NASA/TM—1999-209641

Zero Gravity Research Facility User's Guide

Dennis M. Thompson
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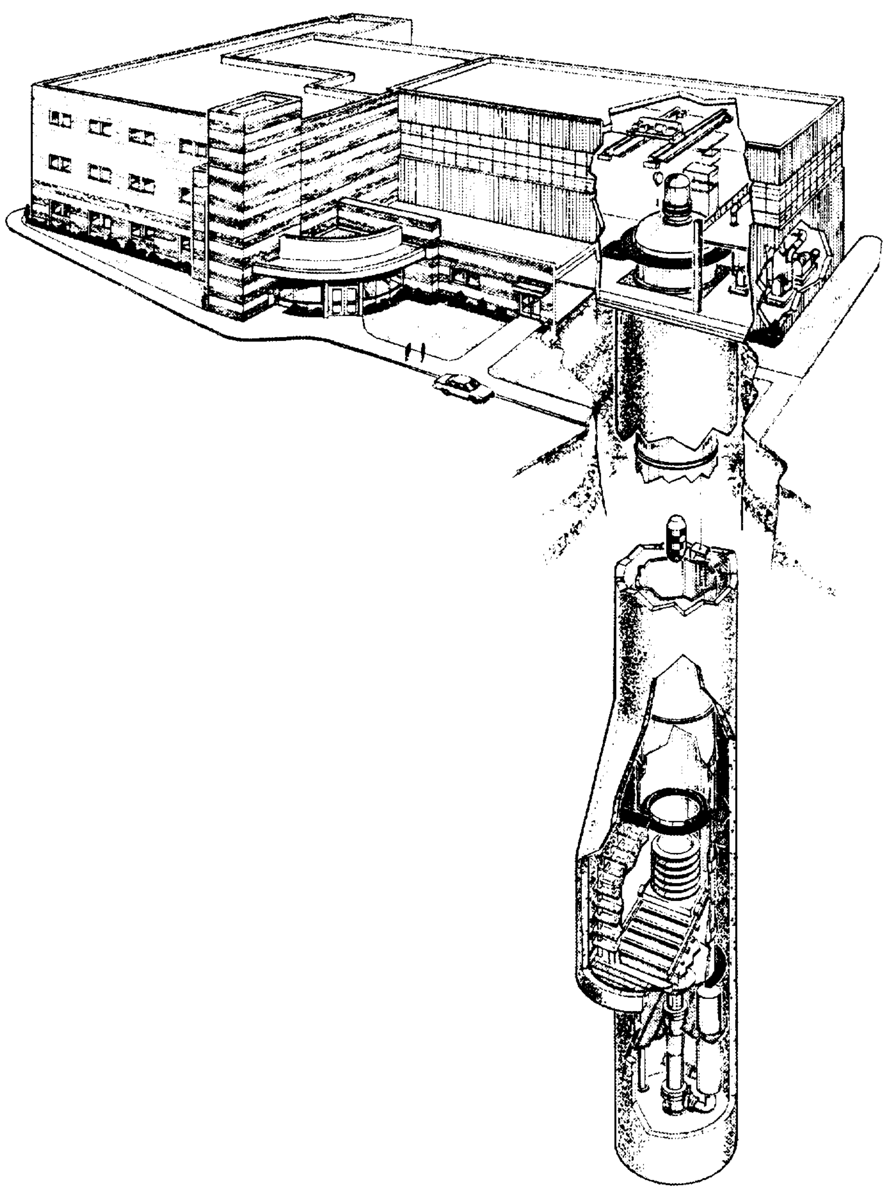

December 1999

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Space Administration

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Foreword

The Zero Gravity Research Facility (ZGF) is operated by the Space Experiments Division of the NASA John H. Glenn Research Center (GRC) for investigators sponsored by the Microgravity Science and Applications Division of NASA Headquarters. This unique facility has been utilized by scientists and engineers for reduced gravity experimentation since 1966. The ZGF has provided fundamental scientific information, has been used as an important test facility in the space flight hardware design, development, and test process, and has also been a valuable source of data in the flight experiment definition process.

The purpose of this document is to provide information and guidance to prospective researchers regarding the design, buildup, and testing of microgravity experiments.

1.0 Introduction

This document is provided to assist investigators in preparing for, and conducting, tests in the NASA John H. Glenn Research Center, Zero Gravity Research Facility. These guidelines include the following topics: a facility description; experiment planning; mechanical, electronics, and instrumentation considerations; documentation requirements; safety permit information; and operations including scheduling, testing, and other logistics.

2.0 Facility Operations Overview

The Zero Gravity Research Facility provides the lowest gravity levels among the reduced-gravity facilities at GRC. The work areas of the ZGF include: a shop for experiment buildup, integration, and testing, electronics support rooms, and an adjacent class 10,000 clean room area if needed.

The heart of the facility is the 510' deep vertical bore in the ground, which contains a steel vacuum chamber 20' in diameter. Experiments are placed on one of the seven available drop vehicles. The drop vehicle is suspended at the upper end of the vacuum chamber, held there by a special quick release mechanism. After the chamber is pumped down to the operating vacuum level, the experiment is enabled and the drop vehicle is released.

The vehicle falls 432' in 5.18 seconds, and achieves a gravity level of 10^{-6} Gs. The test period is ended when the vehicle enters the decelerator cart at the bottom of the chamber. The vehicle comes to a stop in approximately 12', resulting in a maximum deceleration of 65Gs (see figure 1).

The vehicles and the experiment are necessarily self-contained. There is no physical link to the vehicle while it is falling. A telemetry system is used to relay deceleration levels, but all experimental data is recorded on board. After the chamber is returned to atmospheric pressure, the ZGF technical staff retrieve the vehicle and return it to the ground level shop.

