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NEXT-GENERATION SUBORBITAL RESEARCHERS CONFERENCE

February 18–20, 2010 • Boulder, Colorado

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PREFACE

This volume contains abstracts that have been accepted for presentation at the meeting on Next-Generation Suborbital Researchers Conference, February 18–20, 2010, Boulder, Colorado.

Administration and publications support for this meeting were provided by the staff of the Publications and Program Services Department at the Lunar and Planetary Institute.

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Sirangelo M. N.
Commercial Spaceflight Federation, Chairman of the Board

Tarantino F. A.
Universities Space Research Association, President and CEO

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Garver L.
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Worden S. P.
NASA Ames Research Center, Center Director

Nield G. C.
Federal Aviation Administration, Associate Administrator

Stern S. A.
Southwest Research Institute, Associate Vice President and
Suborbital Applications Researchers Group, Chair

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Thursday, February 18, 2010
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10:30 a.m. Canyon/Flagstaff

This session will review the capabilities of various next-generation suborbital launch systems, with an emphasis on their capabilities and plans for carrying out research and education missions.

Chair: Alan Stern

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Stern S. A.
Southwest Research Institute, Associate Vice President

Sirangelo M. N.
Commercial Spaceflight Federation, Chairman of the Board

Worden S. P.
NASA Ames Research Center, Center Director

Attenborough S.
Virgin Galactic, CEO

Greason J.
XCOR Aerospace, President

Thursday, February 18, 2010
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Moderators: Dan Durda
Erika Wagner

Panel Participants

Stern S. A.
Southwest Research Institute, Associate Vice President

Cagle Y. D.
NASA Ames Research Center, Project Scientist and former NASA Astronaut

Davidian K.
Federal Aviation Administration, Program Lead

Durrance S. T.
Florida Institute of Technology, Professor of Physics and former NASA Payload Specialist

Thursday, February 18, 2010
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Col R. A. Searfoss
Chief test pilot for XCOR Aerospace and former Space Shuttle Commander

Chaikin A.
Author, Speaker, Space Journalist

Question and Answer

Friday, February 19, 2010
ASTRONOMY, SOLAR PHYSICS, AND PLANETARY SCIENCE SESSION I
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Chair: **Dan Durda**

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Chair: **Steven Collicott**

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ON DEPLOYABLE VEHICLES SESSION I
8:00 a.m. Century Room

This session addresses the use of suborbital vehicles for the development of new technologies and for the study of physical phenomena through on-board experiments and off-board experiments on deployable vehicles.

Chair: **Richard Miles**

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This session will provide an overview of the various astronomical sciences applications for Next-Gen suborbital research.

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The next generation of suborbital vehicles will provide an unprecedented platform for observations of the mesosphere, lower thermosphere and ionosphere.

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Suborbital flight will provide a unique opportunity for investigating the reaction of living systems to altered gravity; research applications include operational, applied, and basic investigations.

Chairs: **Mark Shelhamer**
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This session will provide a forum for exploring ideas on educating and exciting students and the general public about suborbital science.

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TECHNOLOGY PAYLOADS AND SYMPOSIUM
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2:00 p.m. Century Room

This session addresses the use of suborbital vehicles for the development of new technologies and for the study of physical phenomena through on-board experiments and off-board experiments on deployable vehicles.

Chair: **Richard Miles**

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Moderator: Charles Miller

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LIFE SCIENCES SESSION II
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Suborbital flight will provide a unique opportunity for investigating the reaction of living systems to altered gravity; research applications include operational, applied, and basic investigations.

Chairs: **Erika Wagner**
Mark Shelhamer

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10:00 a.m. Coffee Break

Saturday, February 20, 2010
MICROGRAVITY PHYSICS SESSION II
8:30 a.m. Canyon Room

The talks in this session focus on microgravity as a "laboratory". That is, topics in which the absence of gravitational body force enables unique investigations of physical phenomena.

Chair: **Steven Collicott**

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10:00 a.m. Coffee Break

Saturday, February 20, 2010
ATMOSPHERIC, IONOSPHERIC AND AURORAL SCIENCE SESSION II
8:30 a.m. Century Room

The next generation of suborbital vehicles will provide an unprecedented platform for observations of the mesosphere, lower thermosphere and ionosphere.

Chairs: **Michael Summers**
Christoph Englert

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Saturday, February 20, 2010
PANEL DISCUSSION WITH AUDIENCE QUESTION AND ANSWER:
DESIRED NEXT-GEN VEHICLE ATTRIBUTES
FOR RESEARCH AND EDUCATION MISSION
10:30 a.m. Canyon/Flagstaff

Moderators: Alan Stern
Yvonne Cagle

Panel Participants

Lai G.
Blue Origin, New Shepard Project

Mealling M. H.
Masten Space Systems, CFO and Vice President of Business Development

Vozoff M.
SpaceX DragonLab, Director of Civil Business Development

Sowers G.
United Launch Alliance, Vice President

Attenborough S.
Virgin Galactic, Commercial Director

McKee K.
XCOR Aerospace, Program Manager

Saturday, February 20, 2010
CLOSING SESSION
11:30 a.m. Canyon/Flagstaff

Chair: **Dan Durda**
Wayne Hale

Invited Speakers

Stern S. A.
Southwest Research Institute, Associate Vice President

Chaikin A.
Author, Speaker, Space Journalist

Sirangelo M. N.
Commercial Spaceflight Federation, Chairman of the Board

MAGNETIC BRAKING AND HEAT SHIELD RESEARCH WITH A CAPSULE-TYPE REENTRY BODY.
T. Abe, Institute of Space and Astronautical Science, Yoshinodai 3-1-1, Sagamihara, Kanagawa 229, Japan, tabe@gd.isas.jaxa.jp).

For the reentry body, the aerodynamic heating is the biggest challenge and must be managed somehow. Currently the thermal protection system composed of heat resistant tile and so on is employed for this purpose. The electrodynamic heatshield technique which employs a strong static magnetic field around a reentry body of high speed flight is a promising technique to reduce the heating itself during an atmospheric flight. This can be realized as a result of the interaction between the magnetic field and the weakly ionized flow generated around the vehicle. Through this interaction, the body force due to the Lorentz force acts on the flow directly and enables us to control it. In return, the reaction of the body force affects the vehicle trajectory or its attitude. Because of those expected performances of the technique, the electrodynamic heatshield technique may be able to replace the current heatshield system. In addition, the technique may provide us a way to maneuver the vehicle trajectory and the vehicle attitude without moving parts such as aerodynamic control surfaces.

So far, much research effort has been devoted to realize this technique. The research includes the basic investigations by not only experimental but also numerical methods. For the experimental investigation, several facilities such as arc-jet wind tunnel, shock-tunnel and expansion tube have been utilized to make the flow condition close to the flight condition as much as possible, and the results obtained have successfully verified the technology[1]. For the numerical investigation, detailed investigations have been done and verified that the electrodynamic heat shield technology is reasonably effective in the flight condition from LEO for instance[2]. Furthermore, it was shown that this technique can be applicable to the aerobraking vehicle.

Nevertheless the technology is remained to be verified by a flight experiment which is necessary since the existing ground facility can not provide the proper flight condition. In this study, the feasibility of the flight experiment is critically discussed. Figure 1 shows an example of procedure to realized such flight experiment. For this experiment, a suborbital flight is made used of. Such a suborbital flight can be realized by using a sounding rocket SS-520. Since the flight speed, at least, of 7 km/sec during an atmospheric flight is necessary to demonstrate the technology, the third stage motor, to accelerate the payload downward, is added to the original rocket composed of 2-stages. In the experiment, the payload is a micro-capsule-type vehicle which is equipped with a strong magnetic field generator inside it. Such a vehicle is schematically shown in Fig. 2. The diameter of the capsule is 40 cm and its weight is around 17 kg. The magnetic field generator inside the capsule provides a magnetic field intensity of 1T at the stagnation point of the vehicle. This magnetic field generator can be realized by using the high temperature bulk superconductor[3] installed inside a cryostat especially-designed. For the moment, we have developed an engineering model of such a magnetic field generator. The testing for it is now under way.

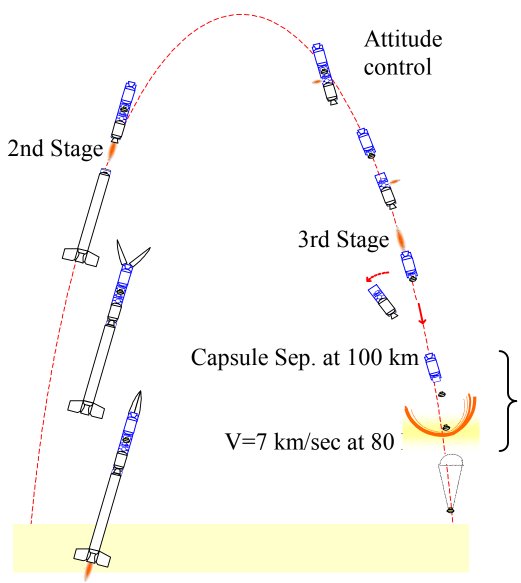

Fig. 1 Suborbital flight experiment.

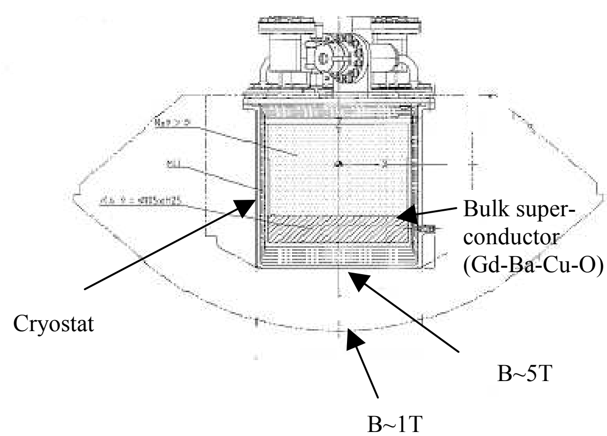

Fig. 2 Capsule type vehicle with the strong magnetic field generator onboard.

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Combustion and Thermal-Fluids Research Opportunities Created by the Expected Commercial Sub-Orbital Capabilities. J. I. D. Alexander[1], [1]Director, National Center for Space Exploration and Research and Professor, Case Western Reserve University, Cleveland, Ohio.

Introduction: The mission of the NCSER is to perform critical path research in fluids and combustion to support NASA's space program and related national initiatives, increase awareness of microgravity research and enhance its scientific, technological, educational, and economic impacts and to support the development of enabling technologies for space exploration. As NASA works towards completing the International Space Station it is also preparing for its greatest venture yet: the human exploration of the moon, Mars and the nearer asteroids. Establishing a long-term human presence beyond low-earth orbit places stringent demands on spacecraft systems that supply power and propulsion and provide human life support. The challenges facing NASA are dominated by energy, air quality, water, astronaut health and food. As it strives to meet these challenges, NASA's human space exploration program will invigorate engineering research and development in this country. Furthermore, there is tremendous potential to develop new approaches to engineering education as younger scientists and engineers become engaged in the quest to extend the boundaries of human presence in space through research programs at universities and at NASA Centers..

Expectation: The 3 to 4.5 minutes of low-gravity test time advertised by the emerging commercial sub-orbital industry is a capability that opens up new possibilities for research. The science community should note form the start that research for topics and applications in both space-flight and for the benefit of life right here on Earth are candidates for micro-gravity experiments. While the NCSER is chartered to focus on NASA's critical needs for space exploration, we need to look broadly at the opportunities that may come available for the NCSER to deliver on this charge. When the commercial sub-orbital research launches become regular, this should be a distinct and valuable change in the "laboratory" settings available for low-gravity research efforts.

Cheaper, more frequent, and simpler to use are performance characteristics that aid experiments when present in research equipment. Such characteristics are desirable to all when shopping for high-speed cameras, data acquisition, laser-diagnostics for combustion measurements, and the like. Access to low-gravity test time is yet another research tool that we all would like more of for lower cost.

Opportunities: Discussed in the talk is how the varied experimental efforts in NCSER and CWRU and the proposed low-gravity capabilities of this new industry lead us to envision enhanced and expanded low-gravity research. Consistent with the charge of NCSER, these experiments address NASA's needs in energy, air quality, water, astronaut health and food. As we strive to meet these challenges, traditional and new low-gravity experiments can also deliver on invigorating engineering research and development in this country.

One example of heritage NCSER/NASA-GRC experiments that would benefit from the anticipated flight profile is the Condensing Heat Exchanger Concept Developed for Space Systems, or CHESS. A more efficient design for water removal from cabin air in space flight would remove the water directly from the air without the need of an additional water separator downstream. For CHESS, researchers at the NASA Glenn Research Center in collaboration with NASA Johnson Space Center designed a condensing heat exchanger that uses capillary forces to collect and remove water and that can operate in varying gravitational conditions including microgravity, lunar gravity, and Martian gravity. The CHESS concept for a condensing heat exchanger involves the use of a highly conductive porous substrate as the cold surface over which moisture condensation occurs. The condensed water vapor is removed through another embedded porous tube insert via a suction device. Thermal properties, porosity, and wetting characteristics of the porous materials are designed to promote efficient condensation and avoid air penetration into the suction tubes. Other engineering concerns, such as priming and the startup and shutdown transients, also influence the selection of the porous media used in the design.

To test this concept and develop empirical heat- and mass-transfer correlations, NASA is building a ground-based test facility at Glenn. The emerging commercial sub-orbital flight programs will provide a great laboratory in which to further develop the technology, including perhaps important studies of transient response of the system.

Conclusion: If the promised flight profiles are delivered, the new commercial sub-orbital rocket industry will create research capabilities that are novel and desirable. The expected increase in affordability would enable more experiments that previously thought possible.

<u>Virgin Galactic and Sub-Orbital Science</u>

Stephen Attenborough

Virgin Galactic was founded by Sir Richard Branson to open spaceflight to a much larger group than ever before. Its aim is to transform space transportation and human spaceflight by creating a profitable company that establishes new standards for spaceflight safety, frequency, flexibility and cost. The designs of the Virgin Galactic spaceflight system and its operations have been built to be flexible in payload and mission profile. As such, they are extremely well suited to the execution of human-tended and autonomous science experiments as well as for space tourism – a market that Virgin Galactic (VG) has successfully established with over 300 paid up customers and more than $40M in deposits.

- VG is the only company building spaceflight vehicles based on a prototype that has already flown to space successfully (SpaceShipOne). Our new system also consists of a carrier aircraft (WhiteKnightTwo - WK2) and an air-launched spacecraft (SpaceShipTwo - SS2).
- Construction and testing of the prototype vehicles for Virgin Galactic's commercial operations is substantially progressed. WK2 is nearing the end of its test flight phase and SS2 will be rolled out for the first time in Dec 2009 prior to commencing its own test flight programme.
- SpaceShipTwo has generous payload capacity (2000+ lb) and large cabin enabling freedom of movement without restraints, with seating for six passengers and two pilots.
- Virgin Galactic's plans are centred and founded on significantly higher levels of safety than any previous spaceflight system. The safety case is built on core characteristics of the system: Air launch, glide to land, composite construction, and patented feathered re-entry system, as well as extensive operations experience of the Virgin Group.
- Virgin Galactic has been funded to date by the Virgin Group, a large branded venture capital organisation, which provides a solid funding stream for the project. In July of 2009, Virgin Galactic announced that it had concluded a deal (subject to regulatory approval) with Aabar Investments, an Abu Dhabi based investment fund which will see Aabar take a 32% stake in the company for $280m. This secures the necessary funding to complete the development.
- Virgin Galactic is built on and leverages the Virgin Group's extensive operating experience: global airlines such as Virgin Atlantic and Virgin Blue, train services such as Virgin Rail, and customer and tourist services around the world.
- Virgin Galactic is the farthest along as a developed business of any suborbital spaceflight provider, over 300 reserved tourism customers, representing more than $40 million of deposits, and an additional 85,000 expressions of interest.
- A comprehensive human training centrifuge program has successfully proven the accessibility of spaceflight to a wide diversity of individuals.

The VG suborbital service is well-suited to scientific research and engineering test processes. Such research could include atmospheric science, meteorological science, life or other science associated with macro and microgravity, astronomy, heliophysics, and earth and planetary science. Other applications could include a cost effective means for testing and verification of equipment for orbital and exploration programs, as well as practical training on such equipment in microgravity. Virgin Galactic's suborbital spaceflights will provide a cost-competitive alternative to sounding rockets with the addition of a human interface environment and a longer window in microgravity for useful training of personnel on specialized equipment or mission scenarios.

