational characteristics:

Power:	0 to 25 kw
Frequency:	100 to 450 wHz
Vacuum:	To 10^{-6} torr
Inert gases:	Argon, helium
Sample shape:	Spherical or cylindrical (Height=diameter)
Sample size:	0.5 to 4 cm^3 (up to 30 g)
Sample type:	Any material which can be levitated and heated inductively



carrier: Designed for ground-based research only (MMSL). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

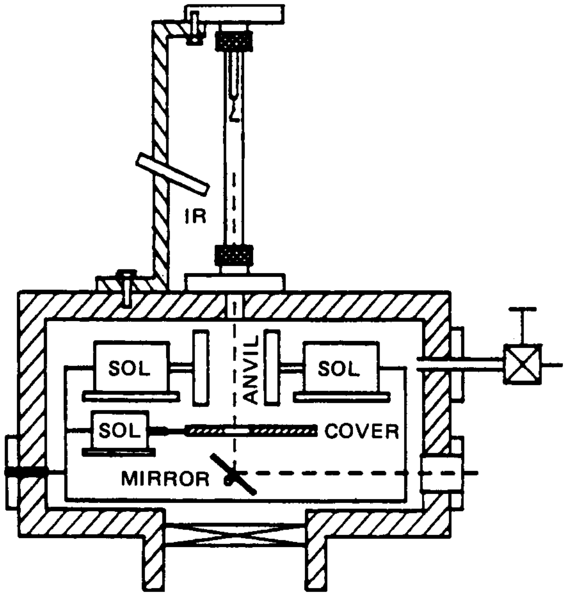
contact: Leslie Greenbauer-Seng, NASA Lewis Research Center (MMSL), Cleveland, OH 44135, (216) 433-5013.

electromagnetic levitation furnace

The Electromagnetic Levitation Furnace is used in a containerless process to melt metallic samples up to about 1 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 x 10^{-5} torr or various gases up to 1 atm.

operational characteristics:

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



carrier: Ground-based research

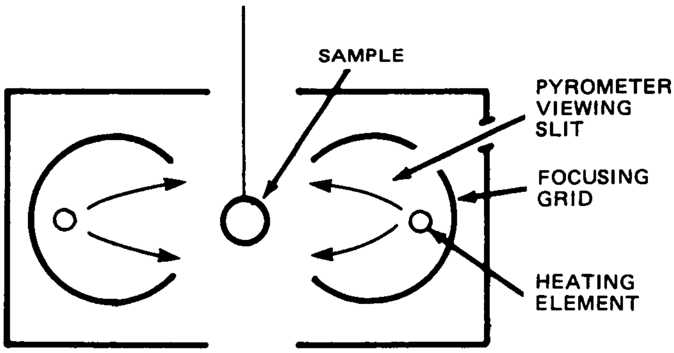
contact: CCDS/Vanderbilt University, Center for Space Processing of Engineering Materials, Box 6309, Station B, Nashville, TN 37235, (615) 322-7053.

electron bombardment furnace

Used for experiments which are conducted in a vacuum environment. Uses a pendulant drop technique with omnidirectional electron bombardment for heating. Samples are heated isothermally. Furnace operates under extreme vacuum environment.

operational characteristics:

Operating temperature:	1,600 to 3,500°C
Physical characteristics:	Not specified
Sample diameter:	0.3 cm



carrier: EB furnace is designed to be used for Marshall Space Flight Center (MSFC) drop tube experiments only. System is fully operational.

contact: Richard Black, NASA/Marshall Space Flight Center MSFC, AL 35812 (205) 544-1983.

f-104 experimental casting furnace

This furnace serves as a high temperature isothermal casting furnace. The furnace has a helium quench gas to resolidify the sample during flight.

operational characteristics:

Operating temperature:	200 to 1,600°C
Cooling rate:	70 to 350°C/minute
Power:	7.0 amps
Voltage:	28 vdc
Size:	61 L x 43 H x 31 cm D
Mass:	24 kg
Sample size:	2.0 L x 1.0 cm Dia max

carrier: Designed to fly on TF-104G research aircraft. Could possibly be modified to fly on KC-135 if necessary.

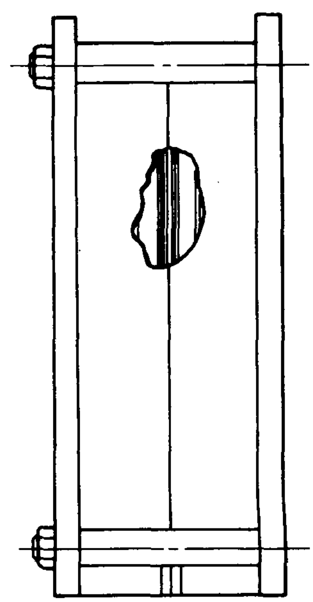
contact: Contact Bob Mixon, NASA/Marshall Space Flight Center, MSFC, AL 35812, (205) 544-1985. Furnace located at University of Alabama/Huntsville.

flat plate heater

The Flat Plate Heater is used to heat a flat sample 114 x 114 mm square. Variable thicknesses of samples are easily 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 two to three minutes. Device can be used to cure epoxy resins.

operational characteristics:

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



carrier: Sounding rockets

contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space, Research Institute Building Huntsville, AL 35899, (205) 895-6620.

float zone experiment system (FZES)

Float Zoner is capable of zone refining high temperature materials, such as silicon, under a vacuum or Argon environment.

operational characteristics:

Power Output:	50 kw
Vacuum:	10^{-6} torr
Physical characteristics:	Not specified
Sample size:	50 L x 5.0 cm Dia max
Translation speed:	0.1 to 50 mm/minute

carrier: FZES was designed to do ground-based experimental studies leading to definition of flight-qualified hardware systems.

contact: I.C. Yates, NASA/Marshall Space Flight Center, MSFC, AL 35812, (205) 544-1991. FZES is no longer used at MSFC, and has been disassembled and crated for storage. System is available but may be difficult to reassemble and reactivate.

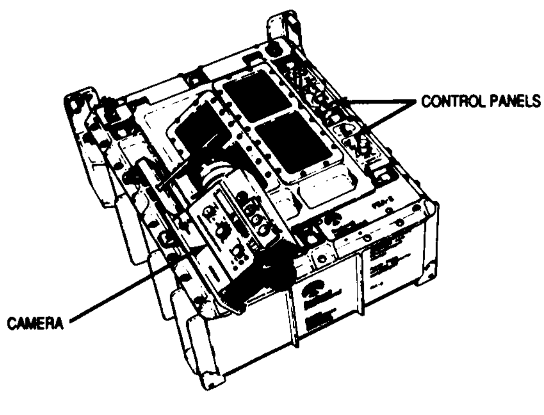
fluid experiments apparatus (FEA)

The FEA is designed to provide industrial users 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, 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-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 L x 36.8 W x 18.8 cm H
Weight:	11.7 kg



carrier: Orbiter middeck - 1 stowage locker

contact: Rockwell International, Space Processing, Mail Code FC46, 12214 Lakewood Boulevard, Downey, CA 90241. This apparatus is available.

fluid science module (FSM)

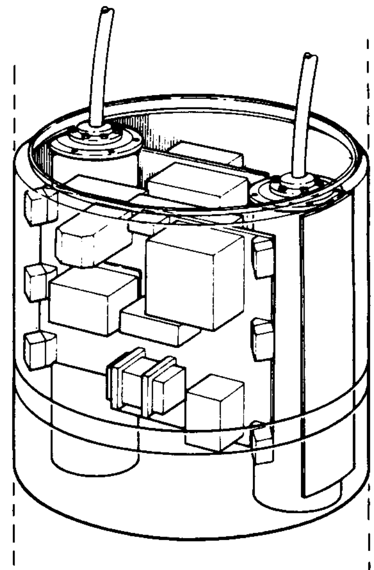
The Fluid Science Module is designed to house three experiments. Two of the experiments are intended for investigation of the Marangoni convection effect, where one will make use of thermocapillary drop motion under microgravity, and the other will study mass transfer from liquid to gas phase. Each of 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 that are 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 L x 438 mm Dia
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 max
Thermal environment for the experiments:	13 to 23°C



carrier: Sounding rockets

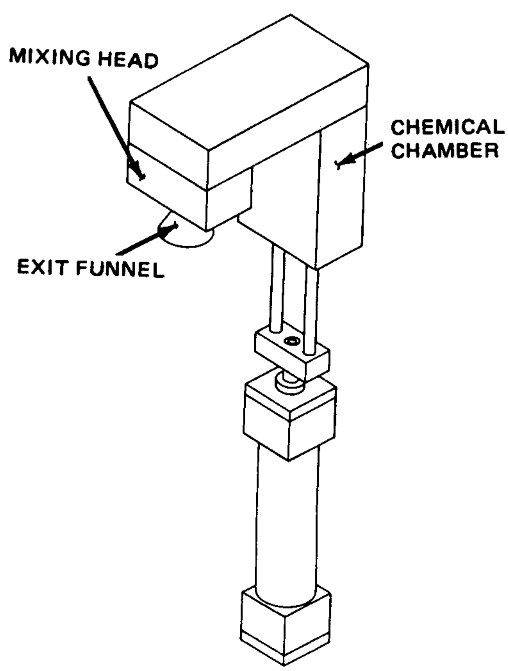
contact: CONATEC, Inc., P.O. Box 171, Glendale, MD 20769, (301) 552-1088. This apparatus is available.

foam formation apparatus

A nitrogen cylinder drives a gas actuated piston that pushes two plungers in separate cylinders. The plungers push out chemicals which flow through a mixing block. These then flow through a funnel and screen to form a volume of foam which expands in microgravity. A camera records the foam formation. Mirrors allow the entire foam to be photographed until the foam obscures the camera's view of the mirror.

operational characteristics:

Size:	617 x 368 x 255 mm
Weight:	16.1 kg
Power:	28 vdc, approximately 20 watts power required to operate camera and flash
Gas operating pressure:	17 atm



carrier: Sounding rockets

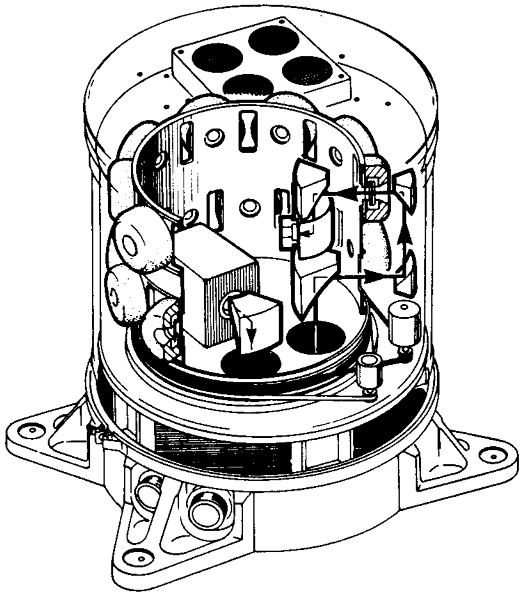
contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space, Research Institute Bldg, Huntsville, AL 35899
(205) 895-6620.

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}



carrier: Orbiter middeck, Spacelab, SPACEHAB

contact: J.R. Reinhardt, 3M/Central Research, 3M Center
Bldg 201-2S-05, St. Paul, MN 55144
(612) 736-6351.
This apparatus is available.

general purpose furnace (GPF)

The GPF simulates the functions of the General Purpose Rocket Furnace (GPRF) flown on the Space Shuttle. It is used for ground-based research only. The GPF has three resistance heater zones, and a water or gas-cooled heat sink at one end. Temperature gradients or near-isothermal heating can be maintained by computer control of the three heating elements and the heat sink.

operational characteristics:

Operating temperature:	25 to 100°
Maximum power/zone:	400 w
Quench gases, standard liters/minute:	Argon 0 to 100 Helium 0 to 200 Nitrogen 0 to 100
Heat sink coolants, SLM:	Argon 0 to 100 Helium 0 to 200 Nitrogen 0 to 100 Water 0 to 2 liters/minute
Sample size:	7.8 L x 2.0 cm Dia

carrier: Designed for ground-based research only (MMSL).
Facility can be used for preflight experiments before
using the KC-135 and Space Shuttle.

contact: Leslie Greenbauer-Seng, NASA/Lewis Research Center,
MMSL, Cleveland, OH 44135
(216) 433-5013.

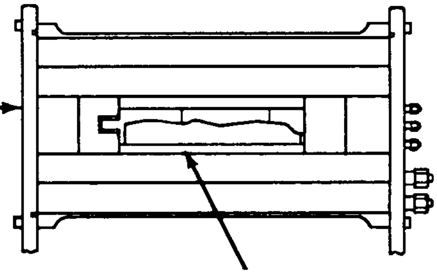
gradient furnace for the get-away-special canister (GFGAS)

The GFGAS has been developed to provide a low-cost quick-turnaround 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 max
Furnace size:	60.96 H x 50.16 cm Dia
Furnace weight:	90 kg



carrier: Get-Away-Special canister mounted in orbiter payload bay

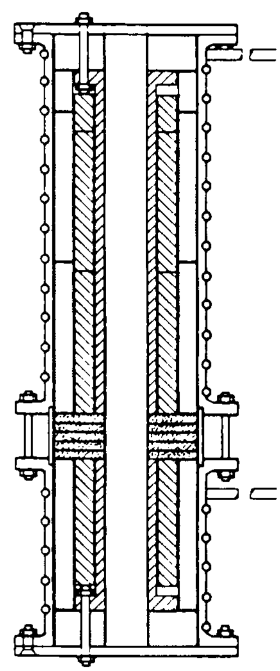
contact: NASA/Lewis Research Center
Space Experiments Division Cleveland OH 44135.
This hardware is being developed.

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/sec
Temperature gradient:	10, 200 and 400°C/cm
Sample shape:	Cylindrical
Sample diameter:	12.7 or 28 mm
Sample length:	20 to 26 cm
Ampoule length:	Approx. 100 cm



carrier: Designed for ground-based research only (MMSL).

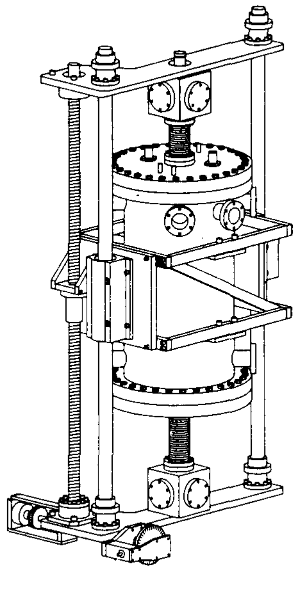
contact: NASA/Lewis Research Center, Code 105-1,
MMSL, Cleveland, OH 44135
(216) 433-5014.

high temperature directional solidification furnace

The High Temperature Directional Solidification Furnace will allow directional solidification experiments on materials with melting temperatures over 2,000°C. Dual water-cooled copper blocks with helium gas convective cooling will provide thermal gradients in excess of 200°C/cm. The equipment can accommodate samples of 1.2 cm diameter x 20 cm long. Furnace translation speeds can be varied from 0.01 to 30mm/minute, with a 30mm/second fast quench capability. The superior electrical, magnetic, or mechanical properties of high melting point samples with unique, directionally solidified structures can be investigated with this apparatus.

operating characteristics:

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



carrier: Ground-based research

contact: CCDS/Vanderbilt University, Center for Space Processing of Engineering Materials, Box 6309, Station B, Nashville, TN 37235, (615) 322-7054. This unit is being fabricated.

high vacuum furnace

General purpose resistance-heated furnace for heat treating metals in a vacuum or an inert gas atmosphere.

operational characteristics:

Furnace size:	15.2 H x 15.2 W x 30.5 cm L
Operating temperature:	260 to 1650°C
Power:	25 kw
Vacuum:	10^{-8}torr
Inert gases:	Argon, helium
Sample size:	20.3 L x 7.6 cm Dia

carrier: Designed for ground-based research only (MMSL). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

contact: Leslie Greenbauer-Seng, NASA/Lewis Research Center (MMSL), (216) 433-5013.

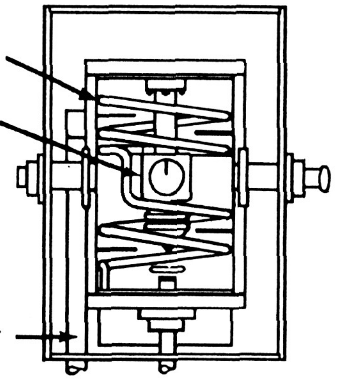
isothermal dendritic growth experiment apparatus (IDGE)

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 succinonitrile (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 to 6 cm Dia
Sample volume:	11 to 35 cm^3
Temperature range:	30 to 60°C
Apparatus size:	45 L x 60 W x 45 cm H
Apparatus weight:	Approximately 100 kg



carrier: Materials Science Laboratory (MSL)

contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135.
This apparatus is being designed.

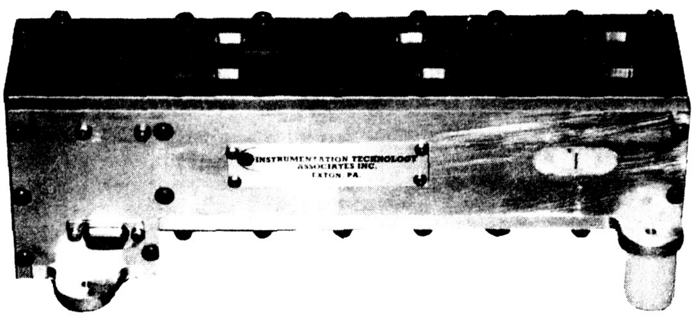
ITA materials dispersion apparatus (MDA)

The ITA Materials Dispersion Apparatus (MDA) is a device that has the capability of mixing 100 to 200 samples of virtually any two fluids in space. The MDA flight hardware weighs less than 5 lbs and occupies a volume of less than 0.4 ft^3. Mixing occurs through the liquid-to-liquid diffusion process, and each test well cavity can accommodate fluid samples in the 50 to 400 microliter range. The apparatus was designed to grow and mass produce high quality protein crystals in space. In addition, crystals of peptides, hormones, and other biologically interesting proteins can be grown.

The MDA operates on the following principle: two blocks of inert material each with an equal number of sample test cavity wells in the upper and lower half are held firmly together under pressure in an aluminum aerospace housing. The test cavity wells are misaligned at launch, thus separating the fluids to be mixed. After zero gravity has been achieved, the blocks are moved into register by means of a motor-cam mechanism, thereby mixing the fluids.

operating characteristics:

Power:	12 to 16 vdc
Nominal test wells:	140
Nominal test well capacity:	100 microliters



carrier: Middeck lockers, GAS cans, EAC containers, ITA Standardized Experiment Modules (ISEMs), Spacelab, and Hitchhiker-G & M.

contact: John M. Cassanto, Instrumentation Technology Associates, Inc., 109 Great Valley Parkway, Malvern, PA 19355
(215) 647-6260/524-1988.

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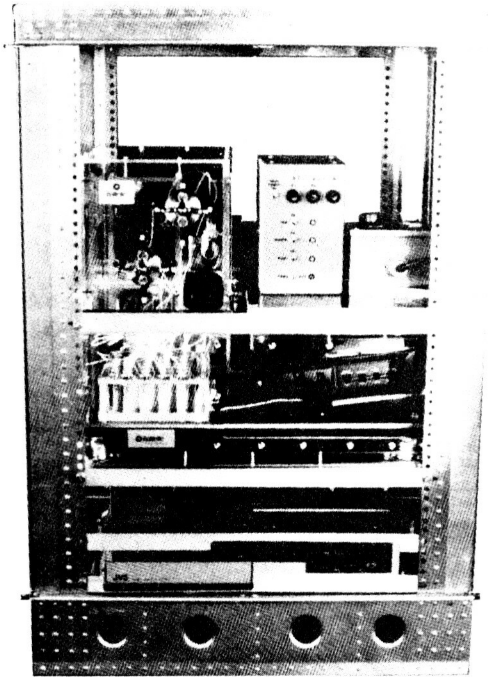
low gravity mixing equipment

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 video cassette 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 of the vibrator, and the timing of video recording needs.



operational characteristics:

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

carrier: Suborbital research aircraft instrument rack

contact: Space Systems and Hardware, Battelle Advanced Materials Center for Commercial Development of Space, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201-2693, (614) 424-4706.
Apparatus is available.

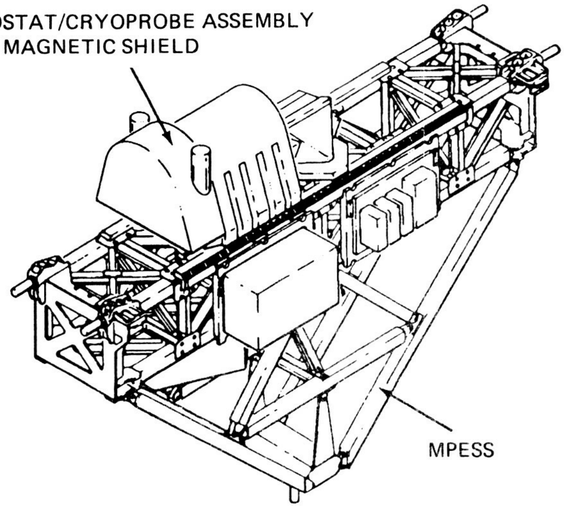
low-temperature research facility (LTRF)

The LTRF provides a facility to conduct experiments that require temperatures as low as 1.5°K and acceleration forces less than 10^{-4}g. The first two planned flights of the LTRF will investigate the bulk properties of superfluid helium and the behavior of superfluid helium at the Lambda transition. This will provide a test of 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 L x 102.87 W x 86.36 cm 81.28 L x 60.96 W x 55.88 cm H 45.72 L x 40.64 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)

contact: NASA/Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109
(818) 354-6336.
This apparatus is available.

master melt furnace

This is an induction coil furnace. It is used to melt high-purity metals in a vacuum or a gas atmosphere.

operational characteristics:

Power (solid-state supply):	15 kw
Vacuum:	10^{-7} torr
Inert gases:	Argon, helium
Sample crucible capacity:	Number 1 0.908 kg Number 2 2.27 kg
Sample mold capacity:	9 samples of desired geometry

carrier: Designed for ground-based research only (MMSL). Facility can be used for preflight experiments before using the KC-135 and Space Shuttle.

contact: Leslie Greenbauer-Seng, NASA/Lewis Research Center
MMSL, Cleveland, OH 44135
(216) 433-5013.

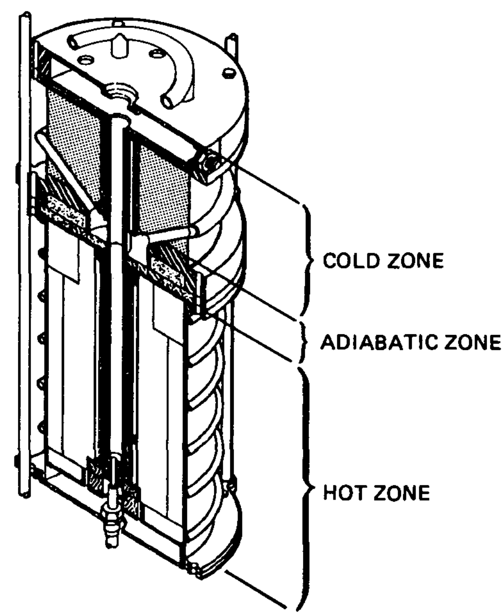
metals and alloys solidification furnace (MASA)

The MASA is a modular furnace able to process more and larger samples and permitting sample exchange on orbit. Samples processed in the MASA will be large enough to be tested for strength. Solidification of metals and semiconductor materials are processed by continuously melting and rapidly cooling at a controlled rate.

Twenty samples per furnace are possible which can be subjected to a hot zone of 1,600°C. The furnace's rate of movement is programmable for individual sample runs.

operational characteristics:

Sample size:	14 L x 4 cm Dia
Temperature range:	600 to 1,600°C
Translation rate:	0.01 to 100 mm/minute
Apparatus size:	To be determined



carrier: Materials Science Laboratory

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812.
This apparatus is being developed.

molecular labelling of particles (MOLOP)

The MOLOP device is used to mix particles in zero-g aboard the NASA KC-135 aircraft. The MOLOP is designed to mix and to separate the components during the 20 to 30 seconds of zero-g aboard the KC-135 and is useful for studying the interactions of cells with viruses. latex with proteins, or any particles with soluble materials. This is achieved by mounting 17 pairs of syringes back-to-back. separated by a 0.2 um pore-size acrodisk filter. At the initiation of low gravity, the plunger of the material passes through the syringe to mix with the particles. As unit gravity approaches, the plunger of the syringe with the mixture is depressed so that the soluble material passes back through the filter, thereby trapping the labelled particles on the syringe. The filter is removed from the syringes and both ends are capped and placed into the storage compartment for transport back to the laboratory. Temperature is ambient at about 25 to 30°C. One mixing is possible per parabola. Operation is manual and requires one person.

operational characteristics:

Number of samples:	17
Operating temperature:	Ambient
Size:	6.0 x 15 x 20 in
Weight:	25 lbs
Soluble volume:	2.0 ml
Particle volume:	0.5 ml

carrier: KC-135 aircraft

contact: J.L. Sloyer, Jr., Ph.D., Eisenhower Medical Center,
Hal B. Wallis Research Facility, 3900 Bob Hope Drive,
Rancho Mirage, CA 92270
(619) 340-3911, ext. 4650.

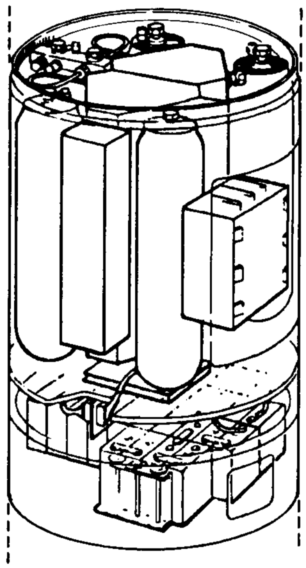
multi-mission mirror furnace module (M4)

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.

The module contains two advanced isothermal mirror furnaces, standing along the center axis. In the lower end of the cylinder there is an aluminum panel on which the furnaces rest. On the other side of the panel the power transistors are mounted, 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 one box containing batteries for electronics and one box for housekeeping functions of the module.

operational characteristics:

Size:	765 L x 438 mm Dia
Weight:	75.5 kg incl. battery module and 2 gas vessels
Material:	Outer structure: magnesium casting Inner structure: aluminum panel
G-forces:	Approximately 14 g max
Number of furnaces:	2
Sample size:	160 mm L x 15 mm Dia
Operation temperature:	50 to 1,000°C
Isothermal properties:	± 0.5°C along the whole sample length



carrier: Sounding rockets

contact: CONATEC, Inc., P.O. Box 171
Glendale, MD 20769
(301) 552-1088.
This apparatus is available.

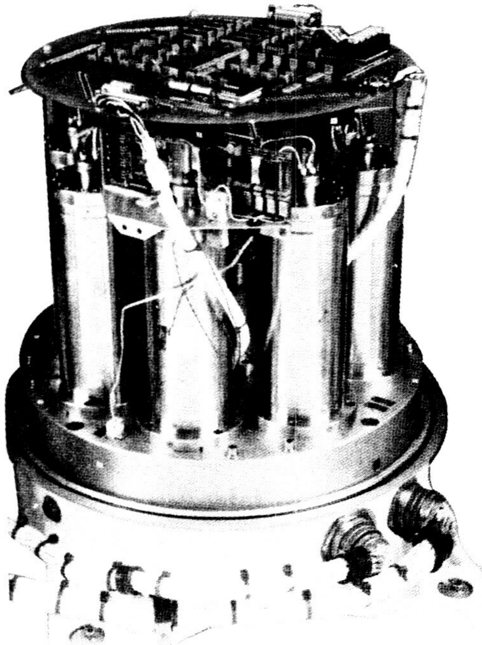
physical vapor transport of organic solids apparatus (PVTOS)

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 currently 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.

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

operational characteristics:

Operating temperature:	400°C (higher temperatures possible)
Power:	20 w
Size:	2 middeck locker spaces
Weight:	230 lbs with EAC



carrier: See text

contact: J.R. Reinhardt, 3M/Central Research, 3M Center, Bldg 201-25-05, St. Paul, MN 55144, (612) 736-6351. Apparatus is available.

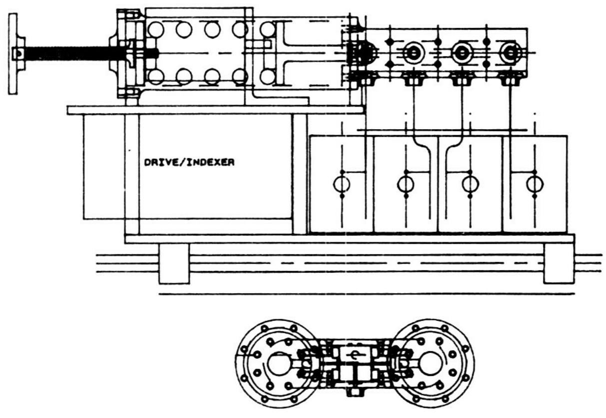
reaction injection molding (RIM) apparatus

RIM is a polymer process where 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 can also 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). This unit is designed for use in the KC-135 aircraft. Modifications of the apparatus are underway for use in an Experiment Apparatus Container, which can be mounted into the Orbiter middeck or cargo bay carriers, Spacelab or SPACEHAB facilities.

operational characteristics:

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



carrier: See text

contact: J.R. Reinhardt, 3M/Central Research, 3M Center, Bldg 201-25-05, St. Paul, MN 55144, (612) 736-6351. Apparatus is available.

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resistance heating capillary tube

The resistance heating capillary tube uses a quartz capillary crucible to contain the sample during melting. The tubing resembles an eye dropper. Samples are melted in an inert gas atmosphere.

operational characteristics:

Operating temperature:	200 to 1,600°C
Physical characteristics:	Not specified
Sample diameter:	Approximately 0.6 cm

carrier: Compatible with the drop tube

contact: Richard Black
NASA/Marshall Space Flight Center,
MSFC, AL 35812
(205) 544-1983.

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. 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 contact lenses for pilots and astronauts.

carrier: To be determined

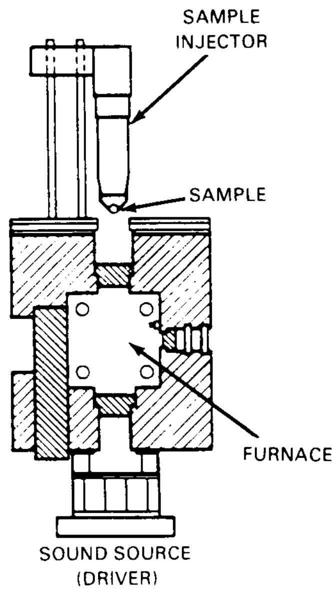
contact: Dr. G. Wood,
NASA/Langley Research Center,
Hampton, VA 23665.
This apparatus is planned.

single-axis acoustic levitation furnace

The Single-Axis Acoustic Levitation Furnace is a combination of a furnace system and an acoustic levitation system designed to allow levitation and melting of samples which are not conductive enough to be processed using the Electromagnetic Levitator. This is a functional duplicate of the Space Shuttle-based acoustic levitation furnace and as such is used mainly for examining the positioning properties of the experiment. Because of the extremely low power level, only small samples of very low density can be levitated in a 1-g environment.

operational characteristics:

Frequency:	15 kHz
Acoustic sound level:	155 to 159 dB
Furnace temperature:	800 to 1500°C
Furnace heating rates:	100 to 300°C/min
Furnace heating elements:	SiC
Cooling gas:	Air
Processing gas:	Air
Sample size:	2 to 8 mm Dia
Sample density:	0.5 g/cm^3
Sample shape:	Sphere, oblate, disk



carrier: Designed for ground-based research only (MMSL).

contact: NASA/Lewis Research Center, Code 105-1, MMSL, Cleveland, OH 44135, (216) 433-5014.

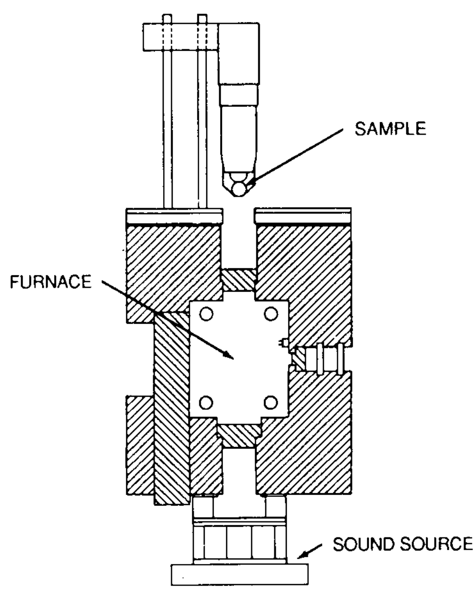
single axis acoustic levitator (SAAL)

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 H x 40.5 cm Dia
Furnace weight:	81.6 kg
Processing chamber:	10.2 x 10.2 x 11.4 cm



carrier: Materials Science Laboratory (MSL)

contact: NASA/Marshall Space Flight Center, Code JA61
MSFC, AL 35812, (205) 544-1979.
This apparatus is available.

space dispenser for carbonated beverages

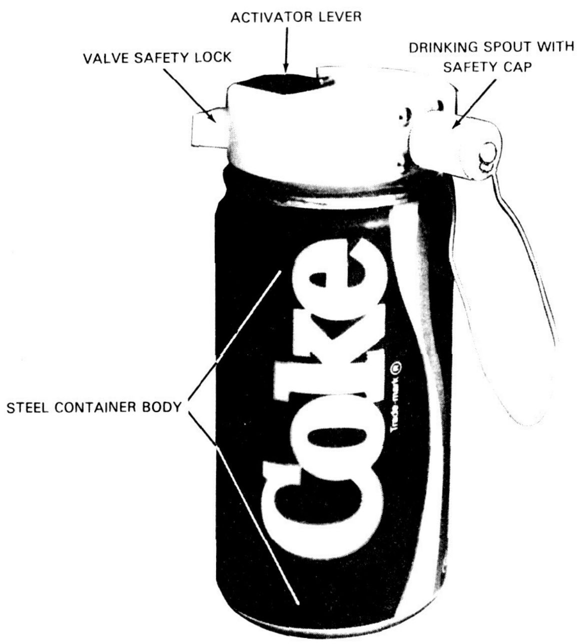
The space dispenser is designed to provide the astronauts with carbonated beverages without foaming. The dispenser features a unique internal dispensing mechanism which compensates for the zero-gravity condition. The dispenser has a drinking spout, a screw-on safety cap, a valve safety lock, a liquid 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 H x 2.5 Dia inches
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: Orbiter middeck

contact: A.S. Gupta, The Coca-Cola Company
P.O. Drawer 1734, Atlanta, GA 30301
(404) 676-4454.