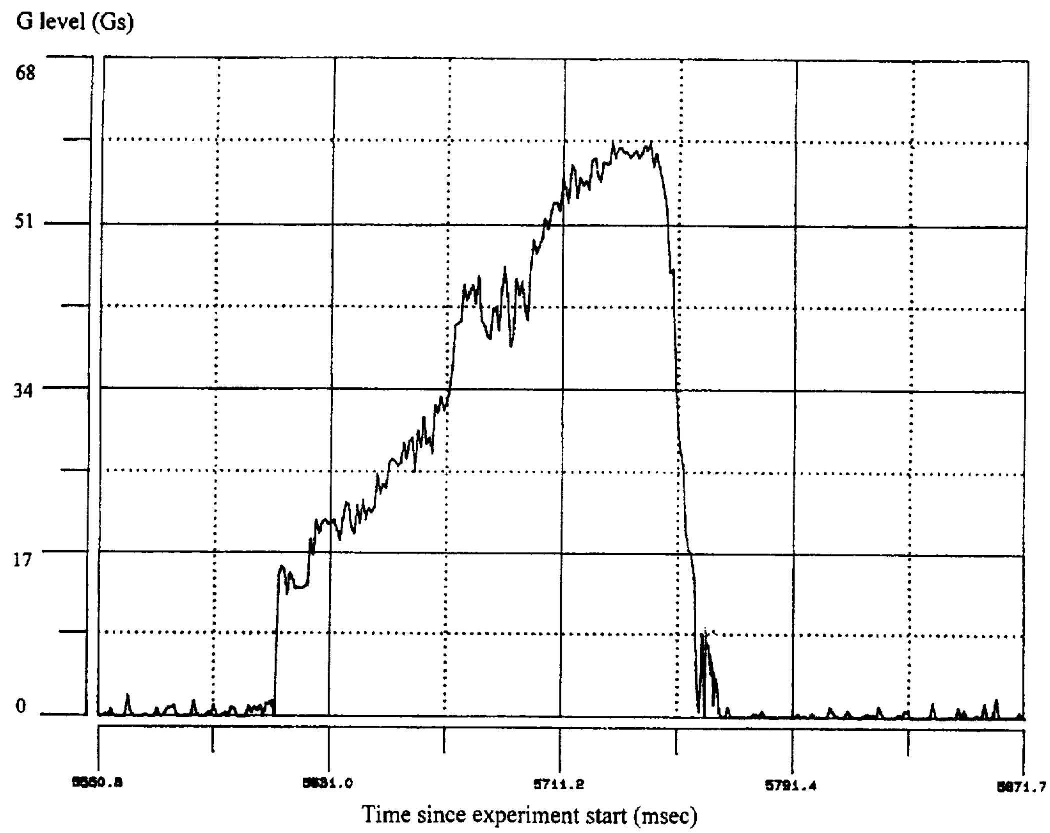


Figure 1.—G levels during deceleration, Zero Gravity Facility.

3.0 Experiment Planning

One of the most important keys to successful testing in the ZGF involves appropriate experiment planning. The start of this process is communication with pertinent ZGF personnel regarding the design and feasibility of performing a desired experiment, component selection, buildup techniques, safety considerations, support equipment at ZGF, facility capabilities, operational procedures, and the like. Experiment planning should include a visit to the ZGF for familiarization and technical discussions, as well as follow-up discussions to monitor progress and the completion of documentation including a test request memorandum and a safety permit request if needed. Timely experiment success depends on this planning phase.

3.1 Role of ZGF Personnel

Several people at ZGF play a role in experiment planning and operations. These include the Facility Manager, ZGF Mechanical and Electronics Engineers, and ZGF Research Laboratory Mechanics and Electronics Technicians. The Facility Manager is responsible for the management and scheduling of resources and test time. He is also responsible for resolving scheduling and resource conflicts. Mechanical and electronics engineering support is available for assistance in experiment layout and assembly, component design, component selection, wiring diagrams, data acquisition and control systems, etc. The ZGF is also supported by a mechanical and electronics technical staff that can provide additional design support. These individuals are also available for experiment buildup and modification, or repair tasks. Although use of the ZGF engineering and technical staff must be coordinated in advance with the Facility Manager, ZGF staff members are available for consultation throughout the planning and buildup phases of a project.

3.2 Preliminary Design Meeting

Prior to the final design and fabrication of an experiment package, it is recommended to have a meeting at the ZGF. The purpose of this meeting is to discuss and review the design and layout of hardware, identify safety hazard issues, determine what ZGF support (personnel/hardware) may be required, examine available drop vehicles, and become familiar with facility operations. Attendees at this meeting should include at least the Project Manager or suitable representative, the Facility Manager, and representatives from the ZGF engineering and technical staff as required.

At this meeting, the Project Manager should be prepared to informally present a conceptual design for the experiment. This conceptual design should include an overall description of the investigation, which details the phenomena being studied, the types and frequency of measurements that are desired, a rough experiment layout with key mechanical and electronic components identified, and a draft milestone schedule. In addition, potential safety issues such as combustible gas mixtures, high voltage, toxic chemicals, high temperatures, pressure vessels, ignition sources, lasers, etc. need to be identified.

Based on the information provided at this meeting, ZGF personnel can provide advice on hardware choices, experiment design and layout, and operations methodologies. Also at this meeting, a plan can be formulated as to what type of support and hardware the ZGF may provide for an experiment.

3.3 Experiment Design

The primary responsibility for experiment design lies with the Principal Investigator. However, arrangements for mechanical or electronics design support may be provided by ZGF staff members.

3.4 Hardware Responsibilities

A ZGF experiment is typically a combination of researcher and ZGF-provided hardware and instrumentation. Hardware and components that typically may be provided by ZGF include but are not limited to the following:

- –Drop vehicle including environmental chamber
- –Data acquisition and control system
- –Motion picture cameras
- –Battery power for the experiment
- –Video recorders
- –RS-232 link from the experiment to the control room.

Investigators are responsible for the remaining experiment hardware, components, fittings, test vessels, chambers, tubing, etc.

3.5 ZGF Support Facilities and Materials

Work space: The ZGF, Building 110, is a relatively small facility that supports numerous experiments. As a result, workspace is limited. When investigators are at the ZGF for testing, they may be assigned a work area in the main shop.

Hand tools—A small supply of community hand tools are provided for investigators. In general, it is recommended that investigators bring their own tools, particularly if a special item is required. The ZGF does have shop machinery that is used by the technical staff.

VCR's and monitors—SVHS and High-8mm video recorders and video monitors are provided in the control room for review of video data.

Support personnel—The technical staff of the ZGF is available for experiment buildup, installation and modification. Requests for this type of support must be made to the Facility Manager and coordinated through the Unit Leader of the technical staff.

Compressed gases—A variety of compressed gases and associated regulators are included in the ZGF inventory. Also a capability is provided for mixing certain gases, filling and evacuating test chambers, etc. The following standard compressed gases are available:

- –Zero Air, (O_2 ranges between 18 and 21 percent)
- –Precision Air, 21% O_2, balance N_2 (O_2 ranges between 20.8 and 21.2 percent)
- –Argon: technical, 99.995 percent
- –Helium: high purity, 99.997 percent
- –Nitrogen: ultrahigh purity, 99.999 percent
- –Oxygen: technical 99.5 percent

Investigators should notify the Facility Manager about their compressed gas requirements six weeks prior to testing. Investigators may need to provide regulators for those gases.

Note: Researchers who require special gases or mixtures must arrange shipment or delivery of those gases to the ZGF through the Facility Manager.

Note: Where possible, investigators should order specialty mixtures, particularly fuel mixtures. The Facility Manager will make the final determination as to which mixtures can be made at the facility. Custom environmental gases consisting of O_2 and various diluents are mixed directly in the on-board environmental chamber by the ZGF technicians prior to each drop.

4.0 Drop Vehicle Mechanical Overview

All hardware shall be designed to withstand a downward acceleration of 65 Gs. Whenever possible, heavy items should be positioned to facilitate balancing of the assembled experiment. The ZGF technical staff will perform the final balancing of the experiment as part of the normal assembly of the drop vehicle.

All equipments shall be designed for operation in a vacuum, or shall be placed in the pressurized environmental chamber.

Note: If your experiment plans include testing the same hardware in the 2.2 second Drop Tower or in reduced-gravity aircraft, special design requirements apply. Contact the ZGF Facility Manager for the coordination of multi facility testing.

4.1 Drop Vehicle Options

Experiments conducted in the ZGF are mounted on one of seven drop vehicles. Three different methods are used to integrate the experiments. The method of integration will be determined in the preliminary design meeting.