> VG will be able to offer researchers several services:
>
> **Researchers will be able to tend their experiments in space by mounting them inside the SS2 flight cabin.** SS2's large volume, substantial payload, and multiple windows make the cabin well-suited to a variety of research goals.
>
> **Researchers will be able to mount experiments in the unpressurized aft bay of the vehicle for exterior research.** Such experiments can take atmospheric samples either inside the bay or eventually via a window enabling access to the airstream.
>
> **WK2 will offer an excellent proving and training environment for SS2's cabin, as well as an excellent high-altitude research platform in itself.** WK2's cabin is virtually identical to that of SS2.
>
> **Researchers will be able to order the management of experiments by VG staff.**

The SS2 / WK2 system offers the following positive characteristics as a platform for science research:

- The system’s characteristics and competitive price enables rapid vehicle turnaround and high flight rate, which can support series missions in quick succession, even back to back.
- The operational flight frequency anticipated offers very short lead time to actual flight and also offers flexibility in scheduling. In other words, the launch window can be tailored to the individual researcher and/or the experiment.
- The system’s characteristics also enable ‘science of opportunity’, such as the study of meteor showers, supernovae, specific climate conditions.
- The system will be competitive in price to sounding rockets.
- Services provided via the SS2 / WK2 system offer more microgravity time than parabolic flight and drop towers, without the associated infrastructure costs.
- WK2 and SS2 provide a useful environment for training on such equipment, giving adequate time to trial functionality and specialist tasks (particularly compared to parabolic flight).
- WK2 is capable of parabolic flight and macro g for researcher training and experiment test.
- As the WK2 and SS2 cabins are very similar, equipment training or mission planning can be carried out in the WK2 prior to an SS2 flight.
- The high-altitude, large capacity and anticipated frequent flight of the WK2 system provides an attractive research platform on its own.
- All data and equipment is recoverable from VG flights.
- SS2 has the ability to maneuver in space through its RCS system
- Down range flight trajectories may become an option in the future and would support extended time at specific altitudes of interest.

Virgin Galactic plans to use the air-launch system architecture demonstrated successfully by Scaled Composites during the SpaceShipOne / White Knight One program. In this architecture, a purpose-built carrier aircraft powered by commercial jet engines carries the spaceflight vehicle to launch altitude (approximately 45,000ft). The spaceflight vehicle is air-launched from the carrier vehicle and fires its rocket motor, executing a turn for a steep climb. The spaceflight vehicle conducts a ballistic arc into space, and deploys its unique and patented ‘feathered’ configuration for re-entry. Following re-entry and descent into atmosphere, the spaceflight vehicle de-feathers and glides to a horizontal landing at its home base.

With proper spaceport and commercial licensing, the SS2 / WK2 spaceflight system will be capable of operating from any typical airfield with a runway of more than 9,000ft. Specialist equipment is limited to the SS2 oxidizer fuelling system and ground loading fixture. \Commercial operations will be centered at New Mexico’s Spaceport America, being constructed adjacent to the White Sands Missile Range.

Spaceport America has many advantages for science-focused flights. These include: (1) Clear surrounding airspace due to remote location & proximity to White Sands Missile Range; (2) Excellent weather conditions conducive to high flight frequency and rapid turnarounds. (3) Distance from major urban areas positive for certain climate and astronomy work, due to low urban particulate contamination and light pollution. (4) Relatively high altitude of site (approx. 4,000 ft) (5) WSMR has extensive technical facilities to augment scientific research via SS2 and WK2. And (6) As “Anchor Tenant”, Virgin Galactic is involved closely with the development of the Spaceport and so can ensure that any specific operational requirements are taken into account.

Virgin Galactic has identified the following specific science areas for potential investigation: Climate science/meteorology/aeronomy/ ionospheric science; Microgravity science Astronomy/Solar Physics; Planetary Science; Earth observation. More application may exist as well; we look forward to hearing your ideas.

Potential Life Science Projects for Sub-Orbital Flights: bridging the gap between applied and basic research

F. Owen Black, MD
Mark Shelhamer, PhD

Very little is known about acute, quantitative physiological effects of sudden changes in gravitational environs, especially in humans. From both animal and human studies, it is known that profound changes in many physiologic systems occur during and after g-transitions. Some of these effects affect crew safety and performance, i.e. present risks. For example, acute changes in gravitational forces on the human otolith system upon exposure to 1/6 g on the Moon and 1/3 g on Mars alter human body segment control, including head, ocular globes, limbs and center-of-mass control. Obviously, such physiological changes will affect many required and critical tasks such as landing and vehicle egress. Investigation of the acute effects of otolith responses to microgravity insertion and return to earth using newly developed techniques will likely provide key data for better understanding of acute adaptive effect on body segment control and provide a scientific basis for the development of effective countermeasures. Time permitting, other examples of possible investigations using sub-orbital flights will be presented. Specifically, the role of tonic otolith stimulation in vestibular evoked myogenic potentials (VEMPs), and in spatial perception, are directly relevant to providing crucial information that assist in helping patients on earth with vestibular disorders and can be readily applied to the study of sensorimotor adaptation in microgravity.

An Experiment Carrier Capsule Demonstrator Project with Hyperspectral Imaging for VTVL Vehicles. R. M. Branly[1,2] and E. S. Howard[1], [1]Broward College, Dept. of Physical Sciences, 3501 SW Davie Road, Davie FL 33314, [2]Air and Space Education Consortium, Box 1614 Cape Cannaveral MPO, 8700 Astronaut Blvd., FL 32920.

Background: The recent NASA/Northrup Grumman Lunar Lander Challenge has clearly demonstrated the feasibility of suborbital flights with Veritcal Take-off Vertical Landing (VTVL) vehicles. Three major teams developed rocket systems capable of accurate vertical landings. Some of the companies have identified experiment payload carrying flights as the next goal in vehicle development.

Summary: A team of researchers and college students has designed and built a payload carrier capsule capable of carrying 50 to 100 kilograms of experiments. The Experiment Capsule Demonstrator consists of a one meter diameter conical external structure with an optional internal structure manufactured from composite materials. The structure is inspired by the spacecraft of the Apollo era. The capsule is designed to ride atop Masten Space System's "Xombie" and "Xoie" (X0.1E) VTVL rocket vehicles. The experimental payloads fit within modular containers that are provided by the launch operator. The payload carrier capsule contains a battery power source independent from the rocket propulsion vehicle. The capsule demonstrator also includes a basic data recording module.

The Air and Space education Consortium in partnership with Masten Space Systems and members of Broward College have designed a Hyperspectral imaging system as a primary payload aboard the Masten Space Systems payload demonstrator project. Hyperspectral imaging is a powerful technique that can be used both in atmospheric and geology remote sensing applications. ASEC and Broward College are using this opportunity to introduce students to the science of spectroscopy through a Project Based Learning initiative. VTBL vehicles provide an opportunity to fly student and faculty experiments often enough to impact existing educational STEM initiatives. The plan incorporates educational examples developed at NASA's Jet Propulsion Laboratory. Early flights are expected in the second quarter of 2010.

COMMERCIAL SPACE UTILIZATION. M. A. Brekke, NASA Johnson Space Center, Houston TX (michele.a.brekke@nasa.gov).

The future of space exploration requires that the commercial space industry be successful in providing low cost space access and utilization services. Commercial space utilization will need policies, plans, ops concepts, safety, legal and many other elements to be formulated, established and put into action as to not be an impediment to the success of the industry. This presentation addresses many of these elements and the status of NASA's activities associated with them.

EFFECTIVE INTERFACIAL TENSION DRIVEN CONVECTION: A PLANNED SUBORBITAL INVESTIGATION P. Bunton[1] and J. A. Pojman[2], [1]Department of Physics, William Jewell College, 500 College Hill, Liberty, MO 64068, buntonp@william.jewell.edu, [2]Department of Chemistry, Louisiana State University, Baton Rouge, LA, 70803, john@pojman.com

Introduction: Korteweg proposed in 1901 that a nonuniform density (concentration or temperature) distribution leads to stresses in a fluid.[1] His paper was the first to propose a model how miscible fluids could behave like immiscible fluids. When two miscible fluids are brought in contact, a large concentration (and density) gradient exists, which relaxes through diffusion. He supposed that stresses caused by the density gradient acted like a surface tension that would also relax with time.

Zeldovich published an excellent work in which he showed that an interfacial tension should exist between miscible fluids brought into contact.[2] Davis proposed that when two miscible fluids are placed in contact they will immediately begin to mix diffusively across the concentration front, and the composition inhomogeneities can give rise to pressure anisotropies and to a tension between the contacted fluids.[3]

Joseph deserved credit for providing an excellent review of the history of this question. Joseph and Renardy have impressive pictures of behavior in miscible fluids that appears to follow behavior attributed to interfacial tension.[4] They also present experiments with drops of water rising in glycerin. He and his colleagues also considered many problems with Korteweg stress. [5-8]

Chen and Meiburg performed numerical simulations of miscible displacement that include Korteweg stress. [9-12]

There have been several reports of phenomena in which the authors invoke an interfacial tension with miscible systems. Garik et al. injected water into a $CuSO_4$ solution or glycerin into water. They proposed that the pattern formation they observed was not viscous fingering but an interfacial-tension induced instability.[13] Ma et al. performed a theoretical work including molecular dynamics simulations of initially miscible fluids showing that the effective interfacial tension relaxes according to a $1/t^{1/2}$ rule.[14] Mungall reported that miscible molten silicates form a meniscus, indicating an interfacial tension.[15] He proposed a theoretical model in terms of the gradient stresses. Castellanos and González proposed that the wave length selection in the electrohydrodynamic instability between miscible fluids of different conductivities can be explained by a transient interfacial tension.[16] Petitjeans and Maxworthy estimated the EIT from the wavelength selection of the displacement of water into glycerin in a capillary tube and determined a value of 0.43 mN/m.[17]

The first definitive measurements of an effective interfacial tension was performed by Pojman et al. [18] and Zoltowski et al. [19]

Convection Caused by Interfacial Tension. Gradients in interfacial tension between two fluids can cause convection. Such gradients can be caused by gradients in the concentration of a chemical species or temperature. Pojman et al. have studied numerically how convection could be caused by concentration and temperature gradients at the transition zone between miscible fluids.[20-23]

Isobutyric Acid and Water: A major problem in studying interfacial phenomena in miscible systems is lack of reproducibility. Because the systems are not at equilibrium, the results for any measurement of an interfacial tension would necessarily depend on the path taken to achieve the conditions and the amount of elapsed since the fluids were brought in contact. Employing fluids with a critical solution temperature can help avoid this. For example, isobutyric acid (IBA) and water exhibit an Upper Critical Solution Temperature (UCST) a 26.3 ˚C, which means that above the UCST the materials are miscible in all proportions but below it they form two phases.Isobutyric acid and water

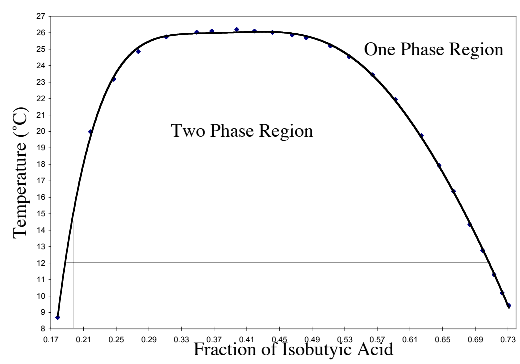

Figure 1. The phase diagram of IBA and water

Experimental Design: We have demonstrated in ground-based experiments that miscible fluids can exhibit an effective interfacial tension if the gradient between the fluids is large. Unknown is whether a gradient of such an effective interfacial tension can be created by a temperature gradient that will result in observable fluid flow. Our attempts in ground-based experiments to observe such Effective-Interfacial-Tension-Driven Convection have been foiled by buoyancy-driven convection. Therefore, we need to perform the experiment in weightlessness.

If isobutyric acid (IBA) and water are mixed below 27 ˚C (the Upper Critical Solution Temperature, UCST), they form two phases. The IBA rich phase floats on top of the water-rich phase. If the temperature is raised above 27 ˚C, the phases are now miscible but diffusion is very slow. This process allows us to create a configuration in which two miscible fluids are separated by a sharp concentration gradient that acts as an effective interfacial tension.

Our experiment is simple: We will use an interface between isobutyric acid (IBA) and water as a model system. A pre-equilibrated system in a glass cuvette will be maintained at 25 ˚C with Peltier heater-cooler. When weightlessness is achieved, the cuvette will be heated to 28 ˚C. Once that temperature is achieved, a heater along the side of the cuvette will be activated to create a temperature gradient. The fluid flow will be imaged by a laser sheet and nickel-coated glass microspheres. A control cuvette containing only water will be heated by a heater to allow us to determine the amount of buoyancy-driven convection caused by the residual acceleration.

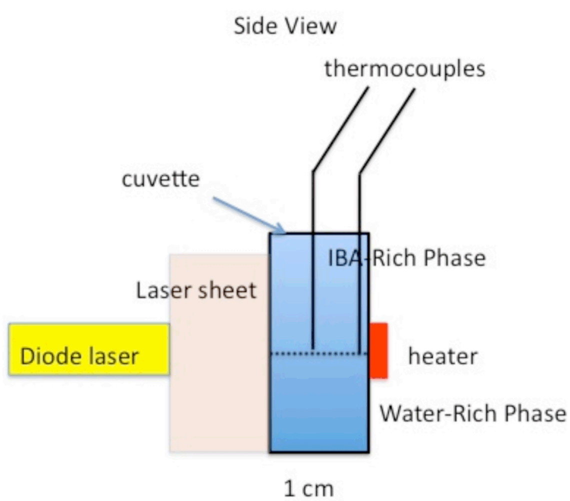

Figure 2. Schematic of planned experiment

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Suborbital Micro-Gravity Research: Tapping the Rich Legacy of Accomplishment for the Next-Gen Launch Vehicle Research Era

By
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David Yoel, CEO
American Aerospace Advisors

Abstract

The next generation of launch vehicles will breathe new life into the near-moribund suborbital micro-gravity research community. Traditionally plagued by high costs and a lack of reliable launch opportunities, the μ-gravity community today stands at the threshold of resurgence when the new generation of commercial reusable higher launch rate vehicles begin routine operations. As a new generation of space researchers considers how tourism-focused suborbital missions and vehicles can be used for research and education, they need only look at the rich legacy of μ-gravity research from the '70s, '80s and '90s. NASA, academia, and the private sector have developed proven flight hardware, performed a myriad of experiments and conducted a wealth of meaningful scientific, commercial, and student experiments on aircraft, sounding rockets, suborbital and orbital platforms. This paper presents an overview of the flight hardware development experience, capabilities and micro-gravity resources available from one surviving American commercial space company founded in the mid 1980's, Instrumentation Technology Associates (ITA). It describes an impressive array of low cost experiment/space processing flight hardware available for lease to researchers applicable for use on aircraft, sounding rocket, nextgen suborbital or orbital platforms. Typical flight results from commercial users, Government users, and students that conducted flight experiments using this hardware on sounding rocket flights will be presented. The paper will also describe the micro-gravity experiment database (the Commercial User Requirements Database), a comprehensive compendium of the types of flight experiments that can or were conducted coupled with their requisite time in μ-gravity requirements. This database was developed under contract to NASA following the Challenger disaster to categorize and classify activity within the μ-gravity community to help determine alternate μ-gravity access options during the Shuttle stand-down.

RESULTS AND LESSONS LEARNED FROM PERFORMANCE TESTING OF HUMANS IN SPACESUITS IN SIMULATED REDUCED GRAVITY. Steven P. Chappell[1], Jason R. Norcross[1], and Michael. L. Gernhardt[2]; [1]Wyle Integrated Science and Engineering Group, NASA Johnson Space Center, 2101 NASA Parkway, Mail Code Wyle/HAC/37C, Houston, TX, 77058, steven.p.chappell@nasa.gov and jason.norcross-1@nasa.gov; [2]NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX, 77058, michael.l.gernhardt@nasa.gov.

Introduction: NASA's Constellation Program has plans to return to the Moon within the next 10 years. Although reaching the Moon during the Apollo Program was a remarkable human engineering achievement, fewer than 20 extravehicular activities (EVAs) were performed. Current projections indicate that the next lunar exploration program will require thousands of EVAs, which will require spacesuits that are better optimized for human performance. Limited mobility and dexterity, and the position of the center of gravity (CG) are a few of many features of the Apollo suit that required significant crew compensation to accomplish the objectives. Development of a new EVA suit system will ideally result in performance close to or better than that in shirtsleeves at 1 G, i.e., in "a suit that is a pleasure to work in, one that you would want to go out and explore in on your day off." [1] Unlike the Shuttle program, in which only a fraction of the crew perform EVA, the Constellation program will require that all crewmembers be able to perform EVA. As a result, suits must be built to accommodate and optimize performance for a larger range of crew anthropometry, strength, and endurance. To address these concerns, NASA has begun a series of tests to better understand the factors affecting human performance and how to utilize various lunar gravity simulation environments available for testing.

