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Users Guide for the 2.2 Second Drop Tower of the NASA Lewis Research Center

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Foreword

The 2.2 Second Drop Tower is operated by the Space Experiments Division of the NASA Lewis Research Center 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 the mid-1960's. The Drop Tower 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 Drop Tower experiments.

1.0 Introduction

This document is provided to assist investigators in preparing for, and conducting, tests in the NASA Lewis Research Center 2.2 Second Drop Tower. 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. The nature of Drop Tower operations, which includes hands-on involvement by research personnel, limited space, sharing of resources, and a high level of activity make it a unique facility in which to work. These guidelines, which have evolved through a consensus of experienced users, will assist researchers in meeting their requirements while sharing the facility with other research programs and facility activities.

2.0 Facility Operations Overview

The 2.2 Second Drop Tower is the most heavily used reduced-gravity facility at Lewis, because of its relatively simple mode of operation, productive capabilities, and associated low cost. It now routinely supports over 1000 test drops per year (the routine daily schedule allows up to 12 drops). A schematic of the facility is shown in figure 1. The work areas of the Drop Tower include: a shop for experiment buildup, integration, and testing; several small laboratories for experiment preparation and normal gravity testing; electronics support rooms; and an eight-story tower in which the drop area is located.

The following summarizes the details of the Drop Tower mode of operation. Experiments are dropped under normal atmospheric conditions from a height of 79 ft 1 in. Air drag on an experiment is minimized by enclosing it in a drag shield. Assembly of the drag shield over an experiment is shown in figure 2. The fully assembled drag-shield/experiment package is shown being raised from the preparation area in figure 3. This assembly is hoisted to the top of the drop area where it is mated with the facility's release mechanism through the use of a block and wire system. The entire assembly remains supported by the overhead hoist and cables until just prior to a drop (see fig. 4). Once the package is in place, electrical connections are made with the experiment. These connections will serve as switches to the onboard systems when a drop is initiated.

The investigator may then perform activities in preparation for a drop such as dispensing a fuel, igniting a sample, or filling a vessel. An investigator also may prepare VCR's for recording video data. (If video cameras are used on a drop rig, they are connected to a fiber optic cable which falls with the drag-shield/experiment assembly.) When the experiment is ready, spacers are removed from the bottom of the drag shield, and the exterior drag shield doors are closed. (At this point, the experiment is actually held to the top of the drag shield, approximately 71/2 in. off the bottom of the drag shield.) Then, the overhead hoist cables are disconnected. The entire package which weighs up to 1075 lb is now suspended by a length of thin hardened steel (music) wire.

To release the package smoothly, a sharpened chisel attached to a pneumatic piston is activated and driven into the wire. The wire is notched, but not cut all the way through. The wire fails almost instantaneously, and the drag shield and experiment rig are released smoothly and independent of each other into free fall. Upon release, the electrical connections are also opened, signaling the onboard systems that the drop has been initiated. Accelerations of approximately 10^{-4} g are obtained as the experiment falls freely a distance of 71/2 in. within the drag shield while the whole assembly falls from a height of 79 ft 1 in.

A drop is terminated when the drag shield assembly impacts an air bag. At the time of impact the experiment package has traversed the available vertical distance within the drag shield and is resting on the floor of the drag shield. The drop sequence is depicted in figure 5. The deceleration levels at impact have peak values of 15 to 30 g. These relatively low impact levels as well as precautions taken during design of the experiment permit the use of many off-the-shelf electronic items including video cameras, low-power lasers, light bulbs, and data acquisition and control systems.

A large variety of experiment packages or drop rigs with differing capabilities have been tested in the Drop Tower. Hardware is integrated into a rectangular aluminum frame to form the experiment package. Details regarding the drop frame options will be given in section 4.1. Two examples of Drop Tower experiment rigs are shown in figures 6 and 7. The experiment rig shown in figure 6 is used for droplet combustion and experiment hardware is mounted in a standard frame. Figure 7 is an example of a multi-user, multipurpose combustion rig with hardware mounted in a custom frame.

Experiment power is provided by onboard battery packs which are generally 28 V dc. Visual data can be acquired by high-speed motion picture cameras supplied by NASA as well as a variety of video cameras that are typically supplied by investigators. Video signals are transmitted to remote video recorders via a fiber optic cable that is dropped with the experiment. Onboard data acquisition and control systems also record data supplied by instrumentation such as thermocouples, pressure transducers, and flow meters. The data acquisition and control system is often supplied by NASA.

The Drop Tower offers the opportunity for hands-on investigations as well as the execution of a large test matrix (some rigs have been used for hundreds of drops) and use of investigator-provided hardware. In most instances drop frames are sent to the investigator's institution for experiment assembly.

Drop Tower personnel are available for consultation regarding all phases of the buildup of an experiment, and also for limited hardware integration and assembly. Investigators are strongly encouraged to take advantage of this engineering consultation. Investigators are ultimately responsible for the testing and maintenance of their experiments. NASA-provided components can include cameras, certain electronics components, data acquisition and control systems, and battery packs. In some cases existing hardware or experiment rigs can be used, which eliminates the need for a new experiment buildup. A summary of the characteristics of the Drop Tower can be found in appendix A. Details regarding experiment buildup and testing will be presented in the following sections of this document.

3.0 Experiment Planning

One of the most important keys to successful testing in the Drop Tower involves appropriate experiment planning. The start of this process is communication with pertinent NASA personnel regarding the design and feasibility of performing a desired experiment, component selection, buildup techniques, safety considerations, support equipment at Lewis, facility capabilities, operational procedures, and the like. Experiment planning must include a visit to the Drop Tower 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. Timely experiment success depends on this planning phase. Details of the entire planning phase and documentation requirements including a time-line checklist will be presented in the latter sections of this document.