Note: There may be a long lead time for a specific Drop Vehicle due to existing test requirements. Check with the Facility Manager before committing a design to a specific Drop Vehicle. **In general, the method outlined in section 4.1.3 provides the most rapid means of conducting tests in the ZGF**.

4.1.1 Using an existing environmental chamber

Three drop vehicles have integrated environmental chambers that are designed to contain a wide variety of experiments. These drop vehicle are the B, G, and H models. The sizes and pressure capabilities of each chamber are listed in Appendix B.

Experiments using an existing chamber will have the majority of the hardware mounted within a chamber. Supporting hardware such as fuel and ignition systems are mounted outside the chamber as required, on support shelves within the drop vehicle.

4.1.2 Stand-alone experiment on a ZGF Drop Vehicle

When an experiment is too large, or requires a special enclosure or configuration, or simply does not require a pressure-tight environmental chamber, it can be mounted on one of three drop vehicle which have the capability to mount stand-alone experimental hardware. These are the D, M, and X-2 Models. Capabilities of each drop vehicle are listed in Appendix B.

4.1.3 Experiments mounted on 2.2 second Drop Tower frames

Experiments that are already assembled on drop frames used in the GRC 2.2 second Drop Tower can be integrated onto one of two ZGF drop vehicles: the X and X-2 models. This capability allows for a rapid integration of an existing experiment. The experiment must have the following criteria taken into consideration:

A. Operation in a vacuum—Unlike the 2.2 second Drop Tower, tests in the ZGF are conducted in a vacuum. The experiment design must take this into account for such items as heat producing devices (lack of convection cooling) and pressure differentials on pressure chambers and systems (with special attention to relief valve settings). Some flow measuring devices use an external hot wire reference that will not operate properly in a vacuum. Additionally, all pressure systems that have the potential to vent gases or liquids must have a design study done of the potential thrust that can be imparted by this venting.

B. Longer operational time on battery power—Designers should allow for a total operating time of at least 2 hours on internal battery power. This allows for the time required to install the vehicle into the vacuum chamber, pump-down of the chamber, the drop, and retrieval time to bring the Drop Vehicle back to ground level.

Many of the problems with electrical devices can be reduced by having the device remotely activated just prior to the drop (see section 4.1.3.D). This can be coordinated with the ZGF electrical engineer.

Battery power is provided on-board each ZGF drop vehicle, and can be used to power the experiment if required. This must be coordinated with the ZGF electrical engineer to prevent ground loops or other damaging electrical problems.

C. Greater deceleration levels—Experiments must be designed to take a deceleration level of 65Gs for 0.15 seconds (see figure 1).

D. Remote operation of controls—Because the experiment is sealed in the vacuum chamber, researchers cannot reach controls such as switches, pressure regulators, etc before the drop. The experiment design must allow for remote operation of these devices, either by remote controlled relays or through the experiment's controller via the real-time RS-232 link to the control room. Coordination with the ZGF electrical engineer is required.

4.2 User-supplied Pressure Systems

Note: Supporting documentation and requirements for user-supplied pressure systems are detailed in appendix C.

The use of researcher-supplied pressure vessels in the ZGF require the adherence to specific precautions and regulations. First, the systems must be certified as safe to operate. This certification verifies that the pressure vessel has been appropriately tested and that relief valves or burst disks in the system are sized properly. All pressure vessels must be designed to withstand a pressure four times the maximum allowable working pressure (MAWP) based on the ultimate tensile strength. A structural analysis must be completed showing all supporting calculations. Once fabricated, the vessel must be hydrostatically pressure tested to 1.5 times the MAWP. The certification of pressure vessels must be in accordance with the applicable national consensus codes such as the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. The investigator is responsible for providing the drawings and documentation including component identification to prove the certification of the pressure vessel and pressurized systems. For individual components, the following identification is necessary: manufacturer, model or part number, and pressure rating.

The fact that the experiment will operate in a vacuum must be taken into account when the pressure rating of a system is specified

4.3 User-supplied Oxygen Systems

Those systems which use a gas mixture of 30 percent oxygen or greater have special requirements. The most important requirement is special cleaning required for oxygen service. Fast-acting valves (ball valves) cannot be used in oxygen systems. Documentation that certifies that components are applicable for oxygen use is required.

5.0 Drop Vehicle Electronics Overview

Brief discussions of each major component of the Drop Vehicle electronics are treated below. Detailed information regarding support electronics is available from the ZGF engineering staff upon request. Example schematics, fabrication drawings, and consultation can be requested via e-mail and/or by phone (see appendix D for ZGF personnel contacts).

5.1 Electrical Power

Sealed, lead-acid, X-cells are used to provide electrical power for experiments performed at the ZGF. A standard ZGF battery pack has a nominal output voltage of 28 vdc, 5 A-hrs. Each Drop Vehicle has several battery packs, depending on the anticipated electrical load.

Dc/dc converters are used for providing power to computers, video cameras, ignitors, etc that require less than 28 volts. If voltages or currents are required that exceed the normal capabilities of the standard battery pack, special battery configurations can be designed by the ZGF staff.

5.2 User-supplied Actuators

Actuators are used on ZGF experiments to provide remote electro-mechanical operation of experimental hardware. Solenoid valves, rotary and linear solenoids, motors, etc. are examples of actuators. For instance, a solenoid-valve could be used to turn on or off a gas or liquid flow, a linear solenoid could be used to move a soot-sampling body or ignitor in and out of a flame, and an electric motor could be used to rotate a spinning disk. (For the purpose of the following discussion, even a motion picture camera can be thought of as an actuator, though its actual purpose is to capture visual information.)

Because most devices that function as actuators are electrically inductive, appropriate surge suppression should be included in the circuit. A simple and effective method (for dc loads) is to tie a diode across the power terminals of the actuator. The diode should be selected according to the operating voltage and steady-state current of the device, and it should be placed (electrically) as close to the device as possible to reduce loop currents. Over current protection is required.

In order to reduce system complexity and cost, every effort should be made to use actuators that will operate via direct connection to a standard battery pack (28 vdc nominal), because the use of devices that require other operating voltages will necessitate the use of dc/dc converters and/or additional custom battery packs. It should not be assumed that a device specified as a 24 vdc actuator requires exactly 24 volts, as this is quite often a nominal specification. Consult the manufacturer to determine if the device in question may be operated at 28 vdc before discarding it as an option.

5.3 Lasers

Lasers have been used for both qualitative (imaging via laser-sheet, seeded back-scattering, etc.) as well as quantitative measurements (transmission ratio, LDV, etc.). Use of lasers may require special electrical considerations (power, noise, etc.) for proper operation as well as laser safety precautions specific to the laser type and operating conditions.

5.4 Video and Motion Picture Cameras

Most experiments will use video and/or motion picture cameras for qualitative or quantitative video capture. Each Drop Vehicle can provide up to three 8mm video recorders as part of the standard equipment.

Video Cameras—Since the requirements for each experiment vary, providing video cameras is the responsibility of the Project Manager. To simplify system design, it is recommended that 12 vdc operated video cameras be specified for inclusion in experiments. Time code generators are available to record a time line on the video recording.