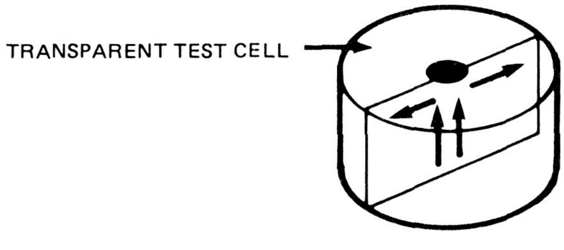
surface tension-driven convection experiment apparatus (STDCE)

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 the 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 with silicone oil. The oil is heated and cooled to produce temperature differences, causing oscillations which can be measured to complete the mathematical modelling.

operational characteristics:

Sample:	10 cs silicone oil
Sample volume:	400 ml
Sample chamber:	5 H x 10 cm Dia
Temperature range:	10 to 65°C
Apparatus size:	50 L x 50 W x 100 cm H
Apparatus weight:	170 kg overall



carrier: Spacelab

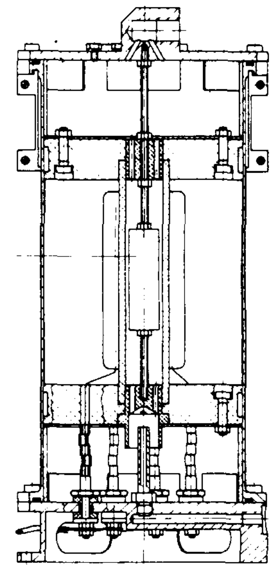
contact: NASA/Lewis Research Center, Space Experiments
Division, Cleveland, OH 44135.
(216) 433-2864.
Apparatus is under development.

texus experiment module TEM 01-1

This module is an isothermal four-chamber furnace, with four heating chambers which are controllable independent of each other, with separately operable cooling systems. The module can be applied to the implementation of melting experiments of any kind which essentially requires isothermal conditions. The furnaces are gas-tight and can be filled with any atmosphere. Samples up to 80 mm in length can be used.

operational characteristics:

Number of Furnaces:	4
Heater type:	PtRh
Measurement points:	4 x temperature per sample
Max. sample temperature:	1,450°C
Energy:	1 kw*h*
Power output:	4 kw
Cooling:	Helium 1200 NL
Furnace heated length:	65 mm
Furnace isothermal zone:	22 mm
Furnace Internal diameter:	15 mm
Furnace Tmax *heater:*	1,600°C
Furnace Tmax *sample:*	1,450°C



carrier: Spacelab, sounding rockets

contact: CONATEC, Inc., P.O. Box 171, Glendale, MD 20769, (301) 552-1088. This hardware is available.

texus experiment module TEM 01-4

This module was developed for improved effectiveness with regard to the ratio of samples to module weight. The weight effectiveness was brought to the 15.8 kg/furnace. This furnace can be used for the same type of experiments as the TEM 01-1, i.e., melting experiments of any kind which require isothermal conditions. Design of cartridge depends on the researcher's arrangement of cartridge in furnace.

operational characteristics:

Sample dimensions:	To be determined
Cartridge dimensions:	To be determined
Physical properties:	To be determined
Temperature-time profile:	To be determined
Temperature-measurements:	To be determined
Cooling rate:	To be determined
Soak time:	To be determined
Heating rate:	To be determined
Handling procedure:	To be determined

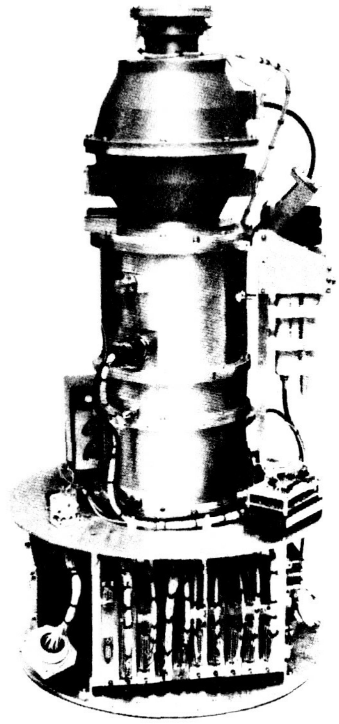
carrier: Spacelab, sounding rockets

contact: CONATEC, Inc., P.O. Box 171, Glendale, MD 20769, (301) 552-1088. This apparatus is under development.

texus experiment module TEM 02-2

A typical application of the furnace is crystal growth. By pulling a cylindrical sample through the focus, crystal lengths of 50-mm can be obtained. A temperature gradient can be produced in the sample by means of an additional unit so that directional solidification will be possible.

The experiment module is equipped with a rotationally symmetric ellipsoid mirror furnace. The sample in the first focus of the ellipsoid is heated without contact by a lamp in the second focus of the ellipsoid.



operational characteristics:

Furnace large mirror axis:	90 mm
Furnace small mirror axis:	80 mm
Lamp power output:	1,000 w
Typical sample temperatures:	1,500°C
Translation rate:	1 to 10 mm/minute
Rotation of sample:	1 to 10 rpm
Sample size:	90 L x 21 mm Dia max
Furnace atmosphere:	Depends on the experiment requirements

carrier: Spacelab, sounding rockets

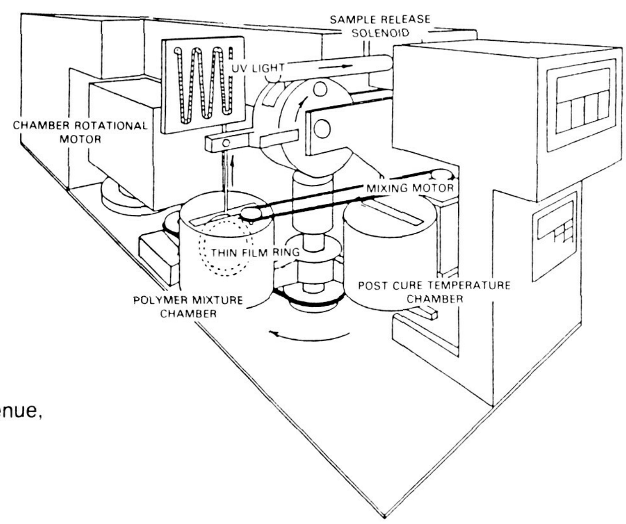
contact: CONATEC, Inc., P.O. Box 171, Glendale, MD 20769, (301) 552-1088.
This apparatus is available.

thin-film reactor system

The thin-film reactor system has been 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. The system currently is configured for drop tower tests, but could be modified for suborbital aircraft testing.

operating characteristics:

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



carrier: Drop towers

contact: Space Systems and Hardware, Battelle Advanced Materials Center for the Commercial Development of Space, Battelle Columbus Laboratories, 505 King Avenue, Columbus, OH 43201-2693.
Apparatus is available.

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, in a rectangular transparent container, is placed. 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 max
Oven step size:	100 nm
Optical magnification:	1 X to 64 X
Sample shape:	Rectangular
Sample size:	10 L x 10 W x 15 mm H

carrier: Designed for ground-based research only (MMSL).

contact: NASA/Lewis Research Center, Code 105-1, MMSL,
Cleveland, OH 44135
(216) 433-5014.

undercooling furnace

This furnace can repeatedly melt and resolidify to achieve desired degree of undercooling. Type R thermocouple monitors and records the sample temperature. Sample can be quenched in a silicon oil bath when recoalescence is observed. Thermal cycling is achieved using a programmable controller.

operational characteristics:

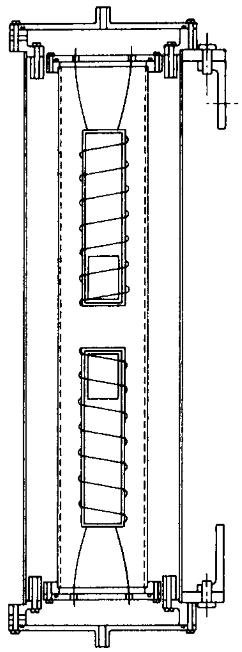
Temperature range:	800 to 1,200°C
Sample diameter:	6 mm max
Inert gases:	Argon, helium

carrier: Designed for ground-based research only (MMSL).
Facility can be used for preflight experiments before
using the KC-135 and Space Shuttle.

contact: Leslie Greenbauer-Seng, NASA/Lewis Research Center
(MMSL), Cleveland, OH 44135
(216) 433-5013.

vapor transport furnace for organic crystals and films

A vapor transport furnace is capable of operating on several different experiment carriers on the Space Transportation System (STS) or on Space Station. The furnace consists of two concentric aluminum tubes with a vacuum space between them. A quartz ampoule containing the chemicals for crystal growth is placed inside of 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 3 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 and other applications in addition to vapor transport crystal growth.



operational characteristics:

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

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

contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, Consortium for Materials Development in Space, Research Institute Bldg, Huntsville, AL 36899
(205) 895-6620.

■ *life sciences/biotechnology*

Life sciences experiments and apparatus share a large inventory as a result of the ongoing manned Shuttle and Spacelab programs as well as the non-human experiments developed for the orbiter middeck and Spacelab.

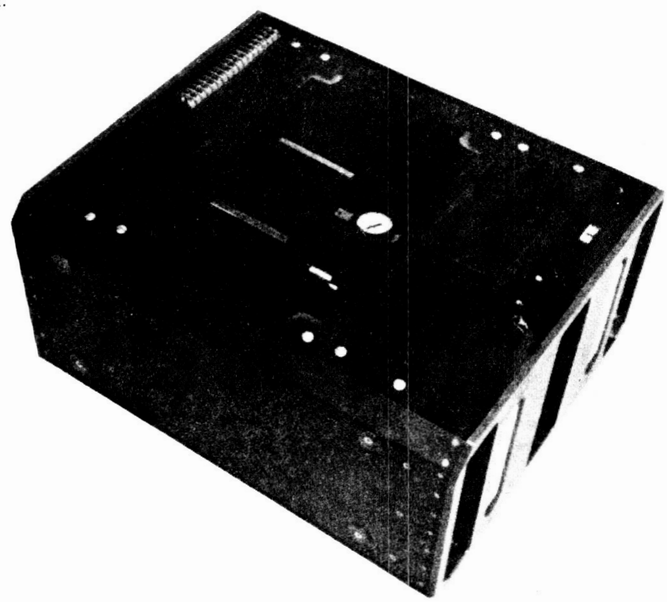
A number of units described in this section deal with investigations not directly involving a human or primate subject and therefore may be of interest to researchers exploring other related areas. In low gravity, the influences of thermal turbulence, buoyancy and sedimentation are reduced, much to the advantage of investigations exploring protein crystal growth, the separation of biological materials and cell culture. Contact the organization listed for the experiment pertaining to your research for additional information.

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 will also fit within the General Purpose Work Station.

The current unit has a 1500 cc and 2000 cc capacity automatic watering unit.



operational characteristics:

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

carrier: Orbiter middeck or Spacelab

contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035, (415) 694-5094. This apparatus is available.

continuous flow electrophoresis system (CFES)

The CFES apparatus separates and purifies living cells and macro-molecules 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.

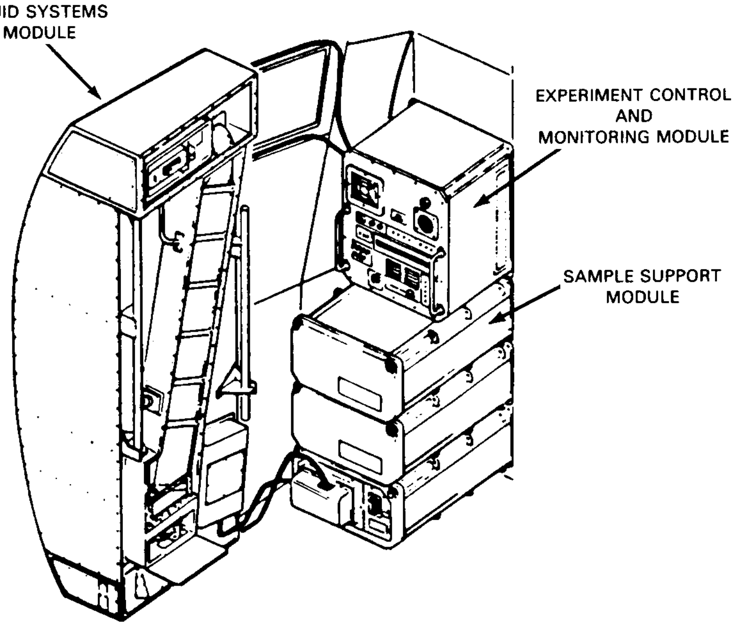
The samples of biological material are injected into a buffer solution that flows through an electrical field in the electrophoretic chamber. The product of interest is collected in the Fluid System Module (FSM) and returned to Earth. It processes one large 2-liter volume sample for a period of up to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

operational characteristics:

Operating temperature: 12 to 16°C gradient

Apparatus size
FSM: 76.2 L x 65 W x 201.7 cm H
Support eq.: 48.9 L x 49.1 W x 27.9 cm H

Apparatus weight: 371.47 kg overall



carrier:

Orbiter middeck

contact:

McDonnell Douglas Astronautics Company,
P.O. Box 516, St. Louis, MO 63166, (314) 232-8179.
This apparatus is available.
or
W.C. Hymer, CCDS/Center for Cell Research,
Pennsylvania State University, 465 North Frear Laboratory, University Park, PA 16802,
(814) 865-9182.
This apparatus is available.

epics 750 flow cytometer

The basic 751 flow cytometer offers unparalleled precision and speed with seven correlated parameters, five detectors and a single highly stable laser. By adding a dye laser with a split-beam optical design, the 752 flow cytometer provides unprecedented accuracy and sensitivity with minimal costs. Adding a second argon laser, the 753 flow cytometer design expands research possibilities with unequalled power and flexibility.

Currently, EPICS flow cytometers are being used in such diverse fields as clinical and research immunology, oncology, hematology, cytogenetics, marine biology, microbiology, botany and veterinary science.

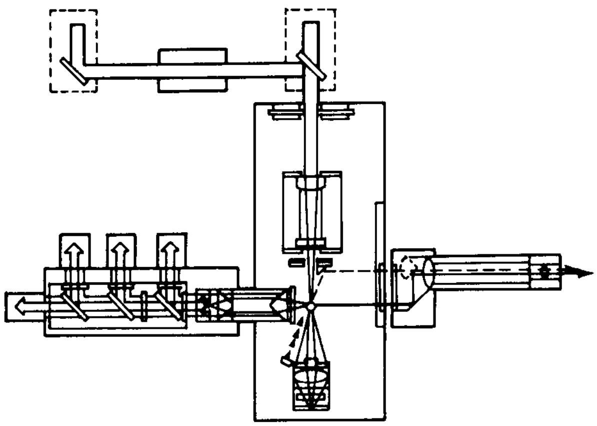
Cells or other particles in the sample stream are delivered under pressure through a small orifice into a chamber where they are surrounded by flowing sheath fluid. The two then pass through a flow cell of narrowing diameter and exit at high velocity, one cell at a time.

carrier:

Ground-based research only

contact:

Patricia Rozek, Coulter, P.O. Box 4486,
Hialeah, FL 33014-0486
(407) 885-0131.
This apparatus is available.



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.

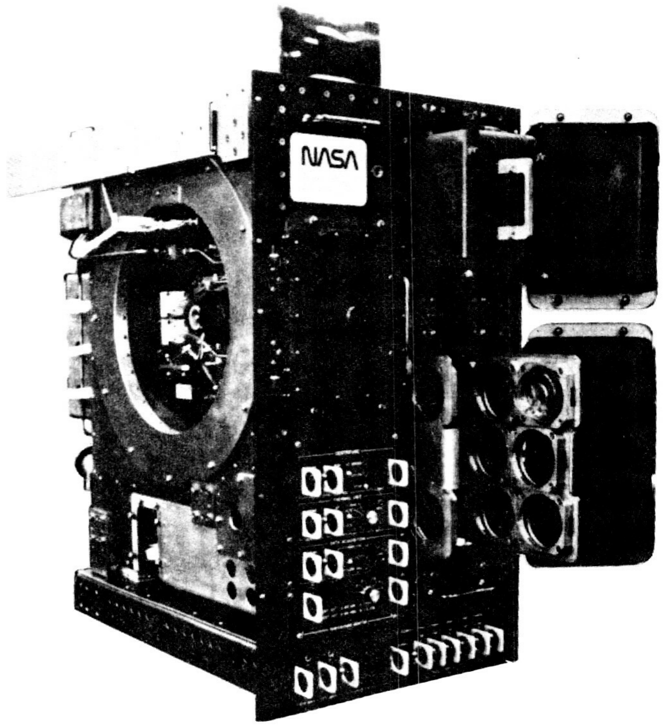
The centrifuge rotates at approximately 60 rpm and yields 1-g, providing a control environment for embryos developing at 0-g. The adult frog chamber will accommodate four female frogs, is removable, and useable at the General Purpose Work Station. The egg chambers are small acrylic structures (3.0 x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

operational characteristics:

Size: Fits lower portion of Spacelab rack, approximately 33 inches H

Weight: 160 kg

Chambers - 56: 28 on the centrifuge
28 in trays in 0-g storage



carrier:
Spacelab

contact:
NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035, (415) 694-5094.
This unit is under development.

general purpose work station (GPWS)

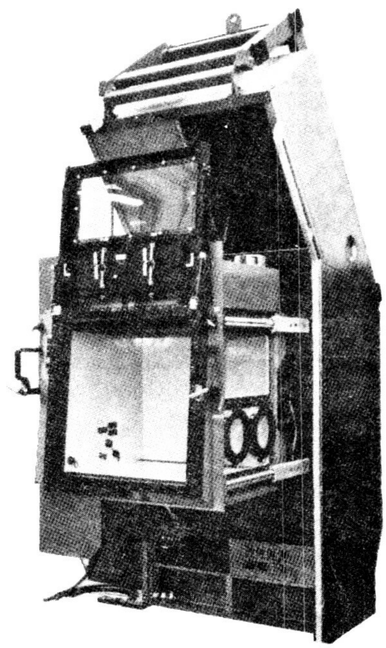
The GPWS is a broad range support facility for general laboratory operations in the Spacelab. It can support animal experiments, biological sampling, and microbiological experimentation.

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 rock-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 W x 108 H x 30 in D

Weight: 765 lbs



carrier:
Spacelab - double rack

contact:
NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035
(415) 694-5094.
This unit is undergoing verification testing.

gravitational plant physiology unit (GPPF)

The GPPF 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.

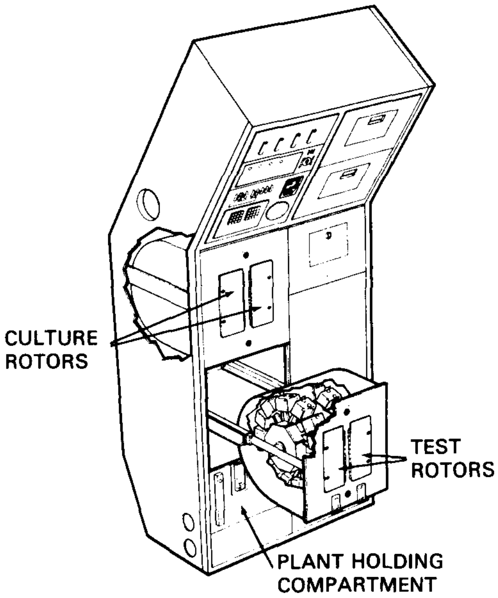
The unit provides for time-lapsed photography of the plant seedlings before and after light stimulus.

operational characteristics:

Capacity:	32 plant cubes
Size:	1 double Spacelab rack, approx. 41.5 W x 108 H x 30 in D
Weight - *culture rotor:*	64.7 lbs
- *test rotor assembly:*	80.5 lbs
- *total:*	363.7 lbs

carrier: Spacelab

contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035, (415) 694-5094.
This unit is under development.



hand-held protein crystal growth experiment apparatus (HPCG)

The HPCG is designed to explore the use of the microgravity environment for growing protein crystals that are of medical or scientific interest. HPCG experimentation also has important implications for enzyme engineering and the design of chemotherapeutic agents and pharmaceutical products. Using the vapor diffusion and dialysis techniques of the HPCG it is possible to organize biological molecules into large, single, symmetrical crystals.

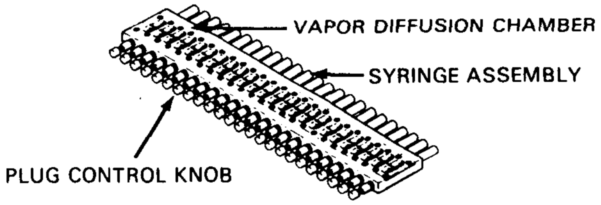
The HPCG is composed of two units. The Vapor Diffusion Apparatus (VDA) produces protein crystal growth via the difference in vapor pressure between protein/precipitant solutions of different concentrations. The crystals are then bombarded with x-rays after they are returned to Earth. The Dialysis Apparatus (DA) contains a protein solution and the precipitant solution, which are activated by shaking the DA. Crystallization then occurs, and the entire apparatus is returned intact for analysis.

operational characteristics:

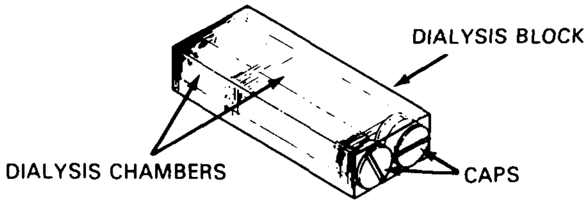
Sample capacity:	48 VDA and 12 DA/flight
Sample volume - *Protein:*	100 microliters/chamber
- *Precipitant:*	1 milliliter/chamber
VDA size:	35.2 L x 1.6 W x 13.33 cm H
VDA weight:	0.86 kg
DA size:	12.32 L x 2.41 W x 4.45 cm H
DA weight:	0.19 kg each
Total weight:	4.14 kg

carrier: Orbiter middeck - modular stowage locker

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812.
(205) 544-1979.
This apparatus is available.



HPCG VAPOR DIFFUSION APPARATUS



HPCG DIALYSIS APPARATUS

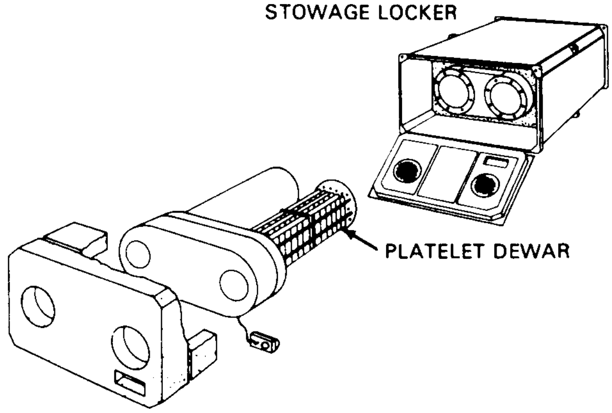
initial blood storage experiment apparatus (IBSE)

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 allows experiments which can evaluate the fundamental cell physiology of erythrocytes, platelets, and leukocytes during storage in space in three different 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 L x 39.2 W x 18.4 cm H
Weight:	46.4 kg total (both dewars)



carrier: Orbiter middeck - 1 stowage locker

contact: NASA/Johnson Space Center, Flight Projects Engineering Office, Code ID, Houston, TX 77058, (713) 282-1830. This apparatus is available.

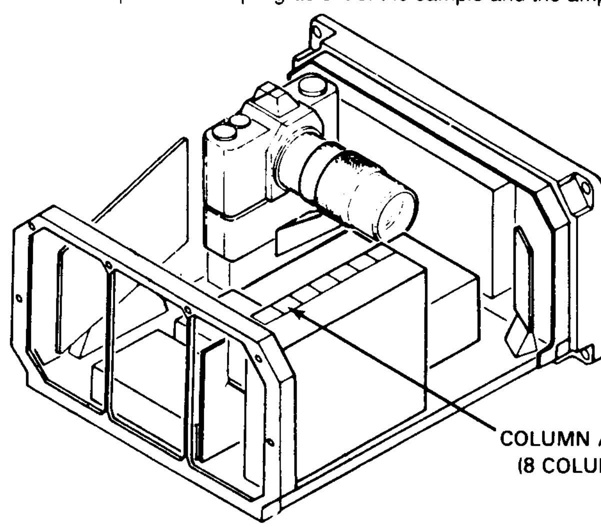
isoelectric focusing experiment apparatus (IEF)

The IEF is used to determine the best experiment design for producing pure separations of proteins, viruses, cells and other biological materials. Isoelectric focusing is the most powerful electrophoretic for separating and purifying biological materials on a small scale. However, fluid convection, or electroosmosis, affects isoelectric focusing, even in space. The IEF will assist in the assessment of electroosmosis which should yield a second generation IEF device for commercial production of biological samples of greater purity.

The IEF has eight columns which hold various samples for a 90-minute operational sequence. The pH gradient of the sample and the ampholyte buffer are recorded photographically and focused samples are harvested.

operational characteristics:

Sample size:	5.08 L x 0.64 cm Dia
Sample volume:	0.82 cm^3
Column assembly (8):	2.54 L x 2.54 W x 9.91 cm H
Column volume:	63.9 cm^3
Assembly size:	53.24 L x 48.26 W x 22.86 cm H
Assembly weight:	28.7 kg



carrier: Orbiter middeck - 1 stowage locker

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812, (205) 544-1979. This apparatus is available.

low-gravity centrifuge

The low-g centrifuge will be used for low-g separation processes and also to maintain certain specimens at low-g states for relatively prolonged periods, as required during Earth orbital flight aboard the Spacelab module.

technical specifications:

G-range:	0.5, 1.0, 1.5 and 2.0 g's
Accuracy:	± 5% of the set point
Temperature:	36.5 to 37.5°C

operational characteristics:

Size:	31.0 L x 43.3 W x 53.3 cm H
Volume:	7.93 x 104 cm^3
Weight:	15.9 kg

carrier: Spacelab

contact: NASA/Johnson Space Center, Life Sciences Experiment Program, Houston, TX 77058.
(713) 483-7328.
This apparatus is available.

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 usually done during normal usage.

The stowage drawers have 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. The different sizes are:

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: Orbiter middeck

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.

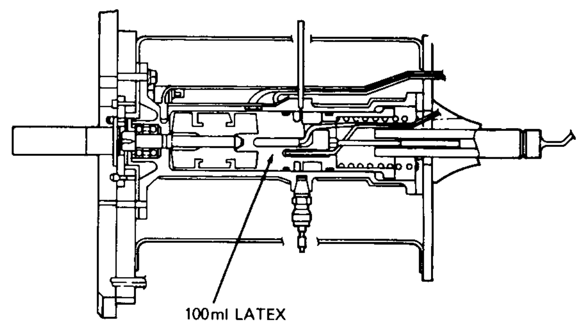
monodisperse latex reactor system (MLRS)

The MLRS apparatus can produce large, highly uniform latex micro-spheres used by industry and medicine in the calibration of sensitive scientific instruments and other applications requiring extremely accurate measurements, such as membrane probes or carriers of drugs or biological specimens. Because the latex solution does not have to be stirred as vigorously to maintain suspension in the space environment, the spheres do not coagulate, and the monodisperse qualities of the latex are maintained.

The MLRS consists of four latex reactors capable of processing up to 100 ml of latex forming material at 70°C or 90°C nominally. Other temperatures can be specified up to 90°C. After 20 hours, the apparatus turns off automatically.

operational characteristics:

Single reactor size:	38.1 L x 20.57 cm Dia
Single reactor weight:	6.75 kg
Single reactor volume:	0.014 m^3
MLRS weight:	71.27 kg
Support equipment size:	26.67 L x 34.54 W x 41.15 cm H
Support equipment weight:	22.5 kg



carrier: Orbiter middeck - 3 storage lockers

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812
(205) 544-1979.
This apparatus is available.

orbiter centrifuge

The function of the laboratory centrifuge is to perform separations inherent in blood-related Life Sciences research. The centrifuge will provide a minimum relative centrifugal force of 1400 g's when fully loaded. There will be an automatic shutdown time that may be manually set for operating durations to 99 minutes in increments of 1 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 L x 41 W x 23 cm H
Weight:	11.36 kg
Volume:	4.62 x 10^{-1} cm^3
Time of test:	Variable in 1-minute increments to 99 minutes

carrier: Orbiter

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058,
(713) 483-7328.
This apparatus is available.

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refrigerator freezer

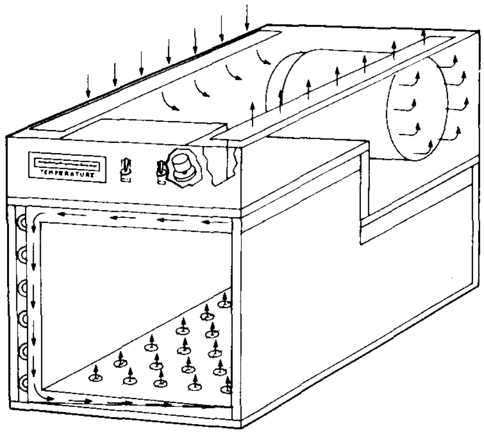
The refrigerator/freezer is an active unit with a temperature range from -22 to +10°C. It can be used to cool blood, body fluids, and cell samples as well as solutions and fluids intended for injection. It also may be used to house small animals, to incubate amphibian zygotes and to stow animal food supplies. It is designed to accept experiment racks, shelves and containers for a variety of purposes. Two units are available: one designed for the orbiter middeck and one for Spacelab.

operational characteristics:

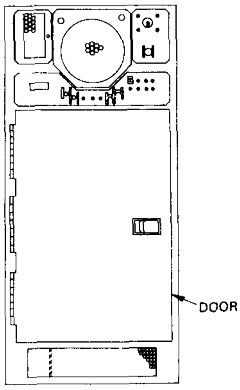
Temperature range:	-22 to +10°C (± 1°)
Cooling capacity:	700 BTU/hr at 4°C 400 BTU/hr at -22°C
Size - Overall: Orbiter: *- Spacelab:*	23.8 H x 18.125 W x 20.3 in. D 36.02 L x 19 W x 31.5 in. D
Weight - Orbiter: - Spacelab:	110 lbs 169.4 lbs
Volume:-	Internal: Orbiter - 1.27 ft^3 Spacelab - 2.5 ft^3

carrier: Orbiter middeck - 2 stowage lockers
Spacelab - 24 panel units in single rack

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.



Orbiter



Spacelab

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 coatings of the foregoing parameters.

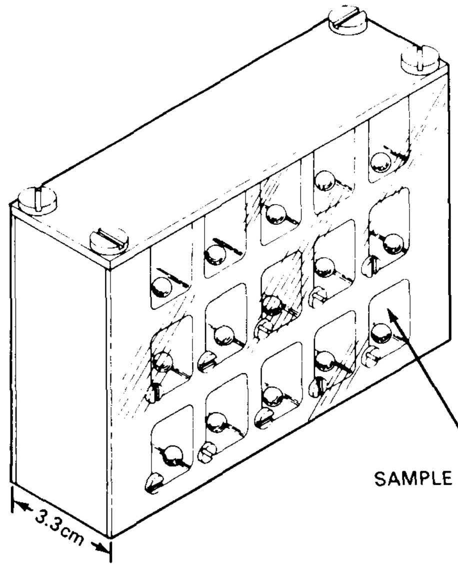
The PPE is configured to study natural coalescence and surface tension, two methods of phase separation. It also allows variations in interfacial tension, phase volume ratio, phase system composition and added particles. Up to 24 separate cavities can be filled with small quantities of two different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

operational characteristics:

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

carrier: Orbiter middeck - 1 stowage locker

contact: NASA/Marshall Space Flight Center
Microgravity Projects, Code JA61
MSFC, AL 35812, (205) 544-1979
This apparatus is available.