3.1 Role of Lewis Personnel

Several people at Lewis play a role in Drop Tower experiment planning and operations. These include the Technical Monitor (grant or contract monitor for the project if it is being performed by an institution external to Lewis), Facility Manager, Drop Tower Mechanical and Electronics Engineers, and Drop Tower Research Laboratory Mechanics and Electronics Technicians. The NASA Technical Monitor is an in-house scientist who serves as the primary contact and communication link for external researchers (Principal Investigators) and graduate students. This individual has several responsibilities regarding use of the Drop Tower such as serving as a technical liaison with Drop Tower personnel regarding projects and consultant duties focused on the feasibility, design, and execution of an investigation. The Drop Tower 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 Drop Tower is also supported by a mechanical and electronics technical staff that can provide additional design support. These individuals are also available for limited buildup, experiment modification, or repair tasks. Although use of the Lewis engineering and technical staff must be coordinated in advance with the Facility Manager, Drop Tower staff members are available for consultation throughout the planning and buildup phases of a project. The Principal Investigator has the ultimate lead responsibility for the buildup, operation, and maintenance of an experiment.

Note: NASA in-house investigators do not use Technical Monitors and thus fulfill those responsibilities of the Technical Monitor as set forth in this document.

3.2 Preliminary Design Meeting (Pre-buildup Meeting)

Prior to the final design and fabrication of an experiment package, arrangements must be made through the Technical Monitor to have a meeting at the Drop Tower. The purpose of this meeting is to discuss and review the design and layout of hardware, identify safety hazard issues, determine what Lewis support (personnel/hardware) may be required, examine existing drop packages, and become familiar with facility operations. Attendees at this meeting should include at least the Principal Investigator or suitable representative, the Technical Monitor, the Facility Manager, and representatives from the Drop Tower engineering and technical staff as required.

At this meeting, the Principal Investigator 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. (Safety issues will ultimately be addressed in a Safety Permit Request document as discussed in section 7.2 of this guide.)

Based on the information provided at this meeting, Lewis 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 Drop Tower 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 Lewis staff members. This type of support will be addressed on a case by case basis and will be negotiated through the Lewis Technical Monitor and the Drop Tower Facility Manager. Lewis engineers will be made available to review designs performed by external institutions.

3.4 Hardware Responsibilities

A Drop Tower experiment is typically a combination of researcher- and NASA-provided hardware and instrumentation. Through arrangements between the Lewis Technical Monitor and the Drop Tower Facility Manager, NASA may provide some of the experiment components or a complete experiment rig. Grant or contractual arrangements for hardware provisions must be coordinated through the Technical Monitor. (The proposal for a grant and subsequent negotiations may have already addressed this issue.) Hardware and components that typically may be provided by NASA include but are not limited to the following:

(1) Drop frame

(2) Data acquisition and control system

(3) Motion picture cameras, lenses and mounts (These are provided for use only at the Drop Tower.)

(4) Video cameras and lenses (A limited supply are available for use only at the Drop Tower.)

(5) Battery enclosures or battery boxes (Metal boxes with external connectors and a circuit breaker are provided. Batteries must be purchased by the investigator and installed in the enclosure.)

(6) Video transmitters and receivers and a two-channel fiber optic cable for the Drop Tower fiber optic system (for use only at the Drop Tower)

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

3.5 Drop Tower Support Facilities and Materials

Work space: The Drop Tower, Building 45, is a relatively small facility that supports numerous experiments. As a result, work space is limited. When investigators are at the Drop Tower for testing, they are assigned a work area in the main shop or a small laboratory in the tower portion of the building. The work area will consist of a minimum of a workbench and lab chairs. A four-wheel cart will be provided for movement of an experiment rig in the facility.

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 Drop Tower does have shop machinery that is used by the technical staff.

VCR's and monitors: SVHS video recorders, Betacam SP™ video recorders, and video monitors are provided as part of the fiber optic video transmission/recording system for drops and for later review of tests.

Support personnel: The technical and engineering staff of the Drop Tower are available to perform the final balancing of your experiment rig and to perform the drop tests. These individuals are available on a limited basis for experiment repair and modification. Requests for this type of support must be made to the Facility Manager.

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

Air: zero ultra high purity, < 1 ppm total contamination (oxygen concentration ranges between 18 and 21 percent)

Argon: technical, 99.995 percent

Helium: high purity, 99.997 percent

Nitrogen: ultrahigh purity, 99.999 percent

Oxygen: technical 99.5 percent

The inventory can also include fuels such as methane, propane, ethylene, hydrogen, etc. Investigators should notify their NASA Technical Monitor 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 Drop Tower through the Technical Monitor.

Note: Where possible, investigators should order specialty mixtures, particularly fuel mixtures. The Facility Manager and Technical Monitor will make the final determination as to which mixtures can be made at the facility.

4.0 Mechanical Overview

All hardware should be designed to withstand a downward acceleration of 30 times gravitational acceleration. The heaviest components should be mounted on the bottom of the frame, as the bottom is fully supported at impact. Lighter components such as electronics can be mounted on shelves in the upper portions of the drop frame. In general, those components or structures which are mounted in a cantilevered configuration do not hold up well to repeated drops. When performing the component layout, an attempt should be made to distribute the weight as evenly as possible to help facilitate a balanced rig. The Drop Tower staff will perform the final balancing of the experiment. If necessary, weight will be attached to the rig during this balancing procedure.

Note: If your experiment plans include testing the same hardware in the Drop Tower and in either the Zero Gravity Research Facility or the DC–9 aircraft, special design requirements apply. Contact the Drop Tower Facility Manager for the coordination of multifacility testing.