Motion Picture Cameras—Motion picture cameras will be provided by the Scientific Imaging Group at GRC (see section 6.0). The most commonly used camera in the ZGF is the 16mm Milliken, which can operate on 28 vdc. The Milliken is available in three sizes (100-, 200-, and 400-foot film capacities) with frame rates from 6 to 500 fps.

5.5 Data Acquisition and Control Systems

An on-board PLC provides the capability to operate switches, valves, etc, at varying times within the drop sequence. In addition to the on-board PLC a data acquisition system is also available to record temperature, pressure, other parameters that are of interest to the experimenter.

5.5.1 Programmable Logic Controller

A Toshiba PLC mounted on each Drop Vehicle is used to control timing of events during the text operation. The PLC has 24 inputs and 16 outputs. A ladder logic program is used to implement the experiment control logic. Programming is done by the ZGF staff.

5.5.2 Data Acquisition System

The Elexor on-board data acquisition system can read and record the following typical list of signals.

(1) Temperature
(2) Pressure
(3) Voltage

The number of inputs that can be scanned is limited by the scan rate, memory size, number of channels, and scan duration. A RS-232 connection is used to download the data to a laptop computer after the drop. In addition to downloading the data, the RS-232 connection also allows for the system to be customized to read different type of input configurations, different scan rates, and different number of channels.

6.0 Imaging Services Support

Researchers utilizing imaging systems as a means of gathering data can look to the GRC Scientific Imaging Group (SIG) for assistance with all their imaging needs. The SIG is a specialized group of individuals within the Imaging Technology Center (ITC), located in room C2 of the Engine Research Building (Bldg. 5). Representatives of the SIG can be reached at (216) 433–5976.

Scientific Imaging Group personnel are available to support the research staff by offering a variety of imaging services to ensure that research imaging data is captured, stored, and analyzed. These services include imaging system design, installation, operation, processing, and image analysis services.

The Scientific Imaging Group has personnel trained in the use of many imaging technologies such as traditional silver halide photography, high-speed (high frame rate) image acquisition, photo instrumentation, video systems, digital capture and display, image processing and analysis, and imaging system integration methods. The group currently has a wide variety of imaging equipment available for data image acquisition, and software programmers able to customize imaging and data reduction systems to individual requirements.

7.0 Documentation Requirements

ZGF Test Request
Safety Permit

7.1 ZGF Test Request

Investigators who are planning to perform new experiments or projects in the ZGF or are planning major modifications to an existing experiment are required to submit a Test Request memo to the Facility Manager. This document should be submitted when the experiment requirements are well-defined. Preparation of this request will follow the initial buildup meeting identified in section 3.2. This document will be used to ensure availability of test equipment and facility resources to meet experimenter needs and schedules.

This request is to be submitted to the Zero Gravity Facility Manager, Mail Stop 110–1. Requests may be emailed to the Facility Manager: dennis.thompson@grc.nasa.gov

The Test Request memo for utilization of the ZGF should include at least the following:

(1) Experiment title
(2) Valid J.O. for time keeping and equipment purchases
(3) Personnel and affiliations: Principal Investigator, Project Manager, and a primary contact for information during buildup and testing.
(4) Brief experiment description and purpose
(5) Description of test hardware
(6) Test procedures (brief outline of steps to be followed in conducting tests)
(7) Potential hazards and precautions (e.g., combustible gases, toxic chemicals, high pressure, lasers, etc.)
(8) Support required (engineering, technical, facility systems such as gases, etc.)
(9) Milestone schedule (estimate of desired dates for buildup and testing and estimated number of test drops required).

Any significant changes to the test plans must be submitted as addendums describing the changes.

7.2 Experiment Safety Documentation

Test operations at the ZGF, as in any GRC facility, are subject to the GRC Safety Permit System. The objectives of this system are to avoid undue risks, injury to personnel, damage to property, or disruption of operations. The attainment of these objectives is accomplished through the use of the following systematic approach: identifying and controlling potential hazards; obtaining an independent, thorough, and timely safety review of technical designs, tests, and operations, permitting the operation of experiments within safe constraints; and instilling safety awareness in all employees. A Safety Permit constitutes a license to operate an experiment within the constraints listed on the Permit.

7.2.1 Experiments utilizing an existing environmental chamber

These tests, using one of the ZGF Drop Vehicles and standard environmental chambers, may be covered by operational safety permits issued to the ZGF. The applicability of these safety permits to the operation of a proposed test will be determined at the Preliminary Design Meeting. These safety permits are:

(1) Permit #4-485, "Operation of Combustion Experiments in a Microgravity Environment Using a Drop Vehicle"
(2) Permit #4-539, "Operation of a Drop Vehicle to Conduct Gas Jet Diffusion Flame Tests"
(3) Permit #4-661, "Laser Diagnostics Operation on a Combustion Drop Vehicle"

7.2.2 Experiments utilizing a 2.2 second Drop Tower frame

Such experiments that have already been issued a safety permit for operation in the 2.2 second Drop Tower will have the safety permit reviewed to determine the applicability of the existing permit to operations in the ZGF. Two copies of the existing safety permit will be forwarded to the Facility Manager

7.2.3. Experiments requiring a new Safety Permit

The requirements necessary to file for a Safety Permit Request include a completed NASA Form C-923 (Safety Permit Request Form which consists of several pages) and supporting documentation. This form includes a Hazard Analysis in which potential hazards must be identified and a description of the hazard controls, precautions, and safety procedures that will be employed to minimize the risks of these hazards. Examples of activities which may involve hazards are the use of fuels and oxidizers, use of chemicals or other hazardous materials, use of compressed gases, high voltage, use of lasers, or use of pressurized systems. Additional documentation must also be provided with the Safety Permit Request Form C-923.

This documentation must include, but not be limited to:

(1) Description of the activity
    (a) Test objectives
    (b) Test description (include materials, gases, flow rates, pressures, etc.)
    (c) Technical description of experiment rig and associated systems in drawing of the rig
    (d) Test schedule milestones
(2) Mechanical documentation
    (a) Mechanical drawings
    (b) Structural analysis (where applicable)
    (c) Hydrostatic certification of pressure vessels
    (d) Parts list and component lists (manufacture and ratings if applicable)
(3) Electrical documentation
    (a) Schematics, fuse protection, wire sizes
(4) Operational procedures
    (a) Step by step procedures for drop preparation and drop

Note that the use of lasers also requires special precautions. Utilization of lasers will be evaluated by the GRC Laser Safety Officer as part of the Safety Committee Review. Laser information to be provided includes class, type, manufacturer, and model number. Continuous wave laser information must also include output power (watts), beam diameter (cm), irradiance (w/cm2), and beam divergence (mrad). Pulse laser information required includes peak power (watts), energy/pulse (joules), average power (watts), beam dimensions, radiant exposure (j/cm2), and pulse duration.

Three copies of the completed safety documentation are to be forwarded to the ZGF Facility Manager (address shown in section 7.1) at least six weeks prior to initial testing. The safety documentation will be reviewed by a GRC Safety Committee, ZGF personnel, and a representative from the appropriate science discipline (i.e., combustion, fluids, etc.). These individuals may request additional information to aid in their evaluation. The Safety Committee has the final authority for safety approval.

