Microgravity Research Competition
Flight to Space and $25,000 Grant

Background Information and
Call for Proposals

Heinlein Prize Trust
January 19, 2009

www.labflight.com

Contents

1 Summary

Microgravity is a unique window on biological and physical processes. Its value has been demonstrated by NASA and international researchers over the past several decades. Examples include:

- Microbes grown in microgravity show unique virulence factors compared to those on Earth, which can help isolate relevant genes and lead to vaccine design.
- Three-dimension tissue specimens grown in microgravity have improved fidelity for pharmaceutical testing.
- Protein crystals grown in microgravity can be superior, thereby enabling successful characterization of target molecule structure for rational drug design.
- Commercially relevant research in material sciences, combustion, metallurgy, and other disciplines has been performed in microgravity.

In the past, it was difficult for the broad research community to access microgravity. In the 2010 timeframe, this is expected to change due to two significant milestones:

- Completion of the International Space Station (ISS)
- Beginning of routine Commercial Orbital Transportation Services (COTS)

Because of limited accessibility, microgravity's benefits are understood by a relatively small segment of the research community. Given that access will soon improve, it is prudent to increase awareness of its applications. In this context, this competition will provide an opportunity to perform innovative research while promoting use of microgravity in a wide range of near-term applications.

The prize offered consists of:

- Flight of an experiment in Earth orbit as early as November 2009
- A grant of $25,000
- A trip for four to see the launch of the winning experiment from Cape Canaveral

The flight is donated by Space Exploration Technologies (SpaceX). The competition is organized by the Heinlein Prize Trust with assistance from the Rice Alliance for Technology and Entrepreneurship. It is open to U.S. universities, colleges, and non-profit organizations with optional industry partners. Notices of intent are requested by February 20 and proposals are due on March 20.

This announcement contains an overview of microgravity applications, information about the competition, and reference material.

2 Practical Applications of Microgravity

We approach a new era of accessibility of microgravity enabling a broader community to conduct leading-edge research. To assist in understanding the potential applications of microgravity, this section reviews several promising applications studied on the International Space Station (ISS), Space Shuttle, Russian Mir, and other spacecraft.

The table at right lists unique aspects of microgravity which can provide significant benefits in academic, commercial, and government research in a wide variety of disciplines. Examples of these applications are discussed below.

Unique aspects of μG

- No sedimentation
- Loss of gravity driven convection
- Decreased hydrodynamic shear
- No hydrostatic pressure
- Mass transfer is limited to the rate of diffusion

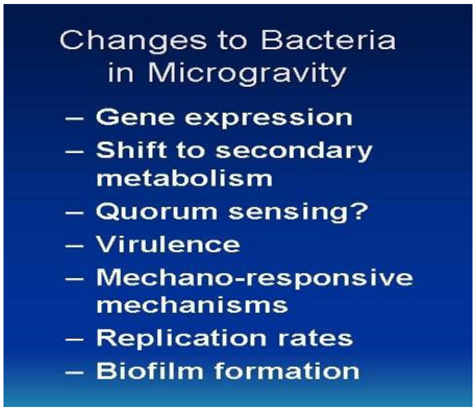
2.1 Biotechnology

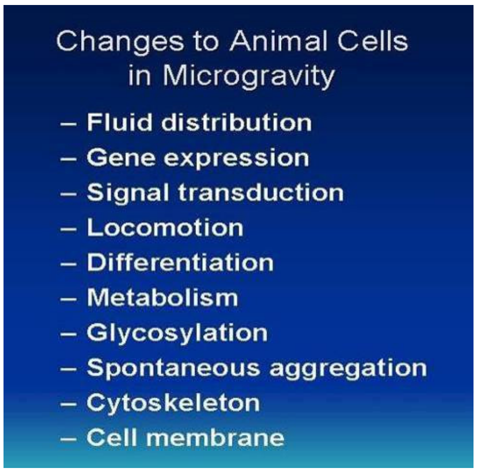
2.1.1 Cell Biology

In biotechnology, particularly in cellular based systems, microgravity has attracted keen interest among nations with space programs. Early findings show opportunities in disease modeling, tissue engineering for research and transplantation, new biopharmaceuticals, vaccine development, propagation of stem cells, and drug testing.

Microgravity provides environmental characteristics which are difficult to obtain on Earth. Using such extreme conditions to investigate life processes affords opportunities for discovery and development of applications which enhance research and the probability for path finding mechanisms in life processes. For example, the elevation of cell culture temperatures brought new concepts to cell biology in the discovery of heat shock proteins and the refined stress response suites observed in gene expression. Indeed, *Thermophilus aquaticus* isolated from marine thermal vents provided the Taq polymerase so critical in molecular genetics advances.

Microgravity thus affords a new window through which to observe life processes. Throughout the evolution on Earth, life has not had to adapt to lowering of the gravitational force. It has been constant for the 4.3 billion years of evolving life. In the short time we have studied microgravity, it is apparent that terrestrial life responds to the physical change in gravity by altering gene expression, inhibiting cellular locomotion, promoting differentiation, and facilitating tissue morphogenesis. Novel adaptational responses have been observed in bacteria, yeast, plants, lower animals, and human cells. Mammalian cells tend to become spherical, alter signal transduction pathways, and produce secretory products. Cells adapt and most survive the transition. In experiments conducted over short durations in microgravity, the changes are





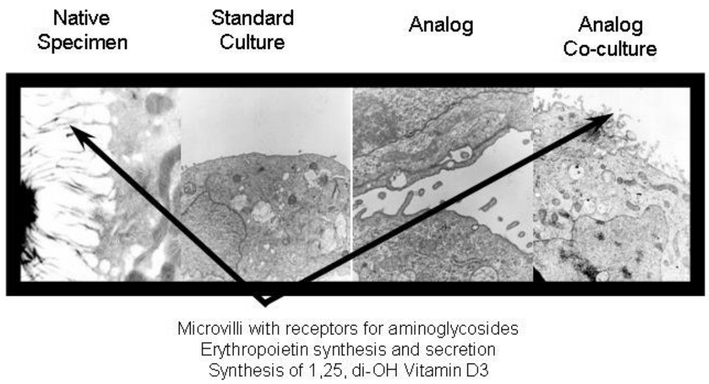
genuinely phenotypic and therefore resolve when returned to 1g. Microgravity is thus a probe which, as with other physical stresses, can reveal novel mechanisms that are fundamental to cell processes, disease process, and the adaptation of living systems to changes in physical forces. Microbial cells do not show the same physical change. Nevertheless, microbes display a profound set of metabolic and genetic changes. No experiments have been conducted for sufficient periods in microgravity to determine if microgravity constitutes a selective pressure leading to emergence of stable genotypic changes.