4.1 Drop Frame Options

A standard aluminum drop frame is available for mounting and drop testing experimental hardware. The drawing for this frame is shown in figure 8. The frame dimensions are 38 in. long by 16 in. deep by 33 in. high. The empty frame weighs 45 lb. The final total experiment rig weight is limited to a total of 350 lb including the frame weight (and balancing weight).

Note: In the drawing there is an area in the center top portion of the frame that must remain clear to accommodate drop operations.

Custom or special frames may be required to meet the particular needs of an experiment. Discuss your requirements with the Facility Manager. These specialty frames must fit within the useable envelope of the drag shield and be compatible with the facility crane and release mechanism. The request for a drop frame should be made through the Technical Monitor at least three months prior to the need date.

4.2 Fasteners

Quality fasteners, Grade 5 or better, must be employed when mounting components to the drop frame. Also, where feasible, locknuts should be used. When using the exterior sides of the frame for mounting, Allen- or aircraft-quality flathead fasteners need to be used.

4.3 Pressure Systems

Note: Supporting documentation and requirements for pressure systems are detailed in appendix B.

The use of pressure vessels and pressurized systems in the Drop Tower 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 or system 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.

4.4 Components for Pressure Systems

All pressurized systems must have a relief mechanism to guard against overpressurization. This device must be set to relieve at a pressure no greater than the lowest MAWP of the system components.

Stainless steel tubing, fittings, and valves are strongly recommended for all pressure systems. Stainless Swagelok® or stainless AN fittings are quality choices for these components. Brass or copper systems may be allowable for certain applications. Consult with the Drop Tower Facility Manager regarding these choices.

4.5 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. If your institution does not have these capabilities, special oxygen-ready components are available from Swagelok[R]. Also fast-acting valves (ball valves) cannot be used in oxygen systems. Documentation that certifies that components are applicable for oxygen use is required.

4.6 Shock Isolation

For those items that cannot withstand the 30 g loading, shock isolation methods are available. Most often, components are mounted on a piece of shock absorbing/damping foam. A custom-designed shelf that actually displaces downward on impact is another alternative. The shock is absorbed by several oil-filled shock absorbers. Special shock isolation is generally not required, however.

5.0 Electronics Overview

A general overview of the basic components of Drop Tower experiment electronic systems is outlined in figure 9, and brief discussions of each major group are treated below. Detailed information regarding support electronics is available from the Drop Tower engineering staff upon request. Example schematics, fabrication drawings, and consultation can be requested via e-mail and/or by phone (see appendix C for Lewis personnel contacts).

It is strongly recommended that experienced engineering advice be sought during the design phase, and that experienced technicians be employed for fabricating the experiment's electrical system, in order to insure successful operation and low-failure rates of the experimental hardware. Both immediate and potential future needs should be examined from the start, since it is much easier to add capabilities to the electrical hardware during initial design efforts than to modify existing hardware. Finally, documentation should be generated for the system including electrical schematics for all modules, as well as interconnect schematics. Proper documentation is essential for trouble-shooting the electrical system at the Drop Tower if it fails.

5.1 Electrical Power

Sources: Batteries are used exclusively to provide electrical power for experiments performed at the 2.2 Second Drop Tower. A distributive power system based on sealed lead-acid cells is used. A standard Drop Tower battery pack has the following characteristics. Electrically, it has a nominal output voltage of 28 to 30 V dc, onboard, overcurrent protection (a circuit breaker is preferred to the use of standard glass-fuses), and has an electrically protected charging port. Mechanically, the cells used to make the battery pack are housed in an internally padded protective enclosure, mounted so that it can be quickly removed from the drop frame when necessary. For safety reasons, electrical connections to and from the battery packs are made through sealed connectors rather than with screw terminals.

Conversion: The use of dc/dc converters for providing power to computers, video cameras, relays, etc., is strongly recommended. In cases where low noise operation, voltage isolation, and/or dual voltage supplies are not required, the substitution of low-cost linear regulators is acceptable.

Distribution: Power distribution is generally handled by a single enclosure containing all dc/dc converters (with the exception of high voltage converters), relays, and most of the overcurrent protection (fusing). Additional guidelines for power distribution include the following:

(1) Accessible, panel-mount fuseholders are recommended to simplify fuse replacement.

(2) Switches are generally placed on the front panel for manual operation of the various relays and voltage sources.

(3) Solid-state relays are used for switching of the various load currents required by the experimental apparatus.

(4) Connectors (receptacles) are generally placed on the back panel for attachment to battery packs, control systems (logic level control signals for instance), and the various loads it will supply.

Wiring: Standard wiring practices should be employed for safe and (relatively) failure-free operation of the experiment. These practices (applicable to both enclosure interiors and external wiring) include, but are not necessarily limited to:

(1) The exclusive use of stranded wire for interconnections whenever possible, both inside enclosures and between enclosures, actuators, sensors, etc.

(2) The specification of and adherence to appropriately gauged wiring based on expected and failure-mode currents

(3) The use of shielded, jacketed cable (external wiring) wherever possible to reduce electrical noise

(4) Termination of cabling via connectors whenever possible for safety and noise reduction

(5) The use of electrical shielding wherever possible to reduce system noise

(6) Organized cable routing and sufficient tie-down points to insure personnel safety, reduce vibrations, minimize signal or power-lead coupling effects, and reduce the likelihood of failures

(7) Appropriate and sufficient labeling of cables, enclosures, switches, overcurrent protection devices, and connectors for identification purposes

(8) All electrical loads should be treated as (at least) two-terminal devices, i.e., each load receiving power from a source should have a corresponding, dedicated return, or common wire. The chassis should not be used as an electrical conductor.

5.2 Actuators

Actuators are used on Drop Tower 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. Overcurrent 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 V dc 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 V dc actuator requires 24 V, as this is quite often a nominal specification. Consult the manufacturer to determine if the device in question may be operated at 28 V dc before discarding it as an option.