For additional guidance regarding the Safety Permit procedure contact the Facility Manager for a copy of the GRC Safety Permit Requester's Guide.

8.0 Test Scheduling and Operations

To request test time at the ZGF for an experiment that is operational, contact the Facility Manager. When requesting the use of the ZGF to conduct an experiment, please include the desired dates and special support requirements.

The Facility Manager will evaluate scheduling requirements to determine if your request can be accommodated. If, after your schedule is approved, changes in dates are necessary, contact the Facility Manager immediately to negotiate changes and schedule modifications.

Note: Before final approval is given for testing in the ZGF, experimental hardware must be fully assembled and checked out. An experiment must have undergone successful, normal-gravity-simulated drop tests.

8.1 Shipping and Storage

Research hardware that must be shipped to the ZGF should be addressed to:

NASA John H. Glenn Research Center
Zero Gravity Research Facility Manager
Mail Stop 110–1
21000 Brookpark Road
Cleveland, Ohio 44135

8.2 Duty Hours for Testing and Operations

The hours of operation and thus access to the ZGF are weekdays from 6:00 a.m. to 4:30 p.m. Any necessary preparation that must be done on the day of a drop should be completed by 8:30. Normally, the ZGF technical staff will prepare the test for the drop. If members of the research team are required to aid in the setup, times must be coordinated with the Facility Manager to allow for timely completion of the test.

A second drop is available in the afternoon on alternate days only (to allow for facility preparation between tests). In general if two drops are scheduled on any day, the two drops will be split between two different Drop Vehicles to allow for proper preparation time for each test.

8.3 Readiness Review

Before an experiment can be tested for the first time or after significant modification, the experiment must undergo a final Readiness Review by the ZGF Staff and members of the research team. This review will consist of at least one full test of the operation of the experiment, utilizing the ZGF ground testing capability.

Appendix A—ZGF Characteristics and Capabilities

Operational Parameters

Low gravity duration: 5.18 sec

Gravitational acceleration: 10^{-6} G

Deceleration levels: a straight line ramp to 65Gs in 0.15 seconds (see figure 1)

Vacuum level: 1×10^{-2} torr

Vacuum pump down time: varies with humidity and temperature. Minimum pump times are attained in the Winter, typically less than 1 hour. Summer pump down times are typically 1½ hours.

Engineering support for consultation

Technical staff for facility operations and certain repairs and modifications

Safety review required

Additional features

Compressed gas (fuels, oxidant, and diluents) storage, handling, and delivery support available

Limited community tool supply

Appendix B—Drop Vehicle Dimensions and Capabilities

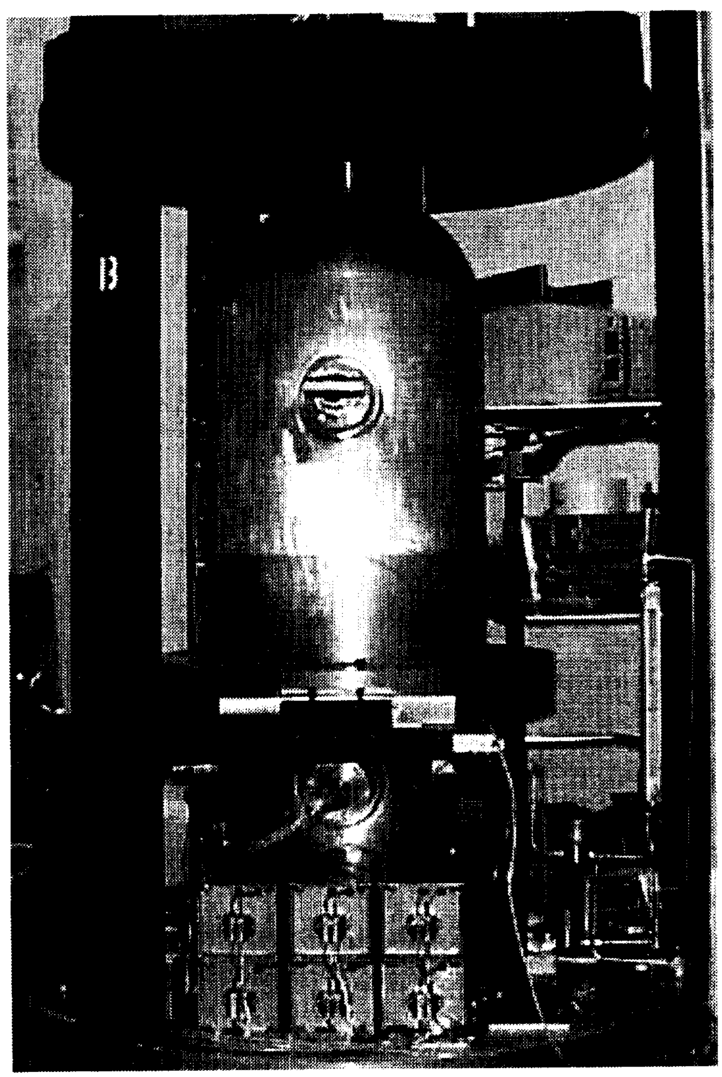
B Model

Equipped with a vertical environmental chamber.

Chamber specifications
- Diameter: 15 ½"
- Height: 33" plus hemispherical end cap
- Depth of lower section: 10"

Viewing ports: 2 total, 2" diameter. Location: top, side.