Objectives: To collect performance data from suited humans during parabolic flight, to compare to and validate ground-based testing results using 2 other lunar-gravity analogs: 1) overhead suspension and 2) underwater buoyancy.

Methods: A custom weight support structure interfaced with a prototype lunar surface spacesuit, allowing manipulation of both suit mass and CG. Three series of tests were completed to either directly compare results with ground-based tests already completed, or to populate gaps in that data due to limitations of the respective analog environments used for those tests (e.g., insufficient lift capacity in the overhead suspension system; limited degrees of freedom). The 3 parabolic flight series were varied mass (VM), varied weight (VW), and varied center of gravity (VC). In the VW series, suit mass (120 kg) was constant at 0.1, 0.17, and 0.3 G for a total gravity adjusted weight (TGAW) of 196, 333, and 588 N, assuming an 80-kg subject. In the VM series, gravity level was constant at 0.17 G and suit mass was 89, 120, and 181 kg, for TGAWs of 282, 333, and 435 N. The 333 N condition was common to both the VW and VM series. Point-by-point comparison of the VW and VM series was not possible due to limited adjustability of suit mass and parabolic profile options. In the VC series, gravity level and suit mass were held constant at 0.17 G and 181 kg, and system CG was varied among 3 locations (B=4.8/1.0, C=7.6/14.4, and P=11.2/20.1 cm, aft/above the reference subject's CG). The CG of the system was defined as the combined CG of the subject, the spacesuit, and the equipment required to change the CG. Weight locations to alter CG were based on a reference subject (81.6 kg, 182.9 cm). Suited testing was performed with the suit pressurized at 29.6 kPa. Six subjects (80.0±10.6 kg, 182.3±6.2 cm) completed 4 tasks (walking, kneel/stand, rock pickup, and shoveling). The kneel/stand task was identical to ground-based testing. For rock pickup and shoveling, fabric bags filled with lead shot were used in lieu of weights and rocks. Walking during parabolic flight was overground across a short distance because the treadmill used during ground-based testing could not be accommodated in the available plane volume. In all conditions, upon completion of each task subjects provided ratings of perceived exertion (RPE) [2] and scores using the gravity compensation and performance scale (GCPS) [3]. GCPS ratings are based on the level of operator compensation required in partial gravity compared to performing the same task, unsuited, in 1 G. On this scale, a rating of 2 is equal to 1-G performance and larger numbers indicate perceived increases in the amount of subject compensation required to achieve desired performance. Motion-capture cameras were used to capture kinematic data, and force plates were used to record ground reaction forces for all tasks except kneel/stand.

Results: RPE and GCPS trends were similar for VW and VM where trends could be directly compared. Extrapolations of the VM data seem to indicate that as TGAW increased beyond 333 N, VM would lead to higher RPE and GCPS ratings than VW, but as TGAW decreased below 333 N, trends for VM and VW were similar (Figure 1).

For the VC series, mean RPE and GCPS were highest at CG location P for all tasks (Figure 2 & Figure 3). Variability was greatest at B and lowest at C, and large variations between subjects at the same CG existed for both RPE and GCPS. These trends were not consistent with results from unsuited CG studies performed in the underwater and overhead suspension lunar gravity simulations.

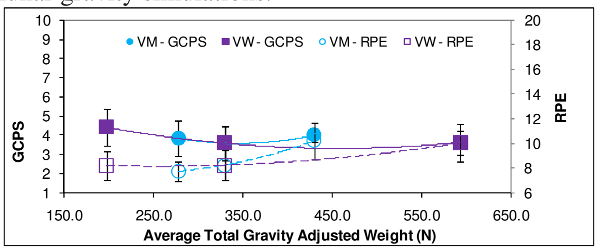

Figure 1. GCPS & RPE comparison of VW & VM series

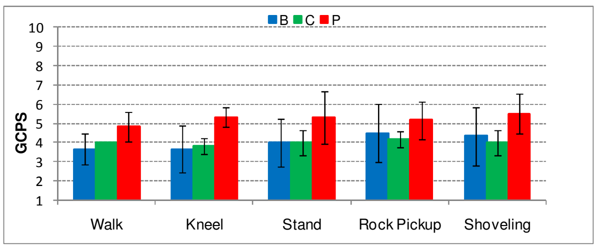

Figure 2. GCPS comparison from VC series

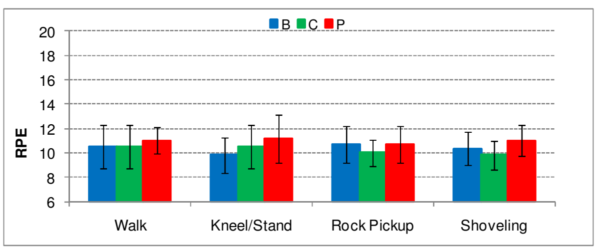

Figure 3. RPE comparison from VC series

Discussion: Modeling a change in suit mass by altering weight alone may be an adequate simulation through a limited range when looking at gross metrics of subjective performance of suited humans, but whether it would be sufficient for more precise metrics of human performance still needs further study. Modifying CG during suited testing at lunar gravity seems to affect subjective performance ratings. However, intersubject variation in subjective ratings at a given CG indicates that further study is needed to evaluate interactions among lunar-gravity simulation, system CG, system mass, and subject characteristics such as anthropometry, strength, and fitness.

The ability to compare results from parabolic flight with those from ground-based tests was limited. Subtle differences in experiment setup, lack of direct crossover test points, and subject population differences may have contributed to the comparability of the results.

Kinematic and ground reaction force data were highly variable due to volumetric limitations and the variability of the acceleration levels during a parabola. Volumetric constraints affected the ability of the subjects to attain a stable gait during walking due to the need to stop, turn, and start in the confined area compared to an uninterrupted treadmill gait on the ground. Acceleration variations during parabolas limited the ability to allocate differences in ground reaction forces to condition changes versus aircraft-induced disturbances.

Conclusions: Suited human performance testing during parabolic flight can provide the most realistic simulation of reduced gravity because the human, suit, and all associated equipment are in the reduced-gravity field. However, limitations of the test environment can affect the quality of the data collected. The short duration of each parabola (15-30 s) precludes assessment of metabolic rate. Airplane cabin dimensions limit data collection capabilities and the tasks that can be performed, and may cause subjects to adjust their gait style. Aircraft acceleration variability can affect the ability to discern condition-related changes. Even with these limitations, much can be done to improve the utility of data collected during parabolic flight and its applicability across other lunar-gravity analogs. Utilization of aircraft and aircrews that can provide maximum-duration parabolas with the required acceleration accuracy will provide the best environment for research. Maximizing the length of the cabin available for tasks such as ambulation or increasing cabin height to allow use of a force plate-fitted treadmill will allow suited subjects to attain a stable gait. To maximize the ability to compare data from parabolic flight with that from other simulated reduced-gravity analogs, tests performed in other analogs should be designed with identical constraints regarding equipment, task duration, methods, and subjects. Finally, the costs associated with performing experiments using parabolic flight must be kept within reach of available research budgets that provide sufficient numbers of subjects and task repetitions. These improvements would maximize the ability to achieve meaningful significant differences and to make the most informed recommendations for future lunar spacesuit designs to optimize human performance.

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ACQUISITION OF A BIOMEDICAL DATABASE OF ACUTE RESPONSES TO SPACE FLIGHT DURING COMMERCIAL PERSONAL SUB-ORBITAL FLIGHTS. J. B. Charles[1] and E. E. Richard[2], [1]Space Life Sciences Directorate (SA2), NASA Johnson Space Center, 2101 NASA Parkway, Houston TX 77058, john.b.charles@nasa.gov, [2]Wyle Integrated Science and Engineering Group, 1290 Hercules Dr., Houston TX 77058, erichard@wylehou.com.

Introduction: There is currently too little reproducible data for a scientifically valid understanding of the initial responses of a diverse human population to weightlessness and other space flight factors. Astronauts on orbital space flights to date have been extremely healthy and fit, unlike the general human population. Data collection opportunities during the earliest phases of space flights to date, when the most dynamic responses may occur in response to abrupt transitions in acceleration loads, have been limited by operational restrictions on our ability to encumber the astronauts with even minimal monitoring instrumentation.

The era of commercial personal suborbital space flights promises the availability of a large (perhaps hundreds per year), diverse population of potential participants with a vested interest in their own responses to space flight factors, and a number of flight providers interested in documenting and demonstrating the attractiveness and safety of the experience they are offering.

Voluntary participation by even a fraction of the flying population in a uniform set of unobtrusive biomedical data collections would provide a database enabling statistical analyses of a variety of acute responses to a standardized space flight environment. This will benefit both the space life sciences discipline and the general state of human knowledge.

Discussion: The potential value of space life sciences research on suborbital flights has recently been reviewed [1, 2]. The physical aspects of the suborbital space flight environment are well-described in [3]. The environment of biomedical interest includes about four minutes of continuous weightlessness between two periods of about a minute each of high acceleration loading, first during powered flight and again during atmospheric entry, and the attendant physiological and psychological aspects of the experience, including the external view, the physical freedom offered by weightlessness and the personal realization of both the significance and the potential danger of the experience.

Several types of physiological adjustment to weightlessness can become well-established in four minutes. This is about eight times longer than the next nearest widely-available opportunity for such exposure, namely parabolic aircraft flight.

A preliminary set of hypotheses to be tested on such flights might include:

- Physiological responses to brief weightlessness, preceded and followed by brief, high acceleration loads, will be influenced by the presence and magnitude of the clinical and operational covariates (discussed below);
- Physiological responses will differ between populations exposed to the different launch and entry loads and flight profiles intrinsic to the variety of flight systems available from the providers;
- Repeat flyers will respond to flight stresses differently than novice flyers.

This last hypothesis illustrates an unprecedented opportunity offered by the approaching suborbital flight era. To date, only a few astronauts have flown as many as seven times. Nonetheless, there is evidence of less dramatic acute responses to repeated orbital flights in some areas (such as reported intensity of space motion sickness) but not others (such as post-flight cardiovascular symptoms). In the suborbital era, it is entirely possible to expect that the spacecraft pilots, and possible some passengers, such as researchers, will fly dozens, perhaps a hundred times in a career, albeit on very short flights [2]. Documentation of the association between intensity of physiological response to flight factors and number of previous flights may provide insights into mechanisms of the human body's adaptability to space flight factors.

High-priority parameters to be recorded for analysis should change dramatically during suborbital space flights which provide physically dynamic phases as described above. These parameters should be readily perceptible to the volunteer participant, so as to provide the personal sensation context of the measurement. They should be amenable to unobtrusive and safe external detection, measurement and recording, and should have clinical relevance to the individual's experience and also be physiologically illuminating in the context of the accumulated database.

A preliminary list of such parameters might include:

Cardiovascular and cardiopulmonary changes including heart rate (from an electrocardiograph or a "pulse-meter"), arterial blood pressure (from continuous-sensing finger or wrist-mounted devices), thoracic blood volume, cardiac output and stroke volume (from impedance plethysmography and arterial waveform analysis), pulmonary function and arterial oxygen saturation (from a pulse oximeter), and regional (head and limb) blood volume from impedance plethysmography;

Sensory-motor changes inferred from cerebral function (by electroencephalography), cerebral blood flow (from near-infrared spectroscopy), visual-vestibular responses (by electrooculography), and behavioral strategies (by video and voice analysis)—and, of course, motion sickness;

Immunological and endocrinological changes documented in sample swabs and possibly automated venous sampling;

*Psychological response*s by video and voice recording, and possibly some brief tests of cognitive performance.

These should all be interpreted in the context of information from body-movement monitors and with spacecraft acceleration records and video- and voice-records assumed to be included in the services offered by the flight provider.

Physiological recordings will require the appropriate suite of sensors, presumably worn on the body. For greatest acceptability and thus use, they should be unobtrusive (non-contact sensors whenever possible), perhaps integrated into the flight clothing for ease of donning, doffing and sensor fixation, compatible with the spacecraft cabin environment, rugged, reusable, and inexpensive. The data recorder should have a low profile so as to be almost unnoticeable to the wearer, and battery-powered to avoid tethering the wearer to a spacecraft power supply. Wireless transmission of data and perhaps power are design features worthy of investigation.

The insights to be gained from the diverse population of expected volunteer participants can be inferred from consideration of the covariates of specific interest among common cardiovascular and cardiopulmonary risk factors, such as:

Uncontrollable risk factors including age, gender and hereditary factors;

Controllable risk factors such as history of tobacco use, cholesterol levels, hypertension, body mass index, history of physical activity or inactivity, behavioral responses to stress, and previous space flight history;

Operational or flight-related factors such as whether the individual is free-floating or restrained within the cabin, wearing a pressure suit or only lightweight clothing, the presence of motion sickness, changes in cabin atmospheric pressure and temperature, and the direction of acceleration loading (head-to foot if seated upright, chest-to-back if recumbent).

An effort to acquire a large and systematic database of human responses to space flight will have a variety of benefits. The quantitative assessment of risks on suborbital flights will permit an increase in passenger base as the flights become demonstrably safer; such data may also limit operator liability if untoward outcomes are shown to be independent of the flight itself. In addition, for what may be the first time in the era of human space flight, duplication of experiments may actually become encouraged instead of avoided, providing space life sciences research with a luxury that has heretofore been avoided as wasteful of limited opportunities and resources. Finally, the general increase in knowledge of the human effects of space flight may illuminate physiological knowledge in general, to the benefit of people in space and on the Earth.

In conclusion, every suborbital passenger will inevitably be the subject of an experiment that has not been possible throughout the evolution of life on Earth until the very recent past: exposure to weightlessness lasting more than a few seconds. The only question may be whether the data will be collected or lost.

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Medical Support For A Manned Stratospheric Balloon and Freefall Parachute Flight Test Program

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Introduction

The United States and Russia conducted high-altitude manned balloon research during the 1950s and early 1960s in support of their impending manned space programs. The US Navy Strato-Lab program demonstrated the operational capability of the Navy Mark IV full pressure suit, which was the basis for the Project Mercury space suits, to an altitude of 113,000 feet. The US Air Force Project Excelsior was a series of high-altitude balloon parachute jumps testing the Beaupre multi-stage parachute system and the standard Air Force MC3 partial pressure suit. The first Excelsior jump resulted in a spin over 100 rpm during freefall. Ultimately this program demonstrated a safe freefall parachute jump from an altitude of 102,800 feet. The Russian high altitude balloon parachute program was conducted from the "Volga" pressurized gondola modeled after the Vostok spacecraft. Exiting at an altitude of 86,156 feet, an experienced test jumper damaged his faceplate upon exiting and died during descent. Project Strato Jump was a US civilian freefall record attempt from a high altitude balloon and open gondola. On the second attempt an altitude of 123,500 feet was reached but the jumper was unable to disconnect and on the 3rd attempt the jumper was mortally injured during inadvertent suit depressurization during balloon ascent. Based on the success of Project Excelsior, a procedure for personal parachute usage during Mercury-Redstone missions was developed. Although never used, the personal parachute system flew on Mercury-Redstone 3 (MR-3) manned by Alan Shepard.

Discussion

In 2009 a privately funded group formed to initiate a manned stratospheric balloon and freefall parachute jump flight test program. Lessons learned were applied from the early manned stratospheric balloon programs. Multiple development paths included space suit, parachute descent and life support system, pressurized capsule, and balloon system. The test program included unmanned balloon and capsule tests, vertical wind tunnel and high troposphere tests of the drogue and main parachute and space suit, low pressure chamber tests of the space suit and integrated thermal/ vacuum chamber tests of the capsule, space suit and parachute/ life support systems, which will ultimately lead to incremental stratosphere freefall parachute jumps. A team was formed to develop and implement medical and physiologic support for this program. Issues addressed included protocol development for oxygen prebreathe for Decompression Sickness risk reduction, medical/ physiologic threat briefing, medical/physiologic monitoring for the thermal vacuum test phase and stratospheric flights, launch and recovery medical planning, and contingency planning. Contingency planning included the development of protocols against two serious known threats during a stratospheric bailout. In response to the threat of exposure to vacuum from a suit depressurization, an ebullism treatment protocol was developed. A protocol was developed to address another serious threat, flat spin with negative Gz acceleration. The selection and testing of the medical/ physiologic monitoring system for use in a pressure suit is a significant challenge. Other activities included safety review, Flight Rule development, Mission Control Center operation, human systems interface and capsule occupant protection evaluations.

Summary

Human stratospheric balloons flights entail many of the same operational risks and medical concerns as human suborbital space flights. The opportunities and mutual benefits for shared lessons learned between human stratospheric balloon and human suborbital space flights will be discussed. The results of this flight test program may have application for crew escape from suborbital spacecraft.