5.3 Light Sources

Illumination of an experiment may require the addition of a light source. A wide variety of sources are available, depending on the experiment requirements. In many combustion-related experiments, natural illumination associated with the combustion process may be adequate. In others, however, the addition of a general purpose light source for interior illumination of a test vessel (such as a pressure chamber) is recommended. A few potential light sources are briefly described below.

Incandescent bulbs are used both for experiment illumination (backlighting of a subject) and general purpose lighting associated with alignment and focusing of video and/or motion picture cameras. These sources should be selected to run off of the nominal battery voltage (28 to 30 V dc) whenever possible. These devices provide a medium intensity source for experiments. No special electrical precautions are necessary to use these devices. Overcurrent protection is required.

Electro-luminescent panels can be used as diffusive backlight sources for certain experiments. They may be a good choice for some experiments due to their low thermal output, mechanical flexibility, size, and low power consumption. Their drawback is limited output intensity (maximum ~120 cd/m^2). They also need a small driver circuit. No other special electrical considerations apply.

Lasers can be used for both qualitative (imaging via laser-sheet, seeded back-scattering, etc.) as well as quantitative measurements (transmission ratio, LDV, etc). Both helium-neon and diode lasers have been used successfully at the Drop Tower. 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 (see section 7.2).

Light-emitting diodes (LED's) are generally used as indicators for the various electronics modules on experiments, and they can also be used to provide a visual drop indication when placed in the visual field of a cinema or video camera.

Xenon arc-lamps can provide a high-intensity, broad spectrum light source for experiments. Examples include experiments requiring the use of color-Schlieren imaging or those that use a strobe-light source for capturing time-dependant events. Utilization requires special electrical considerations. The power supplies are electrically noisy. Overcurrent protection is required.

5.4 Sensors and Signal Conditioning

Many sensors can be incorporated on experiments performed at the 2.2 Second Drop Tower. Appropriate signal conditioning (when needed) can be provided prior to input of the data to a computer or other data-logger. For the purposes of this discussion, the word "sensor" applies to those devices which convert a measured quantity into either voltage, current, or frequency. Common sensors that might be used in an experiment include thermocouples, thermistors, pressure transducers, accelerometers, flowmeters, and photodiodes.

The term "signal-conditioning" refers to modules whose purpose is to convert a sensor's output into a voltage useable by a data-acquisition system's A/D converter. This is realized by amplification, attenuation, differencing, conversion from current or frequency to voltage, and/or other filtering of the sensor's data stream. When using sensors, special care should be taken to reduce noise. This can be accomplished by routing the signal lines away from power lines, shielding signal lines, using isolated electrical supplies for both signal conditioning devices and active (powered) sensors, and when practical, using sensors that employ onboard amplification.

5.5 Video and Motion Picture Cameras

Many, if not all experiments will use video and/or motion picture cameras for qualitative or quantitative video capture. Power for these devices and any associated peripheral devices (video transmitters or timing light generators) should be included on the experiment. This discussion applies only to powering the device(s).

Video: To simplify system design, it is recommended that 12 V operated video cameras be specified for inclusion in experiments. When specifying a voltage regulator or dc/dc converter, assume a nominal current draw of between 250 to 750 mA per video camera to start, referring to the camera's electrical specifications for actual current draw, and ~250 mA @12 V dc per video transmitter. It is recommended that the video camera be powered separately from active sensors, signal conditioning, and data-acquisition/control computers.

Motion Picture Cameras: In the case of motion picture (cinema or movie) cameras, assume a nominal current draw of ~4 to 5 A for low-speed (<128 (frames per second (fps)) cinema, and ~8 A for high-speed (128 to 400 fps) cinema. Cinema cameras are generally powered by a standard battery pack routed through a fuse (for short-circuit protection) and a relay (for remote actuation). Use of surge suppression is recommended.

Timing-light generators (TLG) are used to mark a small segment of the film at specific time intervals. They require approximately 0.8 A @ 28 V dc and may be powered by the same battery pack used to provide power for the camera(s).

5.6 Data Acquisition and Control Computers

While the simplest of experiments can use time-delayed relays (TDR's) for control, the need for data acquisition and accurate event-timing necessitates the use of a more sophisticated control system. Factors to consider when choosing a computer system for the experiment should include the following:

(1) Number of channels of digital control required
(2) Number of analog input channels required
(3) Amplitude resolution required of A/D system: 8-, 12-, or 16-bit
(4) Sampling rate required of the A/D system: 100 Hz, 1 kHz, or 50 kHz
(5) Single-ended or differential inputs
(6) Analog outputs required
(7) Physical space available for installation of the computer system
(8) System power requirements
(9) Memory or other (disk) space required
(10) Selection of compiled "C" or Basic programming under DOS (or derivative) operating system
(11) Ability of system hardware to withstand impact accelerations of 30 g

All of these considerations (the above list is not inclusive) should be addressed with respect not only to immediate needs, but also to future needs, allowing for additional capabilities that may be required of the system during the expected experiment life.

Data-loggers are low-cost, single-board computers which generally have both digital input/output (I/O) and analog inputs on board. Several manufacturers have models that use interpretive language operating systems allowing for quick program changes. Expect the number of digital I/O channels to be limited to about 16 for most units. A single-ended operation supports A/D at resolutions up to 12 bits, though sampling rates will in most cases be limited to sampling rates less than 1 kHz. These units usually take up little space on the experiment.

A computer system called the DDACS (droppable data acquisition and control system), which was developed at Lewis for use with a commercially available data-logger is used extensively at the Drop Tower. Electrical schematics, fabrication drawings, and parts lists for this system are available on request. A brief overview of the DDACS system is included in appendix D. This system can be provided to investigators.