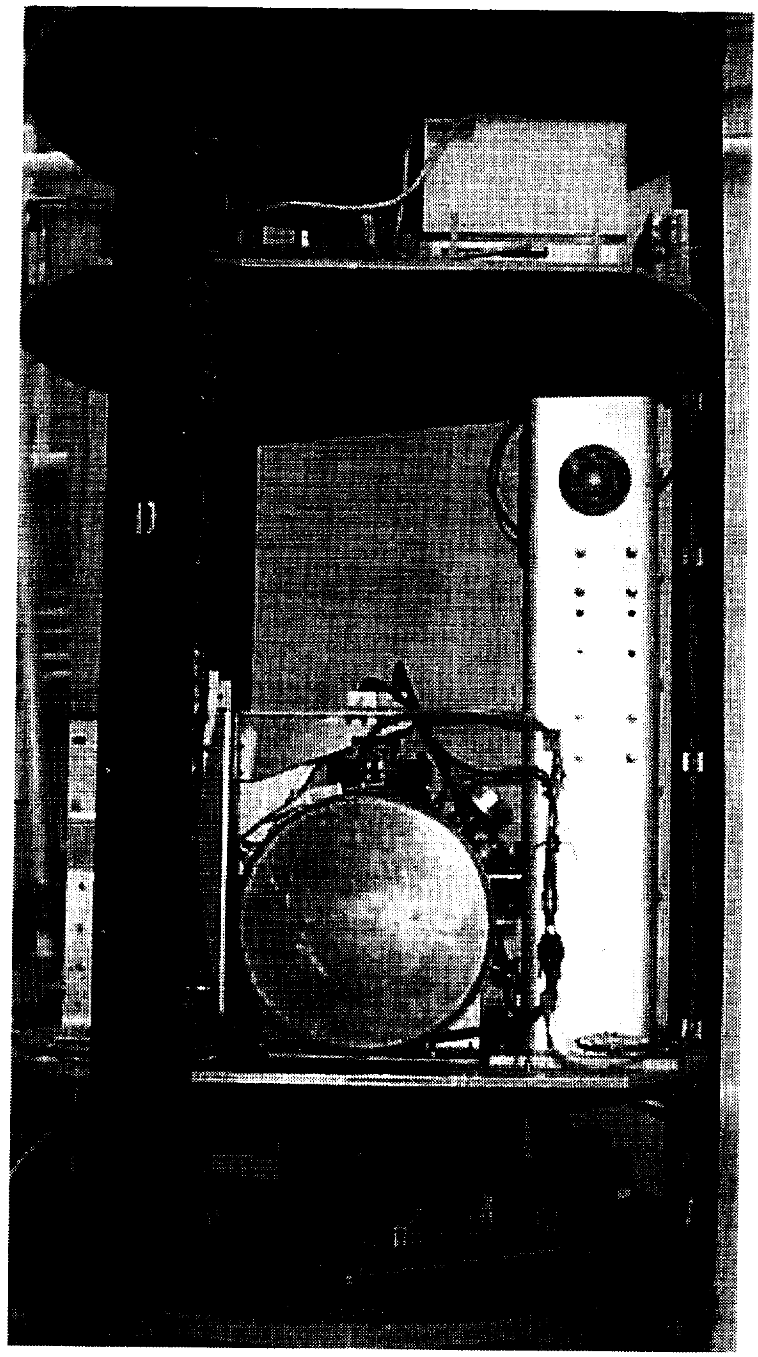
Pressure rating: TBD



D Model

Open platform design (shown with DCE hardware installed).

Maximum experiment height: 38" in current configuration.



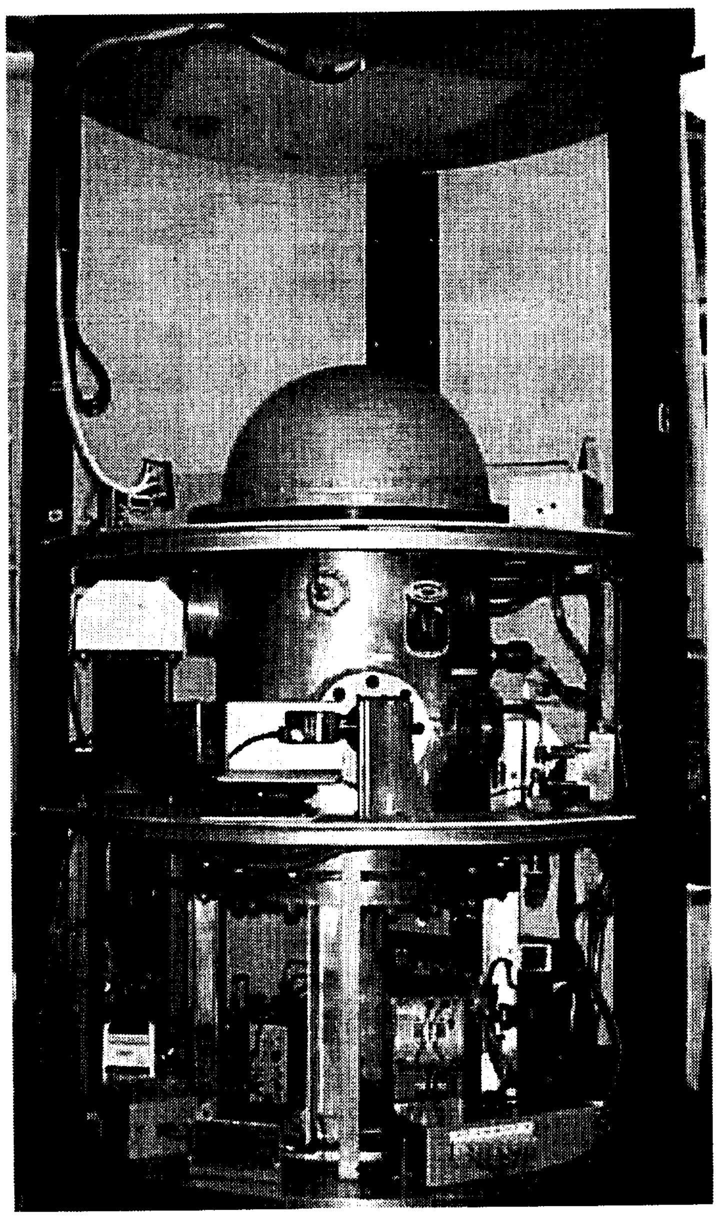
G Model

Equipped with a vertical environmental chamber with hemispherical top cap.

Chamber specifications
  Diameter: 15"
  Height: 20" plus hemispherical cap

Viewing ports: 3 total, (2) 2" diameter, (1) 3" diameter

Pressure rating: TBD



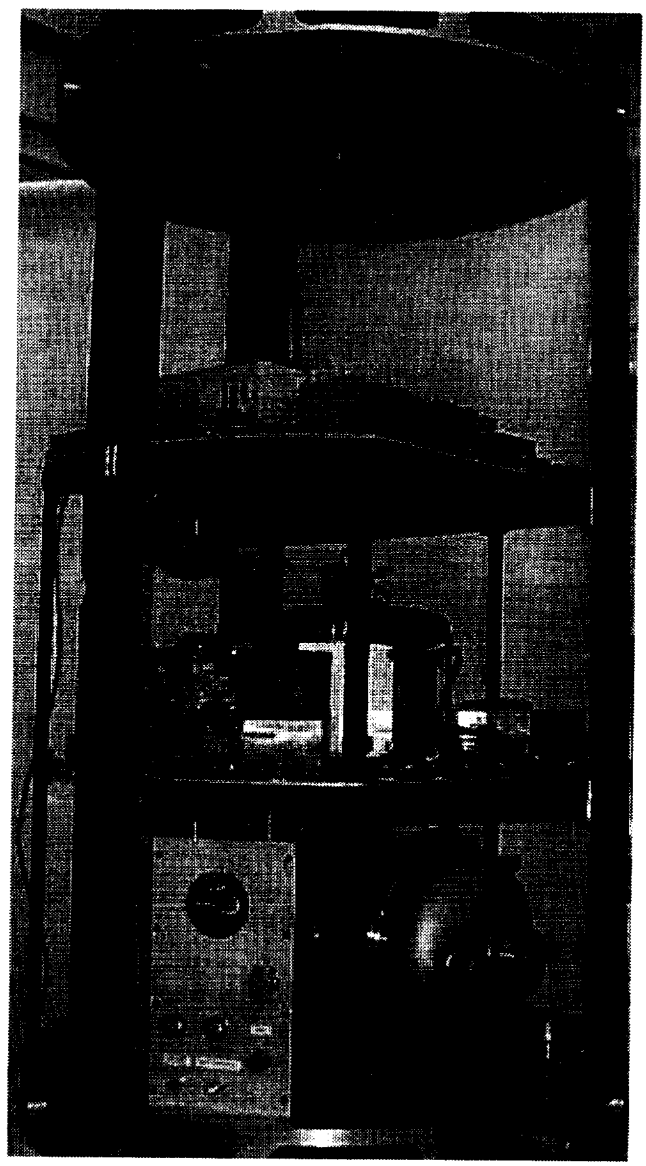
H Model

Equipped with a horizontal environmental chamber with two removable end caps.