Oh, the Places You'll Go! : Using Suborbital Flight Programs to Support Formal and Informal Education (And Vice Versa). Emily A. CoBabe-Ammann, EAC&A, Inc.

Suborbital flight programs have the ability to capture the minds of students and the general public, not just because it's SPACE (how cool is that!!) but because it's SPACE FOR ME. Kids and the general public will begin to see suborbital space programs as their entrée into space, a place realistically that they can go during their lifetime. As such, suborbital programs have the power to grab the attention (and hold it!) of learners both inside the classroom and outside of it. Here, we're not just talking about kids in the classroom (though that's a critical opportunity), but museum goers, artists, musicians – the new classes of Citizen Explorer! In this talk, I'm going to put forward some of the challenges and opportunities involved in bringing the suborbital space program to these learners, including the realities of high-stakes testing in the classroom, how social media is changing how we talk to the world, and why the Lego Robotics competition is only the start! In addition, we'll talk about how those institutions with suborbital programs can use them to their benefit (economic and otherwise).

Armadillo Aerospace and Purdue University Student Experiment Program.

S. H. Collicott[1], [1]Purdue University, School of Aeronautics and Astronautics, 701 W. Stadium Ave., West Lafayette, IN 47907-2045, collicott@purdue.edu

Introduction: In 2009 undergraduate students in the School of Aeronautics and Astronautics at Purdue began designing and building a small, automated low-gravity fluid dynamics experiment. The enabling step was an agreement with Armadillo Aerospace that offered Purdue a ride on a test flight at no cost to Purdue.

Student effort is organized and led through the author's original and long-running class, *AAE 418 "Zero-Gravity Flight Experiments"*[1]. This class was created to maximize student benefits from participation in the annual NASA *Reduced Gravity Student Flight Opportunity Program* (RGSFOP) and, in fall semester of 2009, became the ideal vehicle with which to teach low-g experiment design for rocket launches.

The experiment is one that will explore interface topologies between a pair of immiscible liquids in a circular tube. This is motivated by 3-D computations performed by the author and a researcher at a CDC lab in West Virginia[2]. It is expected that an initial test-flight will not produce zero-gravity but rather something more like Lunar or Martian gravity. So the experiment is designed to explore the fluid physics in these partial gravities. Hopefully collaboration will persist until Armadillo is performing high-altitude zero-gravity flights. At present, Purdue and Armadillo are working through development of their respective hardware and expertise at the same time.

Goals: In this program we seek several goals in science, engineering, and education. Specifically:

1. Science:
   a. Acquire image data for steady-state configurations of low- and mid-Bond number two-phase fluid topologies in various cylinders. Specifically:
      i. Wall-bound droplets,
      ii. Plugs, and
      iii. The less common annular droplets
   b. Acquire video data of transitions between topologies in low- and mid-Bond number conditions. This is not possible in drop towers and aircraft flights are too noisy for this purpose.
   c. Complete an original numerical modeling effort in these two-fluid capillary problems that mix surface tension and gravitational effects. This will first support experiment sizing and will also produce specific hypotheses to test in the flight experiment.
2. Engineering:
   a. Create a functioning original automated single-injection event capillary fluids experiment with video data acquisition on a small budget.
   b. Develop integration and operations procedures with Armadillo for elaborate future experiments.
3. Education:
   a. Provide hands-on original design-build-test engineering education in a challenging, new, and exciting real-world application.
   b. Teach the basics of aerospace program management by immersing a small team of aerospace engineering students in a new spacecraft hardware program for flight testing.

Implicit in all of the above goals is the goal of making our students better prepared for, and hence more attractive to, the aerospace companies and agencies that they wish to go to work for after success at Purdue.

Hardware: Students are designing and fabricating the hardware necessary for this original experiment. Figure 1 shows a number of these parts. The complete experiment is 5kg or less and fits in a shoe-box sized volume. Video data acquisition is from a miniature digital video recorder and camera from the motorcycle helmet-cam market. White LEDs provide illumination. Triggering of the liquid injection event is by accelerometer board available in the high-power model rocketry market – that is, this experiment does not interface with the rocket. The hardware budget is around $1500.

Figure 1. Student-designed and built parts for the Purdue-Armadillo automated low-gravity experiment.

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Capillary Fluids Design for an Expeirment for Next-Gen Suborbital Flight.
S. H. Collicott[1] and L. Sharp[1], [1]Purdue University, School of Aeronautics and Astronautics, 701 W. Stadium Ave., West Lafayette, IN 47907-2045, collicott@purdue.edu.

Introduction: The emerging "Next-Gen" commercial sub-orbital rocket industry is creating new science facilities in addition to the well-publicized tourism opportunities. These several-minute long durations of a quality low-gravity test environment permit capillary fluids experimentation far cheaper and quicker than before. A combination of support from the National Science Foundation, Purdue's College of Engineering, and Purdue's School of Aeronautics and Astronautics has been secured to enable rapid delivery of an original capillary fluids experiment. This will be for automated operation on a commercial suborbital flight.

Experiment Goals: This experiment tests critical wetting predictions from numerical modeling in three-dimensional containers. In other words, the numerical modeling is being performed in conditions for which the critical wetting lacks the solid mathematical foundation of cylindrical containers. Thus the experiment is necessary to permit application of the numerical model to fuel cell water management, pulmonary health, MEMS-based medical and other instrumentation, and spaceflight life support, thermal control, and liquid propulsion systems. "Critical wetting" is the property of a two-fluid system in which the relative wettability of the solid container, described by the contact angle of the liquid on the solid, and the shape of the container determine whether the liquid will form a finite-height single-valued interface near one end of the container[1]. If not, the liquid advances by imbibition, often even against gravity, up one corner of the container to a topologically different equilibrium distribution. The importance of the phenomenon can be seen in the dangers of system failure from liquid in the "wrong" place when the phenomenon is ignored or not fully understood. Fuel cell gas-transport passages can be blocked[2], wicking of liquids in MEMS devices can differ from the desired wicking, condensers in miniature heat-transfer loops can clog, and similar, all from insufficient understanding of the critical wetting phenomenon in 3-D geometries. This Purdue 3-D gap-type critical wetting experiment is this first to explore the phenomenon and to test specific hypotheses formed from extending the numerical modeling from the proven 2-D cases into 3-D.

Experiment Design: The test cell is a spherical container with a pair of adjustable thin vanes, see Figure 1. Here thin means that the differing thicknesses of the two vanes are both much less than the radius of the sphere. Adjustable means that the position of the vane relative to the spherical wall is adjustable during the low-gravity test time. The vanes will begin at the position that creates the largest gap between vane and wall, large enough to prevent any critical wetting. Adjusting the vanes will narrow the gap, creating critical wetting conditions. As the two vanes differ substantially in thickness, the two sides of the container will reach critical conditions at different vane settings. This geometry will show changes in liquid positioning, from approximately the bottom of the sphere to the top, in the weightless test time. Such an investigation can not be performed in 1-g. Weightlessness is required for this experiment so that the critical wetting physics to be observed clearly and unambiguously.

Operation of the fluids vessel in the experiment throughout the mission is sketch in Figure 2. Injection of the test liquid is the first mechanical actuation required and then vane actuation follows. Injection will be as rapid as possible without permitting geyser formation. This can be done through keeping Weber number of the emerging flow under approximately 1.3 or with one or more deflection plates above the entrance[3]. The operations of the injection hardware can be tested in 1g, upside down (-1g), and various sideways or random orientations prior to flight.

Not detailed in the sketches are both non-wetting coatings and unique vane notches to destroy all chance of critical wetting near the upper ends of the vanes.

Numerical Modeling: *Surface Evolver* has been validated against cylindrical critical wetting and against classical capillary instability analyses[4]. No other computer model has such fidelity in contact angle effects. CFD packages such as Flow3-D, Fluent, and the newer OpenFOAM show promise and indeed improve with each generation of computing memory and power, but are fundamentally dynamics codes and are thus intrinsically ill-suited for capillary fluid statics problems such as existence of an assumed free surface topology or linear stability of an equilibrium free surface.

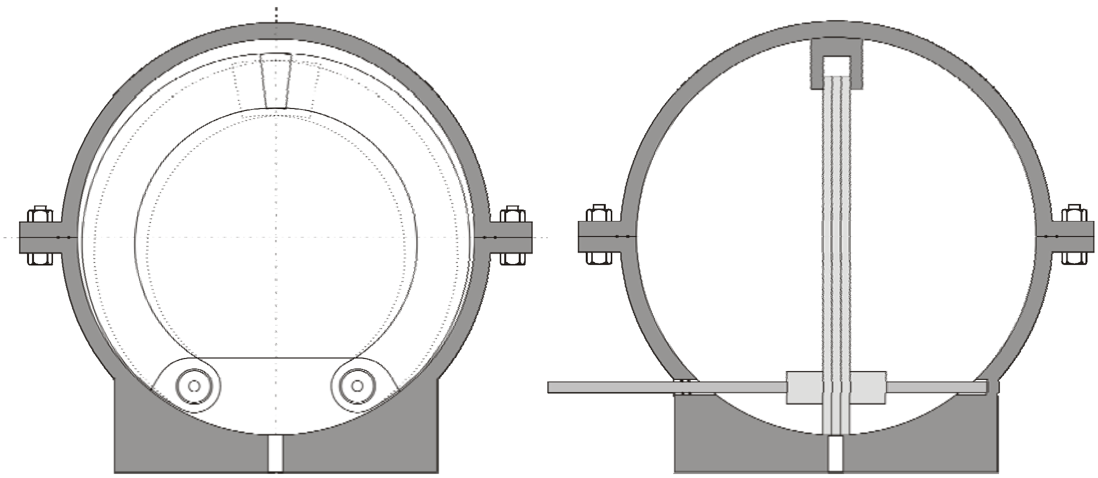

Figure 1. Notional sketches of two views of proposed experiment test cell. The vanes differ in thickness and thus the two non-dimensional gap sizes (gap/thickness) differ for equivalent vane angles. Dashed vane outline shows a large-gap setting.

Acknowledgements: Support from the National Science Foundation Fluid Dynamics program is appreciated. The School of Aeornautics and Astronautics and the College of Engineering at Purdue Univeristy have partnered to support the research.

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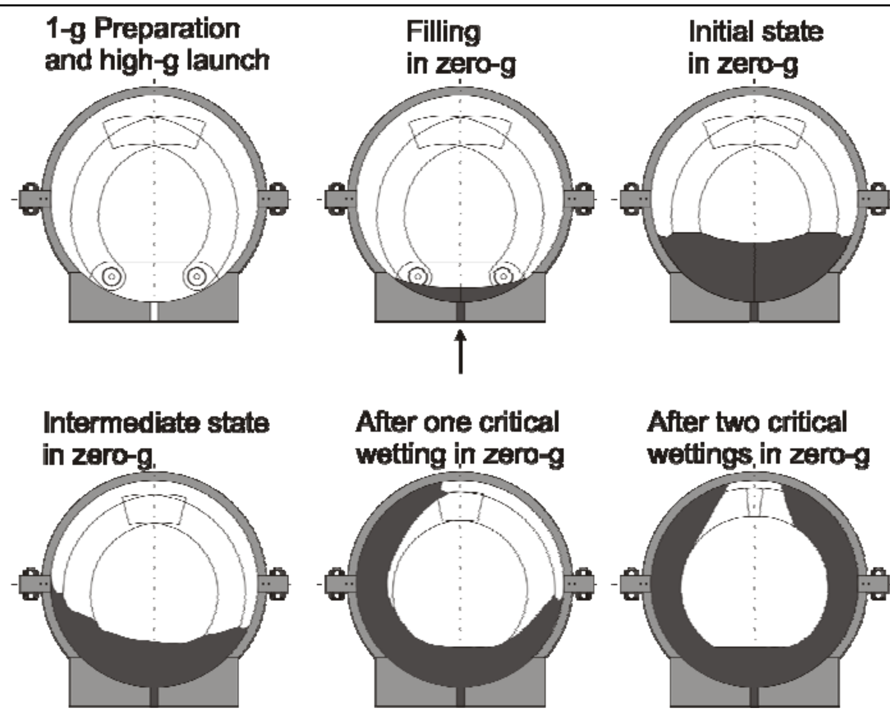

Figure 2. Sketch of operation plan for 3-minutes of zero-gravity. Note the symmetric changes in vane angles that reduce gap sizes. Draining is not required prior to the end of the mission. Vane actuation and stiffening hardware are not shown.

BUILDING PLANETS ON SUBORBITAL FLIGHTS. J. E. Colwell[1], J. Blum[2], and D. D.Durda[3]. [1]Department of Physics, University of Central Florida, 4000 Central Florida Blvd, Orlando FL 32816-2385, jcolwell@mail.ucf.edu. [2]Inst. for Geophysics and extraterrestrial Physics, University of Braunschweig, 38106 Braunschweig, Germany. [3]Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder CO, 80302.

Introduction: The formation of km-sized planetesimals by collisional accretion of cm- to m-sized dust aggregates in the protoplanetary disk depends on the amount of material that is dislodged in collisions compared to the amount accreted. The standard model of planet formation proceeds from the gravitational collapse of an interstellar cloud of gas and dust through collisional accretion of solids into planetesimals and eventual runaway growth to form the terrestrial and giant planets [1]. For more than 30 years there have been two theories about how one critical stage of that process occurs, namely the growth of solid bodies from mm-sized chondrules and aggregates to km-sized planetesimals where gravity becomes an important force for further growth.

The evolutionary tracks of protoplanetary dust aggregates, from µm-sized dust to cm-sized pebbles lead through a parameter space that has not yet been covered by experiments. Multiple collisions among free-flying particles (e.g. dust aggregates) with velocities <0.01 m/s are impossible to perform in the lab due to the overwhelming effect of gravitational acceleration. Thus, free collisions in the sub-cm/s velocity range require a microgravity environment. We are developing an experiment for flight on a next generation commercial suborbital rocket flight to study the collisional physics of the early stages of planetesimal growth and the behavior of the regolith on planetesimals and other objects with very low surface gravity.

Microgravity Experiment on Dust Environments in Astrophysics: MEDEA is an experiment with three modules designed to study the early stages of planet formation and the behavior of regolith in low-gravity planetary environments.

Protoplanetary Dust Evolution Module. At the start of the Protoplanetary Dust Evolution experiment, dust aggregates will be mechanically excited to induce low-velocity collisions. Due to the mutual, highly inelastic collisions among the dust aggregates the collision velocities will decrease following Haff's law.

For relatively elastic, cm-sized glass beads (ε=0.64), drop-tower experiments showed that the initial velocity of v_0=10 cm/s falls to ~0.3 cm/s within 9 s, according to Haff's law [2]. Based on dust-aggregate collision experiments in the laboratory at velocities ~1 m/s [3,4], we expect coefficients of restitution $\varepsilon \approx 0.2$. For small ε, the coefficient of restitution is no longer important so that the temporal evolution of the particle velocities depends mainly on the number density. We envisage the following parameters: aggregate radius r = 1 mm, thus $\sigma = 4\pi r^2 = 1.3\times10^{-5}$ m^2, number density of dust aggregates $n = 10^7$ m^{-3}, coefficient of restitution $\varepsilon \sim 0.2$, initial velocity $v_0 \sim 0.1$ m/s. Thus, we will reach the desired range of collision velocities within ~1 s after injection.

We expect to extend our knowledge on the collisional evolution of protoplanetary dust aggregates down to collision velocities <1 mm/s, being only limited by the residual acceleration, which will ultimately drive the particles to the walls of the experiment chamber. For mm-sized dust aggregates we expect sticking at velocities below 0.5 mm/s and/or the occurrence of a clumping instability. Both effects should be observable in the experiment. As the expected duration of a single experiment ranges between 10 s and 30 s, we will be able to perform a series of ~10 individual runs, thus gaining statistics and being able to vary the grain properties. The collisional evolution of the dust aggregates (i.e. their individual sizes and velocities) will be followed over time using high-speed video imaging. In addition to that, each individual collision will be recorded in three dimensions so that we can map the collisional outcome for the full parameter space (particle masses, impact velocity, impact angle).

Collisions Into Dust Experiment-3. The COLLIDE-3 module will carry out experiments on low energy impacts into regolith to quantify and understand the production of ejecta and dissipation of energy in collisions between sub-m-scale aggregates and particles in protoplanetary nebulae. This module is a modification of the COLLIDE experiment that flew twice on the space shuttle [5,6]. The collisions in this module investigate the dissipation of energy in low-velocity impacts into regolith. Previous experiments have indicated a possible threshold velocity betweeen accretion and erosion near 10-20 cm/s [6]. The experiments performed in MEDEA will therefore be tuned to explore this part of the parameter space. The results from these experiments will also apply to the collisional evolution of planetary rings, where ring particle collision velocities are < 1 m/s, and the abundance of dust within the rings is directly related to the amount released in collisions between the larger particles [7,8].