Parallel emergence of cell culture capabilities in space and the development of a ground-based simulation of some microgravity conditions, has provided the folio of initial observations that spur the interest in the potential for applied research in microgravity. The ground-based Rotating Wall Vessel is an analog culture system which provides a strategy for developing hypotheses and refining protocols for actual flight experiments. To date, there are more than 350 publications on the use of microgravity analogs and microgravity itself in the investigation of mammalian, insect, plant, and microbial cells.

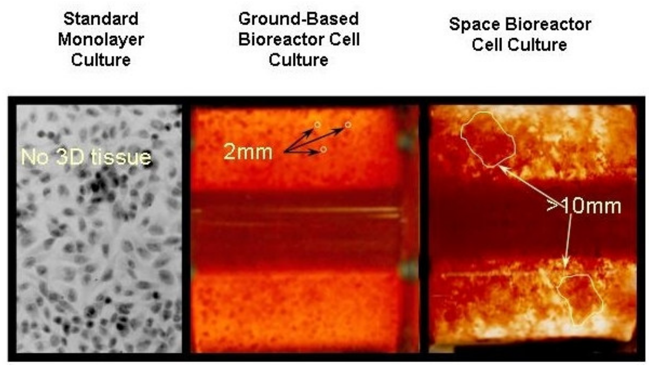
The use of microgravity has driven the development of more autonomous cell culture systems that control pH and other parameters. In these systems, constructs of relatively mature cartilage have been grown continuously for 137 days. The experiment showed the capability of the technology and the ability to promote differentiation and engineer tissue from individual cells. A similar result was reported for human colon carcinoma cells in short term experiments.

The analog system affords insight into the changes in cell products that space may bring to biotechnology. Proximal tubule cells from the kidney are responsible for synthesis of an important hormone in red cell development, erythropoietin, and for synthesis of precursors to vitamin D. The analog system demonstrated in vitro synthesis of native (not recombinant) hormone and vitamin D precursor by living cells.

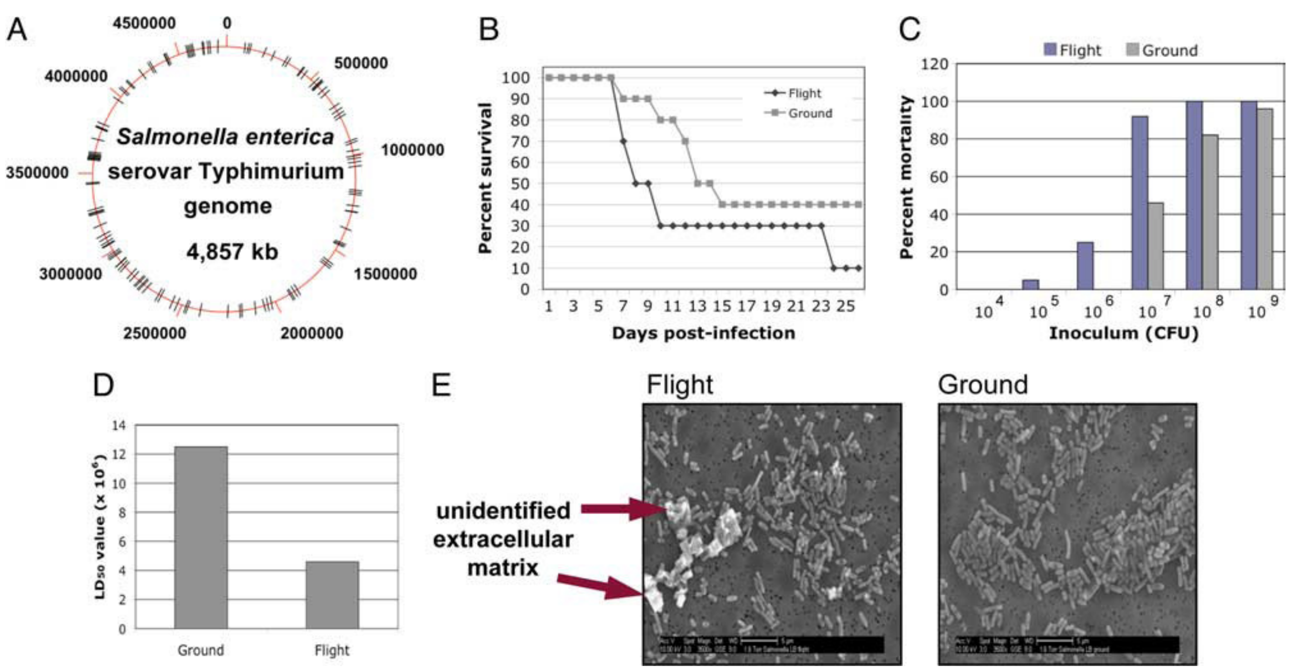
Microbes alter their metabolism in microgravity and produce an array of products which may have commercial value. Additionally, in both the analog and microgravity cultures, microbes increase their intrinsic virulence and produce heretofore unseen mechanisms of virulence. The latter has opened new vistas in vaccine and antibiotic development. For example, *Salmonella* exhibits greater virulence in microgravity, which can aid in developing treatments.



The protozoan *Cyclospora* that causes severe gastrointestinal distress had not been cultured before introduction into analog culture containing small bowel cells. It was the first time that the entire life cycle of the organism was duplicated in culture.



Indeed, microgravity is a provocative environment for terrestrial life systems. Cell culture is easily accommodated and offers promising early applications.



Salmonella Virulence Changes in Microgravity: A-Genes affected by microgravity. B and C-Survival of mice challenged with Salmonella immediately after return from space. D-Number of organisms required to kill half of the challenged hosts. E-Microgravity cell culture induces production of aggregates of organism that secrete biofilm matrix. Wilson et al., 2007, Proc. Natl. Acad. Sci. USA. 104(41):16299-304

2.1.2 Macromolecular Crystal Growth

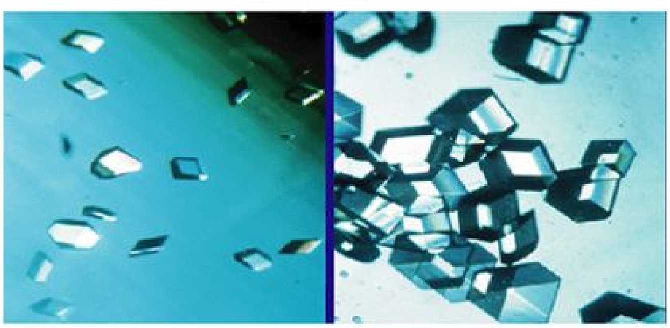
It is widely noted in scientific research that understanding the relevant characteristics and three dimensional structure of a protein enables rational drug design. The biophysical and structural information of a protein supports the development of specific compounds (drugs) that can inhibit, regulate or activate the protein which affects the onset or functions of the disease.