Chamber specifications
- Diameter: 12 ½"
- Length: 24" plus two hemispherical end caps

Viewing ports: 7 total, (6) 4" diameter. Location: two on the top, two each along each side on chamber centerline. (1) 2" diameter on end cap.

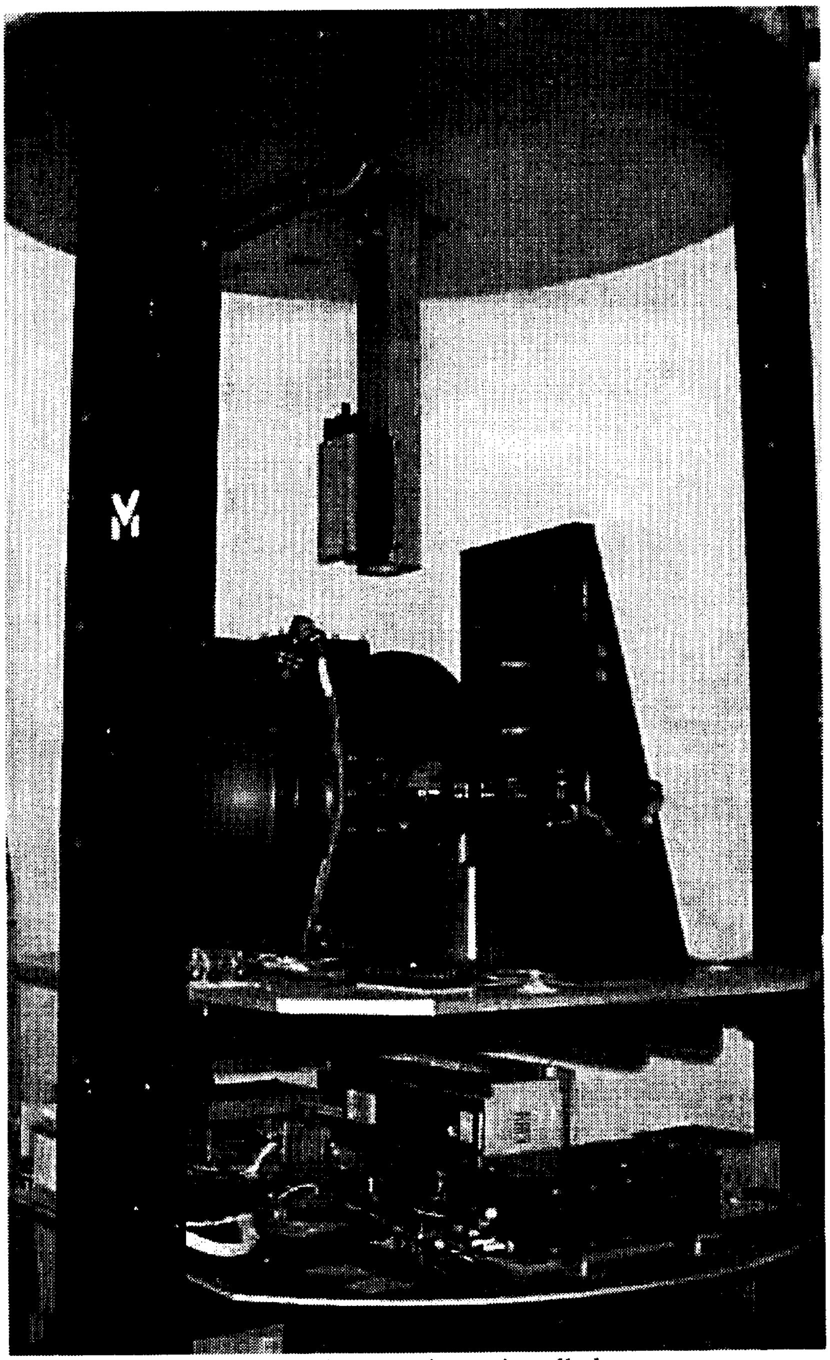
Pressure rating: 90 psi working pressure



M Model

Open platform design.

Maximum experiment height: 39"



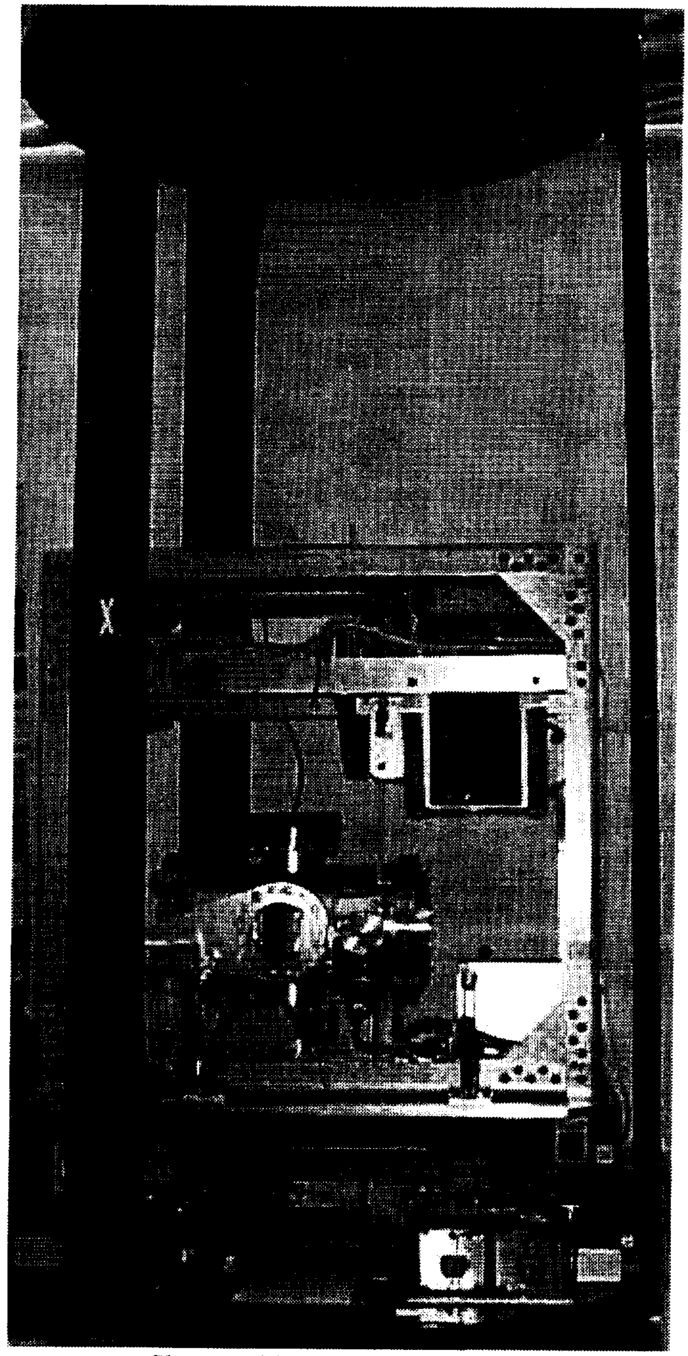
Shown with experiment installed.