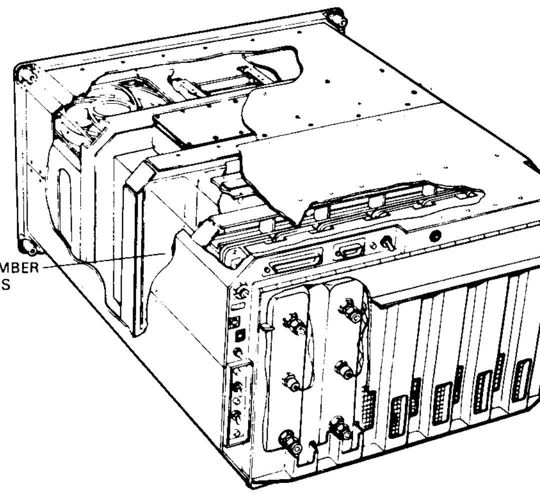
plant growth unit (PGU)

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

carrier: Orbiter middeck - one stowage locker



contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035
(415) 694-5094.
This unit is available.

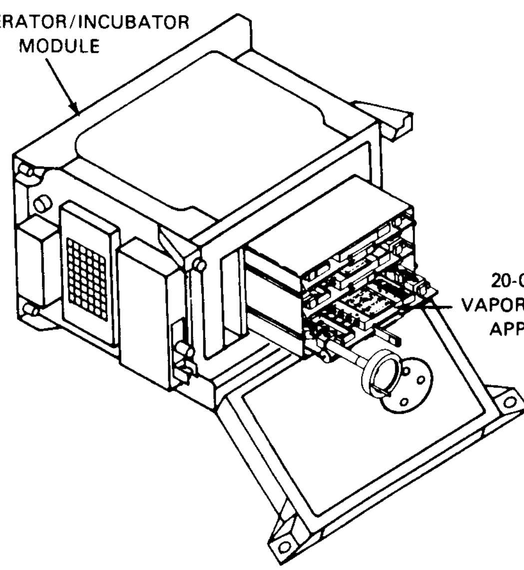
protein crystal growth experiment apparatus (PCG)

Protein crystals grown in the PCG apparatus, because of their potential size, degree of purity and quality, are highly valued for crystallographic analyses. The knowledge gained from analyses of these crystals through x-ray diffraction is of particular interest to the pharmaceutical and chemical industries for rational design of drugs, protein engineering and other biotechnologies.

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. The VDA operates in the same manner as described for the Hand Held Protein Crystal Growth Apparatus (HPCG), 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 L x 25.7 W x 16.2 H cm
Apparatus weight:	13.7 kg
Temperature range (R/IM):	0 to 50°C



carrier: Orbiter middeck - Refrigerator/Incubator Module

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812
(205) 544-5423.
This hardware is being fabricated.

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rack-mounted centrifuge (RMC)

The general purpose RMC provides centrifugal acceleration for separation or processing of samples in hematology, bacteriology, microbiology, immunology and other Life Sciences disciplines. It is installed in the Spacelab experiment rack and has mechanical and electrical interfaces with the rac.k. A number of rotors and tubes may be stowed depending on the particular payload requirement.

Two types of rotors are provided. One bucket type rotor for specimens requiring 50 to 1,600 g's for acceleration, and 35° fixed angle rotors for accelerations to 4,000 g's. Time of testing is adjustable up to 60 minutes.

The nominal specimen capacity of the RMC is:

tube size	quantity
5 ml	48 Bucket rotor
10 ml	48 Bucket rotor or 24 fixed angle rotor
15 ml	48 Bucket rotor or 24 fixed angle rotor
50 ml	10 Fixed angle rotor
5/10 ml	48 Bucket rotor

operational characteristics:

RMC size:	63.5 L x 42.8 W x 31 cm H
Volume:	7.38 x 10^{-2} m^3
Weight:	30 kg

carrier: Spacelab - 7 panel units

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.

refrigerator/incubator module

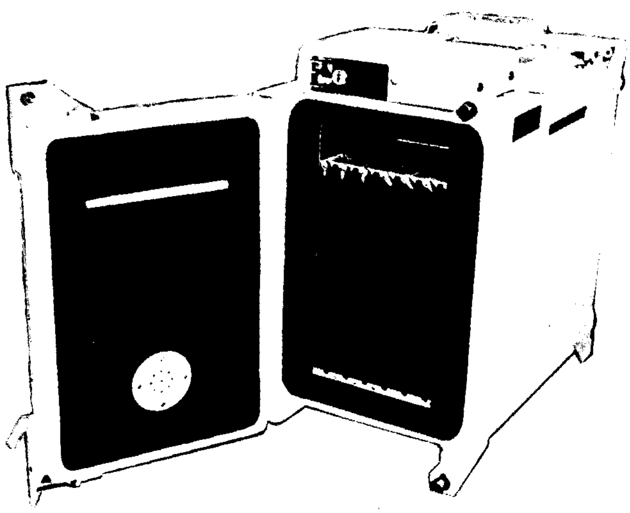
This apparatus is an active unit with a temperature range from 0 to +40°C. The temperature is set using a front-mounted variable potentiometer. Switching between the refrigeration and incubation modes occurs automatically.

operational characteristics:

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

carrier: Orbiter middeck - 1 stowage locker or Spacelab

contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035
(415) 694-5094.
This unit is under development.

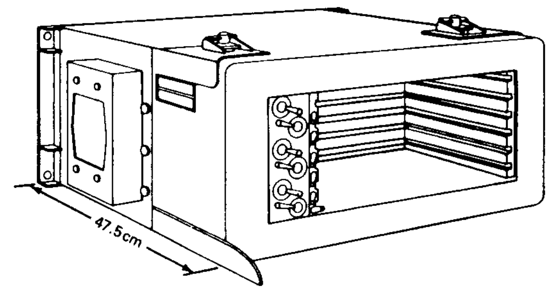


refrigerator/incubator module (R/IM)

This apparatus provides an easily integrated, temperature-controlled storage area for experiment samples, such as living cells, organisms and materials which must be maintained at specific temperatures in preparation for or after processing. This R/IM can be controlled to 1 degree intervals between 4 and 37.5°C.

operational characteristics:

Sample volume:	0.016 m^3
Size	
Inside:	25.7 L x 16.5 W x 37.1 cm H
Outside:	49.0 L x 29.2 W x 47.5 cm H
Weight:	18 kg
Heating rate:	1.8°C/minute
Cooling rate:	0.7 to 0.09°C/minute depending on start point



carrier: Orbiter middeck - 1 stowage locker or Spacelab

contact: NASA/Johnson Space Center, Medical Sciences
Division, Code SD, Houston, TX 77058
(713) 483-7109.
This apparatus is available.

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 using the cage designs described later. The two versions differ only in the design of the cage module. The module provides structural support, air ducts, lights, animal water system components and temperature and humidity sensors.

operational characteristics:

Capacity:	24 350-g rodents or 4 1200-g primates
Size:	1.5 Spacelab racks approximately 41.5 W x 108 H x 29.92 in D
Range:	1-g or 0-g in horizontal or vertical position
Weight:	616 lbs

carrier: Spacelab

contact: NASA/Ames Research Center, Life Sciences Project Office,
Moffett Field, CA 94035
(415) 694-5094.
This unit is available.

research animal holding facility primate cage

The primate cage houses one 1200-g primate; four cages will fit into the RAHF unit. 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 ad lib, and food is dispensed by the subject on a pre-trained program. The unit may also be used to transfer a variety of other biological specimens as required.

operational characteristics:

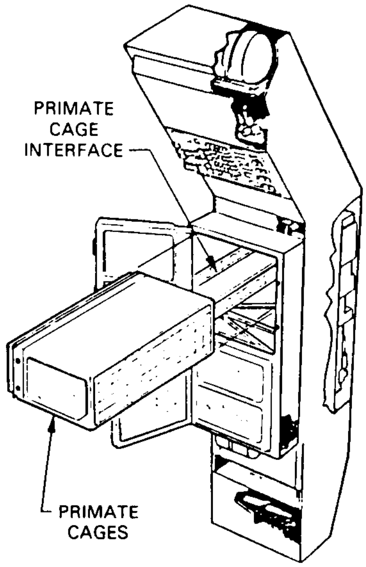
Size
cage: 21.69 W x 36.91 H x 53.34 cm D

Weight
empty: 18.3 kg

carrier: Spacelab - RAHF

contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035
(415) 694-5094.
This unit is available.

SQUIRREL MONKEY CONFIGURATION



research animal holding facility rodent cage

The rodent cage houses two 350-g rodents in separate compartments; 12 cages will fit into the RAHF unit. The cages are fed automatically and water is constantly available. Waste is collected in removable trays and protection against cross-contamination between crew and animal is provided through bacteriological isolation.

operational characteristics:

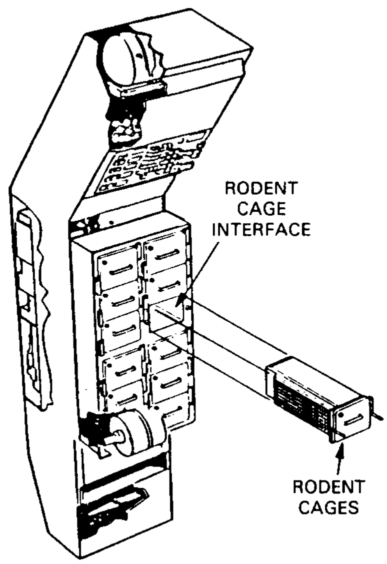
Size
2 compartments/cage: 4 x 4.5 x 10 in each compartment

Weight: To be determined

carrier: Spacelab - RAHF

contact: NASA/Ames Research Center, Life Sciences Project Office, Moffett Field, CA 94035, (415) 694-5094.
This unit is available.

RODENT CONFIGURATION



stowage container - 001

The 001 stowage container is a general purpose locker which will be installed in the upper portion of a standard Spacelab rack. The unit is flush-mounted. The 001 stowage container is hinged on the bottom horizontal edge and across the middle. The door folds down horizontally. It may also be mounted in the rack so that the container is hinged on the top horizontal edge with the door folding up.

operational characteristics:

Weight:	5.2 kg
Clearance (outside):	52.6 L x 48.3 W x 39.9 cm H
Clearance (inside):	38.1 L x 41.17 W x 34.67 cm H

carrier: Spacelab

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.

stowage container - 002

The 002 stowage container is a general purpose locker which will be installed in the lower portion of a standard Spacelab rack. The unit is flush mounted. The door operates by a thumb-finger squeeze latch for one-handed opening. The stowage container can be configured to allow the door to open to the left or right.

operating characteristics:

Weight	
Unit No. 302:	6.8 kg each
Unit No. 301:	9.0 kg each
Clearance (outside):	72.86 L (including door) x 48.26 W x 53.24 cm H
Clearance (inside):	58.75 L x 41.17 W x 48.03 cm H

carrier: Spacelab

contact: NASA/Johnson Space Center, Life Sciences Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.

tail suspension model

Infrequent opportunities for space experiments demand the use of ground-based models of weightlessness. Weightlessness is simulated in animals (rats) by the unloading of hind limbs using an orthopedic back harness or tail suspension. The tail suspension technique is believed to more accurately reflect space-flight conditions.

The tail suspension model is available at the Center for Cell Research.

carrier: Ground-based research

contact: W.C. Hymer, CCDS/Center for Cell Research
Pennsylvania State University
465 North Frear Laboratory
University Park, PA 16802
(814) 865-9182.

tissue culture incubator

This small tissue culture incubator is capable of maintaining 37°C (± 0.5°C). It can house four 15-ml cultures. The culture chambers are made of teflon and glass and are equipped with a septum permitting the addition of material in flight via syringes also stored in the incubator. The syringes may be either modified 5-ml or standard syringes. The cultures are designed to be liquid only. Volume expansion of the culture vessels is achieved by a teflon-sleeved piston arrangement in which the septum is housed. The incubator can be mounted in a standard 19-inch electronics (or experiment) rack or be carried alone in a battery mode removed from the rack.

operational characteristics:

Size: 17.4 x 48.2 x 22.1 cm (rack-mounted)
24.8 x 30.4 x 18.6 cm (removed)

Weight: 6 kg total

carrier: Spacelab (standard 19-inch rack)

contact: NASA/Johnson Space Center, Life Sciences
Experiments Program, Houston, TX 77058
(713) 483-7328.
This apparatus is available.

upper rack stowage trays

A stowage tray structural enclosure is designed to house the stowage trays. It has dimensions of approximately 20 L x 16 W x 12 inches H, 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 completely removed 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 and the heights of the trays range from 2.13 inches to 11.23 inches.

carrier: Orbiter middeck or Spacelab

contact: NASA/Johnson Space Center
Life Sciences Experiments Program
Houston, TX 77058
(713) 483-7328.
This apparatus is available.

■ combustion engineering

The NASA Lewis Research Center is developing four experiment systems to study combustion phenomena in microgravity. The microgravity environment allows the investigation of fundamental phenomena that are associated with flame propagation, extinction and control that are masked by the influence of gravity on Earth.

These experiments hold great promise, considering their applicability to everyday uses such as automotive engines and industrial devices.

drop combustion experiment apparatus (DCE)

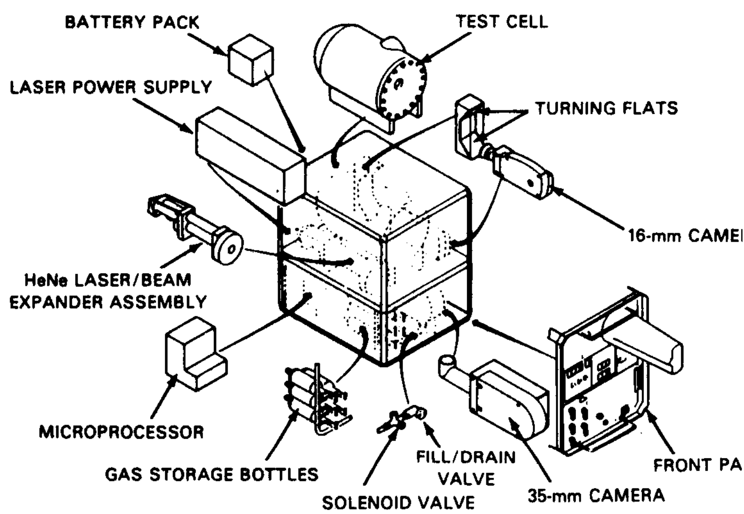
The DCE, using a drop deployment system, will study drop behavior during combustion by measuring burning rates, extinction phenomena, disruptive burning and soot production in burns that are spherically symmetric. It also can handle non-spherical droplets by allowing an increase in drop velocity. This could lead to a better understanding of the combustion process and associated phenomena and eventually to improvements in the efficiency of combustion devices such as automotive engines and power plant furnaces. Up to 25 consecutive tests, each lasting 12 minutes, can be conducted.

operational characteristics:

Sample-size droplets:	0.8 to 2.5 mm
Stored liquid fuel volume:	Less than 0.6 cm^3
Burning time - each test:	0.5 minutes
Overall size:	51.61 L x 53.72 W x 40.04 cm H
Weight:	54 kg

carrier: Orbiter middeck - 2 stowage locker spaces

contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135
(216) 433-2864.
This hardware is undergoing testing.

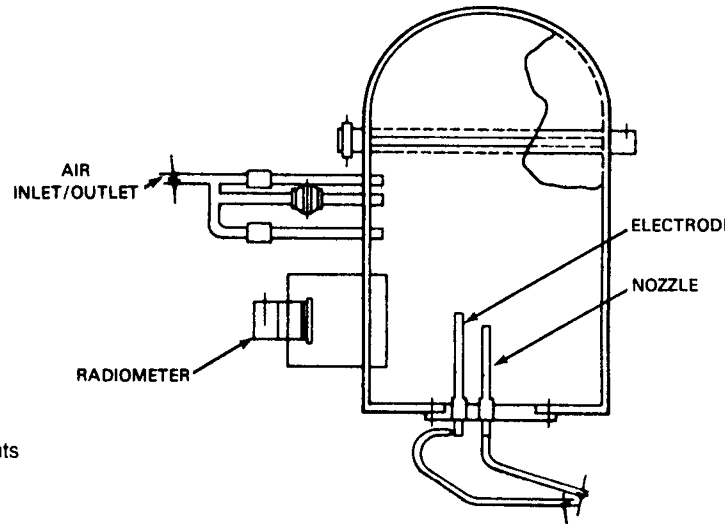


gas jet diffusion flames apparatus (GDFA)

The GDFA will investigate laminar gas jet diffusion flames in a quiescent, low-gravity environment. Gas jet diffusion flames embody mechanisms operant in both unwanted fires and controlled combustion systems. The GDFA is designed to improve understanding of laminar gas jet diffusion flames by isolating the effects of buoyancy in low-gravity. Investigators will be able to study the effects of different nozzle sizes, gaseous fuel types, fuel flow rates, chamber pressures and oxygen concentrations.

operational characteristics:

Sample fuel:	Methane or propane
Fuel flow rate:	1 to 3 cm^3/sec
Chamber size:	40 cm Dia x 70 cm H
Pressure:	0.5 to 1 atm
Atmosphere:	15% to 21% O_2



carrier: 145-meter 0-g Research Facility or KC-135 research aircraft

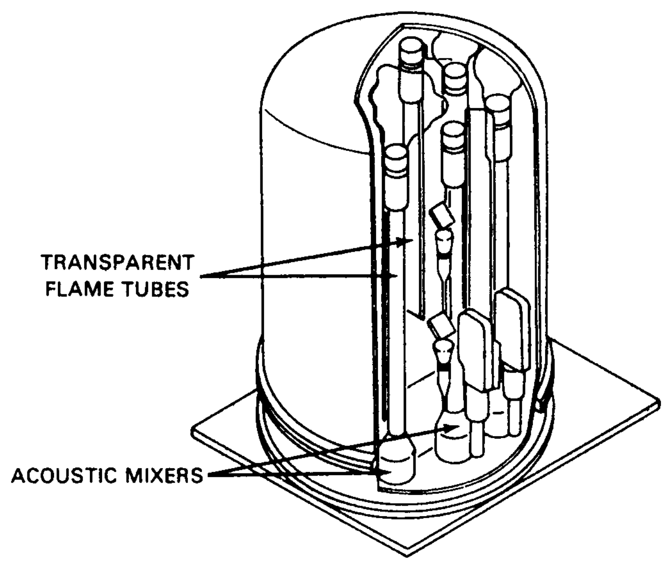
contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135
(216) 433-2864.
This unit is under development.

particle cloud combustion experiment apparatus (PCCE)

The PCCE permits study of fundamental two-phase combustion processes. The uniform clouds of particulates that form in microgravity can be studied for flame propagation and extinction characteristics. In the PCCE apparatus, eight separate quantities of fuel particles are mixed acoustically in transparent flame tubes to obtain quiescent, uniform clouds. Combustion is then initiated automatically and ignition, flame shape, propagation rate and extinction are recorded on film. The PCCE has the capacity for eight fuel-air ratios/flight.

operational characteristics:

Sample particle size:	25 to 55 micrometers
Container size:	129 L x 71 cm Dia
Flame tube size:	75 cm (± 0.2) cm L x 5 cm (± 0.2) cm Dia
Atmosphere:	Dry air 21% O_2, 79% N_2



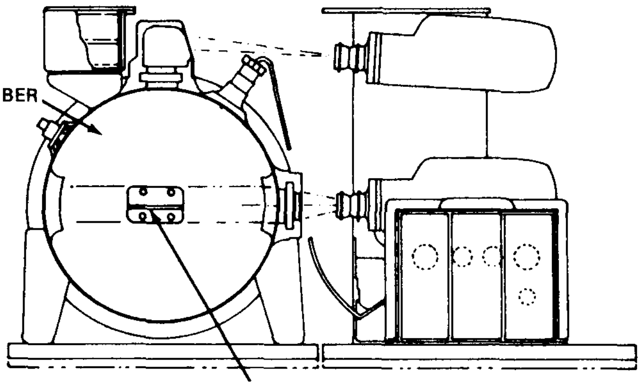
carrier: Materials Science Laboratory

contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135
(216) 433-2864.
This apparatus is being designed.

solid surface combustion experiment apparatus (SSCE)

The SSCE will investigate mechanisms that control flame spreading on solid fuel surfaces to improve 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. The SSCE has the capacity of one sample/chamber and up to three chambers per flight.

operational characteristics:



Sample size	
Thermally-thin fuel:	0.18 cm x 3.0 cm x 10.0 cm
Thermally-thick fuel:	0.315 cm x 0.630 cm x 2.000 cm
Oxidizer (air):	30% and 50% O_2
Overall dimensions:	55.6 L x 92.1 W x 53.3 cm H
Chamber dimensions:	51.3 cm L x 34.3 cm Dia
Chamber volume:	0.039 m^3
Weight - overall:	54 kg

carrier: Orbiter middeck - 2 locker spaces each chamber

contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135
(216) 433-2864.
This hardware is undergoing testing.

■ ancillary equipment

As flight hardware has been developed, tested and flown, certain additional secondary pieces of hardware have evolved.

Foremost among these are a number of measurement and recording devices designed to support the manned flight experiments. The NASA/Ames Research Center and NASA/Johnson Space Center Life Sciences programs developed a number of devices which, although designed with human or non-human subjects in mind, could be adapted to other experimental uses in space. Also developed were a series of devices to measure and record the effects of experiments on humans in space, which must have a human as subject. All of these are grouped in this category under Life Sciences Equipment and further grouped into those available from ARC and from JSC.

During the course of experiment apparatus development, additional systems have been developed. Some of these systems fall into a category of Experiment Flight Support Equipment, which enhances the performance or operational characteristics of previously designed hardware. Three of these devices have been developed by the 3M Company and are included. It is expected that additional enhancements will be made in the future.

A third area of ancillary equipment is being developed to provide additional interfaces, measurement and recording for experimental apparatus. These are spin-offs that provide the needed channels of data to assure experiment operation and verification or to lessen the load on the orbiter facilities. All of these are grouped under Experiment Interface and Monitoring Devices.

The researcher is encouraged to review these systems and devices to determine applicability to any experimental programs that he may have in mind.

life sciences equipment NASA/Ames Research Center

(Contact Life Sciences Project Office for further information, (415) 694-5094)

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.

dynamic environment measuring system (DEMS)

The DEMS is an instrumentation package which records Spacelab vibration, acoustic and acceleration levels during launch and reentry.

general purpose transfer unit (GPTU)

The GPTU is designed to provide a second level of particle contamination during transfer of rodents between the cages and the General Purpose Work Station.

plant canister

The units are designed to hold 15 corn plants each. They are carried in a foam cutout in the Orbiter 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 restraint chair

The 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

The kit contains provisions which can be used for emergency care of squirrel monkeys and rodents during flight. It is stowed in either the orbiter middeck or Spacelab.

life sciences equipment NASA/Lyndon B. Johnson Space Center

(Contact Life Sciences Flight Experiments Program for further information, (713) 483-7328).

articulating rail clamp attachment

This clamp provides mobility for equipment mounted on the fixed rail clamp. It can be rotated 360o or moved via a ball and socket joint.

bicycle ergometer

This provides a quantitative measure of the stress induced in a subject for experiments that evaluate the effects of 0-g on the cardiovascular system.

body mass measurement device

The function is to measure in 0-g the mass of humans and other specimens or objects. The device uses a linear spring/mass pendulum platform technique.

cassette data tape recorder

This is an eight-channel battery-powered recorder. One version has six analog-digitized and two analog channels and one version has eight analog-digitized channels.

echocardiograph

This is an imaging system using ultrasound, computer image enhancement and data storage techniques to generate a video display of cardiac parameters.

electro-oculographic signal conditioner

This unit is lightweight, miniaturized, battery-operated and capable of detecting electro-oculographic potentials generated by the human eye.

electrode impedance meter

The meter can measure the impedance of up to 12 recording electrodes. Impedance is displayed on a digital liquid crystal display.

electromyogram signal conditioner

This is a compact, lightweight, low-power precision instrument designed to monitor a human's heart or muscle potentials.

gas analyzer mass spectrometer

The instrument can perform atmospheric environmental monitoring of the orbiter cabin, specimen holding facilities or other instruments to determine oxygen consumption.

GN2 passive freezer

This freezer is employed to freeze experiment samples and blood samples and can keep them frozen until orbiter landing and recovery.

hematocrit centrifuge

The centrifuge is a lightweight device, which handles nine microliters of blood in each of six capillaries, is hand-held and battery-operated.

in-flight blood collection system

The major items of the equipment contained in this system are kits for blood collection and analysis. Additional equipment can be added as required.

keyboard/display terminal

This terminal is a character-oriented data terminal for interactive computer/communication applications. The communications interface is serial RS232C.

lower body negative pressure device

This device is a cylinder that encloses the lower abdomen and extremities of a human to maintain a controlled pressure differential below ambient.

microcomputer

This is a low-power 12-bit microcomputer for stand-alone operation for use with on-board experiments.

middeck rotator

The middeck rotator is a servo-controlled motor-driven rotating chair and pedestal assembly. It is used to conduct vestibular investigations in the middeck.

mini spectrophotometer

This unit is a compact, lightweight, flight-qualified spectrophotometer with a built-in battery power supply. It features a digital display.

minioscilloscope

The minioscilloscope is a general purpose, dual trace, storage oscilloscope -- a modified Tektronix Model 214.

multi-channel strip chart recorder

This recorder is a variable speed thermal recorder used to obtain a permanent graph record of experimental data.

physiological monitoring system

This system contains equipment to obtain and process electrocardiograms, heart rate and blood pressure data. It has a remote control/display unit.

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.

small mass measurement instrument

This unit will measure solid, semi-solid, and liquid masses plus small laboratory animals.

ultrasound limb plethsymograph

This unit provides a means for measuring and recording limb volume changes during exposure to physiological stresses in 0-g and 1-g environments.

urine monitoring system

This unit provides for the collection, volume measurement and sampling of micturitions in either 0-g or 1-g environments.

venous occlusion cuff and controller

This inflatable cuff is electronically controlled and can be used to induce a physiological stress on a limb to be measured.

experiment flight support equipment

3M heat exchanger

The 3M Heat Exchanger is a heat removal system for the Experiment Apparatus Container to improve thermal management and operation of Orbiter middeck experiments.

contact: J.R. Reinhardt, 3M/Central Research Laboratory
3M Center, Bldg 201-25-05, St. Paul, MN 55144
(612) 736-6351.

3M generic electronics module (GEM/2)

The GEM/2 is a general purpose, process control and data acquisition computer that supervises and operates payloads flown on any man-tended space system or unmanned space platform. Any experiment requiring a high-level microprocessor for control can be supported by the GEM/2.

contact: J.R. Reinhardt, see above.

3M payload support network (PSN)

The PSN is a system to improve the operational environment for Orbiter payloads. It provides substantial interaction between payloads and crew members while lessening demands on the crew.

contact: 3M/J.R. Reinhardt, see above.

experiment interface and monitoring devices

electrokinetic analysis service

The electrophoretic mobility of either particles, soluble materials or mixtures of each, can be determined in minutes using a PenKemm S3000 electrokinetic analyzer. The unit is designed for ground-based use to support experiments which benefit from the measurement of surface charge density and the changes induced by particle and soluble interactions.

contact: John L. Sloyer, Jr., Ph.D.
Eisenhower Medical Center, Hal B. Wallis Research Facility
3900 Bob Hope Drive
Rancho Mirage, CA 92270
(619) 340-3911.

NPS 2000 image processing integrated circuit

The 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" scene representations. A completely pipelined 20 MHz system is capable of continuous video-rate (80 frames per second for 512 by 512 images, 20 frames per second for 1K by 1K images) processing.

contact: D.L. McCubbrey
Environmental Research Institute of Michigan
P.O. Box 8618
Ann Arbor, MI 48107-8618.

orbiter display unit

The Orbiter Display Unit is a high-brightness CRT, 5 x 7 inches, qualification-tested, available for Shuttle applications.

contact: Norden Systems, Inc.
P.O. Box 5300, Norwalk, CT 06856.

shuttle environmental monitoring system (SEMS)

SEMS provides 24 channels of data in the areas of vibration, acoustics, temperature, contamination and pressure.

contact: SPACECO, 9470 Annapolis Road
Lanham, MD 20706.

space acceleration measurement system (SAMS)

The SAMS can measure, condition, and record low-g acceleration levels from $\pm$ 0.5 g to 3 x 10^{-8} g experienced by Shuttle orbiter experiments.

contact: NASA/Lewis Research Center, Cleveland, OH 44135.

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.

contact: Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807-5301.

texus experiment module TV-TC

The TV-TC is a transmitter able to transmit TV pictures in real-time and to permit real time control of an experiment by telecommand. The unit has two transmitters at 10 w total.

contact: CONATEC, Inc.
P.O. Box 171, Glendale, MD 20764
(301) 552-1088.

UAH accelerometer package

The function of the accelerometer package is to: 1) measure low-g accelerations along three orthogonal axes; 2) to generate output signals proportional to these accelerations; 3) to provide these 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; 4) to store the data both on-board and on the ground for later detailed analysis.

contact: Dr. Francis C. Wessling,
CCDS/University of Alabama - Huntsville
Consortium for Materials Development in Space
Research Institute Bldg, Huntsville, AL 35899 (205) 895-6620.

UAH/CCDS computer system

The computer system uses a low-power, high performance single board computer designed for control processing and data logging applications. The software is capable of executing user software upon power-up using either machine code or Tiny Basic user programs.

contact: Dr. Francis C. Wessling, CCDS/University of Alabama - Huntsville, see above.

CHAPTER 5

payload carriers

In general, all of the experiment apparatus units described in Chapter 4 are mounted inside some type of carrier. This carrier may be a no-frills class, such as the Get-Away-Special (GAS) canisters, the full-service accommodations of Spacelab or the planned SPACEHAB. Chapter 5 offers information about carrier hardware so that the user may select the most appropriate type for the accommodation of his payload.

The major emphasis for commercial users in this document is on the shuttle and shuttle-borne carriers. However, some carriers are adaptable for use on expendable launch vehicles or sounding rockets and can offer alternatives to the shuttle.

For convenience, carriers are grouped into the following categories:

- ***pressurized carriers*** - includes Spacelab and several planned pressurized carriers
- ***unpressurized carriers*** - includes a range of carriers designed for mounting in the Orbiter payload bay
- ***containers and mounting hardware*** - equipment which can facilitate installation onto a carrier.

Each carrier is described in some detail in the following section with points of contact listed.

■ *pressurized carriers*

At present, seven pressurized carriers are either available or being planned. In addition, the Office of Commercial Programs recently announced that jettisoned space shuttle External Tanks (ETs) could be made available.

The following conventions have been adopted for use in this category:

Dimensions -	internal user dimensions in feet (ft) L = length, W = width, H = height, D = deep, Dia = diameter
Volume -	available for user experiments in cubic feet (ft^3)
Weight -	maximum user weight in pounds (lbs)
Power -	continuous power available to users in kilowatts (kw)
Cooling -	available to users in kilowatts (kw) L = liquid, A = air
CMD & TLM -	command and telemetry data rates are in kilobits per secon'. (kbs) No (N)
TBD =	to be determined

commercially-developed space facility (CDSF)

The Commercially-Developed Space Facility is being defined along the lines of accommodating standard Space Station racks. This facility may provide an alternative to existing carriers and become a viable option.

Additional information is not available at this time.

Dimensions:	TBD
Volume:	500 ft^3
Weight:	12,500 lbs
Power:	TBD
Cooling:	TBD
CMD & TLM:	1 kbs, 16 kbs

location: Orbiter payload bay

contact: Ralph Hoodless, NASA/Headquarters
Office of Space Flight,
Code M, Washington, DC 20546
(202) 453-2513.
One carrier is planned.

external tank (ET)

Under current launch scenarios, ETs are dropped into a safe ocean area. Through 1994, ETs could be made available to users after jettison either under current launch scenarios or, in certain cases, in low Earth orbit. In the case of low Earth orbit, the user will be responsible for all costs associated with low Earth orbit injection, as well as for all costs associated with providing for safe disposition of the ET. Of the approximately 40 ETs which will be utilized in support of the civil space program through 1994, a number could be made available by NASA without reimbursement for the basic cost of the ETs; however, the exact quantity of ETs is subject to a case-by-case analysis of each launch and the proposed use of the ET on that launch. NASA will not consider any plan by which ETs would be "parked" in orbit for future use. At present, NASA does not envision granting sole rights to all ETs to any single entity.

location: Jettisoned space shuttle ET

contact: NASA/Headquarters, Office of Commercial Programs,
Code CP, Washington, DC 20546, (202) 453-2078.
Up to 40 available.

get-away-special canister (GAS can)

The GAS canister is a standardized, cylindrical aluminum container. It can be evacuated and/or pressurized and 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 canister. While this plate may not be altered, it does include adequate provisions for the attachment of experiment packages.