This experiment consists of impacts by solid, single-particle impactors that are 1 to 2 cm in diameter into a 2-cm deep bed of simulated planetary regolith. JSC-1 lunar regolith simulant will be used as the target material in most of the impact experiments, with quartz sand used as a control in one experiment. The different shapes of the grains in the two materials lead to different responses to the impacts at low energies. Data will consist of high speed (at least 200 frames/s) video to track the ejecta produced as well as precisely measure any rebound of the impactors.

Rubble Pile Evolution Module. The Rubble Pile module will provide the first microgravity experimental study of the mechanical reorientation of ejecta blocks and test methods of reconstruction of the distribution of the blocks from imaging data. Knowledge of the surface properties of small asteroids and comets is important for relating astronomical observations of these objects to geologic "ground truth", for understanding their relationships to meteorites, and for designing technologies and techniques for future robotic and human exploration, resource utilization, and impact hazard mitigation. Detailed observations of the surfaces of near-Earth asteroids Eros and Itokawa as observed by the NASA NEAR-Shoemaker and JAXA (Japan Aerospace Exploration Agency) Hayabusa missions, respectively, make the regoliths (the surface "soil", composed of fragments of rock ground to various sizes by myriad impacts large and small) on these small bodies valuable natural laboratories for evaluating various models of their formation and evolution.

This investigation will examine the settling of regolith blocks in low/micro-gravity conditions applicable to the surface of a small asteroid and the derivation of block shapes from imaging (i.e., comparison of derived axes ratios from 2D projection in images to known true 3D axes ratios). The experiment consists of a simple "box of rocks" (artificial bricks of known size and shape) and a video camera to record images of the settled pile of rubble. The experiment will be executed by imaging the settled positions and orientations of the collection of identically-shaped, unglazed ceramic bricks, a subset of which are artificially colored to distinguish and highlight their shapes in post-flight image analysis using thresholding image processing. Reconstructed dimensions will be compared to the known dimensions of the bricks and compared with similar image analysis efforts conducted by ourselves and others (e.g., [9]) using NEAR-Shoemaker and Hayabusa images to advance our understanding of the morphology of small asteroid regolith structures.

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EDUCATION AND PUBLIC OUTREACH FROM EXTREME LOCATIONS
Keith L. Cowing

During the Apollo 11 mission, hundreds of millions - perhaps a billion people watched live television images from the surface of the Moon.
Since that time it has almost been a requirement that each new accomplishment in terms of exploration and adventure (major and minor) be similarly conveyed to the folks back home. We now have Twittering astronauts in space, blogging scientists in Antarctica, live TV from the summit of Mt. Everest, webcams bolted on the outside of rockets, and helmet cams attached to daredevil's heads.

As we move into newer regimes of exploration and excitement such as suborbital flight, what will become accepted common practice for education and public outreach? Moreover, can such elements of participatory exploration actually be used to leverage support and funding for the activities themselves?

Medical Considerations for Suborbital Spaceflight Operations. C. Marsh Cuttino, Virginia Emergency Physicians, Emergency Consultants, Inc. Address: 9002 Rio Grande Road, Henrico, VA 23229. Docswampy@gmail.com.

Introduction: With the advent of commercial spacecraft capable of repeated suborbital flight the opportunity for spaceflight participants to fly into space is increasing. The suborbital spaceflight medical environment participants will encounter has not been investigated since the early 1960's. While the environment of suborbital spaceflight has been generally characterized, current experience has generally been limited to manned flights above or below this flight region. Participants will have a varied medical background that will affect their response to the spaceflight environment and have changing medical needs during flight operations. Many of these effects may be difficult to predict, but provide an opportunity to expand the knowledge base for future flight operations.

The medical considerations for suborbital spaceflight operations include mitigation of risks, preparedness, response, and recovery. Research into the space life sciences during flight operations will increase knowledge and safety. This creates a positive feedback loop increasing the safety margin for future spaceflight participants.

Discussion: While much has been written and discussed about the medical screening and clearance of spaceflight participants, little discussion has occurred about the continuum of care required as they flow through the flight operations. Providing medical care for participants begins prior to launch activities with preflight testing and screening to determine suitability for flight operations. Spaceflight participants will need preflight safety training, and emergency protective measures taught prior to flight operations. During flight operations support personnel will need to be available for emergency response and recovery. Biomedical and life science research will have experiment specific impacts on flight operations. Post flight recovery and return operations have additional medical implications for the returning spacefarers.

Suborbital spaceflight is considered an extreme environment, and it is the effect of this environment upon the human body that is of interest to medical providers and researchers. These environmental effects have physiologic implications for both the risk to spaceflight participants, and in the provision of care and mitigation of injuries. Some of the effects are unique to the environment, and may be difficult to predict.

Spaceflight Medical Risk Considerations
Acceleration
Barometric pressure
Microgravity
Radiation
Noise
Vibration
Temperature
Life support systems
Behavioral issues
Communication
Traumatic injury

Medical Risk Considerations: The selection and screening of spacefarers has been discussed in the medical literature and the FAA has developed suggested guidelines for medical professionals to use for evaluation of potential participants. [1] While government sponsored astronauts generally are held to higher medical standards, commercial spaceflight participants with significant medical problems have been cleared and successfully flown to the International Space Station without adverse medical consequences. Significant medical testing and preventative treatment were applied prior to medical clearance. [2] It should be noted that the current FAA guidelines do not require spaceflight participants to undergo a physical exam prior to flight, but the rule does require informed consent of the risks of suborbital spaceflight. [3] The rule states that safety critical flight crew must have passed an FAA second-class airman medical certificate not more than 12 months prior to the month of the launch and reentry.

The general framework of the medical risks of preexisting medical conditions and their potential interactions with the spaceflight environment has been well described, but the actual physiological response may be different than that predicted. [4] Ongoing monitoring of spaceflight participants may be beneficial to future travelers, but may be problematic from a privacy issue unless the participants voluntarily agree or federal regulations change to require such tracking. Preflight identification of individuals with significant medical problems will allow for development of effective medical treatment and response capabilities.

During flight operations, the medical needs of the participants may be met through the use of dedicated trained personnel. NASA at the Kennedy Space Center uses a combination of NASA Flight Surgeons, and subcontractors with active experience in Emergency Medicine and Trauma Surgery to provide medical support during Space Shuttle launch and landing operations. [5] Inflight medical support is provided by a dedicated group of flight surgeons. Commercial suborbital flights with their shorter time frame will be able to condense medical support operations to a single group that can be present and active for the duration of flight activities.

Medical needs during flight operations will include emergency medical response, treatment, and evacuation capabilities. Response requirements will vary depending on the type of vehicle, location, number of participants, and failure modes. Careful planning and development of a trained medical response team will be required to provide a robust response to an adverse event.

One of the largest medical impacts inflight will come from the amount and orientation of the acceleration and gravity load on the spaceflight participant. This is a large part will be determined by the flight profile and vehicle configuration. In general, gravity loading from the head of the spaceflight participant down (+Gz or "eyeballs down") is not tolerated as well as gravity loading front to back (+Gx or "eyeballs in"). Significant gravity loading is known to cause arrhythmia even in healthy participants. [6]

Recovery operations will include safely returning the spaceflight participants back to the operations base and ensuring that no adverse events occurred during flight operations. The medical team can monitor reduction of environmental hazards and return from the landing site. In the event of a non-nominal landing medical evaluation of the participants should be a priority.

Life Science Research Opportunities: The opportunity provided by commercial suborbital flights to study physiologic changes and adaptation during spaceflight will provide knowledge and insight to the medical and scientific communities. [7] Areas of interest will include transition physiology from hyper gravity to microgravity, cardiovascular response and adaptation, neurovestibular adaptation, and the response of pathologic conditions to microgravity. Human behavior and performance in extreme environments can be studied in a reproducible manner.

The extended duration of microgravity can be utilized for psychomotor training in the performance of medical procedures, diagnostic studies and pharmacologic evaluations. Suborbital flight operations will allow investigators to interact with payloads and passengers in real time and to minimize the separation between flight and experiment recovery. Investigators will be able to participate in their experiments and interact with subjects directly, depending on the experimental design.

Summary: Commercial suborbital spaceflight will require careful consideration to manage the medical implications of this extreme environment. Evaluation of the participants may be required and careful planning by the medical team will be needed to ensure that all flight operations are completed in a safe manner. A robust preparedness plan will need to be incorporated into flight operations. This difficult environment also provides the opportunity to evaluate and study the environmental effects on human physiology and pathophysiologic conditions.

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SOLAR OBSERVING FROM NEXT-GENERATION SUBORBITAL PLATFORMS

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Much of the interesting physics in the solar atmosphere is invisible from ground level. Solar ultraviolet emission lines reveal the Sun's magnetic structure and high temperature atmosphere far better than can be seen from within our atmosphere. NASA's unmanned suborbital rocket program has long been a proving ground for new observing techniques and new ideas about how our star heats its atmosphere. This status comes because the barriers to entry are low for sounding rockets, compared to orbital and deep-space missions that cost two orders of magnitude more dollars.

The current wave of manned suborbital space flight projects promises to lower that barrier to entry still further, with launch costs an order of magnitude less even than current unmanned rockets. Further, many interesting physical questions are accessible with small "carry- on-class" instruments that could be deployed inside a cabin, either to observe wave phenomena in visible light through an optical quality polycarbonate porthole or plasma dynamics in UV through a special quartz port. With promised weekly to daily flight cadences, small instruments could be tested inflight, refined, and reflown within a week, greatly reducing costs.

I will discuss several scientific lines of inquiry that will benefit from manned suborbital spaceflight, and advocate a strategy to lower entry barriers still further using standardized interfaces to a miniaturized telescope platform.

EDUCATION PARTNERSHIPS IN THE STRATOSPHERE: AIRBORNE ASTRONOMY EDUCATION AND OUTREACH Edna K. DeVore[1] and Dana E. Backman[2], [1]Director of Education and Outreach, SETI Institute, 515 N. Whisman Road, Mountain View, CA 94043, edevore@seti.org, [2]SOFIA Outreach Director, SETI Institute, 515 N. Whisman Road, Mountain View, CA 94043. dbackman@sofia.usra.edu

Introduction: Embedding educators in scientific research environments provides unique learning and teaching experiences. Research experiences have been shown to enhance teachers' STEM (Science, Technology, Engineering, and Mathematics) professional knowledge and skills [1], which impacts the quality of their student's classroom experience and performance [2]. Teacher partnerships also create more opportunities for scientists, engineers and technologists to be engaged in outreach in formal and informal settings. Both communities benefit from teacher research experience programs.

Airborne Astronomy Education and Outreach: NASA conducts research in Earth and space sciences using airborne platforms. The airborne astronomy research aircraft are designed to conduct infrared astronomy possible only from high altitudes or in space. Airborne telescopes have a significant advantage: they perform like space missions but land each morning. Airborne observatories bring together STEM professionals and STEM educators in a unique research environment. This talk will reflect upon the lessons learned from the Flight Opportunities for Science Teacher EnRichment (FOSTER) program conducted cooperatively between NASA Headquarters, NASA Ames Research Center and the SETI Institute. The FOSTER program provided professional development for teachers and flight experiences onboard NASA's Kuiper Airborne Observatory (KAO) from 1991 until 1995 when the observatory was retired [3, 4, 5, 6]. Late in the KAO's service, a series of flights hosted "Live from the Stratosphere," a nation-wide educational broadcast, transmitted directly from the KAO to schools, NASA centers, and science museums. The "Live from the Stratosphere" events point to media-driven outreach opportunities for suborbital vehicles of all types. The KAO's successor, the Stratospheric Observatory for Infrared Astronomy (SOFIA) is designed to support an expanded research experience for teacher teams with the Airborne Astronomy Ambassador program, which draws upon experiences from FOSTER on the KAO and comparable teacher research experiences in diverse scientific environments [7]. Educator's research experiences translate into new classroom teaching strategies and public outreach in their communities.

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Additional Information: For additional information on SETI Institute's Education and Public Outreach programs, please visit: http://www.seti.org and the SOFIA Education and Outreach program at http://www.sofia.usra.edu/

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INVESTIGATING UPPER ATMOSPHERIC DYNAMICS FROM NEXT GENERATION SUBORBITAL PLATFORMS: NOVEL OBSERVATION OPPORTUNITIES AND ACCELERATED DEVELOPMENT OF INNOVATIVE INSTRUMENTATION. C. R. Englert[1], J. M. Harlander[2], D. E. Siskind[1] and D. D. Babcock[3], [1]Naval Research Laboratory, Space Science Division, 4555 Overlook Ave SW, Washington DC, 20375, USA , [2]St. Cloud State University Department of Physics Astronomy and Engineering, St. Cloud, MN, 56301, USA, [3]Artep Inc., 2922 Excelsior Springs Ct, Ellicott City, Maryland 21042, USA.

Introduction: Next generation suborbital vehicles provide an unprecedented, radically different experiment platform, that will influence many scientific fields. They provide previously unavailable access to the thermosphere, relatively long dwell times at the peak altitude, the opportunity to have a human operator on board, and frequent and affordable flights at several locations. The investigation of upper atmospheric dynamics, especially winds, can potentially benefit significantly from these new platforms in two ways: First, the vehicles could be used as platforms for in-situ and/or remote sensing wind instruments to measure winds from the stratosphere, mesosphere, and thermosphere, all of which are by no means well understood at the present time. Secondly, next generation suborbital vehicles can be used to rapidly increase the technical readiness level (TRL) of novel instrumentation, especially, when adequate test measurements cannot be performed from the ground, sounding rockets, or balloons. An accelerated TRL increase will shorten the necessary time to bring a new sensor idea from the conceptual stage to, for example, an operational satellite instrument. Doppler Asymmetric Spatial Heterodyne Spectroscopy (DASH) is a novel optical technique for remotely measuring winds that could take advantage of both of these benefits.

The DASH Concept: A DASH interferometer [1] is a modified Spatial Heterodyne Spectroscopy (SHS) [2,3], optimized to measure the Doppler shift of atmospheric emission lines, which carries the information of the line of sight wind speed. DASH can be regarded as a combination of SHS and the stepped Michelson technique, which was used, for example, for the highly successful WINDII instrument on the NASA UARS satellite [4]. The DASH concept has high interferometric throughput, and does neither require moving parts nor the isolation of a single atmospheric emission line, which eliminates the need for an ultra-narrow pre-filter. In addition, DASH allows the simultaneous calibration of each measurement with an on-board frequency standard.

The DASH concept was first published in 2006 [5] and subsequent laboratory studies have increased its TRL [1]. Recently, the first monolithic DASH interferometer was successfully integrated and laboratory testing of this compact, rugged device is currently ongoing. A photograph of the interferometer is shown in Figure 1.

Desired Vehicle Resources: Using optical remote sensing devices for scientific and instrument development purposes is likely not going to put any unusual power, mass, or size demands onto the vehicle. However, it may require special window materials, and somewhat stringent requirements on viewing geometry, pointing control, and pointing knowledge. Examples applicable to the remote measurement of upper atmospheric winds will be presented.

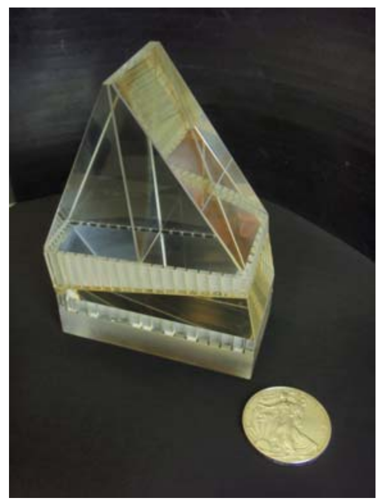

Figure 1: Photograph of the first monolithic DASH interferometer. This interferometer is designed for the thermospheric “red line”. A silver dollar is provided for size comparison.