X Model

Designed with quick-release system for rapid integration of 2.2 second Drop Tower frames.

Maximum experiment height: 66"

RS232 link to control room.



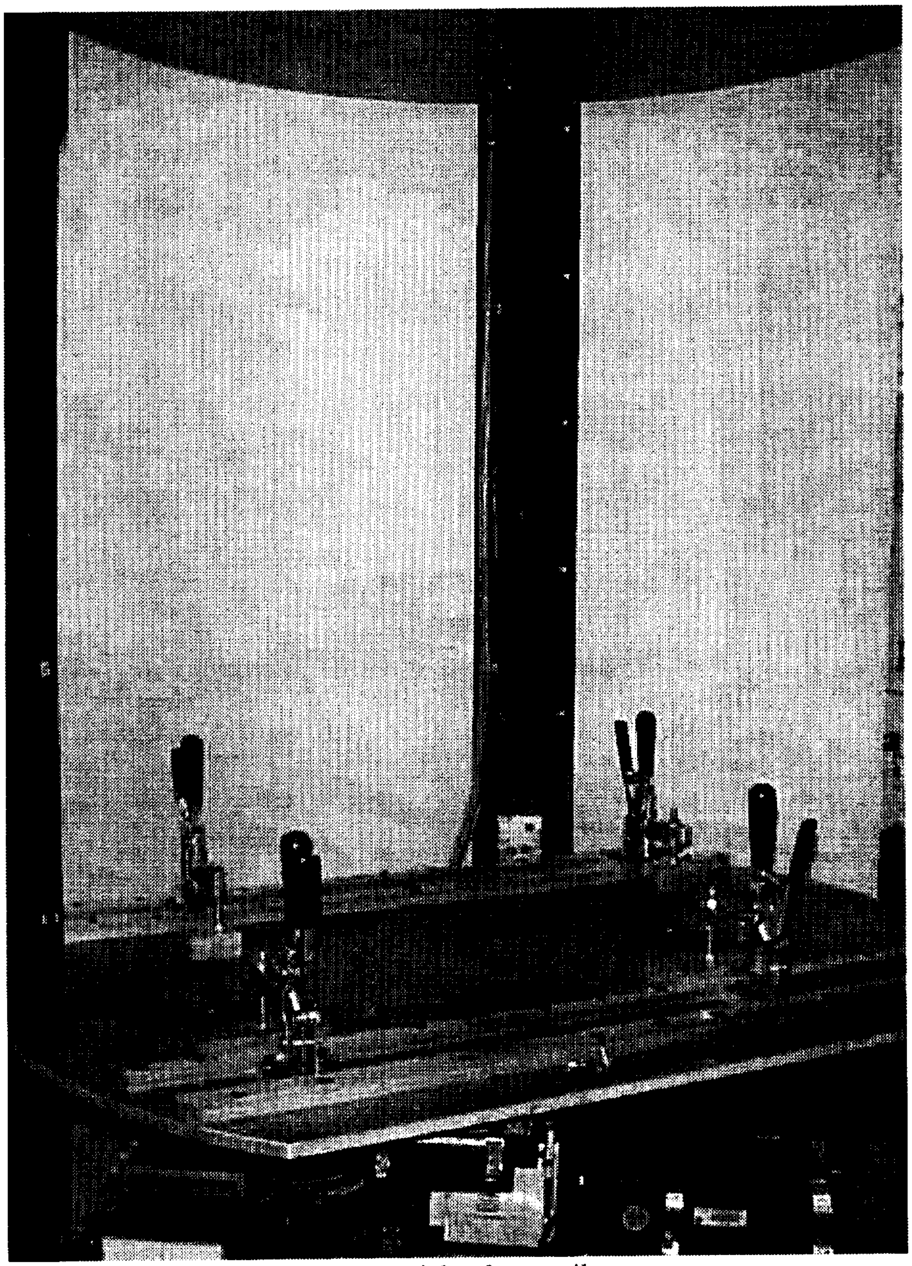
Shown with experiment installed.

X-2 Model

Designed with quick release system for rapid integration of 2.2 second Drop Tower frames.

Maximum experiment height: 41"

RS232 link to control room.



Showing the quick release rail system.

Appendix C—Pressure Vessels and Systems Documentation

The following is a recommended outline for pressure vessels and systems as is required in the safety documentation:

(1) System drawing or sketch initialed by design engineer.

(2) Component identification data:

(a) Relief devices: set pressure, maximum design pressure (MDP), manufacturer, model number, identifying tag for set pressure and service.

(b) Components (valves, filters, regulators, check valves, etc.): manufacturer, model number, and pressure rating. Regulators should be tagged with a certification verification, and all pressure gauges should be calibrated and labeled as such.

(c) Flexible hoses: pressure rating and size.

(d) Tubing and pipe: material, size, and schedule or thickness.

(e) Pressure vessels:

Drawing or specifications that as a minimum specify Maximum Allowable Working Pressure (MAWP), material thickness, material specification, head and shell geometry, and weld joint geometry.

Serial number or unique identifying number.

(3) Certification tests (in accordance with ASME Boiler and Pressure Vessel Code).

(a) Pressure vessels: all pressure vessels require proof-pressure testing. Hydrostatic testing at 1.5 MAWP is preferred. Pneumatic tests must have prior approval from the GRC Safety Committee.

(b) Relief valves: all relief valves require set-pressure testing. Set pressure of the relief valve in no case shall exceed the MAWP of the system.

(c) Flexible hoses: all flexible hoses require proof-pressure testing (hydrostatic at 1.5 MAWP).

(d) System piping: all system piping requires proof-pressure testing (hydrostatic at 1.5 MAWP is preferred). Pneumatic testing requires prior approval from the GRC Safety Committee.

Appendix D—ZGF Personnel Contacts

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1999	Technical Memorandum

4. TITLE AND SUBTITLE

Zero Gravity Research Facility
User's Guide

5. FUNDING NUMBERS

WU-398-95-0D-00

6. AUTHOR(S)

Dennis M. Thompson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E-11972

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM—1999-209641

11. SUPPLEMENTARY NOTES

Responsible person, Dennis M. Thompson, organzation code 7555, (216) 433-5455.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category: 14 Distribution: Nonstandard

This publication is available from the NASA Center for AeroSpace Information, (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The Zero Gravity Research Facility (ZGF) is operated by the Space Experiments Division of the NASA John H. Glenn Research Center (GRC) for investigators sponsored by the Microgravity Science and Applications Division of NASA Headquarters. This unique facility has been utilized by scientists and engineers for reduced gravity experimentation since 1966. The ZGF has provided fundamental scientific information, has been used as an important test facility in the space flight hardware design, development, and test process, and has also been a valuable source of data in the flight experiment definition process. The purpose of this document is to provide information and guidance to prospective researchers regarding the design, buildup, and testing of microgravity experiments.

14. SUBJECT TERMS

Microgravity; Drop tower

15. NUMBER OF PAGES

31

16. PRICE CODE

A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	