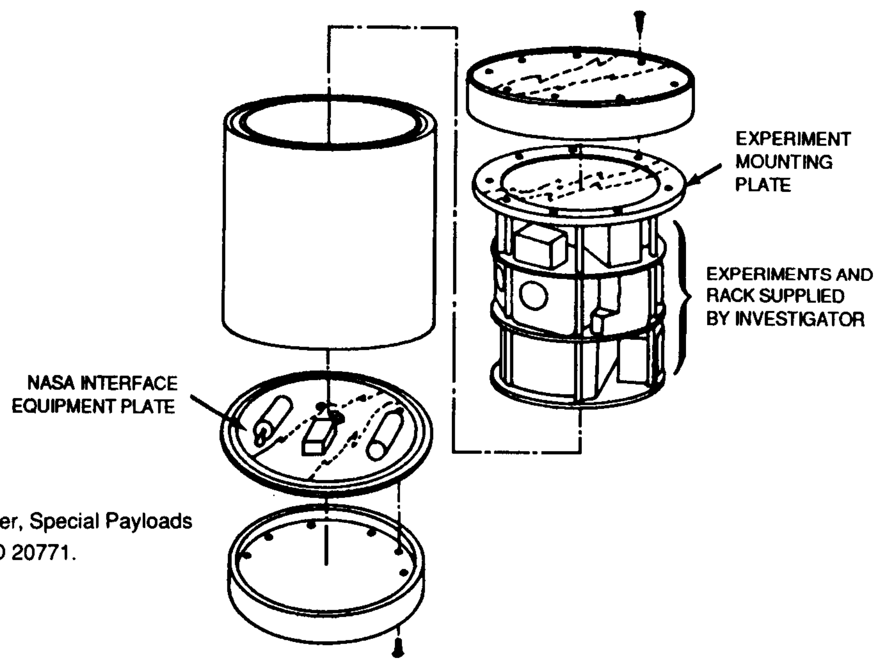
GAS canister operations are independent of the orbiter other than three on/off controls activated by the crew. The experimenter is responsible for providing electrical power, heating/cooling, and data acquisition systems and must consider thoroughly the effects of temperature, vibration, acoustics, acceleration and pressure during design.

operational characteristics:

Dimensions:	28.5 H x 20.0 Dia
Volume:	5.0 ft^3
Weight:	200 lbs
Power:	0 kw
Cooling:	0 kw L, 0 kw A
CMD & TLM:	N, N

carrier: Hitchhiker-G & -M, GAS Bridge

contact: NASA/Goddard Space Flight Center, Special Payloads Division, Code 740, Greenbelt, MD 20771.

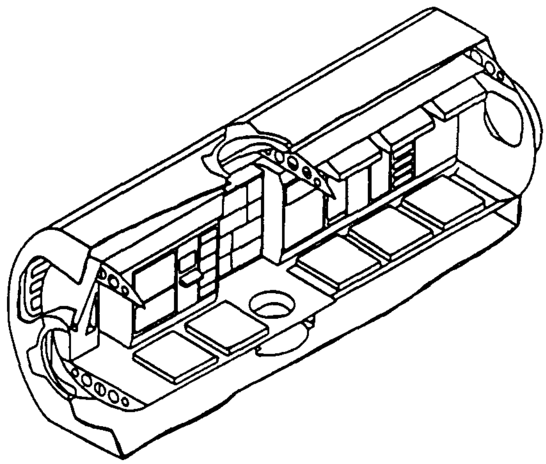


industrial space facility (ISF)

Industrial Space Facility (ISF) is a man-tended free flyer facility. Eventually, the ISF is expected to be a co-orbiting facility with the NASA Space Station. The ISF is designed to provide basic utilities, primarily power and cooling, to its users and to other facilities requiring a power source. The ISF is designed to serve as a research laboratory and, eventually as a materials processing facility. It is also 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 flights.

operational characteristics:

Dimensions:	35.0 L x 9.5 ft Dia
Volume:	332 ft^3
Weight:	6,500 to 13,700 lbs
Power:	11 kw
Cooling:	11.0 kw L, 5.0 kw A
CMD & TLM:	TBD, 16 kbs



location: Orbiter payload bay

contact: Space Industries, Inc., 711 W. Bay Area Blvd.,
Suite 320, Webster, TX 77598-4001
(713) 338-2676.
2 carriers are planned.

orbiter middeck

The middeck contains mounting space for 42 lockers, some of which are to be available for 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) may also be available to investigators using middeck facilities.

operational charactristics:

Power:	0.6 to 0.9 kw each
Cooling:	0 L, 1 kw A
CMD & TLM:	N, N

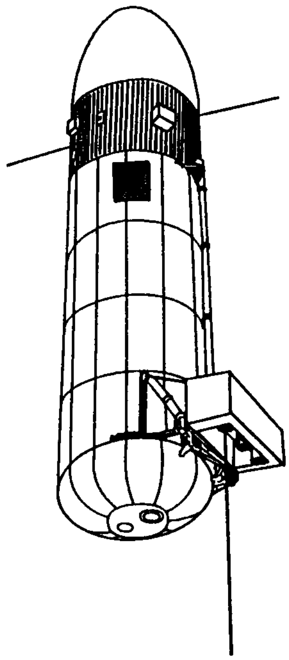
location: Shuttle orbiter

contact: NASA/Johnson Space Flight Center
Customer Integration Office, Code TC4
Houston, TX 77058

OUTPOST: the commercial service and transportation node platform

The OUTPOST Platform is an External Tank (ET) derived platform in low Earth orbit providing long duration flight testing and development services to commercial and government customers. The platform is proposed for orbit in the early 1990's and will provide services to attached technology experiments and other payloads. The platform will be man-tended, serviced by the orbiter, complimentary to Space Station technology development/testing and market-driven. The evolutionary platform will grow from a simple salvaged ET with basic platform subsystems to a revenue producing business enterprise. The platform is intended to fill the gap between the present and the availability of the Space Station and may evolve into a future transportation node in the emerging economy of commercial space.

contact: Thomas C. Taylor, GLOBAL OUTPOST, Inc., 6836 Deer Run Drive, Alexandria, Virginia 22306
(703) 765-6235.



space phoenix program

Space Phoenix is a university-based national program for scientific and commercial use of the shuttle's expended external tanks. The program's earliest application of ETs for research proposes the use of experimental equipment mounted in the unpressurized 5,000 cubic foot intertank section, in suborbital trajectory (30 to 60 minutes). These initial suborbital experiments are expected to lead toward the use in the 1990's of ET intertank and pressurized volumes in orbit. Experiments originally planned for balloons, sounding rockets or unpressurized locations in the shuttle cargo bay are likely candidates for the ET intertank. Research presently planned for this carrier includes measurements of thermosphere density, in-space ET environmental measurements and chemical release experiments including plasma physics and radiation effects.

operational characteristics:

Dimensions:	4 x 4 x 2 ft
Volume:	32 ft^3
Weight:	<400 lbs
Power:	Battery power for up to 60 min
Cooling:	TBD
CMD & TLM:	N, N

location: Intertank section, jettisoned External Tank

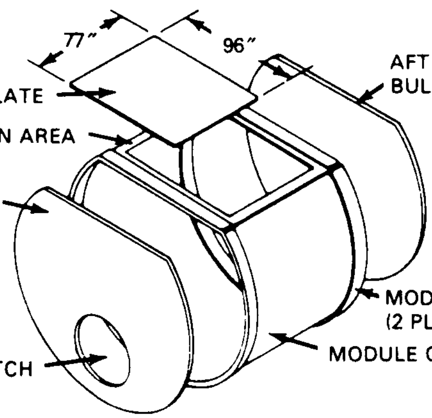
contact: Randolph Ware, External Tanks Corporation (ETCO)
1877 Broadway, Boulder, CO 80302, (303) 444-6221.
Availability 1989-90 (proposed).

SPACEHAB

SPACEHAB is a pressurized space shuttle-based module designed to augment the middeck volume for expanded man-tended research. The module is designed to fit into the forward quarter of the payload bay and is connected to the crew compartment by a short version of the Spacelab tunnel. This allows other payloads to be manifested with SPACEHAB. SPACEHAB modules will increase the pressurized living and working space on orbiters by approximately 1,000 cubic feet. SPACEHAB modules may be configured to contain as many as 72 standard middeck lockers and provide an additional 750 cubic feet of pressurized living and working space. The modules may also be configured with two sets of Space Station double racks plus lockers. The modules will have the capability to carry up to 3.000 lbs of payload.

operational characteristics:

Dimensions:	10.0 L x 12.1 ft Dia
Volume:	129 ft^3
Weight:	3,000 lbs
Power:	1.45 to 3.2 kw
Cooling:	4.0 kw L, 2.0 kw A
CMD & TLM:	TBD, 16 kbs



location:
Orbiter payload bay

contact:
SPACEHAB, Inc., Suite 201 West, 600 Maryland Ave SW, Washington, DC 20024, (202) 544-0063.
One carrier is planned.

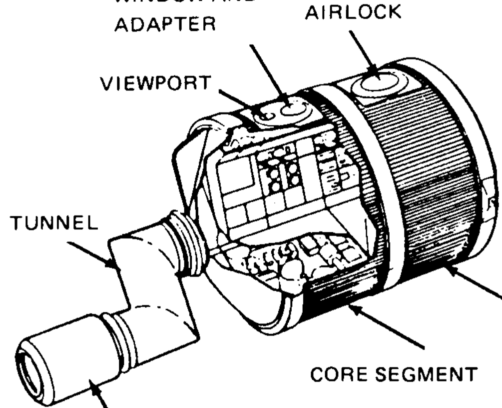
spacelab module (SL)

Spacelab is a versatile research center that provides a shirt-sleeve laboratory aboard the space shuttle orbiter 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, scientists trained to conduct experiments in space without becoming full-time astronauts; 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 L x 12.1 ft Dia
Volume:	285 ft^3
Weight:	10,033 lbs
Power:	3.4 kw
Cooling:	5.2 kw L, 3.1 kw A
CMD & TLM:	70 kbs, 50,000 kbs max



location:
Orbiter payload bay

contact:
NASA/Marshall Space Flight Center, Code JA21
MSFC, AL 35812.
Two carriers are available.

unpressurized carriers

Typically, most unpressurized carriers are a bridge-type structure designed to fit into the orbiter in a cross-bay truss configuration. The two exceptions are the Hitchhiker-G, which is mounted on a side of the orbiter payload bay, and the Pallet, which is a U-shaped platform. Several carriers utilize the Multi-Purpose Experiment Support Structure (MPESS) in different configurations. Sufficient information by way of text, dimensions, payload experiment capabilities and line drawings are included in this section to assist the user in determining which carrier may best suit his experiment.

As in the previous section, the following conventions have been adopted:

Dimensions -	internal user dimensions in feet L = length, W = width, H = height, D = depth, Dia = diameter
Mtg. area -	mounting plates or plates size in feet available for users
Volume -	available for user experiments in cubic feet
Weight -	maximum user weight in pounds
Power -	continuous power available to users in kilowatts
Cooling -	available to users in kilowatts; L = liquid, A = air
CMD & TLM -	command and telemetry data; rates are in kilobits per second, No (N)
TBD =	to be determined

EOS carrier

The EOS Carrier is a proposed carrier following the same general configuration as the Multi-Purpose Experiment Support Structure. It is a cross-bay bridge type structure approximately 3 feet wide in the payload fore-aft direction. Additional information may be obtained from the contact listed below.

operational characterisitics:

Dimensions:	12.2 H x 3.5 W x 14.0 ft L
Mtg. area:	4 surfaces @ 1.35 x 11.0 ft ea and 8 bays @ 3.0 x 1.6 x 1.6 ft ea
Weight:	4,000 lbs
Power:	TBD
Cooling:	TBD, TBD
CMD & TLM:	TBD, TBD

location: Orbiter payload bay

contact: Al Rose, McDonnell Douglas Astronautics Company,
Dept. E463, MC 1067087,
St. Louis, MO 63166
(314) 234-3533
One carrier is planned.

get-away-special bridge (GAS bridge)

The GAS Bridge is an adaptation of the Multi-Purpose Experiment Support Structure (MPESS). 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 payload bay and handle more GAS cans than a Hitchhiker-G of 2 cans.

operational characteristics:

Dimensions:	9.38 H x 2.79 W x 14.24 ft L
Volume:	12 GAS cans @ 5.0 ft^3 ea
Weight:	4,800 lbs
Power:	0 kw
Cooling:	0 kw L, 0 kw A
CMD & TLM:	TBD, TBD

location: Orbiter payload bay

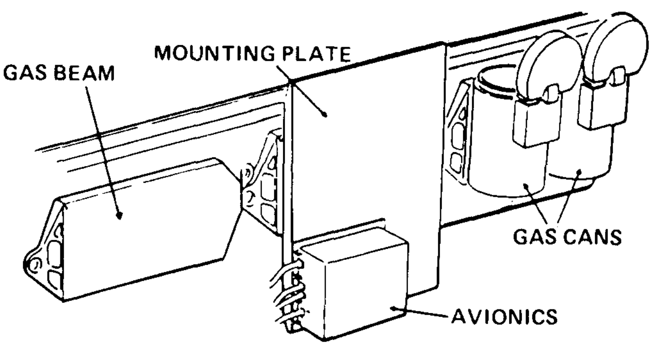
contact: NASA/Goddard Space Flight Center, Special Payloads Division, Code 741, Greenbelt, MD 20771
One carrier is available.

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 payload bay. Hitchhikers are nominally carried in "bays" 2 and 3 near the forward end of the payload bay. 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 reduce the time required to perform electrical integration and check-out of the customer hardware on the carrier. Mechanical interfaces are also 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 H x 10.0 ft L
Mtg. area:	4.2 x 5.0 ft plate
Volume: 2	GAS cans
Weight:	750 lbs
Power:	1.3 kw
Cooling:	0 kw L, 0 kw A
CMD & TLM:	TBD, 1300 kbs



location: Orbiter payload bay

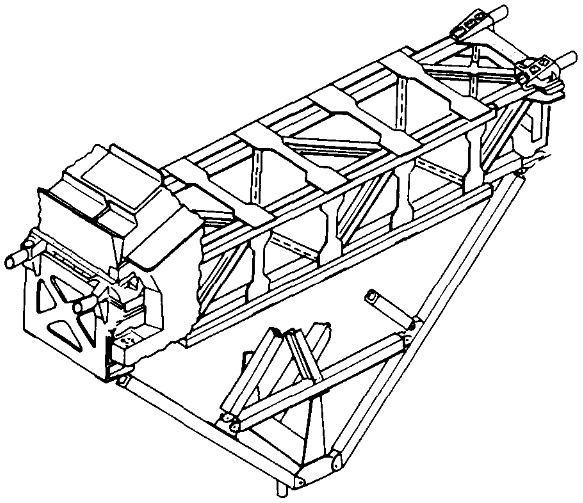
contact: NASA/Goddard Space Flight Center, Special Payloads Division, Code 740, Greenbelt, MD 20771.
2 carriers are available.

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 (eg. several hours) can usually be accommodated.

operational characteristics:

Dimensions:	9.38 H x 2.79 W x 14.24 ft L
Mtg. area:	
3 plates	@ 2.8 x 3.33 ft ea and
3 plates	@ 2.4 x 3.33 ft ea
Weight:	1,170 lbs
Power:	1.3 kw
Cooling:	0 kw L, 0 kw A
CMD & TLM:	8.064 kbs, 1,300 kbs



location: Orbiter payload bay

contact: NASA/Goddard Space Flight Center, Special Payloads Division, Code 740, Greenbelt, MD 20771. One carrier is available.

leasecraft

The payload of a Leasecraft platform consists of one or more experiments. observatories or processing plants. Each Leasecraft accommodates one primary payload although secondary payloads may be attached prior to launch or in-orbit on the shuttle. The Leasecraft is a free-flyer after being placed in orbit.

leasecraft consists of the following major components:

1. *A supporting structure which interfaces with the space shuttle, and supports all of the Leasecraft components and payload modules.*
2. *Standard multi-mission modules with independent structures, self-contained temperature-control and electrical/data connection systems.*

    Communications and data handling system with on-board computer.

    Attitude control system with stellar, solar or earth-pointing capability.

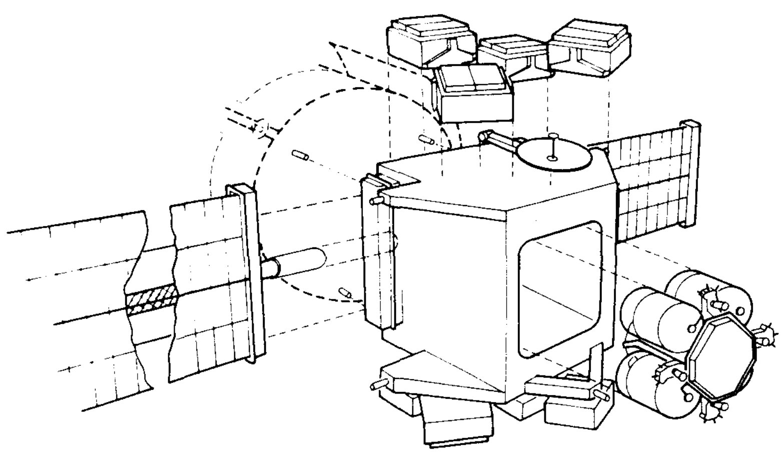
    Power subsystem with batteries, power control and distribution systems.

    Special function module for power switching, heater controls and special equipment.

3. *Deployable/retractable solar arrays.*
4. *Propulsion subsystem for orbit-adjustments and control.*
5. *Communications antennas for links to the Tracking and Data Relay Satellite System.*
6. *Additional support modules for secondary payloads.*

operating characteristics:

Payload Weight:	32,000 lbs primary 2,200 lbs secondary
Power:	7,300 w max
CMD & TLM:	2 kbs, 64 kbs



launch vehicle: Space shuttle to orbit, then free-flyer

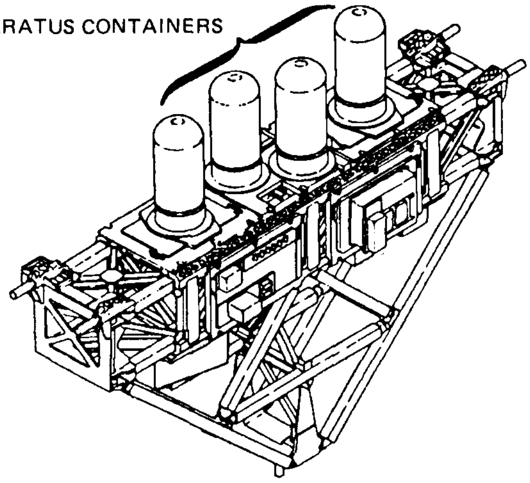
contact: Fairchild Space Company
Business Development
20301 Century Blvd.
Germantown, MD 20874-1181.
This hardware is being developed.

materials science laboratory (MSL)

The MSL carrier accommodates a variety of microgravity science apparatus and is especially adapted for large, heavy payloads. The MSL carrier provides structural support, power, environmental control and command and data handling, reducing the complexity of designing an experiment for a shuttle flight.

The MSL carrier 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 MSL configuration. An experiment may be operated by crewmembers 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.

operational characteristics:



Dimensions:	9.19 H x 2.92 W x 14.47 ft L
Mtg. area:	3 plates @ 2.8 x 3.33 ft ea and 3 plates @ 2.4 x 3.33 ft ea
Weight:	2,040 lbs
Power:	1.41 kw
Cooling:	7.5 kw L, 0 kw A
CMD & TLM:	8 kbs, 1400 kbs

location: Orbiter payload bay

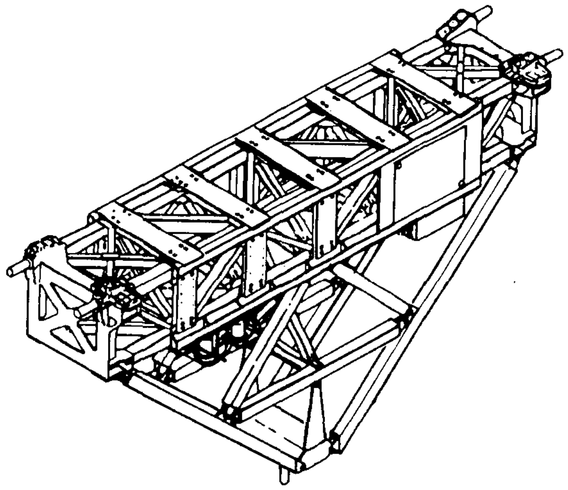
contact: NASA/Marshall Space Flight Center, Code JA21, MSFC, AL 35812.
4 carriers are available.

multi-purpose experiment support structure (MPESS)

The MPESS is a generic structure designed to be integrated into the orbiter payload bay in a cross-bay bridge configuration.

Currently, the MPESS is being utilized in the Materials Science Laboratory, the Get-Away-Special Bridge, Spartan and the Hitchhiker-M carriers.

operational characteristics:



Dimensions:	9.39 H x 2.79 W x 15.0 ft L
Mtg. area:	Mission dependent
Weight:	Up to 4,200 lbs
Power:	Not applicable
Cooling:	Mission dependent
CMD & TLM:	Mission dependent

location: Orbiter payload bay

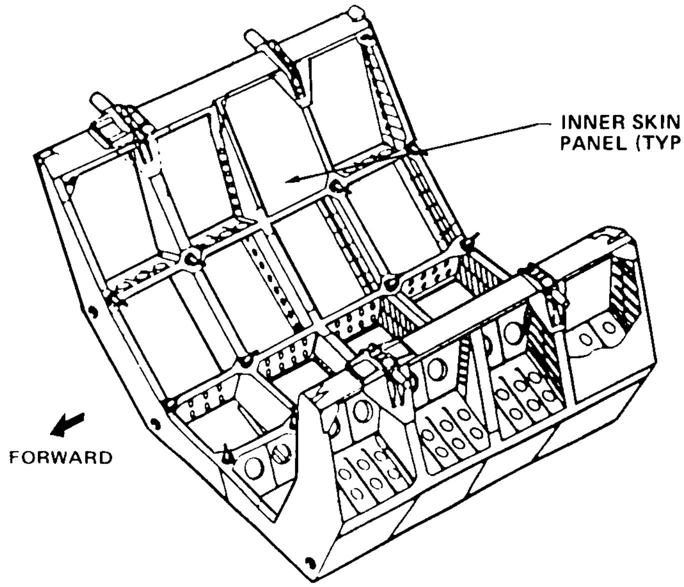
contact: NASA/Marshall Space Flight Center, Mission Management Office, Code JA21, MSFC, AL 35812.
5 carriers are available.

pallet

Pallets are U-shaped structures 13 ft wide by 10 ft long. Pallets consist 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-in. 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/ft^2. 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.

operational characteristics:

Dimensions:	9.84 L x 13.12 ft W, U-shaped
Mtg. area:	122 ft^2 or 155 ft^2
Weight:	6.836 lbs max
Power:	4.4 kw
Cooling:	7.0 kw L, 0 kw A
CMD & TLM:	TBD, TBD



location:

Orbiter payload bay

contact:

NASA/Marshall Space Flight Center, Mission Management Office, Code JA21
MSFC, AL 35812.
5 carriers are available.

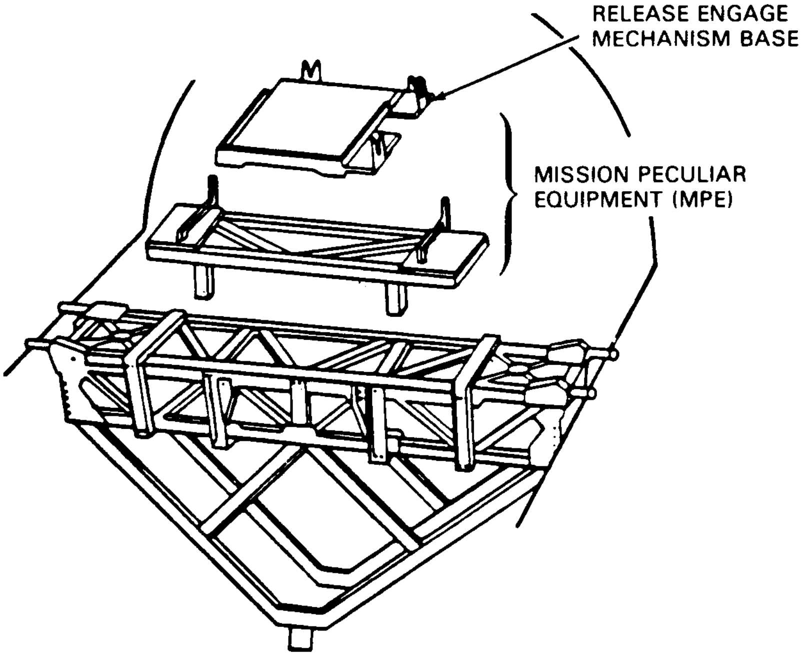
spartan flight support structure (SFSS)

The Spartan base structure is a Multi-Purpose experiment Support Structure (MPESS) with a detachable upper structure which houses the unique instruments for each mission. This structure is released and retrieved by the orbiter during the course of the flight.

The complete Spartan free-flyer 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, IC, the 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 orbiter cargo bay envelope to approximately 120 inches. ACS sensors required for instrument pointing may be mounted both externally on the end of the IC and internally co-aligned with the instrument.

operational characterisitcs:

Dimensions:	9.38 H x 2.79 W x 14.24 ft L
Mtg. area:	TBD
Weight:	5,000 lbs to users
Power:	0.28 kw
Cooling:	TBD
CMD & TLM:	TBD



launch vehicle:

Space Shuttle

contact:

NASA/Goddard Space Flight Center
Special Payloads Division, Code 741
Greenbelt, MD 20771.
2 carriers are available.

■ containers/mounting hardware

The following items of space hardware are considered carriers; however, they themselves never fly alone: they must be installed or integrated into the next level carrier. Some of these carriers have flown on previous space missions, are flight-qualified and are available for future experimental use. Others are in the planning stage and the user is cautioned to ascertain the status of any unit or units he may be considering for flight.

As in previous categories, the following conventions have been adopted:

Dimensions:	internal user dimensions in feet L = length, W = width, H = height, D = depth, Dia = diameter
Volume:	available for user experiments in cubic feet (ft^3)
Weight:	maximum user weight in pounds (lbs)
Power:	continuous power available to users in kilowatts (kw)
Cooling:	available to users in kilowatts (kw) L = liquid, A = air
CMD & TLM:	command and telemetry data; rates are in kilobits per second (kbs) No (N)
TBD =	to be determined.

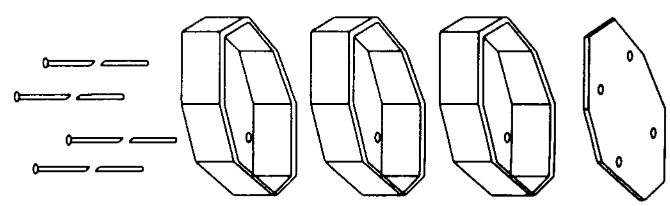
efficient equipment rack for small self-contained payloads

These equipment racks are used for conducting experiments in NASA's Get-Away-Special (GAS) or Hitchhiker-G canisters. The basic rack consists of several experiment trays, a top cover thermal blanket shield, lateral supports, and attachment rods and insets. The trays and top cover are made of lightweight composites. This structure simultaneously provides a convenient set of experiment enclosures, an excellent thermal barrier to the space environment, and large structural factors for safety. The structure weighs less than 1/3 the weight of equivalent metal structures.

The thermal coupling to the outside environment is limited so that battery power is minimized, saving additional weight and volume. A thermal computer model of the system can be conveniently used to size experiments and batteries, and to select experiment timelines. The structure is available in a wide variety of geometries.

operational characteristics:

Size:	2.5 ft^3, 5 ft^3
Weight:	13 lbs, 23 lbs
Thermal time constant:	20+ hours



carrier: Get-Away-Special or Hitchhiker-G

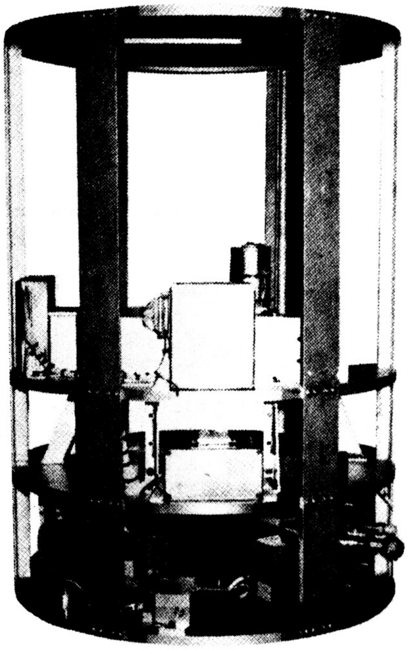
contact: D.W. Yoel, 11805 Alderbrook Street, Moorpark, CA 93021, (805) 523-2486.

ITA standardized experiment module (ISEM-G)

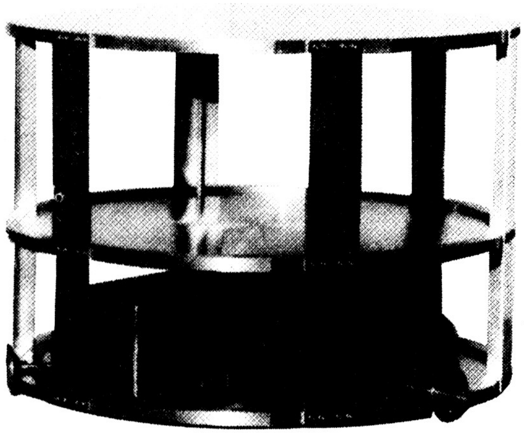
The ITA ISEM-G consists of an aluminum aerospace structure with mounting hard points, support avionics and "housekeeping" instrumentation for experiments/payloads. The ISEM-G is designed to fit within and interface with the standard NASA 2.5 ft^3 and 5.0 ft^3 Get-Away-Special canisters. The standard 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 volume for the experiment/payload. Current ISEM-Gs can accommodate from 3 to 10 experiments.

operational characteristics:

	5.0 ft^3 ISEM-G	**2.5 ft^3 ISEM-G**
Mechanical interface	Standard NASA GAS can	Standard NASA GAS can
ISEM-G structure and avionics weight:	60 lbs	30 lbs
Expt. weight capability:	140 lbs	70 lbs
Expt. volume capability:	3.5 ft^3	1.3 ft^3
Dimensions:	9.75 D x 28.25 inches H	19.75 D x 14.125 inches
Standard battery capacity:	1.2 kwh (lead acid cells)	1.2 kwh
Standard voltage:	5,16, 24 v	5,16, 24 v
Instrumentation:	Accelerometers, pressure and temperature sensors	Accelerometers, pressure and temperature sensors



5.0 ft^3 Experiment



2.5 ft^3 Experiment

carrier: Get-Away-Special

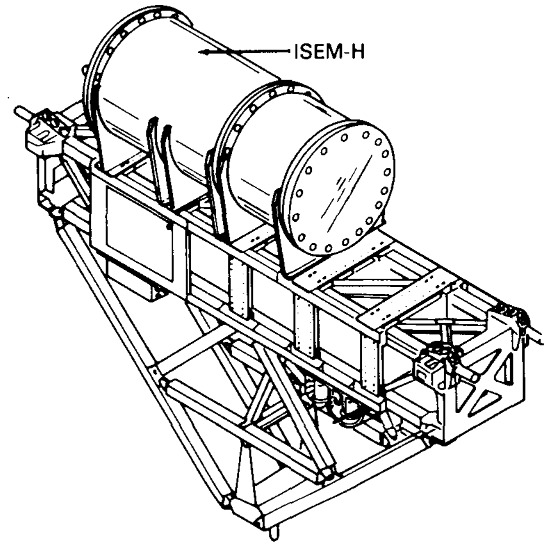
contact: John M. Cassanto, Instrumentation Technology Associates, Inc., 109 Great Valley Parkway, Malvern, PA 19335
(215) 647-6260, 524-1988.

ITA standardized experiment module (ISEM-H)

The ITA Standardized Experiment Module for the NASA Hitchhiker-M carrier (ISEM-H) is for use in the 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 orbiter's resources. 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 ft^3
Power:	1300 w
Energy:	5 kwh to 13.5 kwh/day
Heat rejection:	900 w



carrier: Hitchhiker-M

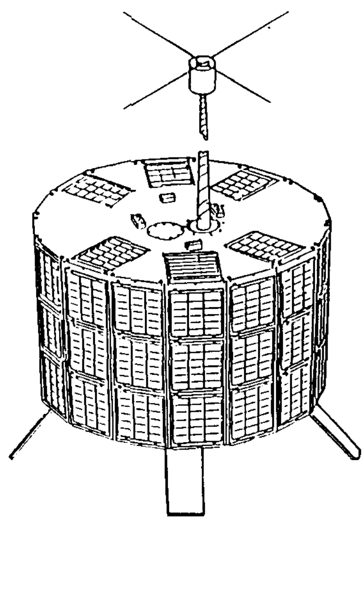
contact: John M. Cassanto, Instrumentation Technology Associates, Inc., 109 Great Valley Parkway, Malvern, PA 19335
(215) 647-6260, 524-1988.

low-cost standard bus

The low-cost standard bus provides maximum power and payload space in a small satellite which can be placed into orbit as a free-flyer. It provides 150 watts peak power with an average of 11 watts. Variable voltages include 6, 18 and 28 volts. The satellite is designed to be compatible with GAS cans and Expendable Launch Vehicles. A wide variety of radios is offered including C and S Band frequencies. The CPU is a CMOS 80086 processor. Antennas are omnidirectional earth pointing. Other antennas are available upon request. Two-axis stabilization is provided by a gravity gradient boom. Attitude sensors include a 3-axis magnetometer and an optional sun sensor. Commanding, telemetry and data storage are sized to suit the payload.

operational characteristics:

Size:	14 in H x 24 in Dia
Weight (empty):	80 lbs
Design acceleration:	18-g's stackable for ELV launch



carrier: Get-Away-Special or Expendable Launch Vehicle

contact: J.C. O'Neil, Defense Systems, Inc., 7903 Westpark Drive, McLean, VA 22102.
(703) 883-1000.

MSL experiment apparatus container (MSL EAC)

EACs are convenient, economical housings or covers for experiment apparatus and are easily integrated onto the Materials Science Laboratory (MSL). The payload bay EAC houses experiment apparatus with greater weight and power requirements than can be accommodated by the middeck EACs.