Two types of macromolecular crystal growth experiments have been conducted in space in order to: 1) produce more perfect crystals for the determination of biological structures by x-ray or neutron crystallography and 2) understand the process of crystal growth. The phrase "protein crystal growth" is often used to describe these experiments even though the "proteins" are viruses, DNA, RNA and complexes of these molecules.

The crystallization of biological macromolecules is an empirical science of rational trial and error. It requires decreasing the solubility of the macromolecule until it no longer remains in solution and forms an ordered crystal rather than a precipitate.

Microgravity has been posited as an ideal environment for biological crystal growth since buoyancy driven convection and sedimentation are greatly reduced. As a result, effects that were previously masked can dominate the crystal growth system, e.g., Marangoni convection, and provide unique opportunities to study the crystal growth process.

Protein Crystal Recombinant
Human Insulin



1g μg

Microgravity crystal growth experiments can be small and simply operated yet have a high scientific impact. For this reason, several nations have performed crystal growth experiments in space. The ability to perform several iterations of crystal growth in microgravity yielded more perfect crystals.

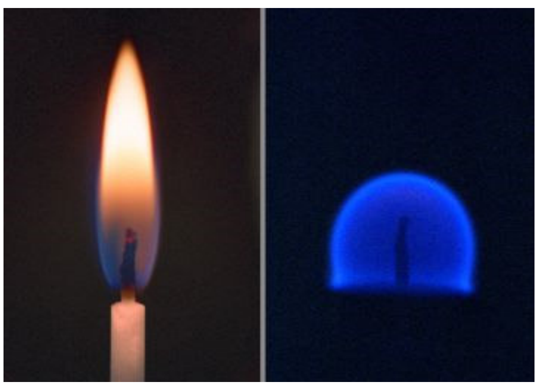
Experiments that study the process of crystal growth are needed to establish the precise relationship between acceleration levels, depletion zones, crystal growth rates, and crystal diffraction quality. Such experiments will advance our understanding of crystal growth, a worthwhile aim in itself, but also needed to make the best use of microgravity.

2.1.3 Micro-Encapsulation

Microgravity research has helped develop microcapsules that are significantly larger and carry more drug than those produced on Earth. A single step process forming tiny liquid-filled, biodegradable, micro-balloons containing various drug solutions has been shown to provide better drug delivery and new medical treatments for solid tumors and resistant infections. Testing in mouse models has shown that these unique microcapsules can be injected into human prostate tumors to inhibit tumor growth or can be injected following cryo-surgery to improve the destruction of the tumors much better than freezing or local chemotherapy alone. The microcapsules can contain a contrast agent that enables C-T, x-ray, or ultrasound imaging to monitor the distribution within the tissues to ensure that the entire tumor is treated. Further experiments could lead to development of anti-tumor drugs which allow the delivery of higher doses of chemotherapeutic agents to specific treatment sites, reducing unwanted side effects.

2.2 Combustion

Combustion plays a major role in the world's economy and environment. Microgravity combustion research offers the potential to produce fundamental knowledge that can be used in developing accurate simulations of complex combustion processes and allowing developers to improve the efficiency of combustion devices, to reduce the production of harmful emissions, and to reduce the incidence of accidental uncontrolled combustion.



The effects of gravitational forces on Earth impede combustion studies more than they impede most other areas of science. Combustion intrinsically involves the appearance of high-temperature gases whose low density triggers buoyant motion under normal gravity conditions, vastly complicating the execution and interpretation of experiments. The effects of buoyancy (proportional to gravity level) are so ubiquitous that we often do not appreciate the enormous negative impact that they have on the rational development of combustion science. Microgravity offers potential for major gains in combustion science understanding in that it offers unique capability to establish the flow environment rather than having it dominated by uncontrollable buoyancy effects, and through this control extend the range of test conditions.

Potential areas of microgravity combustion research include flammability and stability limit phenomena; improved kinetics; flame structure and elementary mechanisms; combustion synthesis and catalysis of materials; fundamental benchmark data; thermophysical properties determination; process transitions, turbulence, and pattern formation; and micro-combustion-based power systems.

2.3 Materials

A key opportunity of microgravity materials science research is to gain a better understanding of how gravity-driven phenomena affect solidification and crystal growth. Buoyancy-driven convection, sedimentation, and hydrostatic pressure can create irregularities in internal structures. Microgravity allows researchers to study underlying events free from these effects. For example, microgravity provides an excellent window on segregation and containerless processing.

Materials science research in microgravity can lead to a better understanding of how materials are formed and how the properties of materials are influenced by their formation. Improved knowledge of the physics and chemistry of phase changes from microgravity experiments could improve design of process-control strategies. Microgravity may permit production of materials of high-quality or unique properties for use as benchmarks.

Microgravity provides insight into influences in the crystallization process as well as production of low-defect crystals for semiconductor and other applications. Microgravity can discover ways to control the processing of ceramics to prevent imperfections for improved optical fibers, higher reliability turbines, and bioceramics.

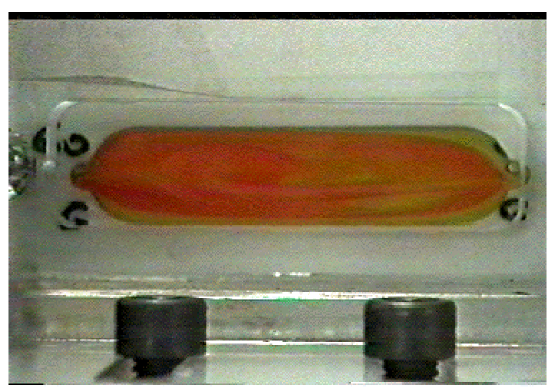
By removing the influence of buoyancy-driven convection, scientists can more closely observe influential processes during solidification of metals and alloys. Some alloys that are difficult or impossible to produce on Earth can be made in microgravity. For example, a company used microgravity to understand the properties of steels with high carbon content. Another area of interest is multiphase solidification of eutectics and monotectics.

Manipulation of polymer bonds under microgravity conditions may lead to the development of processes to produce polymers with more uniform and controlled properties, for potential optoelectronic and photonic applications. Crystallinity in particular may be more easily understood and controlled when removed from the influence of gravity.

2.4 Fluid Physics

Microgravity offers a unique perspective on fluid physics with broad potential Earth applications in such varied areas as energy, agriculture, and manufacturing.

Phase transitions of colloids are easier to observe in microgravity. Foams, which are particularly sensitive to gravity, are more stable in microgravity. In magneto-rheological fluids in 1g, the magnetic particles often fall out of suspension due to sedimentation, but in microgravity this does not occur. Investigations of the behavior of granular systems are likewise more feasible in microgravity. Microgravity can also be used to better understand processes such as boiling, steam condensation, and diffusive transport.