STD-bus computers are much more powerful systems, allowing the researcher to perform nearly any task that can be accomplished on a desktop system. A variety of CPU cards including 386, 486, and pentium cards, and up to 16-bit high-speed A/D cards (both single-ended and differential input cards), are available for data acquisition. Video cards can be included and Ethernet cards are available. These systems require much more space than single-board solutions. It should also be noted that these computers require the use of compiled programs.

PC/104 computer systems have much the same capabilities as those enjoyed by STD-bus systems, but at a lower cost, smaller physical size, and reduced power requirements. These systems may also require the use of compiled programs.

6.0 Imaging Services Support

Researchers utilizing imaging systems as a means of gathering data can look to the Lewis 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 (Building 5) directly across the street from the Drop Tower.

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.

Providing high quality scientific imaging services to the research community is the goal of this group. The SIG philosophy is to provide the best imaging solution to satisfy the science requirements, while considering the many trade-offs associated with imaging and conducting tests in the 2.2 Second Drop Tower environment.

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.

A sample of the hardware available for loan from the SIG includes motion picture cameras, video cameras, high speed video systems, digital capture systems, analog and digital recording methods for video and digital imaging, and traditional still photographic camera systems.

6.1 Motion Picture Cameras

Numerous types of motion picture cameras are available including Milliken, Mitchell, Fastax, Fairchild, Nova, Photo-Sonics, and Arri. These cameras operate at various frame rates depending on the model. Pin-registered versions operate from single frame to 500 fps. Rotating prism models operate from 500 to 10 000 fps. The most commonly used camera in the 2.2 Second Drop Tower is the Milliken, which can operate on 28 V dc. The Milliken is available in three sizes (100-, 200-, and 400-foot film capacities) with frame rates from 6 to 500 fps. Additionally, some models have provisions for fixed or variable speed frame rate adjustments.

6.2 Standard Video Cameras

While the SIG has only a limited number of video cameras available for loan, consultation is provided to researchers regarding video camera selection. Also, as stated earlier, a small number of video cameras are available at the Drop Tower for general use by research personnel.

6.3 High-speed Video Systems

Numerous high-speed video systems are arriving on the market as technology in this area improves. Currently there are a limited number of high-speed video systems sold commercially that are suitable for Drop Tower use, however they are quite expensive.

6.4 Still Photographic Systems

Nikon and Olympus 35-mm cameras and lenses, as well as consultation on digital still capture systems are available.

The ITC maintains a procurement contract with Eastman Kodak, and is capable of supplying a wide assortment of Kodak film and related products. A large supply of 35-mm still films is available. Motion picture films in stock include Black & White reversal and negative films, as well as color negative and reversal films. Additionally, specialized emulsions may be ordered for tests requiring custom formulations or packaging. Onsight processing within the ITC includes 35-mm still films (E-6, C-41, and B&W process), motion picture B&W reversal and negative, and duplication of B&W motion picture films. Color motion picture films (ECN-2 and VNF process) are sent offsite for processing and require approximately 3 days turnaround. The Lewis Technical Monitor makes arrangements for funding for film and processing.

The SIG also provides image processing and data analysis facilities for use by all research personnel. Located on the second floor of the ITC, the Image Processing and Data Analysis Facility is managed by the SIG and is equipped with motion picture film transports, high resolution film scanners, PC-, Sun-, and UNIX-based computer platforms, video recorders and players, and software for image processing and image tracking.

The SIG supports researchers from proof-of-concept systems to shuttle flight experiment imaging. State-of-the-art technologies are constantly being evaluated and added to our existing in-house capabilities, along with continued personnel training in advancing imaging technologies. Expert imaging consultation is available to solve your scientific imaging needs including initial imaging system design, installation, image acquisition, processing, data reduction, and archiving. By managing the entire imaging process, the SIG can insure that the quality of the imaging data will not be compromised before, during, or after a test.

Representatives of the SIG can be reached at (216) 433-5976.

7.0 Documentation Requirements

Drop Tower investigators must fulfill two document requirements, a Test Request and a Safety Permit Request.

7.1 Drop Tower Test Request

Investigators who are planning to perform new experiments or projects in the Drop Tower 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, but not later than **6 months** prior to the desired testing dates. 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. Two copies of this request are to be submitted to:

NASA Lewis Research Center
Facility Manager, 2.2 Second Drop Tower
Mail Stop 45-1
21000 Brookpark Road
Cleveland, Ohio 44135

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

(1) Experiment title

(2) Pertinent experiment personnel and affiliations: Principal Investigator, individual performing tests (e.g., grad student), NASA Technical Monitor (if external investigation), etc.

(3) Brief experiment description and purpose

(4) Description of test hardware (preliminary layout if possible)

(5) Equipment responsibility (PI- provided, NASA-provided)

(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, high voltage, 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. Ongoing investigators who have already been approved through the test request process need to schedule test time as described in section 8.

7.2 Experiment Safety Documentation

Test operations at the Drop Tower as in any Lewis facility are subject to the Lewis 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.

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 (appendix E) 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 temperature operations (over 140 °F), 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 including overall 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 testing

Note that the use of lasers also requires special precautions. Utilization of lasers will be evaluated by the Lewis Industrial Hygiene and Physics 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/cm^2), and beam divergence (mrad). Pulse laser information required includes peak power (watts), energy/pulse (joules), average power (watts), beam dimensions, radiant exposure (j/cm^2), and pulse duration.

Three copies of the completed safety documentation are to be forwarded to the Drop Tower Facility Manager (address shown in section 7.1) at least **six weeks** prior to initial testing. The safety documentation will be reviewed by a Lewis Safety Committee, Drop Tower personnel, a representative from the appropriate science discipline (i.e. combustion, fluids, etc.) and the Branch Chief at Lewis responsible for the discipline being investigated. These individuals may request additional information to aid in their evaluation. The Safety Committee has the final authority for safety approval. Individuals from this committee will inspect your hardware upon arrival at Lewis to determine its final readiness. Some modifications may be necessary at that time (see section 8.4).