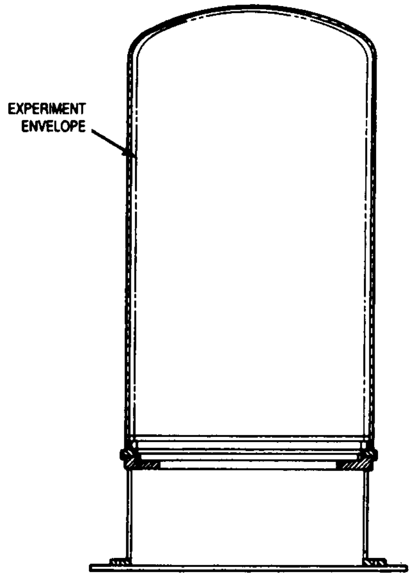
The EAC is a removable, bell-shaped containment shroud that can house a variety of experiment apparatus. The EAC has two sections: a tall shroud that encloses the experiment and a base ring section where the experiment attaches to the EAC. The payload bay EAC is mounted on the MSF carrier and uses the carrier's host subsystems for control and support.

operational characteristics

Dimensions:	32.18 H x 16.82 ft Dia
Volume:	4.2 ft^3
Weight:	275 lbs
Power:	0.47 kw
Cooling:	0.8 kw L, 0 kw A
CMD & TLM:	TBD, 1,400 kbs max

carrier: MSL

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812.



middeck accommodations rack (MAR)

The MAR will increase the space available for small payloads and experiments in the middeck by supplementing the volume occupied by middeck stowage lockers.

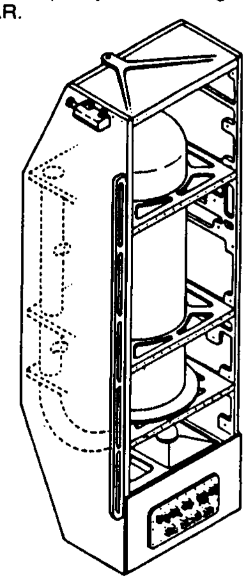
The MAR is designed as a versatile experiment integration facility with the equivalent stowage volume of five middeck stowage lockers. Experiment Apparatus Containers, trays, combinations thereof, or payloads specially sized to the MAR's capacity can be integrated in the carrier. Power distribution and active thermal control options are available to investigators using the MAR.

operational charateristics:

Dimensions:	TBD
Volume:	TBD
Weight:	500 lbs
Power:	0.26 kw
Cooling:	0 kw L, 1 kw A
CMD & TLM:	TBD, TBD

carrier: Middeck Galley

contact: NASA/Johnson Space Flight Center, Customer Integration Office, Code TC4, Houston, TX 77058. This unit is under development.



INBOARD PAYLOAD INSTALLATION

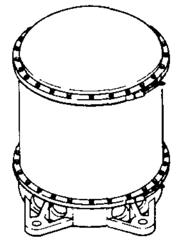
middeck experiment apparatus container (MD EAC)

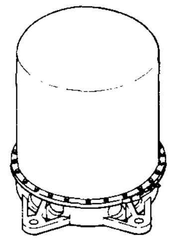
EACs are convenient, economical devices that provide protective housing for experiment apparatus. Middeck EACs may be cylindrical or rectangular and contain experiments that weigh less and have lower power requirements than EAC experiments in the payload bay. Because middeck EACs offer an enclosed and sealed environment, certain safety waivers may be granted to the materials of components enclosed.

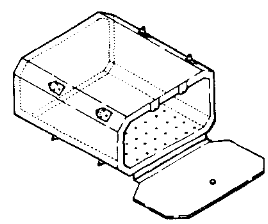
Four kinds of middeck EACs are available. Two are removable, cylindrical housings that can accommodate a variety of experiment apparatus. These EACs have two sections: a cylindrical base on which the experiment is mounted and a taller component that encloses the experiment. One cylindrical EAC has a 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 is also rectangular and provides accommodations for experiment electronics. Middeck EACs are designed for spaces normally occupied by middeck stowage lockers.

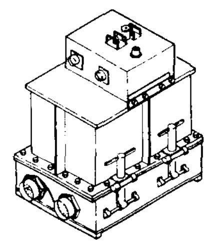
operational characteristics:

Dimensions:	14.45 H x 16.6 ft Dia
Volume:	1.8 ft^3
Weight:	TBD
Power:	0.27 kw
Cooling:	0 kw L, 0 kw A
CMD & TLM:	TBD, TBD


Flat Top Cylindrical EAC


Dome Top Cylindrical EAC


Rectangular Locker-Type EAC


Experiment Electronic Package

carrier: Middeck, SPACEHAB

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812.

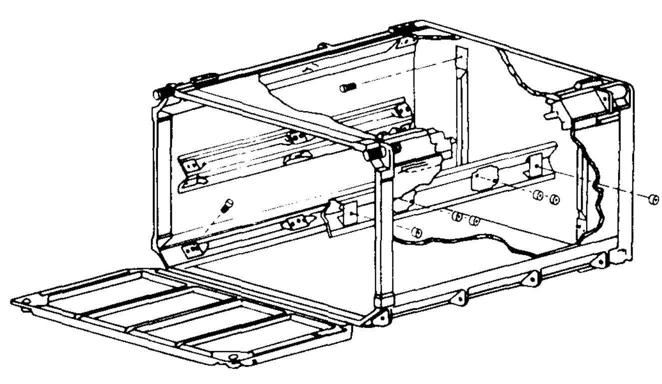
middeck locker (MDL)

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 42 MDLs located in the middeck area which can be used with or without full or half-locker storage tray inserts. A double stowage locker is also available. Experiments contained in these lockers may be operated or observed by crewmembers.

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 H x 17.3 W x 20.0 ft D
Volume:	2.0 ft^3
Weight:	60.0 lbs
Power:	0.09 kw
Cooling:	0 kw L, 1 kw A
CMD & TLM:	N, N



carrier: Spacelab, Middeck, SMIDEX

contact: NASA/Johnson Space Center, Customer Integration Office, Code TC4, Houston, TX 77058.

modular container (MC)

The Modular Container is a structure similar to the Middeck Accommodations Rack being designed for the Industrial Space Facility (ISF). Its capacity is planned as 4 Shuttle middeck locker trays in a 2 x 2 configuration. The ISF can contain up to 6 modular containers in the facility module configuration.

operational characteristics:

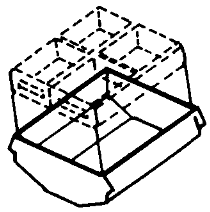
Dimensions:	12.0 H x 36.0 W x 40.0 ft D
Volume:	11.0 ft^3
Weight:	375 lbs
Power:	0.8 kw
Cooling:	0 kw L. 0.8 kw A
CMD & TLM:	2 kbs max, 48 kbs max

carrier: ISF

contact: Space Industries, Inc., 711 W. Bay Area Blvd., Suite 320, Webster, Texas 77598-4001.

FACILITY MODULE
7 RACKS
6 MODULAR CONTAINERS

AUXILIARY MODULE
7 RACKS
8 MODULAR CONTAINERS



ISF MODULAR CONTAINER
(CONTAINS 4 SHUTTLE MIDDECK LOCKER TRAYS)

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).

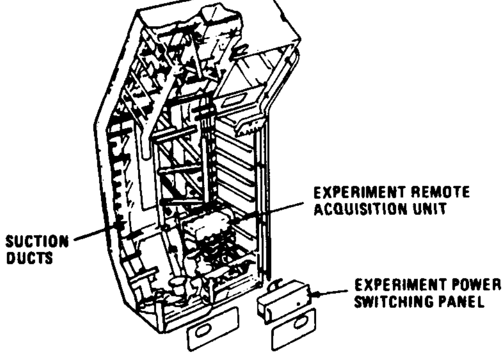
An Experiment Power Switching Panel (EPSP), a Remote Acquisition Unit (RAU), and the Spacelab signal interface unit are located in each rack to serve the user. Also, air cooling is provided to each rack; however, front panels must be sealed to permit satisfactory performance of the cooling loop.

operational characteristics:

Dimensions:	70.0 H x 17.42 W x 24.09 ft D
Volume:	17.32 ft^3
Weight:	640 lbs
Power:	3.4 kw
Cooling:	4.0 kw L, 4.5 kw A
CMD & TLM:	Mission dependent

location: Inside a Spacelab module

contact: NASA/Marshall Space Flight Center, Mission Management Office, Code JA21, MSFC, AL 35812. These racks are available.



Spacelab Double Rack

spacelab middeck experiment (SMIDEX) plates

SMIDEX plates are designed to be installed in either the Spacelab Double or Single Racks. The plates can accommodate either a Middeck Locker (MDL) or the Middeck Experiment Apparatus Container (MD EAC). The capacities are as follows double rack - 4 MDLs 2 EACs; single rack - 2 MDLs 1 EAC. :The user can best determine his desired configuration based on his needs.

operational characteristics:

Dimensions:	40.16 L x 24.1 W
Volume:	8 max
Weight:	240
Power:	Mission dependent
Cooling:	Mission dependent
CMD & TLM:	Mission dependent

carrier: Spacelab

contact:

W.D. Womack. NASA/Johnson Space Center.
Code ID2. Houston. TX 77058
(713) 282-1836.

CHAPTER 6

developmental, test and experimental research facilities

Performing an experiment in space, particularly if unattended, presents a challenge to the designer in assuring his hardware survives the mission. Numerous facilities have been created to assist in meeting this challenge. These facilities include space-related functions, from developing and testing a new material, to a research facility such as the Microgravity Materials Science Laboratory at NASA/Lewis Research Center, which actually simulates a microgravity condition.

If a researcher already has hardware fabricated, he may wish to have it tested to ascertain its survivability. Also, some facilities have computer simulations into which the design characteristics of the hardware can be entered to determine space adaptability. NASA can advise which way will best meet the requirements.

■ developmental and test facilities: nasa, industry and academia

The NASA facilities at the various field centers are grouped into several major classifications. These include basic research, manufacturing processes, 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), industry and university facilities follow the same grouping, although the commercial facilities also include clean rooms and other space-related fabrication areas.

■ experimental research facilities

Experimental research facilities have drop tubes, drop towers, and aircraft which can simulate a microgravity environment for a few seconds.

In general, all test equipment, particularly environmental equipment, is in constant use. Scheduling must be planned sufficiently in advance to permit a user to accomplish his testing as required.

■ *developmental and test facilities: NASA*

As would be expected, over the years NASA has assembled a large inventory of developmental, research, environmental, and test equipment for space-related hardware. In order to conserve space, only the equipment names and/or functions are listed; further information as to capacities and other pertinent data may be obtained by contacting the NASA Center Commercialization Officers listed in Chapter 11.

Most of the information on NASA facilities was obtained from the "NASA Facilities Database User's Manual." Additional information may be obtained from the Commercial Development Division, Office of Commercial Programs, NASA Headquarters.

ames research center

research facilities - life sciences/biotechnology

20 G/Human Centrifuge
Altitude Chambers
Animal Centrifuges
Cardiovascular Research Laboratory
Flight Simulation Facilities
Human Research Facility
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)

goddard space flight center

performance testing facilities

Acoustic Test Facility
Ainsworth Vacuum Balance Facility
Battery Test Facility
High Capacity Centrifuge Facility
High Speed Centrifuge Facility
High Voltage Test Facility
Large Area Pulsed Solar Simulator
Magnetic Field Component Test Facility
Magnetic Test Facility - 45 foot
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

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

jet propulsion laboratory

performance testing facilities

Acoustic Environments Laboratory

Induced Environments Laboratory Ion Chamber

Model Bridge Crane Test Facility

Space Simulator - 10 ft.

Space Simulator - 25 ft.

Thermal Vacuum Chamber (7 ft x 14 ft)

materials testing facility

Low Magnetic Field Facility

Materials Laboratory

research facilities - propellants

Chemical Research Laboratory

johnson space center

research facilities - life sciences/biotechnology

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

manufacturing process facilities

Laser/Electro-Optical Laboratory

Performance Testing Facilities

Crew Systems Laboratory Complex (6 chambers)

Space Environmental Effects Laboratory (14 chambers)

kennedy space center

research facilities - life sciences/biotechnology

Acceleration Sled

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

research facilities - other

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

langley research center

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

research facilities - microgravity

Flow/Solidification Front Apparatus

research facilities - polymer and fiber optics

Gas Permeable Membrane Laboratory

Gas Phase Chemistry (Mass Spectrometer)

Sensible Fibers

lewis research center

performance testing facilities

Space Vacuum Tank

Supersonic Wind Tunnel (10 ft x 10 ft)

Wind Tunnel (Mach 5,6,7)

materials testing facilities

Basic Materials Laboratory

Electron Optics Laboratory

Optical Microscope Laboratory

X-Ray Diffraction Laboratory

materials process facilities

Materials and Structures Laboratory

Materials Processing Laboratory

Metallography Laboratory

Photovoltaic Test Facility

research facilities - microgravity

Gas Analysis Furnaces

Noninstrumental Chemical Methods Laboratory

Spectrometric Analysis

research facilities - other

Space Power Facility

Space Propulsion Facility

marshall space flight center

microgravity research facilities

Advanced Space Furnace Technology Laboratory

Crystal Growth and Characterization Laboratory

General Purpose Rocket Furnace

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

Optical Material and Coating Laboratory

Optical/Electro-Optical Systems Laboratory

Photovoltaics Laboratory

Polymer Development and Evaluation Laboratory

Rubber and Plastics Technology Facility

Superconductivity Thin Film Laboratory

Vacuum Plasma Spray Development Facility

research facilities - life sciences/biotechnology

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

materials testing facilities

Airjet Levitator
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
Mechanical Test Facility
Modal Test Laboratory
Nondestructive Evaluation Facility
Solar Array Laboratory
Thermal Vacuum and Thermal Chambers
Vacuum Chamber (Senspot I)
Vibration Test Laboratory

stennis space center

research facilities - remote sensing

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

wallops flight facility

performance testing facilities

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

■ *developmental and test facilities: industry and academia*

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

advanced components test facility

Solar thermal test bed - 325 kw

Assembly building

- *High bay areas (2)*
- *Machine shop*

Control room

Data system

Closed circuit television system

contact:

Dr. Dan O'Neil
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, GA 30332
(404) 894-3589.

antenna test facilities

Range length - 1,700 ft

contact:

Dr. 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

arnold engineering test facility at U of tennessee

Vacuum chambers (2)

Cryogenic facilities

Combustion test facilities

Diagnostic tools

VAX 11/780 Computer

IBM computer

CRAY computer

contact:

Dr. Fred Speer, Director
CCDS/Center for Advanced Space Propulsion
University of Tennessee/Calspan
P.O. Box 1385
Tullahoma, TN 37388
(615) 454-9294.

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:

Sarah J. Darnall
Teledyne Brown Engineering
Cummings Research Park
Huntsville, AL 35807-5301
(205) 532-1000.

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, which utilizes 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 2000, 1000, 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.

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 influencing 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:

Prof. L.S. Fletcher
CCDS/Center for Space Power
The Texas A&M University System
College Station, TX 77843
(409) 845-7270.

environmental test facilities

Static Load Test Facility

Vibration Test Facility

Space Simulation Facility

Space Chamber

contact:

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

low scanning electron microscope facility

Model JSM-840

Magnification range: 10 x to 300,000 x

contact:

Dr. J.F. Wallace, Director
CCDS/Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Avenue
Cleveland, OH 44106
(216) 368-4222.

payload processing facility

Non-hazardous processing building
Clean room high bay complexes (3)

Hazardous processing building
Clean room high bays (3)

Payload storage building

Customer office building

Warehouse storage building (6,250 ft^2)

contact:

G.D. Baker
ASTROTECH Space Operations, L.P.
12510 Prosperity Drive
Silver Spring, MD 20904
(301) 622-5804.

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:

Dr. 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.

solar furnace facility

90.25-ft^2 flat heliostat

5-ft diameter parabolic concentrator

192-ft^2 data acquisition and office bldg

HP-87 computer

contact:

Dr. Dan O'Neil
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, GA 30332
(404) 894-3589.

space hardware environmental qualifications and testing facilities

Ground-based and space flight hardware environmental qualification testing and analysis

Partial list of environmental qualification analyses/tests available:

Space flight - acceleration (high/low frequency & 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
(205) 837-4411.

space simulation chamber/pulsed power facility

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

Energy storage system for pulse testing

Allen-Bradley computer

IBM-PC-AT computer

contact:

Dr. D.W. Deis, Manager
Integrated Engineering Systems
Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, PA 15235-5098
(412) 256-1600.

subsystems test facilities

Three-axis Servo Table

Class 100,000 laboratory

Battery/cell test area

Solar Array Facility

EMC/EMI facilities

contact:

Dr. 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.

thermal fatigue testing unit facility

Range +250°F to -200°F

contact:

Dr. J.F. Wallace, Director
CCDS/Center for Materials for Space Structures
Case Western Reserve University
School of Engineering
10900 Euclid Avenue
Cleveland, OH 44106
(216) 368-4222.

tribology laboratory

The laboratory studies the compound and fleeting 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 ft^2 and weighs about 700 lbs.

contact: *Dr. R.B. Griffin*
CCDS/Center for Space Power
The Texas A&M University System
College Station, TX 77843
(409) 845-1251.

experimental research facilities

Prior to performing an experiment in space, researchers should consider the ground-based Experimental Research Facilities available at the various NASA centers. These include drop tubes, drop towers, aircraft capable of parabolic flight and specialized facilities, which simulate the microgravity of space flight for a few seconds.

Information on the facilities under this category is outlined in detail on the following pages.

Ground Based Experimental Research Facilities

Ground Based Facility	LOC	Test Time (seconds)	G Level (g)	PAYLOAD Payload Envelope (Meters)	Max. Payload Mass (Kilograms)	Test Cycle
AIRCRAFT						
KC-135 parabolic flt.	MSFC	5.15/20	<0.00g/<.01 Note 1	3.05 x 16.2 x 1.8	Note 2	40 trials/flt.
Learjet parabolic flt.	LeRC	20	<0.02	.91 x .73 x .61	85	5 t rials/flt.
F-104 parabolic flt.	MSFC	30/60	<0.03 g/<0.1	.28 x .35 x .58	16	1 trial/flt.
DROP FACILITIES						
145 m drop tower	LeRc	5.2	10-5	1 dia x 1.5, .4x .61 x .45	230	1-2 drops/day
30 m drop tower	LeRC	2.2	10-6	0.4 x 0.91 x 0.96	54	15 drops/day
100 m drop tower	MSFC	4.3	10-5	0.91 x 0.91 x 0.96	54	1 drop/day
13.2 m cryogenic drop tube	JPL	1.7	10-6	0.13 dia	Note 3	
13.1 m high pressure drop tube	JPL	1.7	10.6	0.15 dia	Note 3	1/day
5 m drop tube	LeRC	1		Note 4	Note 4	10/day
MMSL	LeRC		See Text			

Notes:

1. G Level of 10-4 is possible if payload package is free floated.
2. Load is limited as follows: <200PSF contact pressure, <25 PSI concentrated load structures longer than 3.05 meters must be designed to allow for airplane flexure.
3. Mass is usually the sample size on the order of ~grams.
4. Part of MMSL, see text.

drop tubes

Drop tubes accommodate small, uncontained material samples that are heated to the melt phase and allowed to resolidify under microgravity conditions during free fall in an evacuated tube. These free-fall periods last from 1.6 to 4.6 seconds, depending upon which tube is employed. Experimental requirements for rapid cooling rates are satisfied by backfilling the tube with inert gas before the drop run; however, the gaseous environment causes a small increase in aerodynamic drag, resulting in a slight reduction in the level of microgravity (10^{-6} g) that can be attained. One experimental facility, the 13.1-meter force-free drop tube, has been developed to overcome this drag. Several drop tubes are available for research studies: a 100-meter drop tube at NASA/Marshall Space Flight Center, a 13.1-meter force-free drop tube and a 13.2-meter cryogenic drop tube developed at the NASA/Jet Propulsion Laboratory (JPL). Another drop tube is located at NASA Lewis Research Center. It is a 5 m drop tube facility capable of one second of vacuum-free fall time. Temperatures from 700 to 4,000°C are measured optically by four high speed, two-color optical pyrometers. An additional pyrometer mounted at the bottom of the tube is used to observe samples while they fall during the entire drop. This is achieved by employing tracking optics and higher sensitivity pyrometers.

JPL has a new stainless steel 14-m drop tube, capable of operation at pressures in excess of 10 atm or a vacuum of 10^{-7} kPa. External coolant tubes attached to the five lower drop tube sections provide control from room temperature to -180°C. Each of these five 2.4-m sections can be individually temperature-controlled.

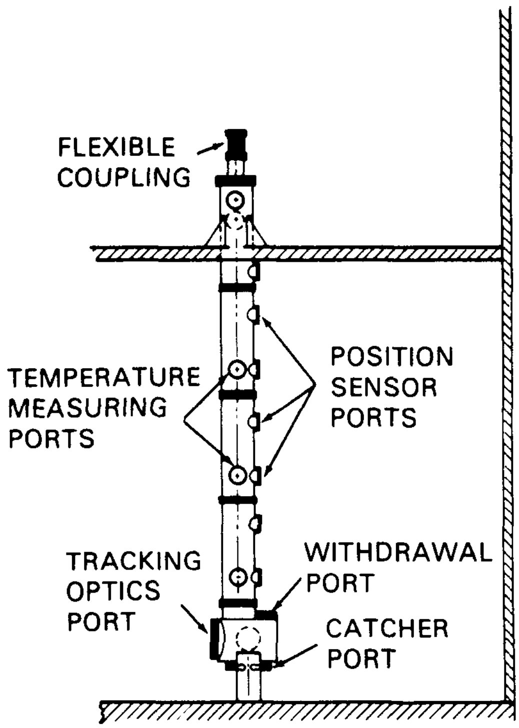
5-meter drop tube

The Instrumented Drop Tube (IDT) provides 1 second of low-gravity freefall to study solidification phenomena such as recalescence. Temperatures from 700 to 4,000°C are measured optically, and up to 10 samples per day may be dropped. A high-speed computer acquires data at over 10,000 readings/second. The data can be printed or plotted immediately.

The Electromagnetic Levitating Furnace (EML) described in Chapter 4 is mounted at the top of the IDT. Specimens can be levitated and heated by induction and then dropped into individual oil-filled beakers at the bottom of the IDT. The entire apparatus may be evacuated or a partial backfill of gas used to increase cooling if increased drag (and, as a result, increased gravitational pull) can be tolerated.

operational characteristics:

Sample shape:	1- to 4-mm Dia sphere or equivalent
Sample material:	Any which can be levitated and heated inductively
Drop time:	1 sec
Temperatures measured:	700 to 4,000°C
Samples per day:	10
Data points per drop:	1,000
Vacuum:	To 10^{-6} torr in 1 hr
Backfill gases:	Argon, helium



contact:

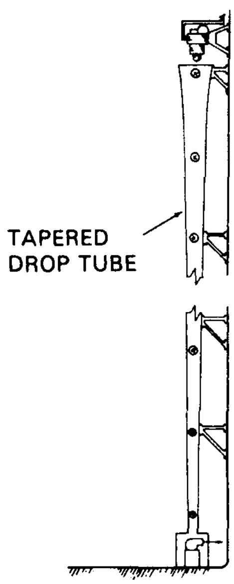
NASA/Lewis Research Center
Code 105-1, MMSL, Cleveland, OH 44135
(216) 433-5014.

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



contact:

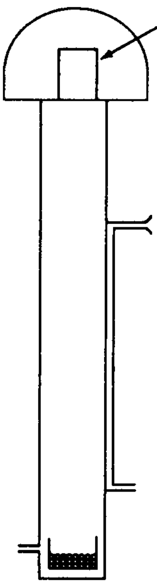
NASA/Jet Propulsion Laboratory,
Applied Sciences and Microgravity Experiments
Section, 4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-6580.

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/liquidus 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 Dia
Internal gas pressure range:	1×10^{-5} torr to 1 atm
Microgravity duration:	1.7 sec
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) 354-6580.

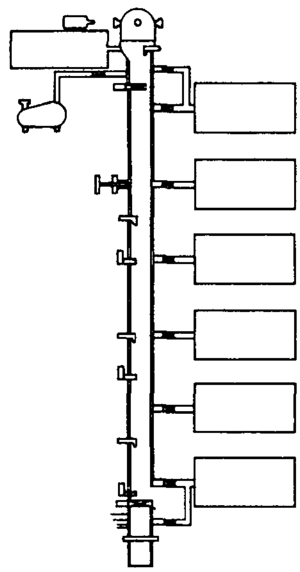
100-meter drop tube

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 Dia
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



contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812
(205) 544-1979.

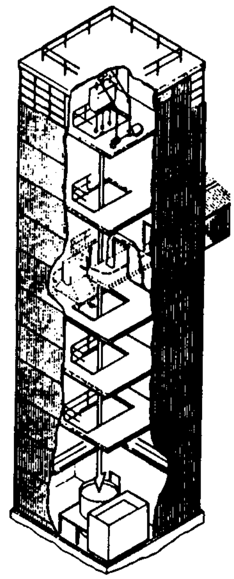
drop towers

Drop towers accommodate large experiment packages, generally using a drop shield to contain the package and isolate the experiment from aerodynamic drag during free fall in the open environment. In the drop towers, free-fall periods range from 2.2 to 5.1 seconds. An auxiliary thrust may be provided to overcome the initial resistance of air friction, but some facilities use an evacuated drop chamber. Accelerations acting on the experiments are less than 10^{-5} g.

Three drop towers are currently available: a 30-meter drop tower (both located at NASA/Lewis Research Center), a 100-meter drop tower (NASA/Marshall Space Flight Center) and a 145-meter zero-gravity research facility with a vacuum drop chamber.

30-meter drop tower

The 30-meter drop tower supports research and development programs involving combustion and the fluid physics by providing a 2.2-second period of microgravity for a variety of experiment packages at low cost. This facility allow investigators to perform preliminary, exploratory tests, particularly in preparation for more advanced flight experiments. It also offers the opportunity for the investigator to be involved closely with experiment package design and development.



operational characteristics:

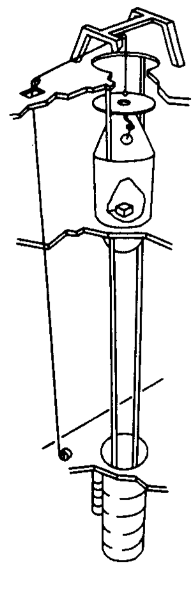
Sample rectangular drop rig:	40.64 W x 91.44 L x 81.28 (to 132.08) cm H
Experiment hardware weight:	54 kg (average)
Drop height:	26.97 m
Drag shield dimensions:	101.6 L x 50.8 W x 137.2 cm H
Microgravity duration:	Up to 2.2 sec (free fall)
Gravitational acceleration:	Less than 10^{-5} g
Deceleration rate:	15 to 20 g

contact: NASA/Lewis Research Center, Space Experiments Division, Cleveland, OH 44135
(216) 433-3459.

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:

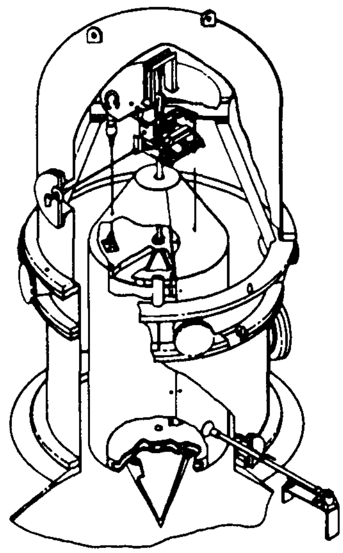
Sample size:	0.9 L x 0.9 W x 0.9 H m
Sample weight:	180 kg max
Sample capacity:	0.73 m^3 max
Drop tower	
Total drop height:	101.7 m
Free-fall height:	89.5 m
Drag shield	
Size:	7.4 m L x 2.2 m Dia
Test area:	1.8 m x 2.4 m
Weight:	1,642 kg
Drag shield free-fall time:	4.275 sec
Drag shield deceleration: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

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812, (205) 544-1979.

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:	3.4 H x 1 m Dia
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 L x 0.5 W x 1.5 m H
Test specimen envelope:	0.61 L x 0.40 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^{-5} g
Microgravity duration:	5.18 sec
Deceleration rate	
Mean:	35 g
Maximum range:	60 g for 20 millisec

contact: NASA/Lewis Research Center, Space Propulsion Technology Division, Cleveland, OH 44135
(216) 433-2439.

microgravity aircraft

The use of experimental aircraft flying parabolic trajectories provides a significant increase in processing time available for microgravity experimentation. Periods of 15 to 30 seconds of microgravity can be achieved during the central portion of the trajectory. During this 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. In an aircraft, however, the variability of the reduced gravity makes precise experimentation difficult. Two aircraft currently perform frequent low-gravity flights: the KC-135 and the Learjet. The typical lead time for scheduling experiments varies between 1 and 6 months and is dependent upon the nature of the experiment and aircraft availability. In addition, there is a modified F-104 jet fighter based at Dryden Flight Research Facility which is available for microgravity research flights. Further information on this aircraft can be obtained from the point of contact listed in this chapter.

learjet

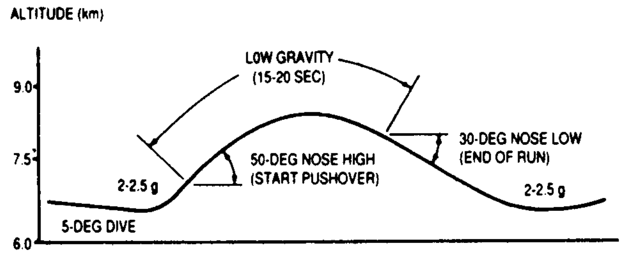
The Learjet Model 25 aircraft provides investigators with a cost-effective way to conduct and observe experiments in simulated microgravity. The aircraft allows 15 to 20 seconds of experimentation in low gravity, significantly longer than the processing times attainable in drop towers and tubes.

The Learjet, like other microgravity research aircraft, achieves weightlessness by flying a parabolic trajectory. The plane climbs rapidly at a 50- to 55-degree angle (pull-up), slows as it traces a parabola (pushover), and then descends at a 30-degree angle (pull-out).

Approximately 1.8 meters of cabin length are available for experiment mounting. Lewis Research Center (LeRC) recommends that research apparatus be installed in LeRC furnished instrument racks, two of which can be mounted in the Learjet.

operational characteristics:

Dimensions:	60.96 L x 52.70 W x 90.81 cm H
Stress limits	
Weight:	84.6 kg
Total moment:	369.46 Nm
Microgravity duration:	15 to 20 sec
Acceleration:	10^{-2} g (approx. minimum)
Number of maneuvers/flight:	6 (maximum at 10^{-2} g)



contact: NASA/Lewis Research Center,
Aircraft Operations, Cleveland, OH 44135
(216) 433-2030.

KC-135 aircraft

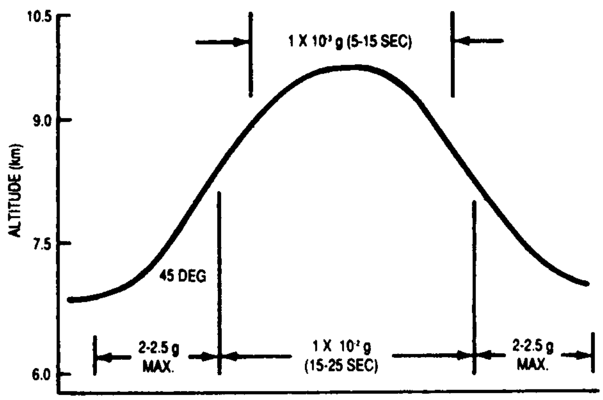
The KC-135 can simulate up to 40 periods of low-gravity for 25-second intervals during one flight. The aircraft accommodates a variety of experiments and is often used to refine space flight experiment equipment and techniques.

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 10.37 km. 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 m^2
Acceleration:	2.5 g
Microgravity duration:	25 sec
Number of maneuvers/flight:	40



contact: NASA/Marshall Space Flight Center, Microgravity
Projects, Code JA61, MSFC, AL 35812
(205) 544-1979.

F-104

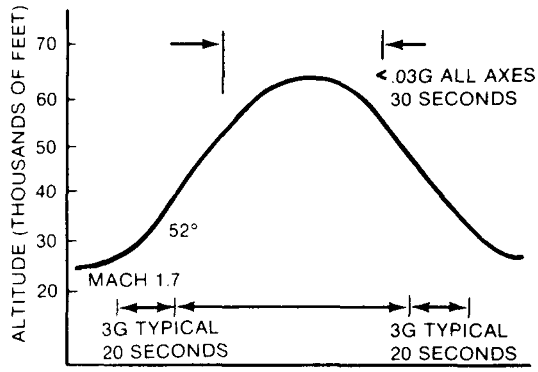
The F-104 is a modified supersonic, 2-man jet fighter. By flying in a parabolic trajectory between 25,000 and 65,000 feet, it is capable of a variable low-g period of approximately 60 seconds. The experimental package must be capable of surviving a 3-g acceleration and is restricted in size and weight by the F-104's small experiment compartment. The equipment is limited in volume to an area 10 by 15 by 21 inches and in weight to 35 lbs. All equipment is restrained during flight and not accessible after one-half hour before takeoff; therefore, all experiments must be fully-automated except for on-off functions and limited to one parabolic maneuver per flight.

operational characteristics:

Low-gravity duration: 60 sec

contact: NASA/Marshall Space Flight Center, Microgravity Projects, Code JA61, MSFC, AL 35812
(205) 544-1985.