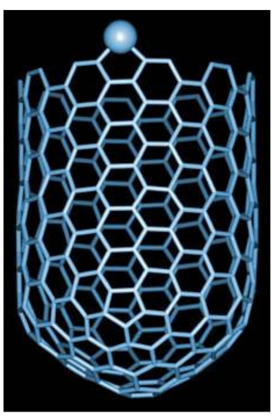
Mixing in μg

Microgravity provides an opportunity to better understand interfacial phenomena, such as the wetting and spreading of immiscible liquids or the spreading of fluid across a solid surface. In reduced gravity, wetting determines the configuration and location of fluid interfaces, thus greatly influencing, if not dominating, the behavior of multiphase fluid systems. Microgravity also allows unique investigation of surface tension forces that are masked in 1g, as well as drop dynamics, capillarity, and magneto/electro-hydrodynamics.

2.5 Nanotechnology

The following phenomena, processes and procedures investigated in the context of microgravity research are relevant for nanotechnological developments:

- Obtaining exact data for the optimization of process technologies in gas phase synthesis of nanopowders and particles.
- Investigation of particle-particle/gas interactions concerning the aggregation in high vacuum, in sprays, in flames and in plasmas.
- Investigation of the formation and stability of nanoemulsions.
- Investigation of thermal transportation phenomena in magnetic liquids.
- Self-organization phenomena.
- Advancement of analytical devices (nano/micro system engineering, lab-on-a-chip systems or laser-optical procedures).



Apart from basic research in fundamental and plasma physics, application-orientated questions like particle coating, the production of nanoporous materials or the optimization of plasma processes in semiconductor industries, can also be examined with the experimental set-up in principle. It is expected that knowledge about complex plasmas obtained in microgravity research will contribute to the optimization of industrial terrestrial plasma processes.

Application fields may include the coating of pharmaceutical drugs and surface refinement in semiconductor technology. Also, the formation of nanoscale carbon structures by electrical arc discharge plasma synthesis has already been investigated in microgravity experiments by NASA. Furthermore, complex plasmas are relevant for processes in which a particle formation is to be prevented, if possible, as, for example, within plasma etching processes for microchip production.

3 Microgravity Research Competition

This section describes this Microgravity Research Competition, defining the award, who can submit, proposal content, deadlines, and selection process.

3.1 The Award

The winner shall receive the following.

1) **Flight of Experiment in Microgravity in Earth Orbit** – An experiment that is provided by the winner will be launched by SpaceX, tentatively on its second COTS demonstration flight (C2), currently scheduled for November 2009. This will be a "free flier" in low-Earth orbit (LEO); it will not go to ISS. It will provide ample periods and levels of microgravity to accommodate a wide range of applications. The experiment, which must meet the requirements of section 4.1, will be launched inside the pressurized Dragon spacecraft by a Falcon 9 launch vehicle from Cape Canaveral, Florida. The spacecraft is planned to orbit for 4.5 days, splash down off the California coast, and be recovered. The experiment will be available to the winner one week after splashdown.

2) **Grant** – The winner will receive a grant of $25,000.

3) **Launch Event** – Four winner representatives will be provided air travel and hotel accommodations to see the SpaceX launch of their experiment in Florida.

4) **Publicity** – The organizers will publicize winner selection and the launch viewing event. The winner is welcome to join in media relations activities.

3.2 Eligibility

Proposing organizations shall be accredited U.S. universities and colleges or other IRS-approved 501(c)(3) U.S. non-profit organizations. The proposing organization can have partners including industry. The Principal Investigator must be a full-time employee of the proposing organization and the experiment must be substantially supported by its staff, students and facilities.

3.3 Proposal Content

Proposals shall have the following sections and total no more than 25 pages (not including appendix) and use 12-point font. Guidelines for section length are given. The content of sections 1) and 2) shall be publicly releasable.

1) **Cover Sheet** – Name of the proposing organization; title of the proposal; Principal Investigator name, email, and phone; and proposal summary of 300 words or less. This shall be the cover sheet. (1 page)

2) **Key Personnel and Partner Information** (1-2 pp.)

   a. Names, roles, and contact information of key personnel

   b. Identification of participating organizations and description of their roles.

3) **Experiment Objective** – Describe scientific basis for the experiment (2-5 pp.)

4) **Commercial Potential** (2-5 pp.)

   a. What is the commercial potential of this research? What are the potential applications? What are the potential benefits?

   b. What are the planned pathways to commercialize this technology? Identify potential partners, including their roles and status on this project if any. What resources may be needed to commercialize this after this flight and what are the potential sources?

   c. Describe any additional work in microgravity (after this flight) that may be required to complete this research or to commercialize this technology.

   d. What are the status and plans for intellectual property used or created?

5) **Experiment** (3-6 pp.)

   a. Provide an overview of the experiment design and operation.

   b. If designed in-house, provide preliminary engineering sketches.

   c. If from an outside source, provide a letter of intent from the provider of the hardware to allow its use on this flight.

   d. What are the samples, materials, tissues, to be flown? What are the preparatory steps? What will take place during experiment operation in microgravity? What post-flight analyses are planned?

   e. List all pressure vessels to be flown. Identify any potential hazards to ground personnel and any pre- or post-flight handling requirements.

6) **Project Plan** – Provide a schedule and budget for the project (2-3 pp.)

7) **Data Restrictions** – State whether any of sections 3 through 6 and the appendix may be publicly released. (1 page)

8) **Appendix** – C.V. of all key personnel listed in section 2.

3.4 Proposal Submission and Deadlines

Potential respondents are requested to submit a notice of intent to compete by February 20, 2009. This notice should be submitted online at www.alliance.rice.edu/spaceprize. It should include the PI name, title, organization, and contact information (email, phone, and physical address); and a maximum 300-word non-confidential summary of the forthcoming proposal.

The full proposal is due on **March 20, 2009 at 5:00 pm Central Time**. It shall be emailed to Sheethal.Lankipalle@rice.edu in a single PDF document. The sender will receive an email acknowledgement of receipt by March 23, 2009.

3.5 Selection

Proposals will be evaluated by a panel of judges selected by the Heinlein Prize Trust. Members of the panel will include experts in relevant research disciplines, spaceflight, and commercialization. Selection criteria are:

1) **Meritorious Research**
   - Sound research and meritorious science
   - Utilization of microgravity
2) **Feasible Experiment**
   - Experiment design consistent with the accommodations and flight opportunity provided
   - Feasible project plan
3) **Commercial Potential**
   - Likelihood and consequence of commercialization

On April 3, the top three proposals will be announced as finalists. By April 7 at 5:00 pm CT, each finalist shall identify the names of two participants who will travel to Houston to present their proposal in the final round of competition at Rice University. It is recommended that the PI be one of the two. (More than two team members can attend the presentation, but only the two identified shall present to the judges.)

Finalists will present their proposals to the judges on April 17 at the Jesse H. Jones Graduate School of Management of Rice University in Houston. Air transportation and hotel accommodations for the two presenters per finalist shall be provided.