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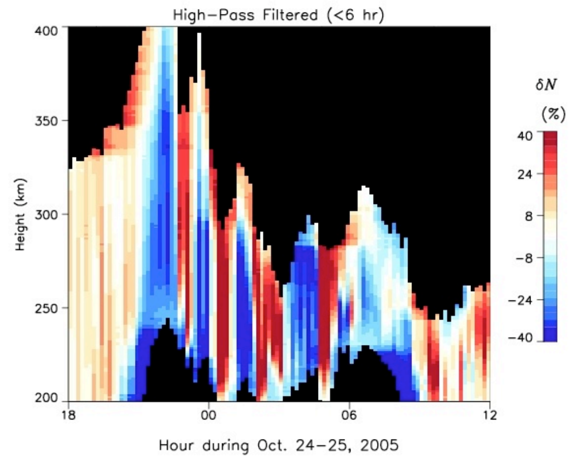
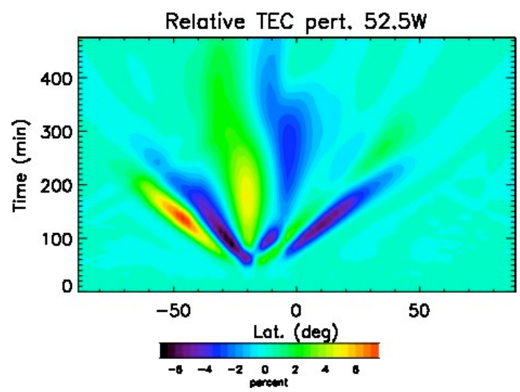
DYNAMIC CHARACTERIZATION OF LUNAR SIMULANTS USING RESONANT COLUMN PROCEDURES. Tonya Freeborn[1], Masami Nakagawa[2], Judith Wang[3], and Michael Weisntein[4]. [1]Graduate Research Assistant, Division of Engineering, Colorado School of Mines, 1610 Illinois Street, Golden, CO 80401; PH (559) 471-6763; email: tfreebor@mines.edu, [2] Associate Professor, Department of Mining Engineering, Colorado School of Mines, 1610 Illinois Street, Golden, CO 80401; PH (303) 384-2132; email: mnakagaw@mines.edu, [3]Assistant Professor, Division of Engineering, Colorado School of Mines, 1610 Illinois Street, Golden, CO 80401; PH (303) 273-3836; email: judiwang@mines.edu, [4]President, Zybek Advanced Plasma, 2845 29th Street, Boulder, CO 80301; PH (303) 530-2727; email:mike@zybekap.com.

Abstract: Stiffness degradation and viscous damping ratio curves provide the necessary elastic and dissipative parameters required to characterize soil deposits for dynamic analyses. Although extensive research has been performed to measure and document shear strain (γ)-dependent shear moduli (G(γ)) and viscous damping ratios (ξ(γ)) for soils encountered in Earth-based construction practices, these dynamic geotechnical properties have not been investigated for lunar regolith. This represents a significant limiting factor in our abilities to predict lunar regolith's physical reactions when exposed to the multitude of dynamic loading situations that will be encountered in the exploration and colonization of the lunar surface. The objective of the presented study is therefore to perform the first small-strain dynamic investigations of lunar regolith, using a resonant column apparatus upon a variety of lunar simulant specimens. In addition to JSC-1, a series of newly manufactured advanced simulants (ZAP™) including agglutinates will be used for dynamic property comparisons. The resonant column device used is a fixed-free torsional device capable of generating G(γ) and ξ(γ) curves along the small strain range of 10^{-4}% to 0.10% under isotropic stress conditions. The dynamic properties of the various simulants and their usage and implications in lunar exploration and construction are then discussed.

NSRC ATMOSPHERE-IONOSPHERE COUPLING SCIENCE OPPORTUNITIES. D. Fritts[1], [1] NorthWest Research Associates/Colorado Research Associates (CoRA) Division, 3380 Mitchell Lane, Boulder, Colorado 80301, dave@cora.nwra.com.

Abstract: Recent studies have demonstrated significant coupling between the neutral atmosphere and ionosphere having influences that extend from the F layer to very high altitudes. The underlying neutral dynamics, comprising various wave motions arising in the lower atmosphere and the mesosphere and lower thermosphere (MLT) are able to propagate directly or map, through neutral dynamics or electrodynamics, well into the ionosphere. These neutral dynamics and their coupling to the ionosphere likely have major influences in the thermosphere-ionosphere (TI) system relevant to "space weather", climate, and numerical weather prediction. This talk will describe evidence for neutral atmosphere – ionosphere coupling via gravity waves occurring at horizontal scales of ~100 to 2000 km and possible measurement strategies and instruments with which these dynamics could be examined in detail. Electron density perturbations seen during the SpreadFEx campaign (after Fritts et al., 2008) and predicted TEC fluctuations with time accompanying larger-scale gravity waves excited by a body forcing event in the lower thermosphere simulated with the NCAR TIME GCM (Vadas and Liu, 2009) are shown at right as two examples of such neutral atmosphere – ionosphere coupling.





The Focusing Optics X-ray Solar Imager. L.Glesener,[1] S. Krucker[1], S. Christe[2], [1] Space Sciences Laboratory, University of California, Berkeley [2] NASA / Goddard Space Flight Center

FOXSI is a sounding rocket payload funded under the NASA Low-Cost Access to Space program and is scheduled to launch in late 2010.

Particle acceleration in small "nanoflares" in the quiet Sun is thought to play an important role in the heating of the corona to millions of degrees Kelvin. In order to measure the non-thermal energy content of nanoflares, high energy sensitivity and a large dynamic range are needed. To date, the most sensitive HXR images are made using a rotating modulating collimator aboard the Reuven Ramaty High Energy Spectroscopic Imager satellite (RHESSI). However, the rotating modulation technique is intrinsically limited in sensitivity and dynamic range.

The Focusing Optics X-ray Solar Imager (FOXSI) will use grazing-incidence optics to focus X-rays at a 2-meter focal length in the 5-15 keV range. FOXSI will achieve a sensitivity ~100 times better than that of RHESSI at energies around 10 keV. FOXSI uses nested-shell, grazing-angle optics and silicon strip detectors to achieve an angular resolution of 12" (FWHM) and ~1 keV energy resolution. With an observation of ~5 minutes, FOXSI will make the first estimates of non-thermal energy content in small flares from the quiet Sun. The focusing optics technique developed by FOXSI will prove useful to future solar HXR observing missions, especially those interested in imaging faint HXR emission from particle acceleration regions in the corona.

Observations will be made for approximately 5 minutes at altitudes above 150 km, in order to mitigate atmospheric absorption of X-rays in the 5-15 keV range.

Three Dimensional Human Tissues as Surrogates for Research into Human Cellular Genomics, Proteomics, and Metabolomics During Suborbital Space Flight

Thomas J. Goodwin, Thomas B. Albrecht, Michael A. Schmidt,
Roy Goodacre, Iraida Sharina, Ferid Murad

Since the Apollo era, microgravity research has been on a quest to discern the governing elements of the microgravity environment, and to discover how those components individually and combinatorially affect human cellular and tissue responses. For more than twenty years, our laboratory at NASA (Disease Modeling and Tissue Analogues Laboratory) has been developing 3D tissue models, which are superior to 2D systems in their ability to emulate many of the physiological characteristics of normal human tissues. This revolutionary development has led to the publication of more than 800 scientific articles and at least 28 US patents over as many years. These advanced 3-dimensional human tissue models have flown on 16 Shuttle and ISS missions, which has given us insight into the rigor of these models under varied space and earthbound conditions.

We propose to employ scientifically validated models of 3D human lung and neural tissues, to study the cellular and subcellular changes observable during suborbital transition to microgravity. This strategy will separate the initial microgravity response from later phenomena, which include radiation and electromagnetic influences. Adaptive cellular responses can also be assessed by concomitant cultivation of human 3D models with human microbes, which are constitutively expressed as a consequence of pre-flight stress and in-flight exposure to a reduced gravity environment. These data can then be coupled with previously acquired data from space flight missions assessing human genomics.

Gene expression and proteomic profiles can be used to characterize the behavior of these human tissue models at various stages of the suborbital trajectory and the suborbital environment. These tissue models can also be used to characterize the metabolome (or the non-targeted small molecule pool) associated with the suborbital environment for the purpose of understanding metabolic networks. 'Omic data (gene, protein, metabolite) can be correlated with physical data (acceleration, G-force, vibration, etc) at each stage of flight to help us better describe the transitional biological and biochemical events associated with suborbital flight. In short, this project allows us to begin mapping the human tissue genome, proteome, and metabolome for suborbital spaceflight. This will help us better understand events associated with human tolerance, host defenses, and array of performance-related issues. Ultimately these analyses will permit us to associate the suborbital changes with adaptations seen in longer term habitation of microgravity, thus serving to predict possible health risks and the need for countermeasure development.

GETTING TEACHERS INVOLVED IN RESEARCH: A POTENTIAL COMPONENT OF FUTURE SUB-ORBITAL MISSIONS V. Gorjian,[1] L. M. Rebull[2], T. Spuck[3], G. Squires[2], and the NASA/IPAC Teacher Archive Research Program Team, [1]Jet Propulsion Laboratory/Caltech (vg@jpl.nasa.gov), [2]Spitzer Science Center/Caltech, [3]Oil City High School

Introduction: One really good way to get the word out about how science works is to have more people experience the process of scientific research. The way we have chosen to do this, since 2004, is to provide authentic research experiences for teachers using *Spitzer Space Telescope* data. We present this as a model for EPO programs arising from the various suborbital missions being considered, and offer the opportunity for collaboration on future missions.

The program originally called the Spitzer Program for Teachers and Students has newly been rechristened NITARP: the NASA/IPAC Teacher Archive Research Program. We partner small groups of high school teachers with a mentor astronomer, they do research as a team, write it up, and present it at an American Astronomical Society (AAS) meeting. The teachers incorporate this experience into their classroom, and their experiences color their teaching for years to come, influencing 100s of students per teacher.

Teacher Selection: NITARP selects teachers from a competitive nation-wide selection process; teachers have to apply via an essay-style application to be accepted. Applications are due annually in September.

The Research Program: The following is a brief description of the cycle that the selected teachers follow in their research project in astronomy. A similar path can be reproduced for any other science mission.

Attending the introductory workshop and first professional meeting: A teacher starting this program attends our workshop held immediately before a January AAS meeting to get rapidly up to speed on the available datasets, tools, archives, etc., and to learn the basics of multi-wavelength astronomy. Then, for most teachers, they attend their first AAS meeting ever (See 2006 team below). This is a critical experience because they need to experience the community of astronomers ("I learned that astronomers are normal, friendly people" – real quote from a participant!), they need to see what an AAS poster is like (because they are going to be asked to write one in the coming year), to meet their team in person for the first time and get started on defining their science program (their first task after returning home is to collaborate and write their proposal), and to network with past, present, and future colleagues (just like professional astronomers).

Main data reduction: The following summer, the teachers and two carefully selected students per teacher attend a workshop at IPAC, home of the Spitzer Science Center, at Caltech. This visit is the heart of the program, and is where most of the hard work on the project takes place. For three days, each of the teachers and their students typically work 10-12 hour days with their scientist intensively learning the astronomy/physics, how to work with their data, developing a work plan for the rest of the project, and talking as a group about how to work their project into their curricula at home.

Attending the second professional meeting and presenting results: Finally, at the second AAS meeting (a year after the first) is when the teams proudly present the work they have done. Each team is expected to present at least two posters – one on the science and one on the educational aspects of their project. The science poster is displayed as part of a regular science session (not an education session), and many of the students are often pleasantly surprised when professional astronomers come by and are eager to learn what they did… and the astronomers are often shocked to learn that they are "just" high school students and their teachers. Often teachers present educational products as part of their educational poster (e.g., curricula or Excel spreadsheets to support working with Spitzer data); these are all collected and shared on our wiki and website.

Program Results: From the eleven major research projects sponsored by the program so far, 31 scientific posters have been presented, and a number of scientific papers have been published. Students involved in the program have received regional and international science fair awards. In terms of impact on the local community, there have been nearly 100 newspaper, radio, and TV reports, and numerous Internet articles reporting on various aspects of teacher and student involvement in the project, and over 100 students feel the program has influenced them to pursue careers in science. Finally, one Texas teacher's involvement in this program played a major role in the state of Texas adopting astronomy as a high school science. ***This program has a record of success, and we can collaborate with you to start a similar program for your mission.***

RESEARCH AND EDUCATION MISSION CAPABILITIES OF THE LYNX SUBORBITAL VEHICLE.
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Introduction: XCOR Aerospace is a private, commercial space transportation company located in Mojave, California. We started in 1999 building rocket engines and quickly evolved to building rocket-powered planes. To date we have designed, built, and tested twelve different rocket engines, two rocket planes, and countless subsystems and components. We are currently in the process of developing and building the reusable launch vehicle (RLV) named Lynx to fly suborbital spaceflight missions.

Our first vehicle, the EZ-Rocket, demonstrated that we could develop safe and reliable rocket propulsion and integrate that into a horizontal take-off/horizontal landing vehicle. The EZ-Rocket has flown twenty-six times and in December 2005 set the National Aeronautic Association (NAA) certified *Distance without Landing* long distance record for a ground-launched rocket-powered aircraft with Dick Rutan as pilot.

The X-Racer is XCOR's second generation prototype plane. It has three times the propellant load as the EZ-Rocket, a proprietary piston pump to get the fuel from the wing strakes and reduce vehicle weight, and rapid and successive restart capabilities. It has flown forty times, including an appearance at the 2008 EAA AirVenture in Oshkosh, Wisconsin.

The Lynx suborbital vehicle is based on lessons learned and hardware from these two prior vehicles. While we will use a new custom-designed airframe, the Lynx engine is very similar in design to the X-Racer engine, which has a full test and flight history. All XCOR rocket engines have regenerative cooling, and all are optimized for maximum reusability and low maintenance. This leads to a high degree of safety and low operations risk and cost, which are all of prime importance in the commercial suborbital marketplace.

XCOR's Lynx is a two-place manned vehicle with a double-delta wing and twin outboard vertical tails. It is designed to take off and land horizontally from a runway using its retractable/extendable tricycle landing gear. Lynx Mark I will be the first design iteration of this vehicle. Its top speed will be Mach 2.4. Peak altitude will be 61 kilometers (200,000 ft), which will enable views down the West coast to Baja California over to the Grand Canyon, across the Pacific Ocean past the Channel Islands, and up to San Francisco Bay. XCOR expects first flight to occur in early 2011.

The Lynx Mark II (Figure 1) follows development of the Mark I flight operations by twelve months. Performance estimates for the Mark II version show considerable improvement, indicating 100 km (330,000 ft) altitude and Mach 3.5 capability. While the flight profile is similar between the Mark I and Mark II, the overall performance envelope is significantly different. Additionally, Mark II will be able to launch a two stage to orbit satellite.

All Lynx maintenance, payload operations, and routine flight operations support will initially be done at the Mojave Space Port. The vehicle is flown by one pilot with no computer assistance except guidance and navigation displays. Aircraft-like capabilities enable it to operate from any airport with a 2,100 m (7,000 ft) runway and appropriate airspace. It will have rapid call-up and turnaround times (from 10 minutes to 1 hour), and the ability to perform up to four sorties per day per vehicle. Its low maintenance of two-hour engine runtime overhaul intervals enables reliable and responsive operations.

Dynamic payload capabilities include a pilot and a researcher (or spaceflight participant). Static payloads can be positioned behind pilot's seat, in place of the participant, or in the aft faring. The Mark II will have a dorsal-mounted pod with an ogival payload volume of 50 cm diameter and 60 cm length that can launch a 100 kg payload on a suborbital mission, or 15 kg into a 400 km circular 28 degree inclination. Alternatively, an external payload of 400 kg can be attached to the upper dorsal of the vehicle.

This presentation will provide a detailed overview of the Lynx vehicle and focus on its specific payload capabilities, requirements, and operations.

Figure 1. Lynx Mark I with pod.

INSPIRING MINDS: CREATING AWARENESS FOR NEXT-GENERATION SUBORBITAL SPACEFLIGHT. G Griffin.[1], [1]Managing Director, Griffin Aerospace Communications, 3101 NASA Parkway, Suite L., Seabrook, TX, 77586, gwen@griffincommgroup.com.

Introduction: The opportunities provided by the unique microgravity environment of next-generation suborbital vehicles are limitless and have potential applications for industries ranging from pharmaceutical and medical equipment to environmental engineering and, of course, the emerging market for space tourism. Although the implications of suborbital spaceflight are well known within the tight-knit space community, educating and creating awareness with the general public is a challenge that has faced the space industry for decades. A well-planned strategic education and public outreach (EPO) program can yield increased awareness and support among the general public and key constituents– ultimately translating into new programs that provide funding opportunities for suborbital research.

There are key steps to developing a strategic EPO plan. Griffin Aerospace Communications takes the approach of "plan your work; work your plan," which includes clearly defining the plan before taking the first steps of implementation. Using various space industry client examples, Gwen Griffin will provide a general outline and overview of successful EPO programs reaching multiple audiences with a variety of tactics that can be tailored for use within the next-generation suborbital spaceflight community.

Establish Key Goals and Objectives: While this seems like a simple task, this can arguably be the most important step in developing an EPO plan. Setting the goal provides a clear reference point to determine implementation tactics for such a program. The goal should be a guidepost allowing a company or organization to ask "will this achieve the goal?" when evaluating implementation and tactical opportunities.