F-104 FLIGHT CHARACTERISTICS



LOW G TIME: <.1G — 60 SEC.
<.03G — 30 SEC.

ground-based laboratories

Ground-based laboratories are available to scientists and engineers from industry, university and government agencies nationwide. The laboratory is equipped with experimental hardware which (1) are functional duplicates of those flown on the Space Shuttle or being developed for use on future Shuttle/Space Station missions; (2) provide a temporary low-gravity environment; (3) emulate conditions of the low-gravity environment; (4) or provide 1-g testing and research capabilities for developing and/or expanding microgravity experimental ideas. The laboratory also provides a place where the process in question can be studied in detail and mathematical modelling employed to remove or enhance the effect of gravity.

microgravity materials science laboratory (MMSL)

The MMSL is a nationally available laboratory open to scientists and engineers from U.S. industry, universities, and government agencies. It is equipped with experimental hardware which does one of three things: 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, or functionally duplicates hardware which is used on the Space Shuttle or is being developed for Shuttle/Space Station missions.

The MMSL is designed to give promising experiments 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 or 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 and 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.

contact: Ms. MaryJo Meyer, NASA/Lewis Research Center,
Mail Stop 105-1, MMSL, Cleveland, OH 44135
(216) 433-5014.

CHAPTER 7: ***aircraft programs and airborne sensors***

CHAPTER 8: ***ground-based facilities***

introduction

The primary goal of earth remote sensing programs is to investigate the Earth as a system from its interior to its magnetospheric boundary. The surface of the Earth may be described as consisting of vegetation, deserts, oceans and ice.

Recent research has made it clear that land, atmospheric, ionospheric, oceanic and biospheric processes are strongly coupled. Advances in satellite remote-sensing technology and in modeling and computational capabilities have demonstrated that there is more to learn about biogeochemical cycles and interactions at the boundaries of ionosphere-atmosphere, land-air, sea-air and sea-land.

Operational systems, which include spacecraft, aircraft and ground systems, have provided a vealth of data on earth resources. A value-added company will have 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 now offered to value-added companies by the Earth Observation Satellite Company (EOSAT).

Commercial applications of remote sensing satellites and airborne equipment have been leveloped to collect and relay data used for crop forecasting, mineral exploration, land use nanagement, aquaculture harvesting, navigation aids, weather observation, archaeological findngs and other activities. Observations may be made visually with camera components, or nrough various wave length modes, such as x-ray or ultra-violet. Data interpretation, image enancement and value-added services play as important a role in the remote sensing industry as ata collection. Therefore, ground-based research will become a widely evolving activity as the equirements and uses of remote sensing data become fully realized. In addition, commercial aplications are planned in the testing of advanced sensor technology, large-scale cameras, data elay devices, data reduction techniques and others.

CHAPTER 7

aircraft programs and airborne sensors

The traditional use of research aircraft has set the pace for progress in several areas of the atmospheric sciences: 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, or local, 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 for a quick observation of newly developed phenomena -- such as a storm, a volcano, a polluted basin, a region of sea ice, drought-stricken crops, or a warm ocean current -- together with its ability to remain on station several hours, makes it an ideal platform for gathering data.

For space-based research, an extension of this activity is the use of aircraft for the development of remote sensors that later may be utilized for orbiting satellites. 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 the progress of the Earth sciences were first developed as airborne instruments.

At present, several aircraft are provided by three NASA centers to support Earth science. The objectives of this activity are to:

Conduct in situ and remote measurements for research in Earth observations.

Develop and simulate instruments for Shuttle and free-flying spacecraft; and

Underfly Shuttle and free-flying spacecraft sensors to acquire "verification" and calibration data.

■ aircraft programs

Remote Sensing programs are supported by aircraft flown from Ames Research Center and from Goddard Space Flight Center's facility at Wallops Island, Virginia. In addition to these, the Stennis Space Center (SSC) operates a Learjet in support of the Land Processes Program. Table 7.1 provides a list of these aircraft and their operational characteristics.

Lockheed ER-2

These two ER-2 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 flown involve collection of data in three principal areas: atmospheric data within the stratosphere, earth and celestial observations using electronic sensors and photographic data acquisition.

Lockheed C-130B

A suite of sensors is provided for use on this multi-purpose remote-sensing platform, including a 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/scatterometer research, wetlands studies and biomass combustion work.

McDonnell Douglas DC-8

The DC-8 is being modified to meet NASA's need for a multipurpose flying laboratory. Researchers may use an assortment of general support equipment, including metric and panoramic cameras, a data recording system, Doppler and weather radars and a radar altimeter.

Lockheed I-188 Electra

The Electra is currently used to support a major atmospheric science program for NASA called the Global Tropospheric Experiment (GTE).

Lockheed NP-3A

The P-3 will support regional and local studies and instrument development work.

Short Brothers SC-7 Skyvan

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

Rockwell T-39 Sabreliner

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

Bell UH-1B Helicopter

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

Gates Learjet

The Stennis Space Center operates a Learjet in support of the Land Processes 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.

RESEARCH AIRCRAFT TYPICAL PERFORMANCE CHARACTERISTICS

Aircraft	Manufacturer	Model	Altitude (Feet)	Range (Miles)	Endurance (Hours)	Payload Weight	Payload Power	Agency
ER-2	Lockheed		70,000	3,200	7.0	2,700		NASA/ARC
ER-2	Lockheed		70,000	2,500	7.0	2,700		NASA/ARC
C-130	Lockheed	NC-130B	24,000	2,000	7.0	20,000	26.0 kw+	NASA/ARC
DC-8	MACDAC	72	40,000	6,000	12.0	30,000	80.0 kw	NASA/ARC
Electra	Lockheed	L-188	25,000	2,000	7.5	19.000	40.0 kw	NASA/WFF
P-3 Orion	Lockheed	P-3A	25,000	2,000	7.5	13,600	33.0 kw	NASA/WFF
Skyvan	Short Bros	SC-7	15,000	650	4.0	5,000	2.8 kw	NASA/WFF
Sabreliner	Rockwell	T-39	41,000	1,400	3.25	1,500	3.0 kw	NASA/WFF
Helicopter	Bell	UH-1B	10,000			2,000	3.5 kw	NASA/WFF
Lear Jet	Gates Lear Jet	23-049	41,000	1,000	3.0	750	4.0 kw	NASA/NSTL

NOTE: Please note that aircraft performance values vary with payload, altitude, air temperature, type of mission, weather conditions, etc. For more details on specific capabilities, please contact the aircraft facility manager for the pertinent agency as listed below:

Table 7.1

contact:
NASA/ARC: Earl Peterson (415) 694-6092
NASA/WFF: David Roberts (804) 824-1541
NASA NSTL: Kenneth D. Cashion (601) 688-1930

■ *airborne sensors and scanners*

NASA has maintained an aggressive satellite remote-sensing development program since its inception and has pioneered new techniques for exploiting the electromagnetic spectrum for research in the Earth sciences.

Generally speaking, earth science satellite sensors are developed by way of a formal Announcement of Opportunity (AO) issued by NASA Headquarters. Typically, these instruments are multi-million dollar investigations which are not readily adaptable to commercial applications. However, sensors developed for the High Altitude Aircraft Program are available to commercial users.

More than fifty different sensors and experiments can be flown aboard the ER-2. Some of these sensors, such as cameras and multispectral scanners, are part of the inventory of the Airborne Science and Applications Program at NASA/ARC. Many experiments and their supporting scientific instruments are designed by investigators from other NASA centers, other government agencies and various universities.

High altitude photography data acquisition utilizes various camera systems and films based on the researcher's requirements. Among the best in the world, these cameras include 9 x 9 inch and 9 x 18 inch mapping cameras and large format panoramic cameras. Use of large format cameras at high altitude enables the ER-2 to acquire photographic data over thousands of square miles in a single flight.

Typical ground coverages for the four cameras available at NASA/Ames Research Center are shown and detailed characteristics follow.

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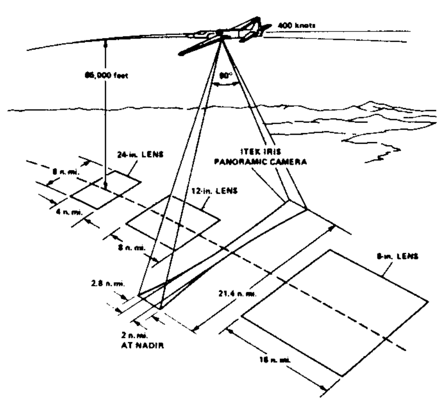
HIGH ALTITUDE CAMERA SPECIFICATIONS



DESIGNATION	LENS	FORMAT	AT 65,000 feet GROUND COVERAGE	NOMINAL RESOLUTION	SCALE
RC-10	6 in. f4	9 x 9 in.	16 x 16 n. mi.	3 – 8 m	1:130,000
RC-10	12 in. f4	9 x 9 in.	8 x 8 n. mi.	1.5 – 4 m	1:65,000
HR-732	24 in. f8	9 x 18 in.	4 x 8 n. mi.	0.6 – 3 m	1:32,500
IRIS Panoramic	24 in. f3.5	4.5 x 35 in. (90°) to 4.5 x 60 in. (140°)	2 x 21.4 n. mi. 2 x 58.7 n. mi.	0.3 – 2 m	1:32,500 (nadir)

A-3 Configuration

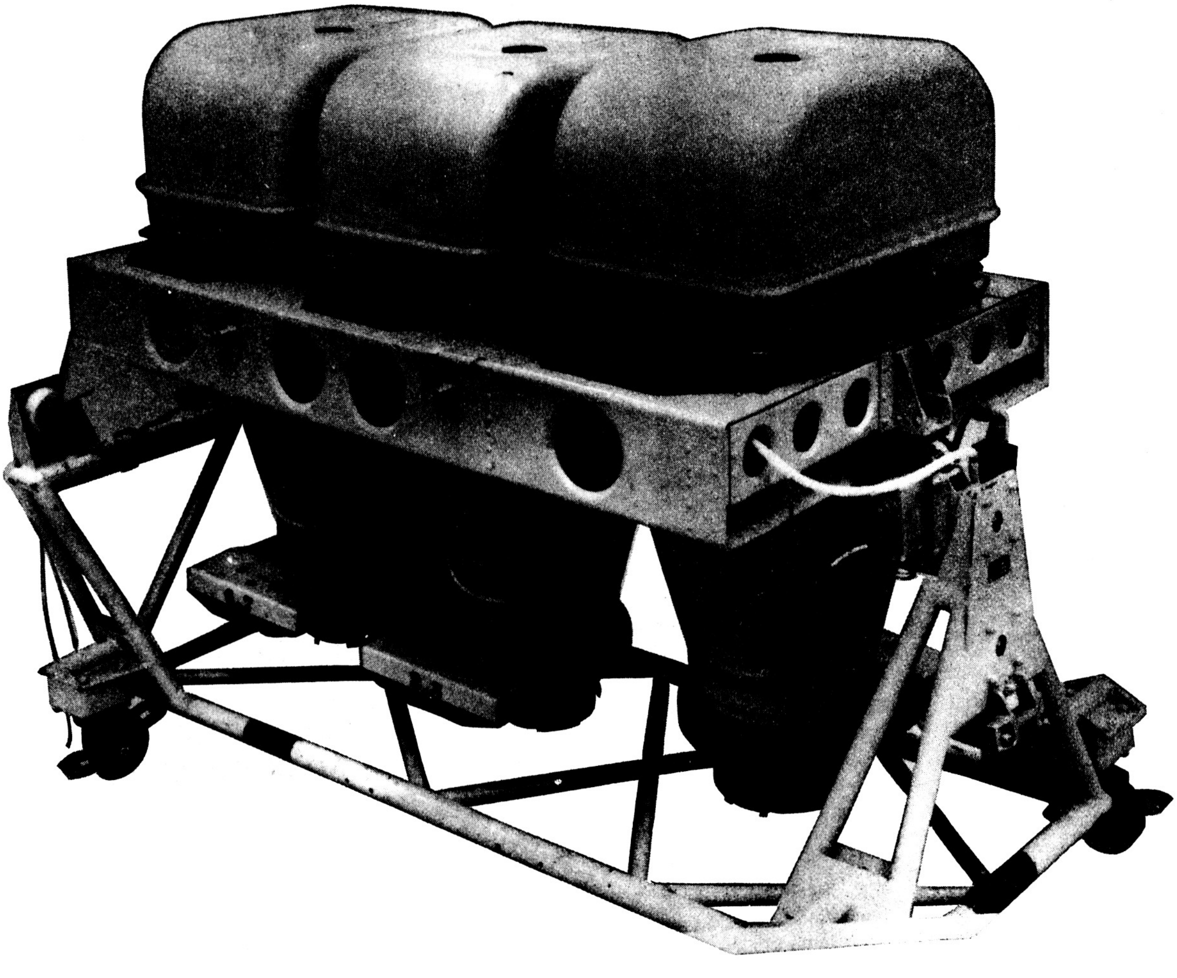
This camera package consists of three HR-732 cameras each with a 24-inch focal length lens cone. This provides for multi-emulsion or multi-spectral coverage of the same ground scene.

operational characteristics:

Package:	3 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 to 15 ft

carrier: ER-2

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035,
Attention: John C. Arveson
(415) 694-5376.
This apparatus is available.



A-4 Configuration

This camera 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 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

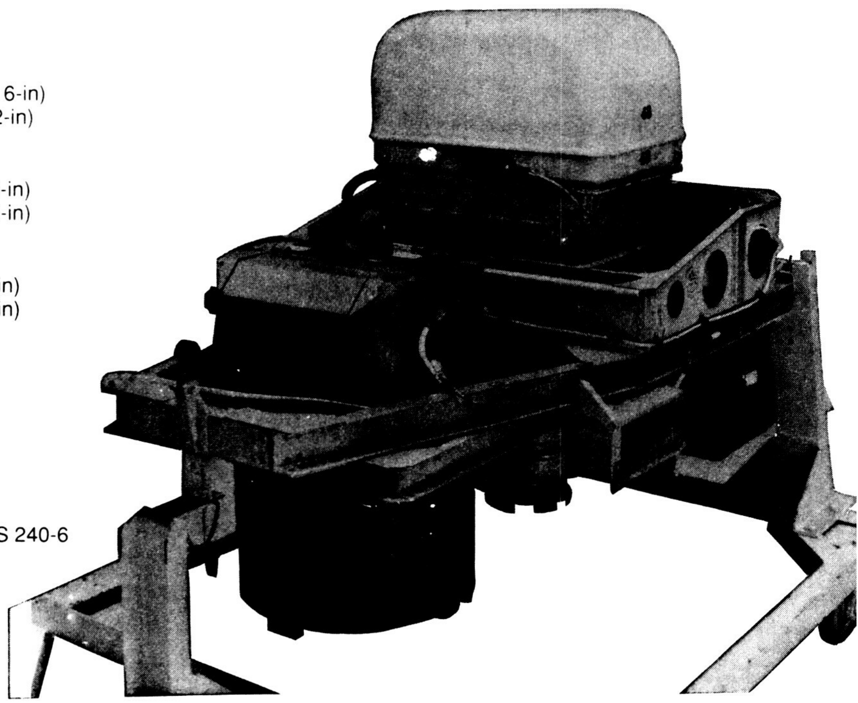
Lens data: 6-in f/4.0 (RC-10)
12-in f/4.0 (RC-10)
24-in 4/8.0 (HR-732)

Format: 9 x 9 in (RC-10)
9 x 18 in (HR-732)

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)

Vertical scale @ 65,000 ft: 1:130,000 (RC-10, 6-in)
1:65,000 (RC-10, 12-in)
1:32,000 (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

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arveson
(415) 694-5376.
This apparatus is available.

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dual RC-10 metric camera system

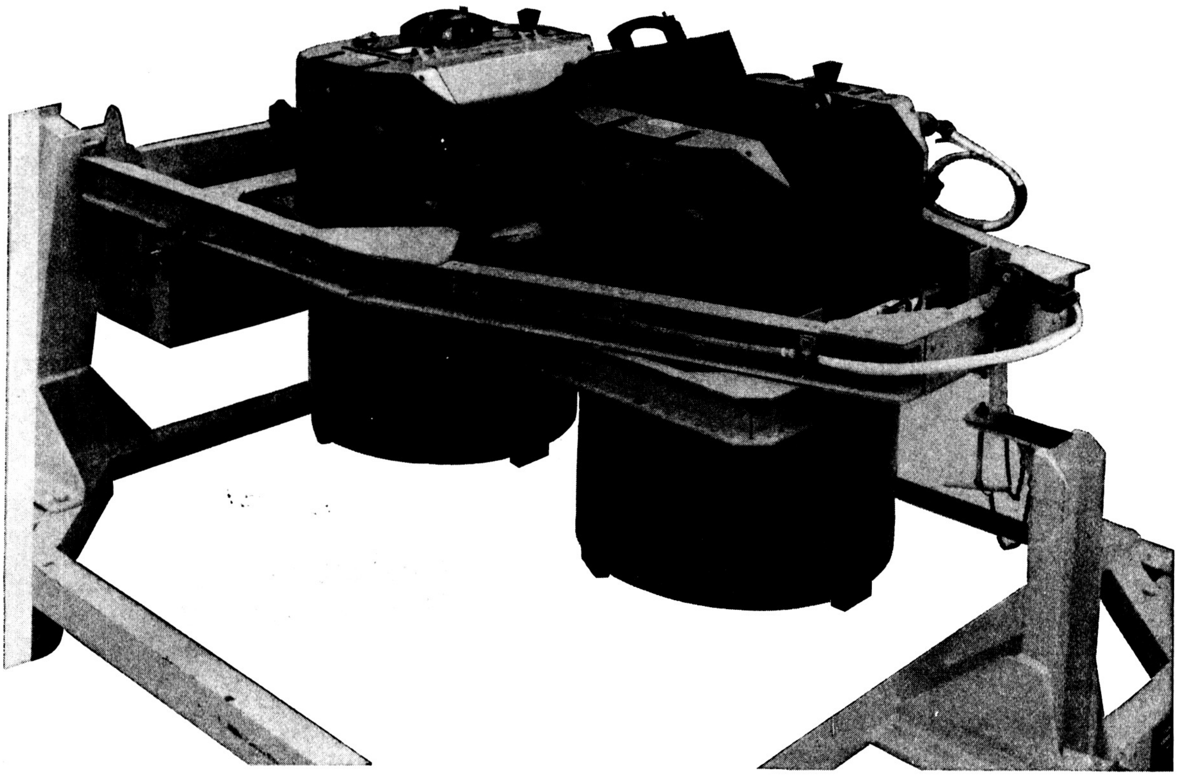
This camera package consists of two RC-10 metric cameras with interchangeable 6- or 12-inch focal length lens cones. This provides for dual scale or dual emulsion for the same scene.

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

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arveson
(415) 694-5376.
This apparatus is available..

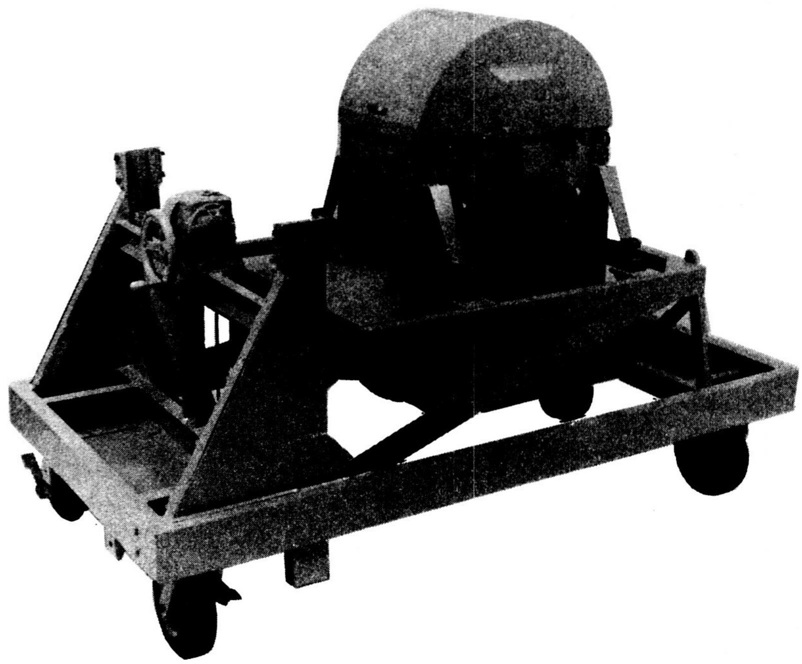


IRIS II panoramic camera

This camera package consists of an ITEK IRIS II panoramic camera with a 24-inch focal length lens cone. This provides for high resolution, wide area coverage in mono or 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 (90o scan)
Vertical scale @ 65,000 ft:	1:32,000
Nominal ground resolution:	1 to 5 ft



carrier: ER-2

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arvesen
(415) 694-5376.
This apparatus is available.

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scanners

In addition to camera packages, several multi-spectral scanners are available for use. A Daedalus multispectral scanner is flown on board the ER-2 aircraft and may be configured as two different scanners, namely, a Thematic Mapper Simulator (TMS) and an Airborne Ocean Color Imager (AOCI). The TMS simulates the performance of the Thematic Mappers on board LANDSAT-4 and -5. The AOCI is a high altitude multispectral scanner designed for oceanographic remote sensing. Bandwidths on this scanner simulate the characteristics of the Ocean Color Imager which has been proposed to follow the oceanographic scanner on board the Nimbus-7 satellite.

The NS-001 multispectral scanner is a NASA-designed scanner flown on board a NASA C-130B aircraft at medium altitudes. It is also configured as a TMS and acquires digital data in the same spectral bands used on the Thematic Mappers on board LANDSAT-4 and -5. This scanner provides larger scale and higher resolution imagery than the Daedalus TMS flown at high altitude by ER-2 aircraft.

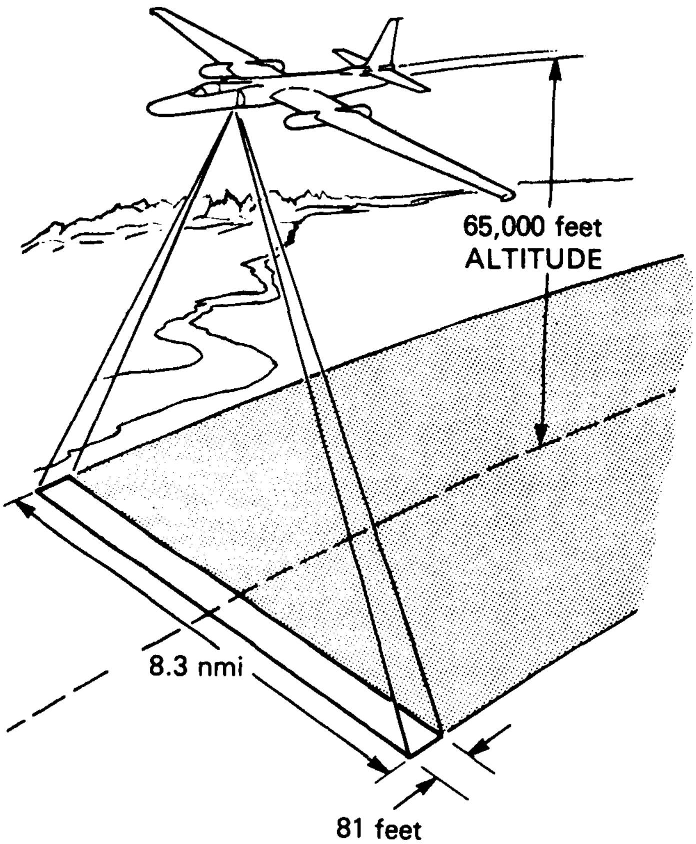
As an aircraft mounted multispectral scanner, the TMS is a valuable earth resources monitoring tool capable of deployment to study sites throughout the United States for purposes of scientific research and applications.

daedalus thematic mapper simulator (TMS)

A Daedalus Thematic Mapper Simulator (TMS) is flown on board the ER-2 aircraft. Simulating the performance of the LANDSAT-4 and -5 earth resource satellites, it replicates the spatial and spectral characteristics of the seven LANDSAT Thematic Mapper bands. Four additional spectral bands of discrete wavelengths are also acquired by the TMS while TM band 6 (thermal data) is acquired as two bands in low gain and high gain settings.

operational characteristics:

IFOV:	1.25 mrad
Ground resolution:	81 ft
Total scan range:	43°
Swath width:	8.3 nmi
Pixels/scanline:	716 (750 following rectification)
Scan rate:	12.5 scans/sec
Aircraft velocity:	390 kts



carrier: ER-2

contact:

High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arvesen
(415) 694-5376.
This apparatus is available.

daedalus airborne ocean color imager (AOCI)

The Daedalus multispectral scanner may also be configured as an Airborne Ocean Imager (AOCI) simulating the spectral characteristics of the proposed second generation instrument to follow the Coastal Zone Color Scanner (CZCS) on board the Nimbus-7 satellite. The AOCI provides eight bands of the visible spectrum with two additional bands in the near and thermal infrared portions of the spectrum. Flown at 65,000 feet aboard NASA ER-2 aircraft, the AOCI provides a readily deployable platform for study of coastal, estuarine, and oceanic processes.

operational characteristics:

IFOV:	2.5 mrad
Ground resolution:	163 ft
Total scan angle:	85o
Swath width:	18 nmi
Pixels/scanline:	716
Scan rate:	6.25 scans/sec
Aircraft velocity:	390 kts

carrier: ER-2

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arvesen
(415) 694-5376.
This apparatus is available.

ns-001 thematic mapper simulator (TMS)

The NS-001 multispectral scanner is a NASA-developed Thematic Mapper Simulator flown on board a C-130B aircraft based at Ames Research enter. This scanner contains the seven LANDSAT-4 and -5 Thematic Mapper bands plus a band from 1.131 to 1.35 micrometers.

The specific bands are as follows:

operational characteristics:

IFOV:	2.5 mrad
Total scan angle:	100°
Pixels/scan angle:	699

carrier: ER-2

contact: High Altitude Missions Branch
NASA/Ames Research Center, MS 240-6
Moffett Field, CA 94035
Attention: John C. Arvesen,
(415) 694-5376.
This apparatus is available.

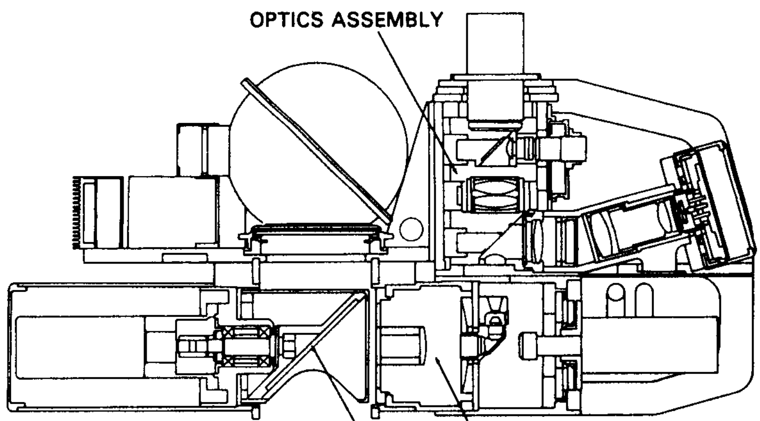
Other airborne sensors are available at the NASA/Stennis Space Center and the National Center for the Commercialization of Space Remote Sensing. These sensors are described in the following section.

calibrated airborne multispectral scanner (CAMS)

The CAMS is a nine channel, airborne imaging device which samples electromagnetic energy in several spectral regions. Scan speeds are adjustable from 6 to 80 scans per second in one-scan-per-second increments. 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

contact: NASA/Stennis Space Center
Commercialization Branch
Earth Resourses Laboratory
SSC, MS 39529
(601) 688-2042.
This apparatus is available.



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 earth in a wide field synoptic mode and 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 Space Shuttle's cargo bay but may also be mounted in a free-flying spacecraft or in an aircraft.

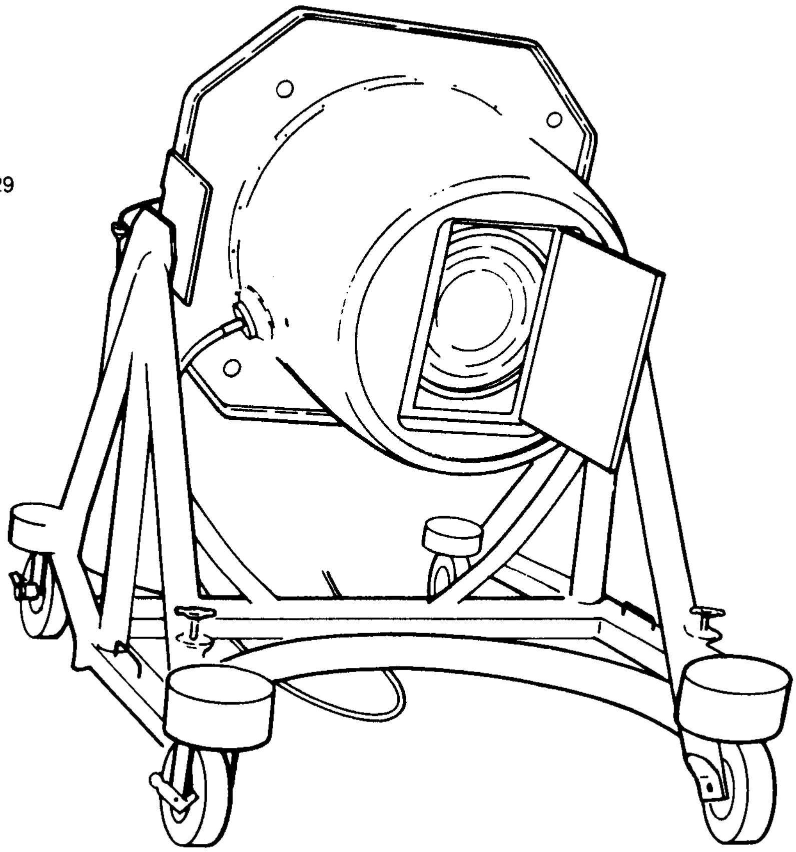
operational characteristics:

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

contact:

NASA/Stennis Space Center
Commercialization Branch
Earth Resources Laboratory
Stennis Space Center, MS 39529
(601) 688-2042.
This apparatus is available.



aerial data acquisition program

The Aerial Data Acquisition program uses a Daedalus 1260 Digital Multispectral Scanner (DMS). This scanner offers 1 broad thermal infrared, 2 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 Faults and fractures
Detection of:	Rooftop heat loss and moisture damage Problems in buried steamlines. condensate return, and 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

contact: CCDS/ITD Space Remote Sensing Center
Dr. George A. May
Building 1103, Suite 118
Stennis Space Center, MS 39529
(601) 688-2509.

CHAPTER 8

ground-based facilities

Although remotely-sensed information is gathered by space-based and airborne vehicles and instruments, the majority of the activities associated with remote sensing actually take place on the ground. The ground segment of remote sensing systems includes a wide variety of highly sophisticated computer hardware, software and other subsystems.

The technology's primary significance from any standpoint lies in the manipulation of the data once it reaches the Earth. Consequently, in addition to data acquisition from satellites and airborne vehicles, the areas of data reception (antennas and receivers), data pre-processing (formatting and recording) and data storage and dissemination (archiving and reproduction) are gaining growing attention from commercial developers who are researching advanced technologies for applications of products and services derived from remote sensing data. Examples of these developments are commercially-developed Positioning Determination Systems, which provide tracking and navigation data for transportation vehicles such as ships and trucks; and the use and computational manipulation of combined data and media, such as topographic, multi-dimensional, multi-spectral and video imaging, which may be used for commercial applications such as real estate, agribusiness and mining.

Facilities devoted to sensor development, data processing, and data distribution play an important role in the Remote Sensing Programs. These facilities include NASA Field Centers, CCDS centers, other government agencies and the private sector.

■ nasa centers

The NASA centers with capabilities to support commercial users are the Stennis Space Center (SSC) and the Ames Research Center (ARC). SSC, designated as the lead NASA center for commercial applications of remote sensing, has two specific laboratories: the Sensor Engineering and Development Lab and the Data Analysis Lab, which assist commercial researchers in participating in the remote sensing arena. In addition to these two labs, SSC has implemented a Visiting Investigator Program (VIP) designed to encourage industry to utilize the center's facilities.

Stennis Space Center (SSC)

sensor engineering and development laboratory

This laboratory contains the following equipment:

Ten-inch off-axis collimator system (80-inch focal length)

Visible/IR reference standards

Scanning monochromator (0.3 to 13.0 m)

Three-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

Twenty-inch integrating sphere (0.3 to 1.1 m)

Fourteen-inch integrated 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 (VIP) is designed to provide an opportunity for industry to utilize the specialized resources at NASA's 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 March, 1988, at SSC with plans to have one or two VIP participants per quarter. SSC is acquiring a remote sensing end-to-end micro-based data processing system that will support their commercialization effort.

contact: NASA/SSC, Earth Resources Laboratory
(601) 688-3326.

Ames Research Center (ARC)

image processing laboratory

ARC has an Image Processing Laboratory, concentrating on photographic and electronic data processing, which is used in conjunction with their remote sensing programs. Further information on these capabilities may be obtained from NASA/ARC, High Altitude Missions Branch, (415) 694-5376.