For additional guidance regarding the Safety Permit procedure contact the NASA Technical Monitor or Facility Manager for a copy of the Lewis Safety Permit Requester’s Guide. These individuals will provide assistance with this exercise.

8.0 Test Scheduling and Operations

To request test time at the Drop Tower, contact the Facility Manager (or Technical Monitor) at least **three months** prior to your desired dates. (Note that in general, Drop Tower activity is the most intense during the summer.) It is advantageous to request test time as far in advance as possible so that appropriate planning and coordination of the large number of experiments can be accomplished. When requesting the use of the Drop Tower to conduct an experiment, please include the desired dates (generally testing periods of two to three consecutive weeks can be accommodated) and special support requirements. Your request should include a primary and secondary block of time (in case your first choice is not available).

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.

A Timeline for planning purposes is included as appendix F.

Note: Before final approval is given for testing in the Drop Tower, experimental hardware must be fully assembled and checked out. A rig must have undergone successful, normal-gravity-simulated drop tests. Once at Lewis, technical support is available for balancing a rig and for repairs and small modifications on a limited basis. Also, the first visit to the Drop Tower for testing should be viewed as a check-out and evaluation session. Hardware may not work as expected for the first series of tests or results may be surprising. Follow-on test periods are more productive after the experiment has been evaluated further at the investigator’s institution.

To assist in planning your trip to Lewis, maps of the local area (with notations of some local hotels and restaurants) and a map of Lewis are included in appendixes G, H, and I. Phone numbers for Drop Tower personnel are included in appendix C.

8.1 Shipping and Storage

Research hardware that must be shipped to the Drop Tower should be addressed to:

NASA Lewis Research Center
Facility Manager, 2.2 Second Drop Tower
Mail Stop 45-1
21000 Brookpark Road
Cleveland, Ohio 44135

There is very limited storage space at the Drop Tower. Experiment rigs may be temporarily stored at the facility between visits. Arrangements are to be made through the Facility Manager. The Technical Monitor will assist external investigators with the shipping of hardware from Lewis.

8.2 Security and Badging Procedures

Researchers visiting the Drop Tower must be registered and cleared with NASA Security. The Technical Monitor is responsible for facilitating this clearance and obtaining visitor badges. External investigators who are U.S. citizens or permanent resident aliens, must contact their Technical Monitor at least **one week** prior to their arrival for processing.

International visitors who are not permanent resident aliens require specific approvals and must contact their Technical Monitor at least **eight weeks** prior to their arrival for this processing. International visitors must present their passport as a condition of entry onto the Center. These visitors must have their passports with them at all times. Individuals who possess a Permanent Resident Alien Card, I-551 ("green card"), must also have this card with them at all times. While at the Lewis Research Center, all personnel must display their badges and all international visitors must be escorted.

8.3 Duty Hours for Testing and Operations

The hours of operation and thus access to the Drop Tower are weekdays from 7:00 a.m. to 5:30 p.m. Drops are performed during 45-min intervals beginning at 7:30 a.m. A two-week drop schedule is maintained in the facility. Investigators can sign up for a minimum of two drops per day. Contact the Facility Manager two weeks prior to your arrival to schedule drop times. If the schedule permits, additional drops may be possible. The Facility Manager is responsible for resolving drop schedule conflicts.

While at the Drop Tower, researchers are responsible for the operations, maintenance, and modifications of their experiment rig. Even though the Drop Tower has a small supply of community tools, investigators should be prepared with their own tools and spare parts. Investigators are responsible to maintain good housekeeping habits.

8.4 Safety and Readiness Review

After an investigator and hardware arrive at Lewis and before an experiment can be tested for the first time or after significant modification, the experiment must undergo a final Safety and Readiness Review by the Safety Committee and Drop Tower Staff. This review, which is coordinated by the Facility Manager, will occur after an investigator has had the opportunity to set up the hardware and supporting systems. The investigator will be responsible for describing the experiment and test procedures referring to the Safety Permit Documentation if necessary. Some modifications may be required based on the findings of this meeting. Typically, Drop Tower personnel can help with these modifications.

8.5 Summary of a Drop Tower Visit

The following information represents a typical list of events an investigator may expect in a visit to the Drop Tower for testing, after having completed all requirements identified in appendix F, the Investigator Timeline Checklist.

(1) Ship or personally transport hardware to the Drop Tower.
(2) Facility Manager assigns work space and experiment cart.
(3) Receive visitor guideline information such as personnel responsibilities, charge batteries, make drop schedule changes, etc.
(4) Unpack and set up experiment rig and supporting systems.
(5) Undergo Safety and Readiness Review by Safety Committee and Facility Staff after hardware is ready, which is generally within one to a few days of arrival. (This review is only necessary for new experiments or for those which have been significantly modified.)
(6) Perform modifications to experiment if required by Safety and Readiness Review.
(7) Perform drop tests per daily schedule. (Schedule changes are possible, but must be coordinated with appropriate personnel.)
(8) Complete test matrix.
(9) Discuss future scheduling requirements with Facility Manager.
(10) Clean work area.
(11) Arrange for return of hardware to investigator institution.

9.0 Closing

This Users Guide has been prepared to assist investigators in the design, buildup, and testing of reduced gravity experiments. While it covers the majority of issues and details regarding testing in the Drop Tower, it probably has not addressed all questions. Thus it is recommended that investigators call the individuals identified in this document as necessary.

The mission of the Drop Tower staff is to make testing as productive and successful as possible.