During the evening of April 18, the winner will be announced at the awards banquet for the 2009 Rice University Business Plan Competition hosted by the Rice Alliance for Technology and Entrepreneurship. Two members of each finalist team will be provided complimentary admission to the awards banquet (business attire). At least one representative must be present to win.

3.6 Additional Information

For questions about the competition, the prize, judging criteria, and the content of submissions, please contact Sean Thompson, Heinlein Prize Trust, sean.thompson@dula.com, 713-861-3600**.**

For questions about the online submission process, please contact Sheethal Lankipalle, Rice Alliance for Technology and Entrepreneurship, Sheethal.Lankipalle@rice.edu, 713-348-3622.

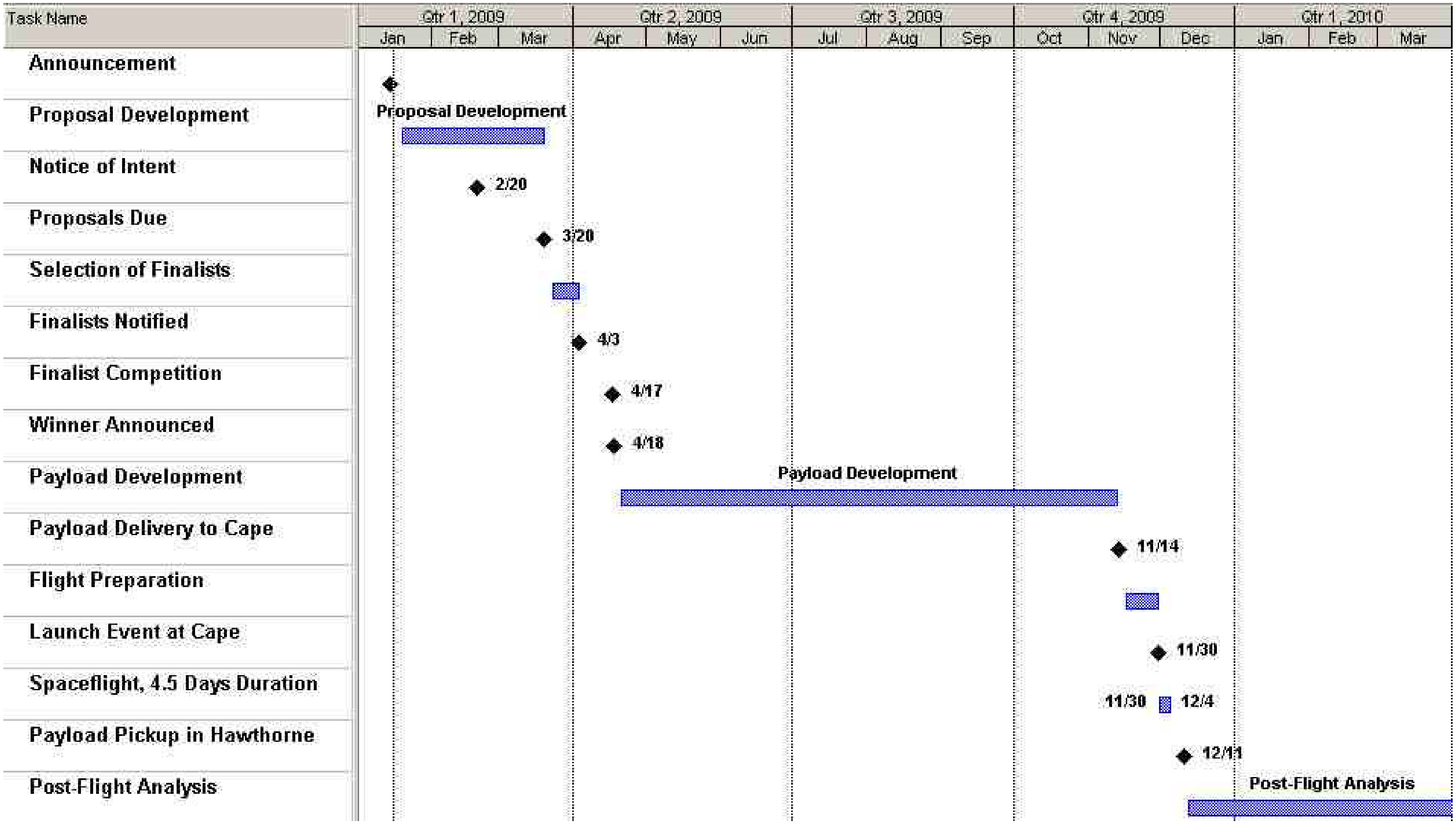
The winner and the Heinlein Prize Trust will enter into an agreement outlining terms and conditions associated with the launch. Terms are expected to include:

- The proposer retains all intellectual property rights resulting from its experiment.
- Competition organizers, sponsors, and contractors shall not be liable for any loss or damage to the experiment hardware.
- The experiment hardware may not fly if it does not meet schedule or technical requirements.
- SpaceX reserves the right to fly the winning payload on a subsequent mission instead of the C2 COTS Demo flight.
- If the flight fails in any way, the organizers shall not be obligated to provide another flight opportunity.

This competition is neither organized nor endorsed by NASA.

3.7 Schedule

The overall schedule for the competition is depicted below. The launch date is tentative.