NASA high altitude missions photography archive

ARC also hosts the NASA High Altitude Missions Photography Archive, which contains particularly thorough coverage of the western and eastern states, including Alaska and Hawaii, with smaller but significant coverage of the South and Midwest. Urban, suburban, agricultural, and even the most remote mountain regions are represented. Archive photographs present unusually wide ground coverage and precise definition of ground objects: each 9 x 9 inch or 9 x 18 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 is of three types: natural color, black and white and color infrared. Color infrared film is the most widely used because it produces photographs that reveal information from a portion of the spectrum not normally seen by the eye. Color infrared photographs are particularly useful for noting the subtle differences within land cover types (water, soil and vegetation).

data management facility

The Data Management 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 then verify their selections before actually accessing rolls of film.

Viewing equipment is provided at the Data Management Facility so that visitors can carefully study films which interest them. 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 easily obtained by contacting the Earth Remote Observation Sensing Data Center in Sioux Falls, South Dakota, 57198. Telephone: (800) 367-2801 or (605) 594-6950 (see EOSAT later in this chapter).

contact: Airborne Science and Applications
Data Management Facility
NASA-Ames Research Center
MS 240-6
Moffett Field, CA 94035
Attn: Gary A. Shelton
(415) 694-5344.

CCDS/ITD Space Remote Sensing Center

Building 1103, Suite 118
Stennis Space Center, Mississippi 39529

consulting capabilities

Sensor analysis and design
Aircraft data acquisition
Image data processing

contact: Dr. G.A. May, Acting Director
(601) 688-2509.

data processing facility

MASSCOMP 5600 and 5450
AT&T 3 B2 Minicomputers (2)
Optical disk storage device
Colcomp and geophysics digitizer tables
Matrix camera
Image processing workstations (5)

CCDS/Center for Mapping

Ohio State University
404 Cockins Hall
1958 Neil Avenue
Columbus, Ohio 43210-1247

general facilities

Cray X-MP/24 Supercomputer
Digital Vax 8530
Image Processing System
Eikonix A80-A Digital Camera (4096x4096)
SUN Color Workstation 3/150C-4-P5
Tektronix 4129 Display with DI-3000 3D Driver
Timble 4000SX GPS Receivers

contact: Dr. John D. Bossler, Director
(614) 292-6642.

NOAA: Satellite Data Services Division

A prime source of remote sensing data is that 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., the 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.

The view from space has become important to many diverse communities in our society: scientists seek satellite data for studies related to climatology, coastal zone management, hydrology, agriculture, and a host of other areas of research; lawyers use satellite data in weather-related litigation; editors use satellite pictures to illustrate publications and advertising; many state and local organizations want views of their home states and significant local weather; and students at every educational level seek satellite information. Global applications of polar-orbiting satellite data are also useful to foreign nations. The clientele is large and growing.

Environmental data files at the Satellite Data Services Division contain imagery from the current polar orbiting (NOAA Series) and Geostationary Satellites (GOES). The Division 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.

Data on magnetic tapes include digitized imagery from the polar orbiting and geostationary satellites and atmospheric sounding raw radiance data. Other satellite digital data include that acquired by the Defense Meteorological Satellite, SEASAT, and the NIMBUS-7 Coastal Zone Color Scanner.

Environmental monitoring satellites are operated in two basic types of orbits: polar orbiting, for global coverage, and geostationary, for generally covering the Americas or the Western Hemisphere. Both imagery and digital (quantitative) data are collected by instruments aboard these satellites.

Those interested in obtaining additional information may contact SDSD and request NOAA Technical Memorandum NESS109, National Environmental Satellite Service Catalog of Products, Current Edition.

contact: NOAA/NESDIS/NCDC
Satellite Data Services Division
World Weather Building, Room 100
Washington, D.C., 20233
(301) 763-8111.

Earth Observation Satellite (EOSAT) Company

In the private sector, the Earth Observation Satellite (EOSAT) Company is marketing data from the LANDSAT series of satellites. Successor LANDSAT satellites are planned and may be joined in the future by organizations from other countries.

The Land Remote Sensing Commercialization Act of 1984 laid down extensive guidelines for the conduct of U.S. commercial operations. The research community will need access to commercial data at prices commensurate with the resources of realistic research budgets. Such access is also essential for the effective translation of research knowledge into practical benefits for human societies.

EOSAT has some two million LANDSAT images in digital archives and with new processing techniques can present that data in ways never before available. The company offers thematic mapper imagery on personal computer floppy disks: seven spectral bands available in sets of seven disks.

Value-added companies have developed software for personal computers to manipulate multi-spectral data. The use of personal computers and floppy disk media are considered only one step in the promise to bring LANDSAT imagery to many users without enormous computer resources. Geocoded imagery with standard map references and "moveable scenes," positioned anywhere along the LANDSAT flight path, have given customers useful data tailored to their particular requirements. Value-added companies are merging Landsat imagery with pictures and topographical data. New analyses of old data can reveal significant trends for census projections and other applications.

A listing of EOSAT products and services follows:

landsat products

image products and approximate scale

Black & White Film Negatives: 1:1,000,000

Black & White Film Positives: 1:1,000,000

Black & White Paper Products: 1:1,000,000/1:500,000/1:250,000

Color Film Positives: 1:1,000,000

Color Paper: 1:1,000,000/1:500,000/1:250,000.

digital products

Standard Computer Compatible Tapes (CCT)

Thematic Mapper (TM) - full scene and quadrand, includes 7 bands

Multi-Spectral Scanner (MSS) data - full scene only, includes 4 bands

All tapes are 9 track, 1600 BPI or 6250 BPI.

digital geocoded image data

Geocoded products are unenhanced digital data processed to a simple relationship to a predetermined base map. This allows the user to relate the digital data in raster format to a base map without rotating or translating the image. Geocoded data enable the user to select image framing options, map projections, output window and pixel size. Image sizes range from the USGS 1/2 x 1 degree map sheet size to full scenes (185 km x 170 km).

thematic mapper movable digital sub-scenes and mini-scenes

LANDSAT Thematic Mapper movable digital scenes are data that can be positioned anywhere within a given LANDSAT path. This allows users to more closely frame their area of interest. Movable scenes are available in two sizes: 100 km x 100 km and 50 km x 100 km.

floppy disk

EOSAT is offering a new product for PC-based systems: 512 x 512 pixel windows of TM data on 5.25-inch floppy disks. The disks are in MS-DOS and PC-DOS format, and may be read by all PC-XT or PC-AT compatible computers. The floppy disk is available for TM scenes that are currently in the Eros Data Center library.

data search service

If you are interested in data for a particular area, contact the EOSAT Customer Service Department in Lanham, Maryland. This service is free and covers all types of LANDSAT data acquired since 1972.

To request a search, it is necessary to provide at least one of the following:

1) Latitude and longitude coordinates for the center points of the selected study area;

2) A satellite path/row (available from World Reference System maps or other published sources). Path/row maps are available free of charge from EOSAT's Customer Service department, and show the path/row for LANDSAT 1 to 5. Computer printouts of data scenes will automatically include LANDSAT 1 through 3 if no data is available from LANDSAT 4 and 5; or,

3) A specific location, such as a city name or major geographic feature.

Options: Maximum Acceptable Cloud Cover, Minimum Quality Rating Acceptable, Time of Year for the Acquisition.

contact: EOSAT Management And Administration Headquarters
4300 Forbes Boulevard; Lanham, MD 20706
(800) 344-9933, (301) 552-0537.

data orders: EROS Data Center; Sioux Falls, SD 57198
(800) 367-2801, (605) 594-6950.

SECTION FOUR: *directory*

introduction

After the commercial developer has reviewed this catalogue, he may ask, "Where do I start?" The answer is found in this Directory of Resources and Services: Chapters 9, 10 and 11. If you have an idea for a potential commercial endeavor in space, you may contact a relevant Center for the Commercial Development of Space (CCDS) or a NASA Field Center. You may also want to contact one of the companies listed, as appropriate. Be advised that charges for services or products may be expected, but all organizations will inform you of these charges, if any, in advance.

Chapter 9 contains a listing of transportation products and services which are either currently available or are being developed, including launch vehicles and launch services. Chapter 10 offers a listing of businesses and industries which provide services and products for space-related applications. Chapter 11 includes a listing of the NASA and CCDS points of contact who may serve as primary sources of information.

CHAPTER 9

transportation products and services

Numerous commercial companies are now able to furnish launch vehicles and launch support services. These range from sounding rocket class vehicles to full scale Titan III and Atlas class boosters. Some of the commercial companies will offer a full range of launch services by mid-1989. The potential user should contact companies directly for further information.

ASTRA B medium lift launch vehicles

E Prime Aerospace Corporation (EPAC)

The EPAC ASTRA B 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 be configured to place payloads of up to 16,000 pounds into Low Earth Orbit, or payloads up to 6200 pounds into Geosynchronous Transfer Orbit).

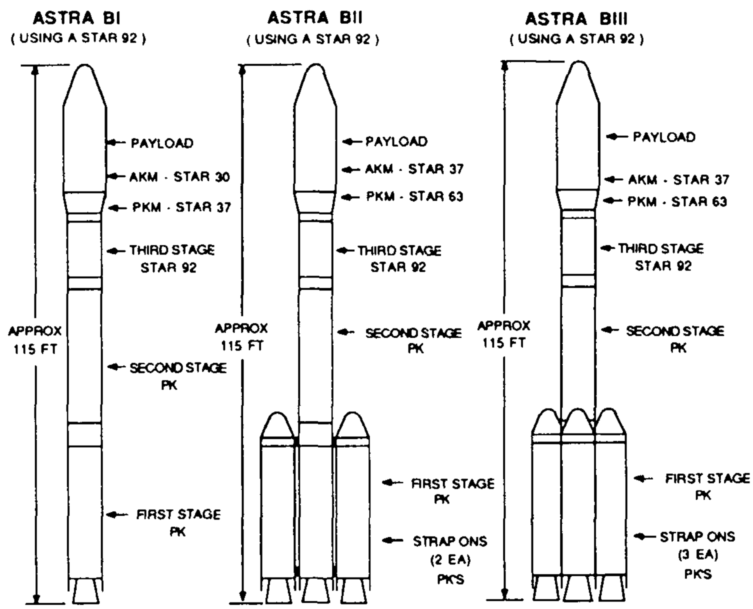
The EPAC ASTRA B launch vehicle is a six-configuration family providing an efficient means of propelling a wide range of space payloads into planned trajectories. The SRMs are chosen to meet the propulsion requirements of the payload orbital position specifications. Two, three or four SRM stages are 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 GTO.

E Prime's overall program planning includes accommodations for payloads ranging from low earth orbit payloads to communications satellite assemblies with geosynchronous insertion motors.

These vehicles range from approximately 76 feet to approximately 115 feet, depending upon the motor stage configuration. Payload capacity ranges from 1,500 pounds to approximately 16,000 pounds.

contact: E Prime Aerospace Corporation
P.O. Box 792, Titusville, FL, 32781
(407) 269-0900.

EPAC ASTRA B
COMMERCIAL FAMILY



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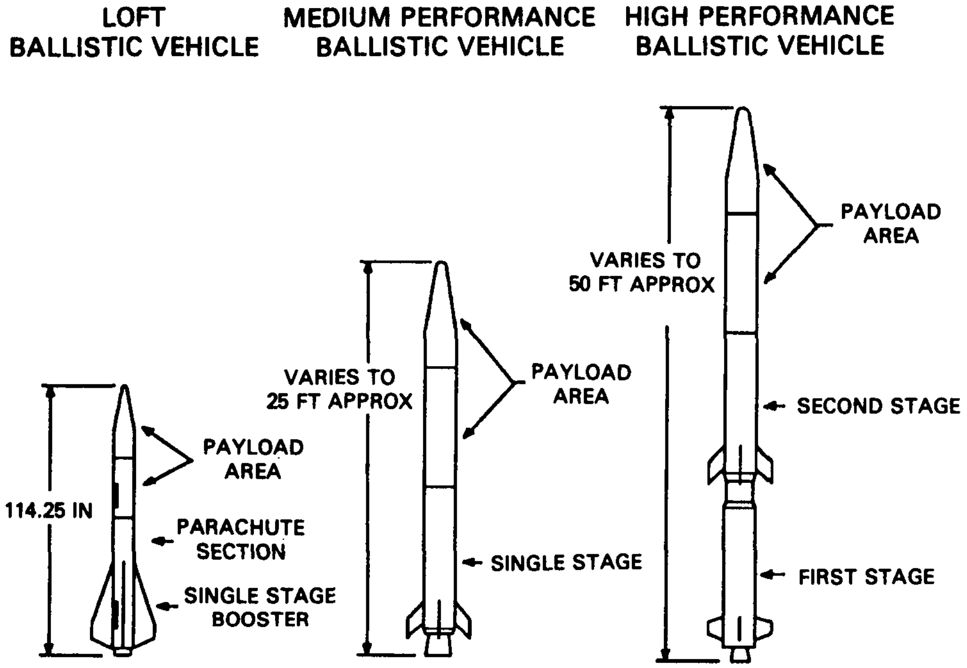
ballistic (sounding) rockets

E Prime Aerospace Corporation (EPAC)

E Prime is developing three sizes of ballistic launch vehicles capable of placing payloads of up to 250 lbs into ballistic flight trajectories, achieving as much as 15 minutes of microgravity. Payloads that require recovery would descend via parachute to either a land or water recovery area. Tracking and telemetry services can be provided by E Prime.

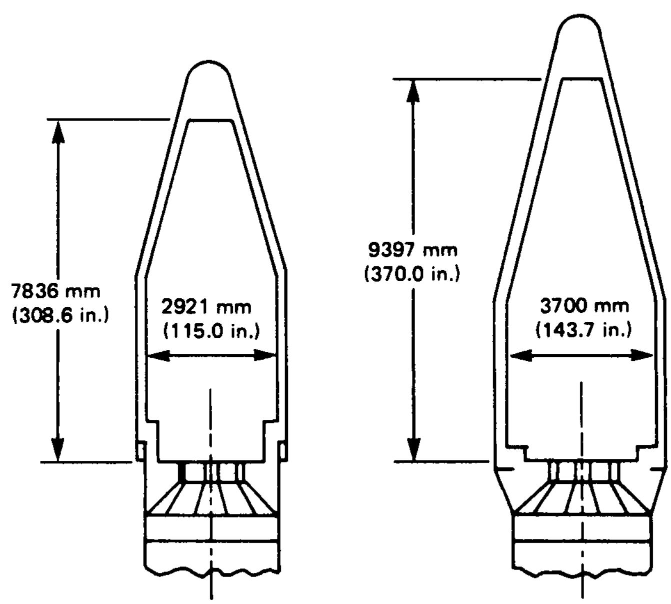
contact: E Prime Aerospace Corporation
P.O. Box 792, Titusville, FL 32781
(407) 269-0900



Commercial Atlas

General Dynamics Corporation

The Commercial Atlas launch vehicle family consists of the Atlas I, currently in production; the Atlas II and Atlas IIA, available in 1991; and the Atlas IIAS, planned for 1992.



MEDIUM FAIRING (3.3 m)

LARGE FAIRING (4.2 m)

Atlas configurations and payload capabilities are listed in the following table.

Atlas Configurations & Capabilities

	Atlas I *(In Production, Currently Available)*		Atlas II *(In Development, Available 1991)*		Atlas IIA *(In Development, Available 1991)*		Atlas IIAS *(Planned, Available 1992)*	
	Medium Payload Fairing	Large Payload Fairing	Medium Payload Fairing	Large Payload Fairing	Medium Payload Fairing	Large Payload Fairing	Medium Payload Fairing	Large Payload Fairing
Missions *(Typical Missions Shown)*	Performance Capability							
Geosynchronus Transfer Orbit 167 x 35,786 Km (90 < 19,324 nmi) 28.5° Transfer Orbit Inclination	5,150 lbs	4,950 lbs	6,100 lbs	5,900 lbs	6,400 lbs	6,200 lbs	6,950 lbs	6,750 lbs
Low Earth Orbit 185 x 185 Km (100 x 100 nmi) 28.5° Orbit Inclination	13,000 lbs	12,550 lbs	14,950 lbs	14,500 lbs	15,700 lbs	15,250 lbs	16,850 lbs	16,400 lbs
Earth Escape C3 = 0	3,350 lbs	3,100 lbs	4,270 lbs	4,020 lbs	4,620 lbs	4,370 lbs	5,220 lbs	4,970 lbs

Atlas Launch Vehicle Specifications

Item			Specification			
			Atlas Vehicle Configuration			
			Atlas I	Atlas II	Atlas IIA	Atlas IIAS
Overall Vehicle	Length	Medium Fairing	(133 ft.)	(150 ft.)		
		Large Fairing	(144 ft.)	(156 ft.)		
	Diameter		(10 ft.)			
	Gross Lift Off Weight	Medium Fairing	(361,300 lbs)	(412,600 lbs)	(412,900 lbs)	(434,100 lbs)
		Large Fairing	(362,200 lbs)	(413,500 lbs)	(413,800 lbs)	(435,000 lbs)
Centaur	Length		(30 ft.)	10.1 m (33 ft.)		
	Propellant		LH2 & LO2 (Liquid Hydrogen & Liquid Oxygen)			
	Propellant Weight		(30,400 lbs)	(37,000 lbs)		
	Total Thrust (Vacuum)		(33,000 lbs)	(33,300 lbs)	(40,500 lbs)	
	Specific Impulse Iso (Vacuum)		444.4 sec	442.3 sec	448.9 sec	
Atlas	Length		(73 ft.)	(82 ft.)		
	Propellant		LO2 & RP-1 (Liquid Oxygen & Kerosene Type of Fuel)			
	Propellant Weight		(303,200 lbs)	(344,500 lbs)		
	Booster Engines Total Thrust (Sea Level)		(377,500 lbs)	(408,000 lbs)		
	Booster Engine Specific Impulse Isp (Sea Level)		259.1 sec	263.1 sec		
	Sustainer Engine Thrust (Sea Level)		(60,500 lbs)			
	Sustainer Engine Specific Impulse Iso (Sea Level)		220.4 sec			
	Vernier Engines Total Thrust (Sea Level)		(1,328 lbs)	Not Applicable		
	Vernier Engine Specific Impulse Isp (Sea Level)		196.7 sec			

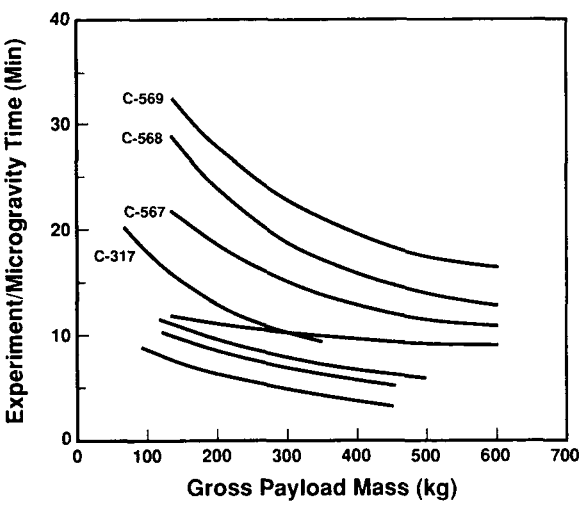
contact: Mr. Don Charhut
General Dynamics Commercial Launch Services
P.O. Box 85911
San Diego, CA 92136-5911
(619) 496-4004.

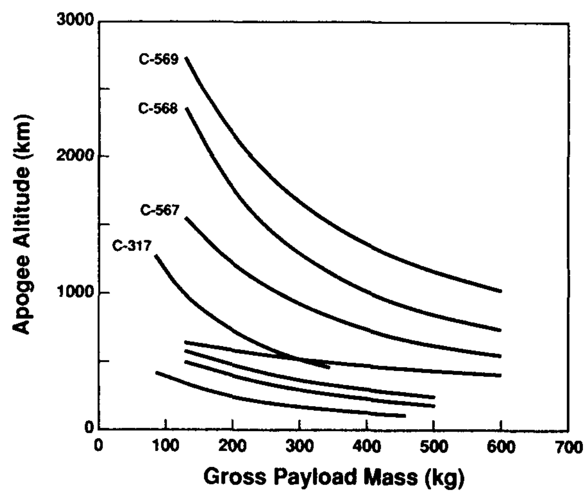
CONATEC, Inc.

CONATEC offers four suborbital launch vehicles: C-317, available now, and the C-567, C-568, and C-569 planned for 1989. The C-317 is a three-stage Black Brant X and offers from 5 to 7 minutes of microgravity time per launch. The other three vehicles are derived from the Talos-Castor I, using it as a "core" vehicle for the first and second stages, and adding an appropriate third stage.

Families of curves comparing microgravity experiment time versus payload mass are shown. Also shown are curves relating apogee altitude to payload mass for the four vehicles.

contact: Wayne H. Montag
CONATEC, Inc.
P.O. Box 171
Glendale, MD 20769
(301) 552-1088.





Conestoga Launch Vehicle

Space Services, Inc. (SSI)

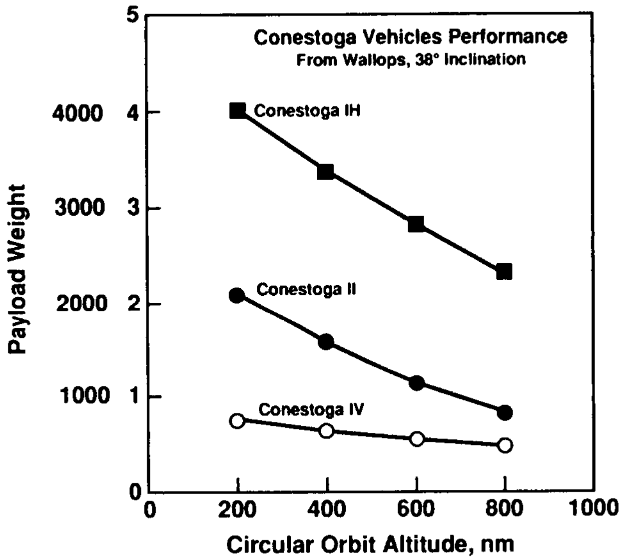
The Conestoga Launch Vehicle is an all-solid scout to Delta-class expendable booster, based on the build-up of Castor IVH solid rocket motors in a strap-together configuration. The vehicle, which is also proposed for launch at Kennedy Space Center, Florida, can be launched from Wallops Island, Virginia, and Vandenberg AFB, California. Space Services, Inc., provides all launch services at these sites.

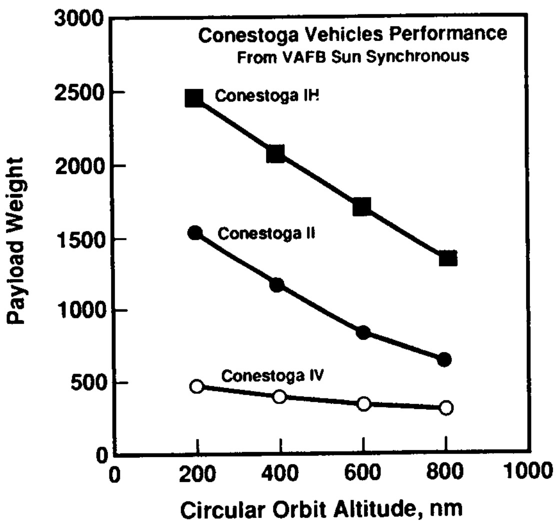
There are three basic configurations of the Conestoga: the Conestoga IH, II and IV. Their performance is shown in the capabilities figures.

operating characteristics:

System height:	64.5 ft max
Weight:	unknown
Guidance:	Inertial Cold gas attitude control system on upper stage
Payload Envelope:	30.0 ft^3

contact: Mr. Charles M. Shafer
Space Services, Inc.
600 Water Street, SW, Suite 207
Washington, DC 20024
(202) 646-1025.





Delta II

McDonnell Douglas Astronautics Company

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, Florida (ESMC) or Vandenberg AFB (WSMC), California. Orbit inclinations at Cape Canaveral are from 28.5° to 51° and at WSMC are from 63° to 145°. Payload fairings for the various launch vehicles are shown in the accompanying chart. The vehicles are designated as 6925, 7925, 6920, and 7920.

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 Eliptical Orbit (HEO) from California.

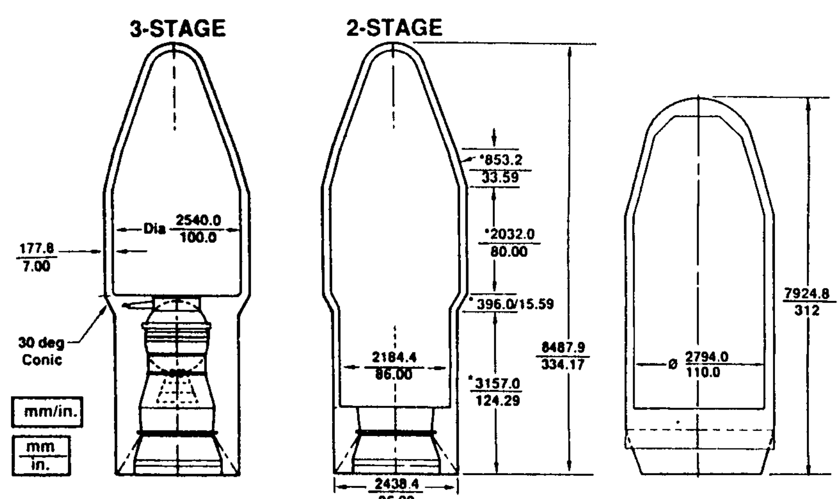
operating characteristics:

VEHICLES/ORBIT [(1)]		SPACECRAFT	WEIGHT (LBS)
THREE-STAGE VEHICLES		6925	7925
GTO (100 X 19,323 nmi, i=28.7 deg) ESMC		3190	4010
GPS (Hc=10,898 nmi, i=55 deg) ESMC	(Launch AZ=50 deg)	1875*	2500*
	(Launch Az=112 deg)	1850*	2350*
HEO (200 x 21,649 nmi, i=63.4 deg) WSMC		2120	2810
TWO-STAGE VEHICLES		6920	7920
Sun Synchronous (Hc=450 nmi, i=98.7 deg) WSMC		5660	7000
LEO (Hc=100 nmi, i=28.7 deg) ESMC		8780	11110
LEO (Hc=100 nmi, i=90 deg) WSMC		6670	8420

(1) 9-foot fairing

* Includes empty weight of the Star 37XFP AKM after circularizing burn

contact: Mr. William P. Morris
McDonnell Douglas Astronautics Company
1225 Jefferson David Highway, Suite 800
Arlington, VA 22202
(703) 553-3876.



Industrial Launch Vehicle (ILV) family

American Rocket Company

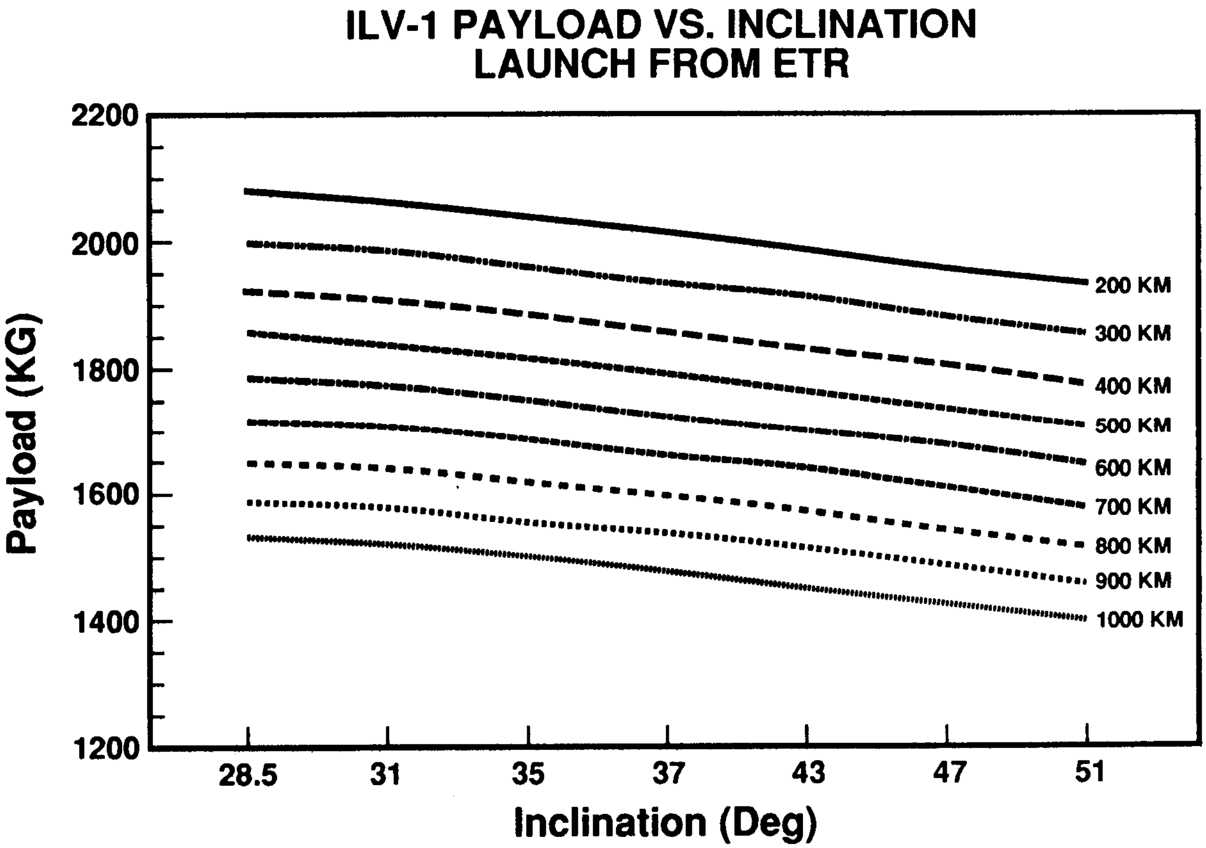
The Industrial Launch Vehicle-One (ILV-1) is the largest vehicle planned in a family of suborbital and orbital vehicles under development to serve U.S. and international space transportation needs. ILV-1 is a four stage vehicle that will place 1,400 kg in a 250-km polar-circular orbit. It will be comprised of 22 essentially identical hybrid engine modules. A single module suborbital launch vehicle (SLV) will evolve into a standard single module sub-orbital and 3-module (ILV-S) orbital vehicle to meet the needs of an increasing market for small satellites. ILV-S will be capable of delivering 225 kg into the orbit mentioned above.

Payload Accommodations

The payload adaptor for the ILV family will mimic the Delta/PAM-D/Ariane mounting interface. The ILV-1 nose fairing offers a dynamic clearance envelope 7.5 ft in diameter and 9 ft high, topped by a 6-ft conical section. The ILV-S fairing allows a 4-ft diameter dynamic clearance with a height of 5 ft topped by a cone of similar height. The nose fairing for the single module vehicle is the conical portion of the ILV-S fairing.

capabilities:

The following figure shows the payload lift capabilities for the ILV-1 vehicle.



contact: Mr. James C. Bennett
American Rocket Company
847 Flynn Road
Camarillo, CA 93010
(805) 987-8970.

ORBUS® space motors

United Technologies Corporation

The ORBUS® series of space motors was developed to satisfy various space requirements and have supported the following applications:

***ORBUS 6** - Space Shuttle payloads, Titan 34D payloads*

***ORBUS 6E** - Space Shuttle payloads*

***ORBUS 6S** - Titan 34D Inertial Upper Stage apogee motor, Space Shuttle Inertial Upper Stage apogee motor*

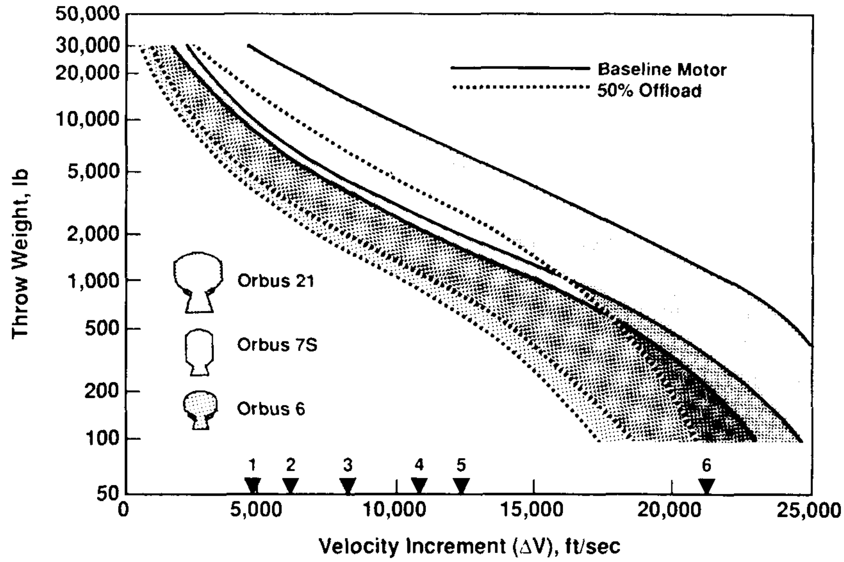
***ORBUS 7S** - Perigee motor for Hughes HS-393 series communication satellites*

***ORBUS 21** - Titan 34D Inertial Upper Stage, Space Shuttle Inertial Upper Stage*

***ORBUS 21S** - Perigee motor for INTELSAT-VI satellites*

The capabilities of the ORBUS® motors are shown.