Appendix A
2.2 Second Drop Tower Characteristics and Capabilities

Operational Parameters

- Low gravity duration: 2.2 sec (free fall: normal atmosphere with drag shield system; drop height: 79 ft 1 in.)
- Gravitational acceleration: ~10^{-4} g
- Peak deceleration levels: 15 to 30 g for 0.2 sec

Experiment envelope summary

- Standard drop frame (aluminum bus for mounting hardware)
  - width (depth): 16 in.
  - length: 38 in.
  - height: 33 in.
  - variations of standard frame are feasible
- Experiment rig maximum weight: 350 lb (including frame weight: 45 lb)
- Drag shield weight: 725 lb

Experiment instrumentation/data acquisition capabilities

- High speed movie cameras
- Video cameras (fiber optic link to recorders)
- Battery packs
- Data acquisition and control system
- Thermocouples
- Pressure transducers
- Flow meters
- Lasers

Mode of operation

- Engineering support for consultation
- Technical staff for facility operations and certain repairs and modifications
- Technician and investigator perform drops
- Twelve drops per day
- Safety review required

Additional features

- Compressed gas (fuels, oxidant, and diluents) storage, handling, and delivery support available
- Limited community tool supply

Appendix B
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:

(i) 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

(ii) 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 Lewis 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 Lewis Safety Committee

Appendix C
Lewis Personnel Contacts

(1) Drop Tower general phone number:
(216) 433-5002

(2) Drop Tower Facility Manager:

Jack Lekan, Mail Stop 500-216 (or 45-1)
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-3459, Fax (216) 433-8660

e-mail address
jack.lekan@lerc.nasa.gov

(3) Drop Tower Lead Research Laboratory Mechanic:

Mike Johnston, Mail Stop 45-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-5060, Fax (216) 433-8660

e-mail address
johnston#m#_michael@lims-a1.lerc.nasa.gov

(4) Drop Tower Electronics Engineer:

Andy Jenkins, Mail Stop 45-1
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-5001, Fax (216) 433-8660

e-mail address
andrew.j.jenkins@lerc.nasa.gov

(5) Scientific Imaging Group (SIG), Mail Stop 5-2
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-5976, Fax (216) 433-3139

Appendix D
DDACS — Droppable Data Acquisition and Control System

The DDACS (droppable data acquisition and control system) is a microcomputer system developed at the Lewis 2.2 Second Drop Tower for experiment control and low-speed data acquisition. The DDACS is based on an Onset Computer® "Tattletale" model 4A, single-board computer and an inhouse-designed daughter-board that provides several ancillary functions not supplied by the Tattletale.

The DDACS is normally used in conjunction with groups of batteries, dc/dc-converters, relays, actuators, sensors, and signal conditioning modules selected specifically to meet a given experiment's science requirements, thereby providing the researcher with a complete data acquisition and control system.

DDACS system features:

• 16 digital (TTL logic-level) input/output (I/O) channels, divided into 4 programmable groups of 4 buffered channels

• Over-current and voltage protection for all digital I/O

• 12-bit, 8-channel (default) , or 10-bit, 11-channel A/D converter. Any unused input channel(s) may be disabled by use of dip switches

• 0-5 V single-ended inputs. Default sample rate of 100 Hz (8 channels) and sample rates up to 1400 Hz (1 channel). Note: source impedance 2800 ohm max

• 28 K configurable onboard memory. (Default configuration: 16 K of program memory, 8 K of data memory, and 1 K of @array memory)

• TTBasic (subset of BASIC) interpreted command language. Supports immediate command mode, i.e., interactive operation

• RS232 communication @ 9600 baud (N-8-1), thru standard DB9 null-modem cable

• 12 V operation, low power (~1.2 W max, 0.4 W normal)

• Reverse voltage protection for power input

• Overcurrent protection (fusing) for power input

• Optional remote I/O-status circuit for visual indication of digital I/O logic states

• Overall dimensions: 5 × 7 × 2 in.

• Rugged, positive-lock, keyed connectors

Appendix E—Safety permit request form

SAFETY PERMIT REQUEST	DATE RECEIVED (Completed by Committee Chair)	PERMIT NUMBER (To be provided by Committee)

TITLE: ______________________________

(Limited to 70 characters including blank spaces)

TO: ____________ SAFETY COMMITTEE (Provide area number or special committee name)	FROM: ____________ (Safety Permit Requester, print name)

EMERGENCY CONTACTS (Provide information below for an emergency contact and alternate knowledgeable of activity. The Safety Permit Requester can be an Emergency Contact)

NAME	WORK PHONE	HOME PHONE

ORGANIZATION	WORK PHONE	MAIL STOP

LOCATION OF ACTIVITY: ____________ (Indicate facility name, number, cell)

EXPECTED DURATION (Indicate month and year)

Start		Complete	

ACTIVITY SCHEDULE (Mark an X below for all that apply)

☐ Workday ☐ Night ☐ Weekend

TEST RUN LENGTH (Hours, days):

DESCRIBE ACTIVITY (If a precedence exists for this activity, provide details including related safety permit number(s)).

Mark with an X the Supporting Documentation Attached:

- ☐ Technical Description
- ☐ Schematics, Drawings
- ☐ Parts List
- ☐ Plot/Barricade Plan
- ☐ Hazards Analysis
- ☐ Operating Procedures/Check Sheets
- ☐ Lockout/Tagout Procedures
- ☐ Material Safety Data Sheets
- ☐ NASA-C–580 Qualified Operators List
- ☐ NASA-C–197 Users Radiological Training and Experience Record
- ☐ Pressure System Test Certification
- ☐ List of Alarms and Shutdowns
- ☐ Emergency Response Plan/Shutdown Procedures
- ☐ Laser Documentation
- ☐ Radiation or Radioactive Material Information
- ☐ Other (Specify)

ENVIRONMENTAL DISCHARGE PRODUCTS (Provide below the name(s) and estimated amounts of the discharge product(s), what it will be discharged to (e.g., air, sewer), plans for abatement/treatment, the method of detection used to measure the amount/type of discharge, and the frequency of discharge sampling. Indicate if none.)