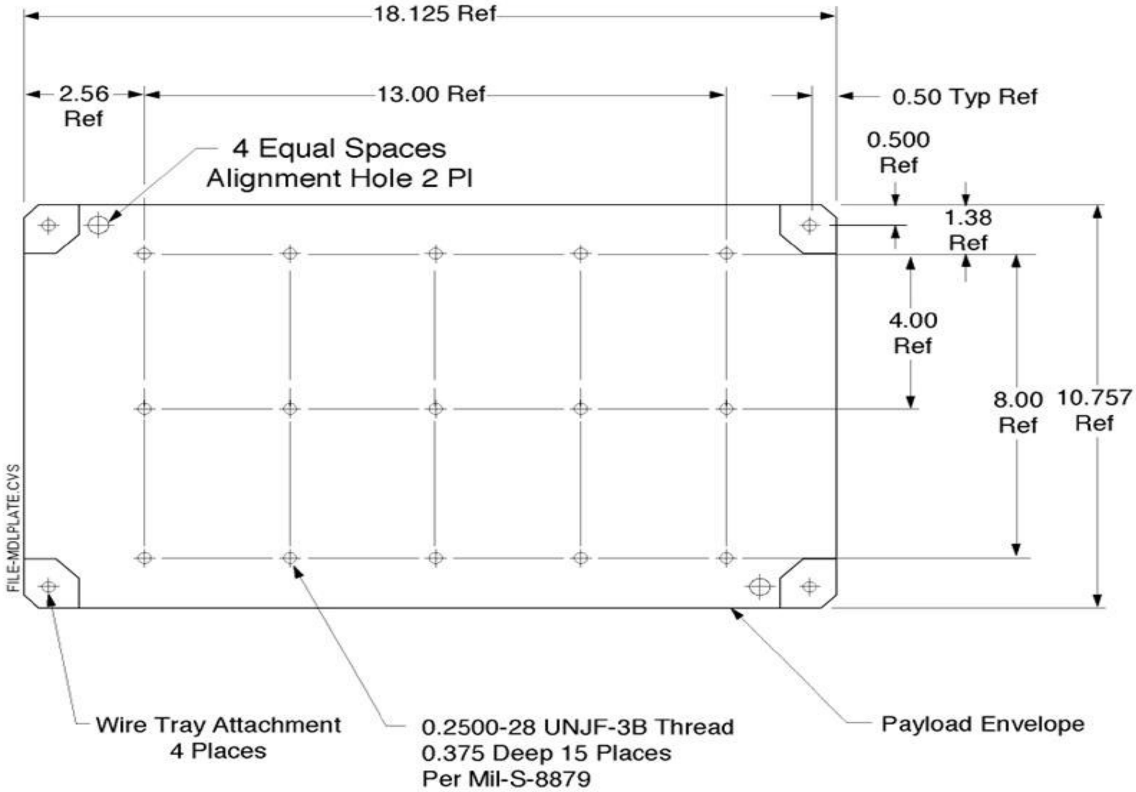


4 Reference Information

4.1 Technical Requirements for this Flight

The table below defines the accommodations provided to the winner's experiment on this flight. It should be noted that these are the accommodations on an early demonstration mission of the Dragon spacecraft; future operational missions will provide more flexible and robust accommodations.

Experiment Accommodation	
Volume	The experiment shall fit within the envelope of a standard single Shuttle Middeck Locker (shown in the diagram below with a maximum height of 22 inches), although minor deviations from this standard form factor will be considered.
Mass	Maximum mass of 32 Kg including any locker or chassis.
Power	Continuous unregulated power of 18-36 VDC shall be available during installation for check-out, on the launch pad, throughout the flight, and during splashdown. There is no power for up to 14 days from installation until day of launch, or for up to 7 days from landing to return. (The experiment can have batteries for use during those periods.) Optionally, power can be activated at a fixed time after launch and switched off prior to return. Information on the power connector will be provided.
Data	There will be no data interfaces with the experiment.
Crew	There will be no crew, so the experiment must be automated.
Mechanical	The experiment shall mount on the plate depicted below. All dimensions are in inches.
Thermal	The experiment shall convectively cool to cabin air. This may require a fan to ensure circulation, as there is no convection in microgravity. Cabin air shall be 10-46^{O}C, 25-75% relative humidity, and pressure 13.9-14.9 psia.
Pre-flight	The experiment shall be delivered to SpaceX in Cape Canaveral, FL 16 calendar days before launch. Integration into the spacecraft will occur two days later. No late access is allowed.
Post-flight	The experiment shall be available from SpaceX in Hawthorne, CA 7 days after splashdown.



4.1.1 Microgravity Environment

The on-orbit microgravity environment will nominally be in the 10^{-5} g range. However, orbital maneuvers and attitude adjustments will cause disturbances of various magnitudes and durations.

The spacecraft will cycle through certain operational modes over the course of the 4.5-day mission. The initial approximately 60 hours of the approximately 110-hour mission will involve orbital maneuvers and attitude variations affecting the microgravity. Maximum linear accelerations during this phase are in the 0.04 g range. This is followed by approximately 15 hours of advanced spacecraft checkouts during which only attitude adjustments are planned. The table below provides expected acceleration envelopes during this relatively quiescent phase of the mission. The final approximately 35 hours of the mission involve de-orbit preparations and execution.

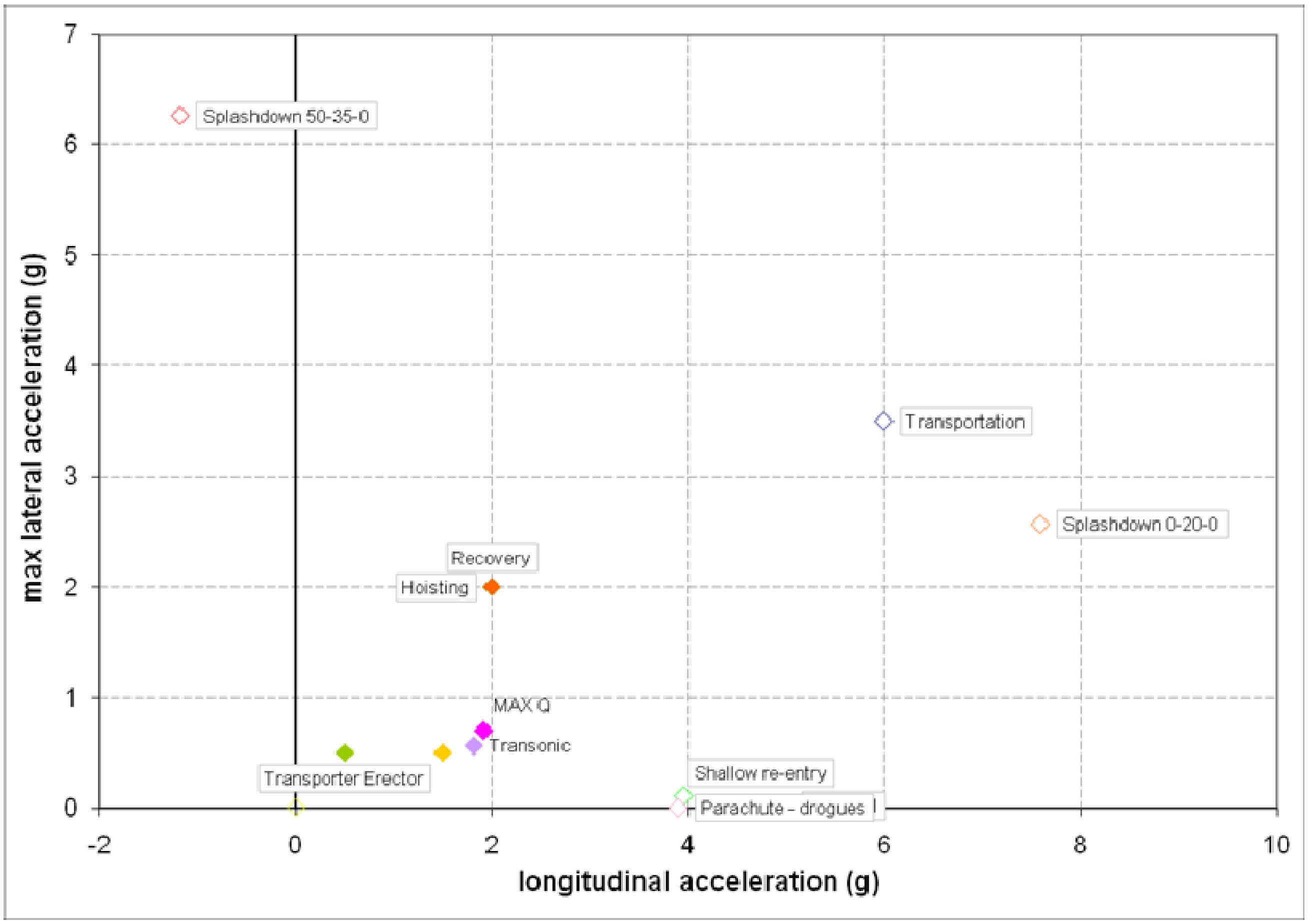
g	Below this value…
1.0E-01	At all times while in orbit
6.0E-03	Exceedance twice per orbit
1.0E-04	Exceedance once per 20 s for less than 250 ms
1.0E-06	-