Capabilities of Baseline for Orbus® Motors Orbital Lift



contact: A.T. Tsugawa, Manager - Space Maneuvering Systems
United Technologies/Chemical Systems
P.O. Box 50015
San Jose, CA 95150-0015
(408) 779-9121.

Pegasus™ Winged Launch Vehicle

Orbital Sciences Corporation

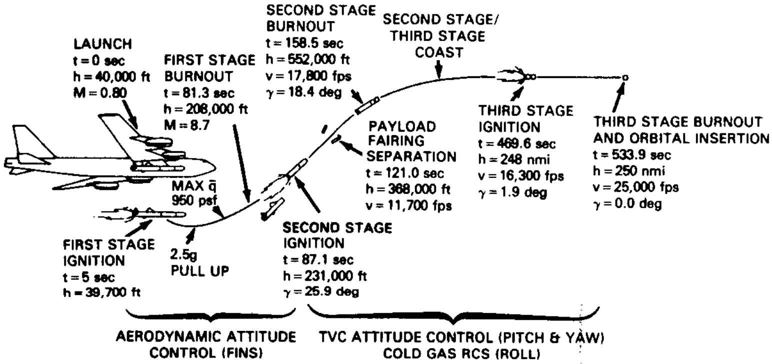
The Pegasus™ design involves three newly-developed Hercules solid rocket motors using lightweight graphite composite cases linked to a payload fairing. The vehicle is air-launched from a modified B-52 aircraft; its overall vehicle length is 49.2 ft; the craft weighs 40,000 lbs; and a delta wing with a 22-ft span is mounted on the first stage. The vehicle's overall length and wingspan are nearly identical to those of the North American X-15 research rocket aircraft, which also was air-launched in the 1960s from beneath the wing of NASA's B-52.

Currently in development, Pegasus™ will be carried under the right wing of the aircraft. Following the drop, the first-stage motor will ignite and Pegasus™ will use its wing to fly a shallow ascent trajectory to Mach 8.7 and 208,000 ft, where first-stage burnout and separation will occur.

The second- and third-stage rocket motors will 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 at 40,000 ft provides significant satellite payload-to-orbit weight benefits. A typical launch trajectory is shown below. Pegasus™ will have the capability of placing 600-lb spacecraft into 250-nmi polar orbits and 900-lb payloads in 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, will accommodate innovative satellite designs, including imaging spacecraft requiring large diameter optics.

contact: Mr. David W. Thompson
Orbital Sciences Corporation
12500 Fairlakes Circle
Fairfax, VA 22033
(703) 631-3600.



PEGASUS LAUNCH TRAJECTORY INVOLVES FIRST STAGE FLIGHT TO MACH 8.7 AND 208,000 ft. THE VEHICLE WILL BE INJECTED INTO ORBIT ABOUT 534 sec. AFTER DROP FROM THE B-52.

RL10-A-3-3A space engine

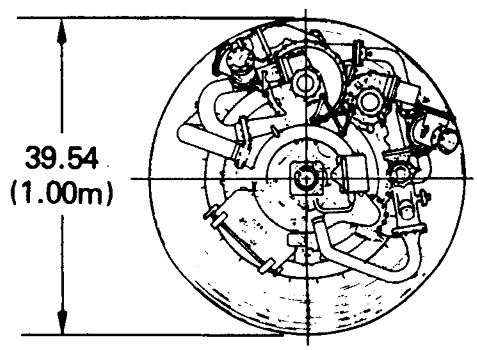
Pratt & Whitney

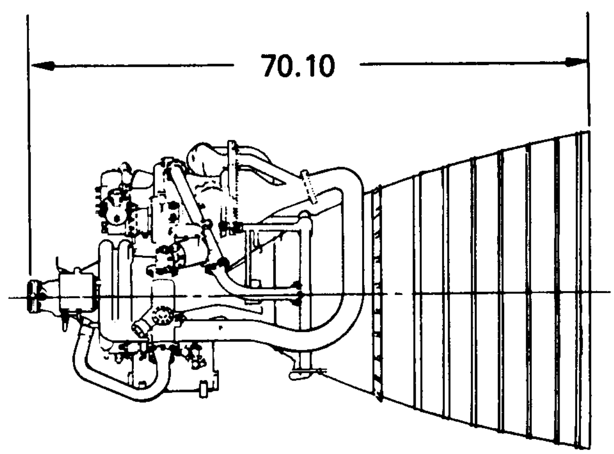
The RL10-A-3-3A is a liquid hydrogen-fueled engine with a highly-efficient expander cycle, ideally suited for applications requiring restart capability, with large variations in coast periods between firings. The engine can be modified for lower (down to 7,500 lbs) or higher (up to 22,000 lbs) thrust ratings to adapt to future needs. The mixture ratio is variable from 4:1 to 7:1. The nozzle area ratio can also be tailored to specific vehicles and two-position nozzle extensions are under development.

operating characteristics:

Thrust vacuum:	16,500 lbs
Weight:	305 lb
Mixture ratio (lb O_2/lb H_2):	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

contact: Mr. James R. Brown, RL10 Engine Program Manager
United Technologies/Pratt & Whitney
P.O. Box 109600
West Palm Beach, FL 33400-9600
(407) 796-3371.





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Space Shuttle Orbiter (STS)

NASA

Use of the shuttle vehicle offers a variety of support equipment that is available to payloads as needed. Users are helped to design payloads that are compatible with in-stock equipment. Provisions also exist for a commercial user to lease or purchase equipment. Payload carriers plus the Orbiter form the basic inventory of STS hardware.

The standardized flight types (or purposes) are: payload deployment, on-orbit servicing of satellites, payload retrieval, and on-orbit operations with attached payloads. The routine flight phases are: prelaunch, launch, on-orbit, deorbit, entry, landings and postlanding. Specific flight phases are adaptable to payload needs on each flight and include various orbital maneuvers, rendezvous, deployment, retrieval and on-orbit servicing.

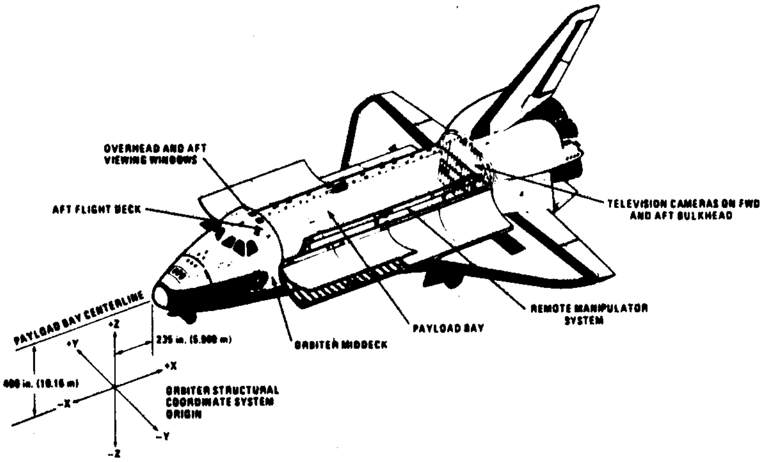
operating characteristics:

Launch site	Inclination degree	Altitude nautical miles	Wgt capability lbs
KSC	28.5	160	65,000
KSC	57.0	160	56,000

Shuttle overall length: 184.2 ft

Shuttle height: 76.6 ft

Shuttle system Weight *Due east:*	4,490,800 lbs
Payload weight *Due east:*	65,000 lbs
Orbiter payload bay:	60 ft L x 15 ft Dia
Orbiter weight *Inert:*	162,000 lbs
Landing *With payload:* *Without payload:*	 Approximately 211,000 lbs Approximately 179,000 lbs



contact: NASA/Headquarters
Commercial Development Division, Code CC
Washington, D.C. 20546
(202) 453-1890.

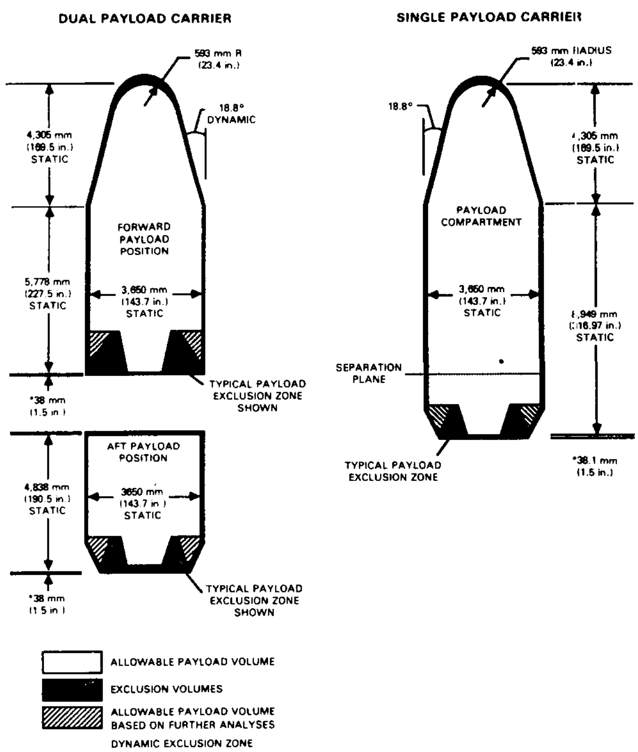
Martin Marietta Commercial Titan, Inc.

The baseline mission for the Titan III commercial launch vehicle is to insert payloads into a low-Earth parking orbit. Missions will be flown into a park orbit of 80 x 140 nmi at an inclination of 28.6°. The Titan III will deliver 31,600 lbs into this low-Earth orbit 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 will be 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 capability of the Titan III commercial launch vehicle is scheduled for mid-1989.

operating characteristics:

System height:	Up to 155.0 ft
Payload carrier length:	Up to 52 ft
Payload carrier diameter:	10.5 or 13.1 ft



contact: David B. Gunter, Manager - Government Programs
Martin Marietta Commercial Titan, Inc.
P.O. Box 179, Mail Stop 5-5011
Denver, CO 80112
(303) 971-2017.

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CHAPTER 10

other products and services

Support services for the commercial developer play an important role in space-related research. We have organized companies responding to our request for information into four general areas as follows:

- ***management services***
- ***technical data repositories and databases***
- ***technical services : other***

We have listed information on all categories as received from the manufacturers and providers.

Early Signals

214 9th Street, N.E.
Washington, D.C. 20002-6216

commercial space services:

Strategic planning
Management and trend analysis
Training workshops

contact: Lena Lupica
President
(202) 547-5751.

The Egan Group

1701 K Street, NW, 12th Floor
Washington, DC 20006

commercial space services:

Liaison/coordination
Business planning
Financial analysis/marketing
Market study and analysis
Policy formulation
International activities

contact: John J. Egan
President
(202) 775-0720.

Futron Corporation

7315 Wisconsin Avenue
Suite 1250-W
Bethesda, Maryland 20814

space systems commercial development services:

A company of space systems specialists, Futron is experienced in all facets of manned and unmanned space systems R&D, and knowledgeable of NASA programs, capabilities and processes.

Washington, D.C. representation
Strategic and program planning and formulation
Project development and implementation
Technology cost assessments
Systems studies

contact: Joseph Fuller, Jr.
President
(301) 657-7732.

Horizon Aerospace

18333 Egret Bay Blvd., Suite 300
Houston, Texas 77058

payload advance planning and program development:

Payload program and project programmatic, technical, engineering and science planning

Requirements definitions
Resource Planning
Budget development and analysis
Training program development
Long-range forecasting
Statistical analysis
Briefings, presentations and graphics support

contact: Mr. L. Neal Jackson
(713) 333-5944.

Transpace Carriers, Inc.

5900 Princess Garden Parkway, Suite 450
Lanham, Maryland 20706

commercial space support services:

contact: Robert Shutak
(301) 982-7800.

Program management
Market analysis
Financing
Insurance
Licensing
Contract administration
Policy enhancement
Staffing
Public affairs

United States Aviation Underwriters, Inc.

One Seaport Plaza, 199 Water Street
New York, New York 10038

satellite and other space-related risks insurance coverage:

contact: C.T.W. Kunstadter,
Senior Vice President
(212) 952-0100.

Launch
On-orbit

American Institute of Aeronautics and Astronautics

Technical Information Service
555 West 57th Street
New York, New York 10019

the aerospace database

Combined electronic version of International Aerospace Abstracts (IAA) and Scientific and Technical Aerospace Reports (STAR)

International Aerospace Abstracts

Abstract/index periodical of published literature in aeronautics, astronautics, and related areas

contact: Geoff Worton, Director, Marketing, (212) 247-6500.

COSMIC

The University of Georgia
382 East Broad Street
Atlanta, GA 30602

COSMIC

A computer software management and information center: 1,200 computer programs inventory of scientific and engineering software, including NASA programs.

contact: Al Lester
(404) 542-3265.

national space science data center (NSSDC)

Code 633.4
Goddard Space Flight Center
Greenbelt, MD 20771

space science database

NSSDC was established by NASA to serve as 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 has also been collected. In addition, NSSDC has collected some 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 that are obtained from spacecraft and ground-based observations. Disciplines that are represented include:

Astronomy
Astrophysics
Atmospheric Sciences
Ionospheric Physics
Land Sciences
Magnetospheric Physics
Ocean Sciences
Planetary Sciences
Solar-Terrestrial Physics

A user may obtain documents in any of the following ways:

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

contact: NSSDC, (301) 286-6695
Telex No.: 89675 NASCOM GBLT
TWX No.: 7108289716
SPAN Address: NSSDC::REQUEST

North Carolina Science and Technology Research Center

P.O. Box 12235
Research Triangle Park, NC 27709-2235

documents database - topics included:

Applied science and engineering
Physical sciences
Business, finance, economics
Life sciences
Social sciences
Patents, trademarks, and registered names
Current events
Demographic data

contact: NC/STRC CUS Representative
(919) 549-0671.

Southern University Industrial Applications Center

Department of Computer Science
P.O. Box 9737
Baton Rouge, LA 70813-9737

network resources and technical assistance residing in 500 computerized databases:

Technical
Marketing activities
Demographic trends
Patentability
Requests for bids

contact: Dr. John Hubbell
Director
(504) 771-6272.

Space Business Research Center

University of Houston - Clear Lake
Houston, TX 77058-1090

Information clearinghouse/200 databases:

Customized seminars
Research capabilities
Publications
Custom databases

contact: Peter Bishop
Director
(800) 243-1533.

Wyle Laboratories

P.O. Box 1008
Huntsville, AL 35807

utilization, logistics, and manifesting software:

This software operates on Wyle's Space Station payload database which contains payload operational and logistics data throughout the 5 phases of a payload Space Station life cycle:

Prelaunch ground operations
Transfers-to-orbit
On-orbit operations
Transfer-from-orbit
Post landing ground operations

contact: Robert A. Hall
Manager - Space Programs
(205) 837-4111.

3M/Central Research Laboratories

3M Center
Bldg. 201-2 South-05
St. Paul, MN 55144

Microgravity materials processing experiments:

General consultation
Payload development
Ground operations
Flight operations
Flight deintegration

contact: Jolene R. Reinhardt
(612) 736-6351.

Bendix Field Engineering Corporation

One Bendix Road
Columbia, MD 21045-1897

mission operations services:

Program development
Mission planning
Mission readiness test
Mission operations

carriers supported:

Expendable Launch Vehicles
Shuttle
Spacelab
ETR/WTR launch processing
Other platforms and rocket launch sites
Attached shuttle payloads

contact: P.H. Johnson
Vice President - Space Operations
(301) 286-2914.

Defense Systems, Inc.

7903 Westpark Drive
McLean, VA 22102

satellite master ground station:

Monitor and control of several satellites simultaneously

contact: J.C. O'Neil
(703) 883-1000.

E Prime Aerospace Corporation

P.O. Box 792
Titusville, FL 32781

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
(407) 269-0900

GE-TACL

GE-Appliance Park
Building 35-1004
Louisville, KY 40225

technical consulting, product development, piloting, and low volume parts manufacturing center:

Provides totally integrated and broad scope resources to design, development, test, and support manufacturing transition of new components and systems for aerospace applications.

contact: Mr. Jon Jacoby, Manager - Marketing, (502) 452-4739.

Horizon Aerospace

18333 Egret Bay Blvd., Suite 300
Houston, TX 77058

payload technical and engineering support

Flight and ground operations and analysis:
Hardware development schedules and costing
Ground processing and logistics planning
Payload integration planning
Analytical integration engineering support
Artificial intelligence expert system development
Technical studies
Trade-off studies
KC-135 manifesting and payload support

Instrumentation Technology Associates, Inc.

99 Great Valley Parkway
Malvern, PA 19355

engineering services, experiment testing and payload integration

payload integration for secondary payloads, including:
Get-Away-Special canisters
Hitchhiker - M
Hitchhiker - G
Middeck lockers
Experiment apparatus containers
Materials science laboratory
Multi-purpose experiment support structure

experiment design validation:
Centrifuge to simulate Shuttle ascent and reentry

contact: John M. Cassanto
(215) 524-1988.

Interferometrics, Inc.

8150 Leesburg Pike
Vienna, VA 22180-2799

satellite tracking interferometer:

Tracking of geosynchronous communications satellites

contact: B.J. Horais
Vice President
(703) 790-8500.

Satellite Systems Engineering, Inc.

7315 Wisconsin Avenue, Fifth Floor East
Bethesda, MD 20814

Space systems design and trade-off studies

contact: W.L. Pritchard
President
(301) 654-9220.

Science and Technology Corporation

P.O. Box 7390
Hampton, VA 23666-0390

engineering/technical studies:

Research and development
Test and evaluation activities
Plans and reports
Technical training support
Meetings, seminars, symposia
Computer support services

contact: Dr. Paul D. Try
Senior Scientist
(804) 865-1894.

Technomatix, Inc.

30200 Telegraph, Suite 179
Birmingham, MI 48010

ROBCAD

Engineering software and services for design and real-time graphic simulation of kinematic mechanisms and robotic systems. Software runs on the Silicon Graphics and Sun 3 workstations.

contact: M.J. Cartwright
(313) 258-3900.

WESPACE

105 Mall Blvd., Suite 200W
Monroeville, PA 15146

engineering design services:

Spacecraft structure
Data management hardware and software
Guidance systems
Navigation and control
Propulsion
Management and protection
Tracking, telemetry and command
Electronic power
Automation and robotics

other services:

Systems integration
Ground operations
Payload processing
Program management

contact: Nancy S. Kury
Business Development
(412) 374-7298.

Wyle Laboratories
P.O. Box 1008
Huntsville, AL 35807

payload hardware design, development, fabrication and integration:

A complete range of services for payload development including the requisite ground and flight support equipment is available. The range of services includes defining the requirements, trade studies, conceptual design, detail design, supporting analyses including thermal and structural, fabrication, verification, ground and flight integration and support for on-orbit operations.

A complete range of services for the design and construction of special purpose test facilities for payload and payload-related testing is available. The services available for facility development projects range from conceptual design and trade studies to turn-key responsibility for design, construction and commissioning of an operational test facility.

structural, dynamic and thermal analysis of payload systems:

1.) Development of dynamic loads, stress and thermal models to establish detailed design, test and life criteria

2.) Analysis and evaluation of payload systems for response to multiple environmental inputs

3.) Definition of test requirements, methods, procedures and instrumentation to demonstrate equipment reliability throughout all operational conditions.

contact: Robert A. Hall
Manager - Space Programs
(205) 837-4411.

CHAPTER 11

resources

Resources, in the context of this catalogue, is a listing of NASA or NASA-chartered centers who can offer assistance. Each NASA field center has a Commercialization Officer whom the user should contact regarding the various facilities, equipment or other pertinent resources. Also for each NASA center, the areas of major capabilities, as far as an outside user is concerned, are identified. This should assist the user in determining where to call or whom to contact.

A map of the United States showing the relative locations of the NASA Field Centers is included at the end of this chapter.

■ *nasa field centers*

ARC: Ames Research Center

National Aeronautics and Space Administration
Moffett Field, CA 94035
Mr. Laurence A. Milov
Mail Code 223-3
(415) 694-4044

capabilities include:
Aeronautics, life sciences, access to ground\airborne remote sensing facilities, payload design.

GSFC: Goddard Space Flight Center

National Aeronautics and Space Administration Greenbelt Road
Greenbelt, MD 20771
Mr. Donald Friedman
(301) 286-6242
Mail Code 702.0

capabilities include:
Remote sensing, hitchhikers, Get-Away-Specials, Wallops Flight Facility, satellite-tracking and data handling.

JPL: Jet Propulsion Laboratory

National Aeronautics and Space Administration
4800 Oak Grove Drive
Pasadena, CA 91109
Mr. Marshall Alper
(818) 354-7340
Mail Stop 502-307

capabilities include:
Materials processing, remote sensing, systems engineering, image enhancement.

JSC: Lyndon B. Johnson Space Center

National Aeronautics and Space Administration
Houston, TX 77058
Mr. William J. Huffstetler, Jr.
(713) 483-6511
Mail Code EA-111

capabilities include:
Space transportation, life sciences, robotics, payload integration.

KSC: John F. Kennedy Space Center

National Aeronautics and Space Administration
Kennedy Space Center, FL 32899
Mr. George Mosakowski
(407) 867-3494
Mail Stop PT-PMO

capabilities include:
Expendable Launch Vehicles, robotics, life sciences, payload integration, launch vehicle processing.

LaRC: Langley Research Center

National Aeronautics and Space Administration
Hampton, VA 23665
Mr. Fred Allamby
(804) 865-3661
Mail Stop 356

capabilities include:
Aeronautics, electronics, structures, materials, ultrasonics.

LeRC: Lewis Research Center

National Aeronautics and Space Administration
221000 Brookpark Road
Cleveland, OH 44135
Mr. Harvey Schwartz
(216) 433-2921
Mail Code 0170

capabilities include:

Microgravity ground-based facilities, materials processing, electronics, power, Expendable Launch Vehicles.

MSFC: George C. Marshall Space Flight Center

National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812
Mr. Ken Taylor
(205) 544-0640
Mail Code PS05

capabilities include:

Materials processing, rocket motors, payload carriers, energy management, test and evaluation, drop tubes and towers.

SSC: John C. Stennis Space Center

National Aeronautics and Space Administration
Stennis Space Center, MS 39529
Mr. David Brannon, (601) 688-2043
Mail Code HA31

capabilities include:

Remote sensing, image enhancement.

■ centers for the commercial development of space (CCDS)

The charter of the CCDS has these major objectives:

1) Stimulate high technology research which takes advantage of the characteristics of space, and

2) Lead in the development of new products and services which:

Have commercial potential, or
Contribute to possible new commercial ventures.

The CCDS centers are committed to assisting the commercial user toward his goals.

The CCDS centers are listed below by their titles.

Center for Advanced Materials

Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201-2693
Mr. Frank Jelinek, Director
(614) 424-6376

Battelle's CCDS focuses on multi-phase materials processing research in four technical areas:

1) catalysts
2) glass and ceramics
3) polymers
4) electronic and optical materials.

Center for Advanced Space Propulsion

Universitv of Tennessee/Calspan
c/o Univ. of Tennessee Space Institute
P.O. Box 1385
Tullahoma, TN 37388-8897
Dr. Fred Speer, Director
(615) 454-9294

This center focuses on propulsion technologies that are considered prime in achieving the three basic space flight mission objectives for the next few decades:

1) economic and reliable access to space and Space Station
2) high-performance systems for lunar and interplanetary missions
3) effective means of orbital transfers between low earth orbit and geostationary orbits.

Center for Autonomous & Man-Controlled Robotic & Sensing Systems (CAMRSS)

ERIM
P.O. Box 8618
Ann Arbor, MI 48107-8618
Dr. Charles Jacobus, Director
(313) 994-1200, Ext. 2457

The CAMRSS has three major focuses:

1) To develop Key Space Industrialization Enabling Technologies:

   Machine vision and sensing systems
   Robotics & automated manufacturing concepts and systems
   Biological technology for life support systems

2) To foster cooperation between major state research institutions and universities, private industrial firms, and NASA Centers.

3) To become the national focal point for space industrialization, enabling technology development and the crossroad for technology transfer from NASA to the private industrial base and back.

Center for Bioserve Research

University of Colorado/Boulder
School of Aerospace Engineering Sciences
Campus Box 429
Boulder, CO 80309
Dr. Marvin Luttges, Director
(303) 492-7613

The Center focuses on:

1) accelerated pharmaceutical testing.
2) bioproducts production & evaluation
3) advanced film and membrane technology
4) agrigenetics materials production.

Center for Cell Research

Pennsylvania State University
465 North Frear Laboratory
University Park, PA 16802
Dr. Wesley Hymer, Director
(814) 865-9182

The Center's main goals are 1.) definition of the fundamental mechanisms of mammalian cell function on earth and in space, and 2.) commercialization of the findings in cooperation with business and industry.

Secretion and related phenomena are emphasized.

Center for Development of Commercial Crystal Growth in Space

Center for Advanced Materials Processing
Clarkson University
Potsdam, NY 13676
Dr. William Wilcox, Director
(315) 268-2336

The Clarkson University CCDS focuses on:

1) developing commercial crystal growth in space by developing larger more perfect unique crystals in the space environment; and
2) investigating a broad spectrum of crystal growth techniques, e.g., melt, solution and vapor, theoretical modelling, complementary thermophysical property measurement and structural and electronic characterization in one-gravity and microgravity.

Center for Macromolecular Crystallography

University of Alabama/Birmingham
262 BHS, THT-Box 79, University Station
Birmingham, AL 35294
Dr. Charles Bugg, Director
(205) 934-5329

This Center specializes in space grown crystals of biological materials which are identified by participating firms in pharmaceutical, biotechnology and chemical industries. The Center's goal is to develop the technology and applications for the space based material processing of biological crystals.

Center for Mapping

Ohio State University
1958 Neil Avenue
Columbus, OH 43210-1247
Dr. John Bossler, Director
(614) 292-6642

The objective of this center is to develop and integrate data and information processing capabilities to enhance commercial opportunities for the suppliers of space remote sensing systems.

Center for Materials for Space Structures

Case Western Reserve University
School for Engineering
Department of Materials Science and Engineering
10900 Euclid Avenue
Cleveland, OH 44106
Dr. John F. Wallace, Director
(216) 368-4222

The objective of this center is to provide materials for space structures that are capable of being processed in space and capable of withstanding the space environment. Research projects focus on five areas:

1) films and expandable structures,
2) forms,
3) composites,
4) coatings, and
5) tribology (self-lubricating composites).

Center for Space Automation and Robotics

University of Wisconsin
Madison College of Engineering
1513 University Avenue
Madison, WI 53706
Dr. John B. Bollinger, Dean
(608) 262-3482

The mission of this center is to conceive, demonstrate, and stimulate commercial opportunity of automation and robotics technology use in space for ASTROBOTICS™, ASTROCULTURE™ and ASTROFUEL™.

Center for Space Power

Space Research Center
Zachry Bldg., Room 218
Texas A&M University
College Station, TX 77843
Dr. Alton Patton, Director
(409) 845-7441

Activities cover a broad range of tasks including operation and management of commercial space power systems, energy generation and conversion including photovoltaic, solar dynamic and nuclear systems, power transmission, energy storage, thermal management and power-related services such as electrolysis of water to produce hydrogen and oxygen.

Center for Space Processing of Engineering Materials

Vanderbilt University
Box 6309 Station B
Nashville, TN 37235
Dr. Robert Bayuzick, Director
(615) 322-7047

Vanderbilt University's CCDS focuses its effort on the space processing of metals, alloys, ceramics, and glasses. This includes both metal matrix composites and ceramic matrix composites. Principal areas are: containerless processing, directional solidification, casing, welding and some vacuum solid state processing.

Center for Space Vacuum Epitaxy

University of Houston - University Park
4800 Calhoun
Houston, TX 77004
Dr. Alex Ignatiev, Director
(713) 749-3889

The Space Vacuum Epitaxy Center (SVEC) focuses its primary research efforts on exploring R&D and commercial possibilities of thin film growth and materials purification in space. Recent discoveries in high temperature superconductors made by Dr. Paul Chu, former director of SVEC, have brought major recognition to SVEC and SVEC's R&D efforts, and have aided SVEC's research efforts in thin film epitaxially-grown superconductors.

Consortium for Materials Development in Space

University of Alabama/Huntsville
Research Institute Bldg.
Huntsville, AL 35899
Dr. Charles Lundquist, Director
(205) 895-6620

The University of Alabama in Huntsville focuses its CCDS on commercial materials development projects that benefit from unique attributes of space, e.g., microgravity, low vacuum, and select atomic species. The projects also rely on innovative applications of physical chemistry, material transport and their interactions.

ITD Space Remote Sensing Center

Bldg. 1108, Suite 118
Stennis Space Center, MS 39529
Dr. George May, Acting Director
(601) 688-2509

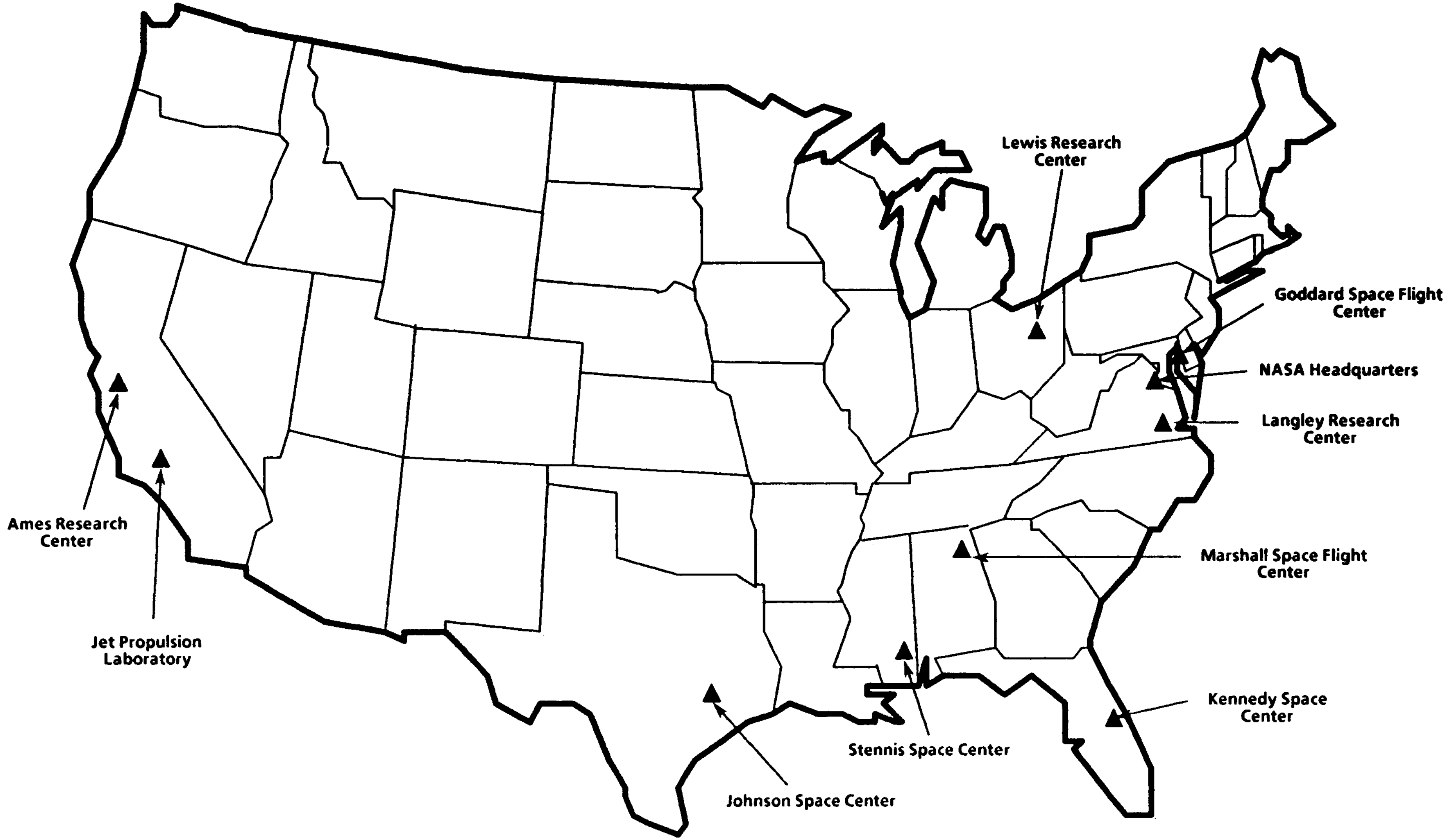
The Space Remote Sensing Center (SRSC), a Division of the Institute for Technology Development (ITD), is providing commercial technology applications development of satellite remote sensing, image processing and geographic information systems. SRSC conducts an applications development program aimed at end users, and a technology innovations program aimed at the value-added services and support industry.

Space Power Institute

Auburn University
231 Leach Center
Auburn, AL 36849-5320
Dr. Raymond Askew, Director
(205) 826-5894

The overall objective of this Center is to identify critical technological impediments to the economic deployment of power systems in space, advance these technologies, and develop new products to meet power generation, storage, conditioning, and distribution needs.

NASA INSTALLATIONS



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SUBMISSIONS

If your company offers services or products that are available to commercial users for applied research in space, please submit descriptive information, specifications and illustrations (if appropriate) as formatted in various chapters of this catalogue. We will review your materials for consideration in the next edition.

The type of information I am submitting concerns:

______ *microgravity* ______ *remote sensing* ______ *other*

______ *apparatus* ______ *carrier* ______ *facility*

______ *product* ______ *service*

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