SAFETY PERMIT REQUESTER (Sign and date)	SUPERVISOR OF REQUESTER (Print name, sign and date)	WORK PHONE

NASA TECHNICAL SUPERVISOR (Required if Safety Permit Requester is a contractor. Print name, sign and date)	WORK PHONE	INSTRUCTIONS: Send this request and all supporting documentation to the appropriate Safety Committee Chairperson. Refer to the Lewis Safety Manual, Chapter 1, for additional information

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Appendix E—Continued.

HAZARD CATEGORY	DESCRIPTION OF SPECIFIC HAZARD(S)	DESCRIPTION OF PLANNED HAZARD CONTROLS OR SAFETY PROCEDURES	RISK INDEX
COLLISION		☐ Overspeed Control ☐ Crane Proofloading ☐ Guards ☐ Lockout/Tagout Procedures ☐ Barricade Plan ☐ Blast Shield ☐ Critical Speed Analysis ☐ Triburst Calculations ☐ Other	
CHEMICAL		☐ Ventilation ☐ Detectors ☐ Proper Storage ☐ Personal Protective Equipment ☐ HazCom Training ☐ Proper Labeling ☐ Spill Response Procedures ☐ Respiratory Protection Program ☐ Other	
ELECTRICAL SHOCK		☐ Grounding ☐ Guards ☐ Designed per NEC ☐ Current limiting devices ☐ Lockout/Tagout Procedures ☐ Other	
TEMPERATURE EXTREMES		☐ Temperature Controls ☐ Temperature Alarms ☐ Personal Protective Equipment ☐ Other	

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Appendix E—Continued.

HAZARD CATEGORY	DESCRIPTION OF SPECIFIC HAZARD(S)	DESCRIPTION OF PLANNED HAZARD CONTROLS OR SAFETY PROCEDURES	RISK INDEX
FIRE		☐ Control or Removal of Ignition Sources ☐ Ventilation of Combustion Gases ☐ Over-Temperature Protection ☐ Smoke/Fire Detectors ☐ Fire Suppression ☐ Other	
EXPLOSION/ IMPLOSION		☐ Designed per ASME Boiler & Pressure Vessel Code and LSM Chapter 7 ☐ Temperature Controls ☐ Relief Devices ☐ Detectors ☐ Alarms ☐ Pressure SystemTest per LSM Chapter 7 ☐ Quantity-Distance Calculations ☐ Contamination Control ☐ Barricade Plan ☐ Welding Inspection ☐ Other	
HIGH NOISE		☐ Engineering Controls ☐ Hearing Protection ☐ Barricade Plan ☐ Signs ☐ Hearing Conservation Program ☐ Other	
CORROSION		☐ Corrosion-resistant materials ☐ Other	

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Appendix E—Concluded.

HAZARD CATEGORY	DESCRIPTION OF SPECIFIC HAZARD(S)	DESCRIPTION OF PLANNED HAZARD CONTROLS OR SAFETY PROCEDURES	RISK INDEX
LASER RADIATION		___ Laser Radiation Form ___ Compliance with ANSI Z136.1 ___ Interlocks ___ Annual Eye Exams ___ Shielding ___ Barricade Plan ___ Signs ___ Other	
NUCLEAR RADIATION		___ NRC License Review ___ Radiation Detection Equipment ___ Shielding ___ Barricade Plan ___ Signs ___ Other	
OTHER RADIATION		___ Shielding ___ Barricade Plan ___ Signs ___ Other	
LOSS OF HABITABLE ATMOSPHERE		___ Ventilation ___ Detectors ___ Confined Space Entry Procedures ___ Temperature Control ___ Other	
BIOLOGICAL		___ Personal Protective Equipment ___ Bloodborne Pathogen Program ___ Disposal Methods ___ Other	
OTHER			

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Appendix F
Investigator Timeline Checklist

Test Title: ____________________

Tentative Test Date(s): ____________________

Action	Date Required	Date Accomplished
1. Pre-Buildup Meeting at the Drop Tower	After approval of project	____________
2. Request for Drop Frame from Facility Manager	After approval of project	____________
3. Submit Test Request Memo to Facility Manager (new investigators)	At least six months prior to testing	____________
4. Request Drop Test Dates from Facility Manager (new and ongoing investigators)	At least three months prior to testing	____________
5. Initiate Visitor Request for International Visitors with Technical Monitor	Eight weeks prior to testing	____________
6. Submit Safety Permit Request and Supporting Documentation to Facility Manager	Six weeks prior to testing	____________
7. Inform Drop Tower Staff of compressed gas cylinder requirements	Six weeks prior to testing	____________
8. Schedule Drop Times with Facility Manager	Two weeks prior to testing	____________
9. Initiate Visitor Request for U.S. Citizens with Technical Monitor	One week prior to testing	____________

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13. ABSTRACT ***(Maximum 200 words)***

This document provides guidelines and information for investigators who are planning to perform tests in the 2.2 Second Drop Tower research facility which is operated by the Space Experiments Division of the NASA Lewis Research Center. Included are a description of the Drop Tower and guidelines for experiment planning in the following areas: mechanical, electronics, and instrumentation considerations; documentation requirements; safety permit information; and roles and responsibilities of various NASA personnel. A description of test operations, scheduling, and other logistics is also provided. The nature of the Drop Tower operations, which includes hands-on involvement by research personnel, limited space, sharing of resources, and a high level of activity make it a unique facility in which to work. This document has evolved through a consensus of experienced users and is meant to assist investigators in meeting their requirements.

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