Define the Audience: Depending on the company or organization, the audience could include fellow scientists, major funding providers, Congress, corporate decision makers, educators or students. Identifying the appropriate primary, secondary and tertiary target audiences allows the development of definitive strategies to target each audience specifically, ensuring that the message is received in the best medium.

Create the Message: The foundation of a well-defined, organized EPO plan is key message development. What information needs to be shared with the target audience(s) and how? For instance, much of the technical information and industry jargon that makes sense to the suborbital science community needs to be reworded and simplified for various external audiences.

Implementation: Once the goals, audience and messages are established, it is time to evaluate the opportunities available to push out the message utilizing the right tactics to begin creating strong awareness for the value and importance of next-generation suborbital science. With so many tactics available including traditional media relations, thought leadership campaigns, web/social media, advertising, industry events, white paper development, grassroots marketing and industry relations, it can be difficult to choose the best avenue to reach the audience. It is important to evaluate each option and again review the established goal to once again answer the question "will this achieve the goal?" If the answer is yes, then you must evaluate the opportunities at your disposal to create the ideal EPO mix.

Evaluation: What is success? With any successful EPO campaign, evaluation tactics must be considered to determine if the plan has been effective or if different strategies should be implemented or refined. Establishing ongoing monitoring and evaluation as part of the EPO program which allows you to revise tactics along the way is critical to the campaigns success.

Collisional evolution of many-particle systems in astrophysics

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Low-velocity collisions play a fundamental role in various astrophysical environments like protoplanetary disks (planet formation) or the Saturnian rings (e.g. dynamics and stability). These collisions are likely to occur at velocities in the cm s^{-1} range and below, and a satisfactory experimental realization of the lowest velocities is so far not possible even in microgravity environments like a parabolic flight aircraft or a drop tower facility. Moreover, many-particle effects can play an important role, e.g. for clustering (Miller and Luding [1]), which are ignored when only performing single particle-particle collisions. A perfect environment to perform the desired many-particle collision experiments is under microgravity condition with a microgravity time of few minutes, in which a particle system would be collisionally 'cooled' to velocities down to millimeters per second.

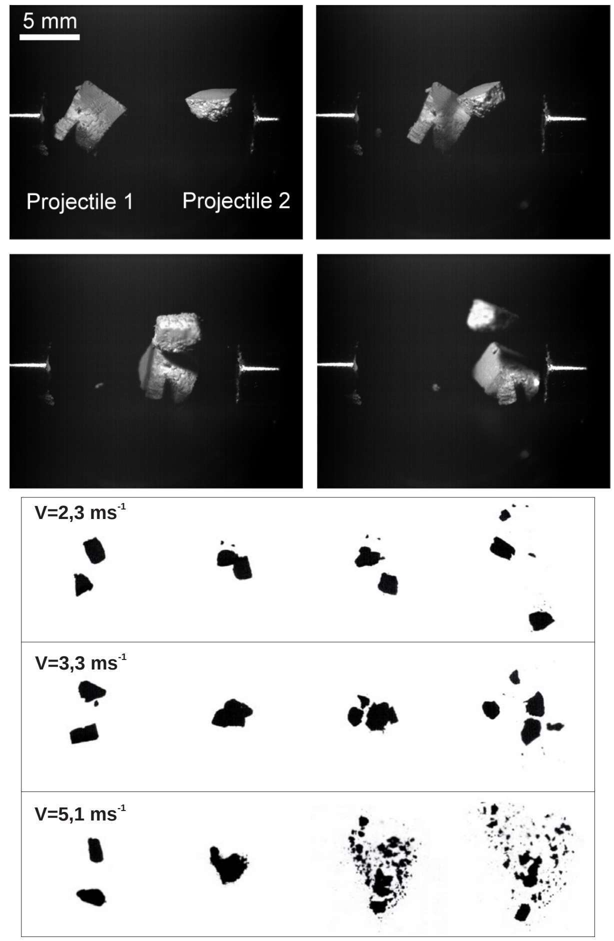

Figure 1: Collisions of millimeter-sized, porous dust aggregates typically lead to bouncing (top) or fragmentation (bottom), depending on the collision velocity. Courtesy: [3, 4].

Previous collision experiments

The formation of planets starts with collisions between (sub-)micrometer sized dust particles, which stick and grow to larger aggregates. This process has been experimentally studied by Blum et al. [2], who performed a Space Shuttle experiment in which they dispersed micrometer-sized dust grains to a dense cloud and observed their evolution. This is an example for a many-particle collision experiment, which showed the efficiency of the initial growth of protoplanetary dust grains into small fractal aggregates consisting of many grains.

Their growth leads to larger, porous dust aggregates, which still collide but their sticking efficiency rapidly falls, such that various collisional outcomes (i.e. sticking, bouncing, or fragmentation) are possible, depending on collision parameters like mainly their collision velocity (see review by Blum and Wurm [5] and refs. therein). Most of the relevant collision experiments were performed at velocities of the order of one meter per second, i.e. bouncing collisions at 0.4 m s^{-1} (Heißelmann et al. [3]) or fragmenting collisions at 2 – 5 m s^{-1} (Lammel [4]) Examples are shown in Fig. 1. A new evolution model for protoplanetary dust aggregates (Zsom et al. [6]), based on these laboratory experiments compiled to a collision model by Güttler et al. [7], clearly identifies a lack of experiments at velocities of centimeters per second and below. At these velocities, it is still not clear whether aggregates stick to each other or just bounce like observed at velocities of 0.4 m s^{-1} [3], which is clearly one of the most fundamental questions to understand their growth.

Collisions at similar velocities are also important in the rings of Saturn: water ice particles in the size range between 1 cm and 10 m collide at velocities of typically less than 0.5 cm s^{-1}. Here, it is not expected that these particles stick to each other but bounce inelastically. The energy loss in these inelastic collisions strongly influence the evolution and the stability of Saturn's rings as an efficient process to dynamically 'cool' these. Heißelmann et al. [8] performed collision experiments between centimeter-sized water ice particles and found that the coefficient of restitution $\varepsilon = v_{\mathrm{after}}/v_{\mathrm{before}}$ can span a wide range from virtually 0 (completely inelastic) up to 0.8 (nearly elastic), being randomly distributed.

Moreover, Heißelmann et al. [8] performed a multi-particle experiment in the drop tower in Bremen, Germany, that showed the behavior of a system of about 100 glass beads with 1 cm diameter. The particles collided and lost about 60 % of their collisional energy in each collision, which leads to a mean velocity evolution following Haff's law, i.e.

$$v(t) = \frac{1}{\frac{1}{v_0} + (1-\varepsilon)n\sigma t},$$

where $v_0 = v(t=0)$ is the initial relative velocity, and n and σ are the number density and the collisional cross section of the glass spheres. After nine seconds of experiment time, they observed mean velocities as small as 0.4 cm s^{-1}, but also a strong deviation from the above law, which is most probably the onset of clustering.

Plans for future many-particle collision experiments

We are currently planning a new experiment in which we plan to observe the evolution of an ensemble of dust aggregates like in the experiment of Heißelmann et al. [8]. In contrast to Heißelmann et al., this experiment will be performed onboard a suborbital flight vehicle with 180 seconds microgravity duration (see abstract by Colwell, Blum & Durda). This has the advantage that we will not only observe many more collisions but that we will also be able to observe collisions far below the velocities of Heißelmann et al. Furthermore, this many-particle system will also allow us to observe collective effects (e.g. clustering) which have so far never been studied in dust aggregation experiments. The results of these experiments will directly go into the collision model by Güttler et al. [7] and the evolution simulation of dust aggregates under protoplanetary disk environments (Zsom et al. [6]). Additionally, sounding-rocket investigations of ensembles of centimeter-sized water-ice samples are planned to provide insight into the long-term collisional evolution of dissipative many-body systems like planetary rings.

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Experiments in the Lower Ionosphere Enabled by The Next Generation Sub-Orbital Vehicles.

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Sounding rockets traditionally allow study for limited times to regions of the lower ionosphere that would not otherwise be accessible. These experiments have become increasingly more complex consisting of mother-daughter payloads and multiple launches to diagnose a targeted process in the ionosphere. The complexity and cost of these investigations is further exacerbated by the difficulty in recovering and refurbishing the payload. While the next generation of sub-orbital vehicles may not offer the capability to deploy multiple payloads of to conduct multiple launches, they do offer the advantage of carrying a more complex instrument to space and reuse of that instrument in follow-on experiments.

Differentially pumped ion mass spectrometers can be used effectively to examine the constituent populations of ions in the mesosphere. These populations may include water clusters and minor constituents requiring high sensitivity and extremely clean systems with a large mass range. In addition the role of charged dust particles should be investigated.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT FOR HUMAN SPACE VEHICLES - MICRO/PARTIAL-GRAVITY TESTING NEEDS. K. M. Hurlbert[1], [1]NASA Johnson Space Center, 2101 NASA Parkway, MC: EC1, Houston, Texas, 77058.

Introduction: The Enviromental Conrol and Life Support System (ECLSS) is considered critical for all human spacecraft. Design validation, performance testing, and certification are significant activities for these systems prior to flight. These can be even more challenging if the overall system, its components, and/or the working fluids behave differently in a micro- or partial-gravity environment. This presentation provides an overview of recent proposed or developed flight experiments in support of advancing ECLSS technologies for future spacecraft. The benefits of potential suborbital flight tests are considered. Recommendations for future collaboration are also provided.

Example ECLSS Flight Experiments: Provided below are example flight experiments to be discussed, which all exhibit gravity-sensitive traits. This listing represents the minimum content to be included in the presentation;

Immobilized Microbe Microgravity Water Processing System (IMMWPS) Flight Experiment – technology demonstration of a microbial water processor for microgravity use,

Two-Phase Extended Evaluation in Microgravity (TEEM) – demonstration of a closed-loop, two-phase system for extended on-orbit operations,

Water Offset Nutrient Delivery Experimental Research (WONDER) – technology demonstration of components for a microgravity vegetable production unit, and

International Space Station (ISS) Water Processing Assembly (WPA) KC-135 Testing – testing of sensors to be used on the ISS WPA in Node 3 to ensure water quality.

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Performing Atmospheric and Ionospheric Science Experiments at the Edge of Space

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The prospect of regularly scheduled visits to the boundary of space suggests an important new opportunity for low-cost investigations to address current questions regarding ionospheric and atmospheric processes. Several possible areas of interest will be discussed, including investigations of atmospheric oxygen density, the ionospheric E-layer, and temperature retrievals in the mesosphere and lower thermosphere. Suborbital observations lack global coverage, but can provide regular access to a region of space that has always presented difficulties to experimenters interested in the chemistry and coupling of energy and momentum from the middle atmosphere to the ionosphere, essentially to space.

An important goal of any such investigation should be to become an integral and unobtrusive part of the ”routine”. The example of commercial airlines not carrying simple GPS receivers capable of making important ionospheric measurements that are currently only made from ground is an example of an outcome that could easily be avoided. As suborbital programmes are nascent, now is the time to identify particular vehicular and operational capabilities that feasable scientific measurements would require, and identify those requirements can be met with little difficulty. Some instrument and observation concepts immediately point to several possible requirements that may pertain to a larger set of measurements than those immediately envisioned.

SEISMIC SHAKING EXPERIMENTS IN MILLIGRAVITY ENVIRONMENTS. N. R. Izenberg, [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD, 20723, USA (noam.izenberg@jhuapl.edu).

Introduction: Understanding the surface features, processes, of low gravity bodies in our solar system are critical to their evolution. Craters on the rocky and icy planets and moons, and on small bodies are fundamental tools in determining relative age, and provide geological windows into the subsurface. The cratering process itself is extensively studied, but the effects of moderate to small-scale impact events on low gravity bodies is not well researched. Seismic shaking and reverberation from small impacts causes significant local mobilization of surface materials, and affects the apparent age of a small body. In milligravity environments the impact process (or any other induced seismic signal) also may transport quantities of surface materials for some distance over some time, which may have effects on potential future robotic and human exploration of small bodies.

Planetary and Spacecraft observations. Recent spacecraft observations [1-4] indicate that seismic shaking due to impact cratering may play a key role in the surface evolution of asteroids. Indeed, such a process could be one of the reasons for the decrease in the spatial density of small craters on asteroid 433 Eros (200m diameter and below) relative to an empirically saturated surface, with an increase in boulder spatial frequency [5-7] (Fig. 1). Seismic shaking may also best explain the removal of craters up to 500 m in diameter in the vicinity of the large (7.5 km) crater Shoemaker on Eros [2], and the observations of surface flow and imbrications seen on Itokawa [4].

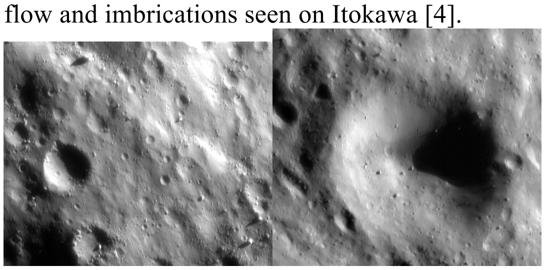

Fig. 1. Left: Degraded, bouldered terrain on Eros; Right: Eros crater with smoothed rim, and evidence of slope failure.

The lunar record [8, 9] suggests that seismic shaking is potentially very important on small bodies. Substantial seismic signals [2, 10-13] could not only destroy small craters, but also significantly modify the appearance of the entire surface. However, while spacecraft observations show the record of events from ancient to modern, no spacecraft observer has had the capability or opportunity to an impact event and its downrange seismic effects in real time.

Numerical and Simulation. Simple modeling [7] to rigorous numerical simulations [12,13] show that seismic signals from craters as small as 300m in diameter may be able to modify surface regolith to significant distances from their rim (Fig. 2). Global ringing effects can destabilize regolith on all slopes, while lower energy impacts and/or impacts into more fractured bodies (i.e. "rubble pile" asteroids with greater interior attenuation) result in more localized seismic effects. As well, smaller individual effects may aggregate over time into significant surface modification. Theoretical modeling also indicates that seismic shaking might: contribute to the development of "ponds" on 433 Eros [14]; affect the placement and evolution of boulders on Eros' surface; and affect the evolution of regolith on other small bodies (e.g. 25143 Itokawa, Phobos, Deimos) and to some extent bodies resolved to lower resolution (e.g. 243 Ida and 951 Gaspra [15, 16]).

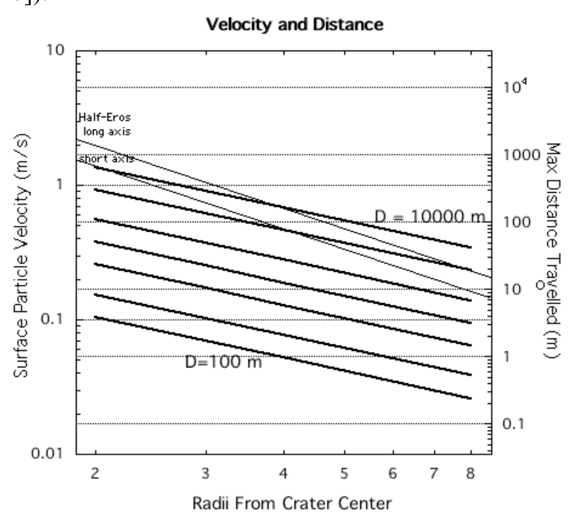

Fig. 2 Simple models derived from [9] showing the initial velocity of and maximum flat-surface distance traveled by a regolith particle mobilized by an impact a given distance away on asteroid 433 Eros. Depending on attenuation effects, even small craters can mobilize surfaces multiple crater radii away.

Early laboratory shaking experiments [7, 17-19] have demonstrated that small seismic jolts, both individually and in aggregate, can induce slumping of crater walls, migration of boulders, smoothing of regolith topography (Fig. 3). Single large jolts may induce larger scale changes more quickly, and result in significant horizontal transport of regolith in ballistic trajectories if the mobilizing acceleration is at an angle to local gravity.

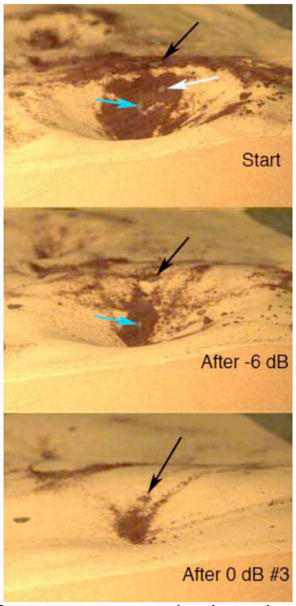

Fig. 3. Vertical laboratory seismic shaking sequence showing slope failures in model asteroid regolith, terrain smoothing, and "boulder" movement.