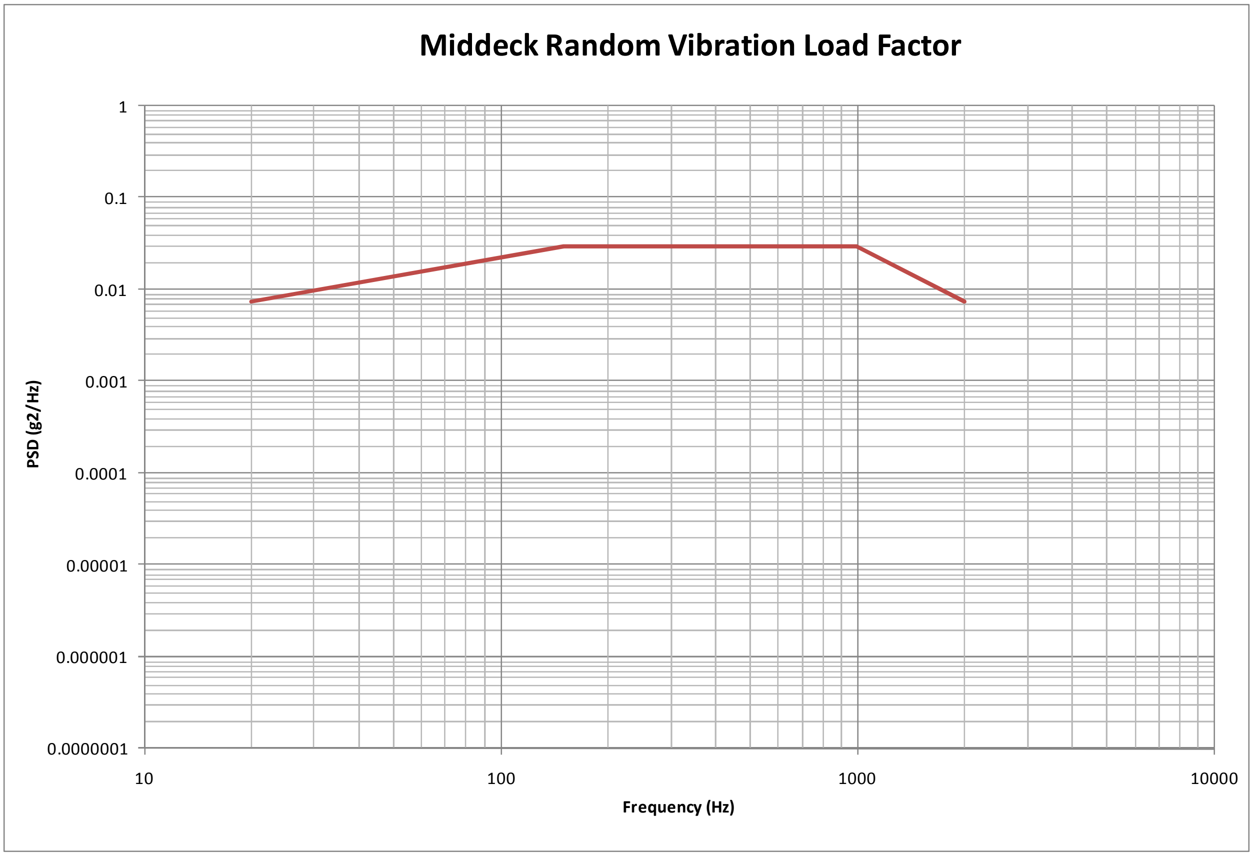
Experiments can be executed at any time during the mission although the advanced checkout phase will provide the optimal period of microgravity.

4.1.2 Structural and Dynamic Environments

In general, the Dragon spacecraft will provide payload environments which are consistent with those of the Space Shuttle middeck. However, the dynamic environment experienced by a specific experiment is a function of the mass of the experiment itself, its location in the spacecraft, the specific mechanical mounting scheme, and the total mass of payloads in the spacecraft. For this reason, a coupled loads analysis is typically performed once all these parameters are defined to provide realistic values for a specific payload.

The figure below plots major accelerations expected at various times. Two splashdown points indicate the range of possible accelerations depending upon splashdown conditions. On the following page is a plot of vibration load factors. These provide the expected dynamic envelop for the purposes of experiment design. SpaceX will work with the winning institution to define the expected environments further. Mounting fixtures may incorporate vibration isolation if necessary to attenuate undesirable vibration and shock.





4.2 *Experiment Hardware*

The interface provided by SpaceX will accommodate a single middeck locker, a standard container used on the Space Shuttle. Although existing middeck locker or other hardware might be available, a simple solution designed and built in-house can also be considered. In either case, the experiment must verifiably comply with the above technical requirements, with verification per MIL-STD-1540D (available from store.mil-standards.com), to preclude damage to the Dragon spacecraft.

For organizations desiring technical assistance or considering use of existing hardware, listed below are several independent organizations which have developed and integrated microgravity payloads. Please note that there is no guarantee that any services and hardware are available and that these organizations may request funding for their assistance.

BioServe Space Technologies, Boulder, CO

- Contact: Louis Stodieck, stodieck@colorado.edu
- Web Site: www.colorado.edu/engineering/BioServe
- Potentially Available Hardware

- Fluids Processing Apparatus
- Group Activation Pack
- Isothermal Containment Module
- Small Habitats (Nematode, cell culture, plant development, butterfly, spider, and silicate garden habitats)
- Camera Modules
- Gas-Exchange Fermentation Apparatus
- Illuminated Culture Vessel
- BioServe Culture Apparatus
- Isothermal Containment Module

SPACEHAB, Houston, TX

- Contact: John Porter, jporter@spacehab.com
- Web Site: www.spacehab.com
- Potentially Available Hardware
  - SPACEHAB Locker (mates directly to Dragon interface plate)
  - Bags, custom foam inserts

Center for Biophysical Sciences and Engineering (CBSE), Birmingham, AL

- Contact: Lee Moradi, moradi@uab.edu
- Web Site: www.cbse.uab.edu
- Potentially Available Hardware
  - Microgravity Experiment Research Locker Incubator
  - High Density Protein Crystal Growth
  - EXPRESS Air Generic Locker Equivalent
  - Protein Crystallization Facility
  - Video Control and Monitor System
  - Commercial Refrigerator Incubator Module (Modified)

Techshot, Greenville, IN

- Contact: Paul Todd, ptodd@techshot.com
- Web Site: www.techshot.com/sol_spaceflighthardware.html
- Potentially Available Hardware
  - Avian Development Facility
  - Advanced Space Experiment Processor

- CellCult Automated Cell Culture System

Paragon Space Development Corp., Tucson, AZ

- Contact: Grant Anderson, ganderson@paragonsdc.com
- Web Site: www.paragonsdc.com
- Potentially Available Hardware
    - T-Cell Growth System
    - Autonomous Biological System

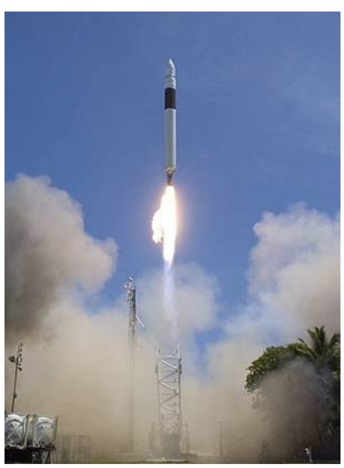
4.3 Future Access to Microgravity

This competition aims to increase awareness among the research and development community of the practical applications and accessibility of microgravity. In that context, this section provides an overview of significant NASA and private-sector initiatives to make microgravity more accessible. Researchers can consider using commercial transportation to Earth orbit, a commercial "free flier" for automated experiments in orbit, and impressive human-operated laboratory capabilities of ISS. Microgravity for short durations is also available using drop towers, parabolic airplane flights, and suborbital flights. For more information on ways to "remove gravity" in your research, please see www.labflight.com.

4.3.1 Commercial Orbital Transportation Services

NASA is providing significant financial resources to stimulate the development of commercial space transportation which can provide routine access to microgravity. NASA's Commercial Orbital Transportation Services (COTS) initiative has two phases:

- Phase 1 – NASA is providing $500M for development and demonstration of commercial cargo services to LEO. It is funding cargo demonstrations of two companies, SpaceX and Orbital Sciences Corp., under Space Act Agreements.
- Phase 2 – NASA recently awarded these companies up to $3B in contracts for commercial resupply services for the ISS.



SpaceX is an entrepreneurial firm which is developing the Falcon family of launchers. Under COTS, SpaceX is building the Falcon 9 launcher and Dragon spacecraft to deliver cargo to ISS and return cargo to Earth. It plans three demonstrations culminating in a mission to ISS in 2010. The winner's experiment is tentatively scheduled to fly on the second SpaceX COTS demonstration mission (C2).

For more information on COTS, please see www.nasa.gov/offices/c3po/home.

4.3.2 International Space Station

The ISS, planned for assembly completion in 2010, is a unique partnership between the U.S., Russia, European Space Agency, Japan, and Canada. It is the largest facility ever built in space. It has a full-time crew of six and robust capabilities for microgravity research, including bioreactors, freezers, glove boxes, and special-purpose facilities. Examples include:

- Combustion Integrated Rack includes an optics bench, combustion chamber, fuel and oxidizer control, and five cameras.
- Fluids Integrated Rack hosts investigations in colloids, gels, bubbles, wetting and capillary action, and phase changes.
- Commercial Generic Bioprocessing Apparatus provides programmable, precision temperature control, from cold stowage to a customizable incubator, for experiments on cells, microbes, and plants.

For more information on using ISS, please see www.nasa.gov/iss-science.

4.3.3 Commercial Free Flier

In addition to taking experiments to ISS, SpaceX plans to fly experiments on its DragonLab missions beginning in late 2010. The DragonLab is a version of its Dragon spacecraft which would orbit Earth and return. For DragonLab specifications, see www.spacex.com/DragonLab_DataSheet.pdf.

4.4 *References on Microgravity Applications*

There have been numerous publications on research in microgravity. The following may be useful starting points:

1. A Strategy for Research in Space Biology and Medicine in the New Century. Committee on Space Biology and Medicine; Space Studies Board; Commission on Physical Sciences, Mathematics, and Applications; National Research Council. National Academy Press, Washington, D.C., 1998.
2. Cogoli, A. Strategies of Cell Biology Experiments in Space. J. Gravit. Physiol. 11:111-116, 2004.
3. Walther, I and Cogoli, A. Space Biology Group: Basic Research, Biotechnology, Tissue Engineering, and Instrument Development. Chimia 57:321-324, 2003.
4. Cell Growth in Microgravity, Sundaresan, A. et al., Encyclopedia of Molecular Cell Biology and Molecular Medicine, Volume 2, Wiley-VCH, 303-322, 2004.
5. Kundrot et al, “Microgravity and Macromolecular Crystal Growth”, Crystal Growth and Design, 1, 87-99, 2001
6. Lorber, “Crystallization of biological macromolecules under microgravity: a way to more accurate three-dimensional structures?”, Biochimica et Biophysica Acta, 1599, 1-8, 2002

The web site, www.labflight.com, provides information about microgravity applications and access, as well as news regarding this competition.

4.5 *Competition Organizers*

This competition is organized and sponsored by the Heinlein Prize Trust, a non-profit foundation which promotes the commercial uses of space. It provides financial prizes to commercial space entrepreneurs, enhances public awareness of commercial space, and uses space to inspire students about opportunities of the next frontier. For more information, see www.heinleinprize.com.

Space Exploration Technologies (SpaceX) is an entrepreneurial provider of space transportation services to world markets. NASA has awarded SpaceX a $1.6B contract to transport cargo to and from the International Space Station. SpaceX previously won a $278M Space Act Agreement with NASA to develop and demonstrate space transportation to LEO. SpaceX is developing the Falcon family of low-cost launch vehicles, the Dragon spacecraft to carry cargo to and from LEO and ISS, and the DragonLab free-flier. For more information, visit www.spacex.com.

Assisting the Heinlein Prize Trust in organizing the competition is the Rice Alliance for Technology and Entrepreneurship. The Rice Alliance is a non-profit organization and part of Rice University in Houston, Texas. The mission of the Rice Alliance is to support the commercialization of technology innovations and the launch of new technology-based start-up companies. (Rice Alliance and Rice University have no role in selecting judges, finalists, or winner of this competition.) For more information about the Rice Alliance, see www.alliance.rice.edu.

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For further information on this competition, please contact Sean Thompson of the Heinlein Prize Trust at sean.thompson@dula.com or 713-861-3600 or visit www.labflight.com.