Current laboratory simulations of asteroid regolith processes must compensate for the fact that Earth gravity is orders of magnitude higher than surface gravity on small bodies. Earlier work [7,17,18 attempts this by recording shaking experiments with a high-speed video camera, slowing high frame rate to scale time down to simulate lower accelerations. This approach has achieved some success in simulating low gravity effects, but the validity of the scaling of time for gravitational acceleration is unverified. The limits of frame rate in available cameras can approach scaling to around 0.0100 to 0.0025 g at best (1000-4000 frames per second scaled to playback of 10 fps), when surface gravity of bodies the size of 433 Eros is on the order of 0.01g or smaller. Finally, current laboratory simulations must be carried out in air, where air resistance and displacement may affect particle motion of small grains of regolith simulant.

Suborbital Experiments (VASE) The scientific goals of a suborbital Variable Angle Seismic Experiment (VASE) would be to determine the behavior of a simulated asteroid surface subjected to a seismic impulse in both simulated and actual microgravity conditions, and in both air and vacuum. A direct comparison between near-identical experiments in simulated microgravity (1-g observations with high speed camera observations) and actual microgravity (in suborbital flight) will provide crucial ties between laboratory simulations and space environments. On-ground observations in air and vacuum will determine the fidelity of pressurized and vacuum simulations microgravity experiments.

The VASE is a self-contained experiment box, designed to be "reloadable" and reusable in both ground experiments and sub-orbital flight. The approximately 2-foot transparent (Lucite) cube is mounted on a metal plate, attached to a shake-table on ground, or a "seat"-mount in a flight vehicle. The cube is half-filled with an asteroid regolith simulant (Fig 3). This simulant can be a variety of materials from simple beach or playground sand, to pebbles, to a more complicated and accurate lunar or other simulated soil, to a mixture of multiple grain sizes and shapes. A starting "terrain", initially either a crater-shape or a hill-shape is formed into the surface by a mold-like cover that is manually raised when the experiment is ready to be executed. The mold/cover will be designed to lock in the closed position pre-flight, to be unlatched and opened by the operator in flight. The cover edges and box penetrations for the opening mechanism will be sealed by gaskets to permit movement of the mechanism, yet prevent escape of regolith simulant to the outside environment. An alternative design for a low vacuum experiment box is in preparation. The hand-lifted molt cover will likely need to be replaced with an automated door-type operation as in the COLLIDE experiments [20, 21].

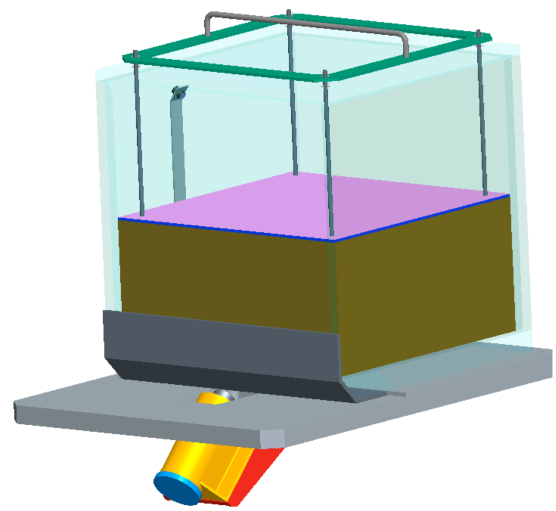

Fig 3. VASE prototype nonvacuum design with in "closed" state with thumper facing the kick plate in the 45° configuration. Camera is mounted to the left wall of the transparent cube. Not shown are lighting brackets, and mounted accelerometers.

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PRIZES AS A TOOL FOR ENGAGING RESEARCHERS AND STUDENTS. N. Jordan[1] and E. B. Wagner[2], [1]X PRIZE Foundation (5510 Lincoln Blvd, Suite 100, Playa Vista, CA 90094; njordan@xprize.org), [2]X PRIZE Lab@MIT (77 Massachusetts Ave., #37-219. Cambridge, MA 02139; erika@mit.edu).

Introduction: The mission of the X PRIZE Foundation is to bring about radical breakthroughs for the benefit of humanity. In doing so the organization has fostered innovative, high profile competitions that motivate individuals, companies and organizations across all boundaries to solve the grand Challenges that are currently restricting humanity's progress. To accomplish such innovation, the organization has adopted the concept of Prizes. Incentive Prizes attract outside investment and are a proven instrument for innovation particularly when the path to a solution is unclear. They are most effective where progress is blocked and where market forces, government, and non-profits cannot readily solve a problem.

Background: The applicability of incentive prizes to the international aerospace community has been demonstrated for decades, most recently with the successful Ansari X PRIZE for suborbital Spaceflight and the Northrop Grumman X PRIZE Lunar Lander Challenge. Importantly for the research and education markets, recent Lunar Lander winners Armadillo Aerospace and MastenSpace are already in the process of developing their technologies for carrying scientific and other payloads to the "ignoreosphere", and the $30M Google Lunar X PRIZE remains a substantial carrot for private development of complex space systems, engaging both industrial and university partners.

REM Prizes: This paper will describe the ways that Incentive Prizes can be used to attract high quality payloads for suborbital research and education missions (REM). This concept challenges students, young professionals, and entrepreneurs to think creatively about breakthroughs to complex problems, creating opportunities for suborbital research and private investment. We will present a variety of potential future competitions intended to engage participants from middles school through post-graduate studies, as well as professional researchers in both academia and industry.

Incentive Prizes and other models of Open Innnovation may be used to foster both the development of new payload systems, as well as the novel use of existing hardware, software, and data streams.

Besides educating within our industry, with this approach we hope to engage other participants by removing the very constraints they find most limiting, and encouraging them to invest every intellectual and financial resource at their command to tackle the challenges offered by suborbital flight. This is a concept that might be well adopted by other aerospace entities searching for innovation and success across the industry.

An Agenda for Sensorimotor Research in Sub-Orbital Flight

The excitement of space travel will be open to thousands of people by new commercial sub-orbital operations. Experience with changing g levels during space flight and parabolic flight suggests that sensorimotor disruptions are likely in these travelers, including postural stability, eye movements and motor coordination. We believe overcoming these sensorimotor disruptions will require a framework that delineates how approaches should differ from those applied to orbital flight and between sub-orbital passengers and pilots. For example, while most passengers are interested in maximizing enjoyment and flying only once, pilots are interested in maximizing precision and safety, and fly often. Strategies for overcoming disruptions include sensorimotor adaptation, re-adaptation, pre-adaptation, pharmaceuticals and cognitive training. Approaches should also account for differences in frequency of flights and mission objectives when selecting appropriate strategies.

Sensorimotor adaptation is one strategy for overcoming disruptions. However, for it to be effective in sub-orbital flight with periods of reduced and enhanced gravity lasting less than five minutes, it will have to occur quickly. We have performed experiments on sensorimotor adaptation during parabolic flight, in which we tested subjects over four consecutive days of flying. The reflex we tested, the pitch vestibulo-ocular reflex, took a few days during to overcome an initial disruption. This suggests that sensorimotor adaptation will be important for sub-orbital pilots, and that sub-orbital passengers may benefit from previous exposure to parabolic flight. This is supported by our previous work on context-specific adaptation, where we found that g-level dependent sensorimotor adaptation was retained for days and possibly months.

To improve comfort and safety during sub-orbital operations, we recommend using parabolic flight to pre-adapt sub-orbital passengers, and we recommend continued research in this area to understand the best timing for these flights, and the optimal set of tasks for passengers to conduct during altered g levels. We also recommend emphasizing recency of experience for sub-orbital pilots.

USING DSMC MODELING OF ROCKET AERODYNAMICS AS A MEASUREMENT AID IN THE MESOSPHERE. S. Knappmiller[1], J. Gumbel[2], M. Horanyi[1], S. Robertson[1], and Z. Sternovsky[1], [1]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309, [2]Institute of Meteorology, Stockholm University, Sweden.

The Direct Simulation Monte-Carlo method has been used to find the aerodynamic flow around rocket payloads in the mesosphere. For dust impact detectors and gridded dust collectors the flow near the instruments was calculated. In a separate code, nanoparticles were placed in the calculated flow to determine whether or not the particles would impact the detection or collection surfaces. For electric field booms, the shock compression from the DSMC code was used to find the compression of the ion density in bite-out regions and to find the change in the floating potential of the probe due to the shock. For mass analysis of particles, the flow through an electrostatic mass spectrometer was calculated and the trajectories of nanoparticles were found within the instrument, thus providing a mass calibration. The DSMC code has also been used to design a vent that will act as a vacuum pump and reduce the air density in instruments to a value below the ambient density.

The Key to Our Future Ability to Lead and Compete

Christopher Koehler

This country's ability to not only lead, but to also compete is dependant on the quality of our future workforce. This future workforce can be found today in our Nation's colleges and universities. The quality of this future workforce is directly affected by the type school attended, the grades achieved and, most importantly, the experiences received. Hands-on projects provide the best opportunities for students to apply what they are learning and thus the importance of what they are learning. Tying these hands-on projects to meaningful and real-word projects greatly enhances quality of the engineer or scientist ultimately produced. Nothing both excites and motivates future engineers and scientists than projects that will go to space. Providing access to space today for students and the faculty supporting them, is an essential ingredient to the creating the best engineers and scientists of tomorrow.

The Development of a Novel Infrastructure for Biomedical Monitoring of Space Participants

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Introduction:

The emergence of commercial spaceflight provides an unprecedented opportunity to introduce individuals with various medical backgrounds to the spaceflight environment. In contrast to traditional astronauts, Space Participants (SPs) may range from being exceptionally healthy to having significant preexisting morbidity. Biomedical monitoring of SPs offers a chance to both refine medical risk assessment for potential SPs as well as advance medical research with regard to studying the effects of spaceflight on human physiology and pathophysiology [1], [2], [3]. Furthermore, biomedical monitoring provides a unique test bed for the development of novel physiologic monitoring devices and other medical technology.

We report upon the efforts of several working groups listed in Table 1 and propose the adoption of scalable software infrastructure designed to interface with an array of monitoring devices. Our approach functions as both a raw data archive of SP biomedical data and as a server to specific end users. A modern approach to the archive of raw biomedical SP data should accommodate existing data mining and analysis tools, peer-to-peer information sharing standards, as well as the incorporation of industry standard data formats for medical information storage. Any adopted approach should ensure capability of SP data with current electronic medical record keeping standards.

Sources of biomedical information: Our envisioned biomedical database infrastructure is designed to capture biomedical data from SPs by utilizing an array of existing and experimental hardware devices. We make reference to two concepts of data management that our infrastructure can support. Horizontal data management refers to individual SP biomedical information collected from their preexisting health record, progression through training, spaceflight, and post flight phases as shown in Figure 1. Vertical data management refers to serving the collective biomedical data from several SPs to distinct end users as shown in Figure 2. A working list of potential end users is included in Figure 3.

End Users: We surmise that the end users of biomedical data span a wide assortment of interested parties ranging from individual space participants, associated health care professionals, commercial spaceflight organizations, researchers, and even policy makers. We envision each distinct group of end users utilizing our infrastructure to gain access to specific, relevant data subsets based upon their needs. While social networking, modern data visualization tools, and peer to peer networking technology may be priority for individual SPs to reflect and review their spaceflight experience, the incorporation of data mining tools that enable efficient and powerful analysis of biomedical data may be more important for researchers and commercial space providers.

Software and Hardware Architecture: The software architecture will consist of a back-end and front-end system. The back-end server is designed to accept and securely store biomedical data from various hardware devices and space vehicle systems. In accordance with standards for clinical medical data storage we plan on utilizing data formats such as the continuing care record (CCR) and HL7 terminology when appropriate to describe disease states, diagnostic findings, and treatment administered. Additional options for back-end infrastructure development include leveraging electronic medical records infrastructure such as Google Health, Microsoft Health Vault, and open source personal health record software. Other options include building new systems incorporating novel object-oriented programming methods (such as COOP-ER) which, when coupled with a scientific database and associated FIND engine such as Omnidex, allow for anomaly and pattern detection within high dimensional datasets. The front-end infrastructure, an interface between the raw data and the end user, can be customized to utilize advanced search, filtering, data mining, data visualization, and peer to peer networking technology depending upon the specific end user.

Table 1:

Working Groups for Space Participant Biomedical Data Management: Key Focus Areas
Interface to Space Participants: Ownership of Biomedical Data, Privacy, HIPAA Compliance
Interface with the Research Community: Needs of Specific Researchers, Core Physiologic Parameters Conceptual Interfaces
Interface to Commercial Spaceflight Providers: Feedback and Integration with Space Vehicle Hardware, Certification and Testing
Hardware Infrastructure: Integration with Existing Biomedical Devices, Conceptual Interfaces
Software Infrastructure: Compatibility with Existing Data Archives, Leveraging Modern Health Record Technology, Development of a Real Time Data Acquisition Standard, Analytis, Graphical User Interface Development

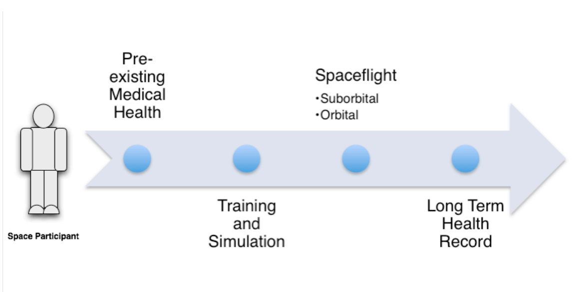

Figure 1. Horizontal Data Management

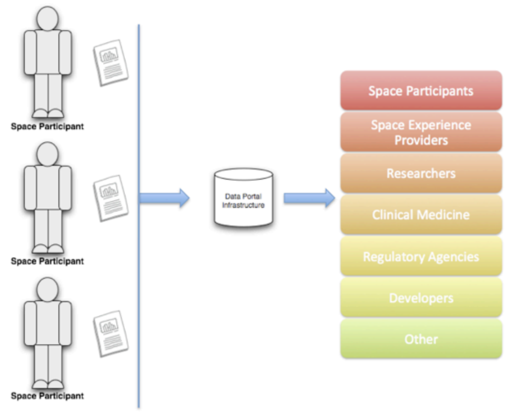

Figure 2: Vertical Data Management

Figure 3: Initial List of Proposed End Users for Biomedical Data

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NEXT GENERATION SUBORBITAL ACTIVITIES: ASSESSMENT OF A COMMERCIAL STEPPING STONE. D. I. Lackner[1], O.M. Al-Midani[2], [1]ALPS Ventures, Ltd., 1177 California St #533, San Francisco, CA 94102, USA, dlackner@alps-ventures.com, [2]ALPS Ventures, Ltd., 3 Wigmore Place, Cavendish Square, London, W1U 2LN, UK, oalmidani@alps-ventures.com.

Introduction: Business plans for the commercial use of space are numerous, but only a handful have received meaningful investments – and fewer market validated. Without logical stepping stones of ascending difficulty – and commercial success – the businesses that may emerge from suborbital research will remain an untouchable prospect for all but the most risk-prone angel investors.

Changing Risk Structure: Commerce in any regime is characterized by two types of risk to be mitigated: technical and market. If next generation suborbital activities reach a critical volume of frequent flights, the risk/reward ratio will reach an inflection point. With a growing set of underlying data, the financial world can address suborbital endeavors as forecastable, investable opportunities – progressing from the buds planted by today's small cadre of speculators.

Non-monetary returns on investment are realizable in the early phases of suborbital flight. The quick turnaround, hands-dirty, low cost approach that will be enabled is likely to lead to novel experimentation, increased risk-taking, and participation by industries formerly uninterested in the microgravity environment.

Analogous Ecosystems: The struggle to identify probable business models has been preceded by the search for a useful analogy to the current state of the space enterprise. Whether it is best represented by the railroad systems, early airmail carriers, or the competition to decipher the east west position (longitude) of a ship at sea matters not. What each of these comparisons is actually looking for is a representation of an ecosystem with all the right parts to stimulate an industry. That ecosystem has triggers necessary for each part of the value chain, including but not limited to: entrepreneurs, engineers, investors, service providers, users, customers, government stakeholders, and even celebrity advocates.

Growth of the application space. Next generation suborbital research opportunities are materializing as a result of anticipated tourist revenue. These two applications are examples of complementary activities that are likely to foster each other's expansion. Operational experience will create a beneficial learning curve, thus reducing recurring costs. Tourists will be willing in many cases to act as scientists. New industrial players are more likely to perceive the benefits of a crystallography experiment, for example, when innovation can be performed rapidly and cost effectively. The elongated periods of microgravity that would become available through some suborbital scenarios will allow further inspection of largely abandoned microgravity manufacturing techniques like thin film deposition. Just as likely and important, certain areas will manifest different levels of success, as is the case already with electrophoresis, which showed promise during International Space Station (ISS) testing, but was eclipsed by investments in terrestrial techniques. A necessary pruning process will validate some winners and exclude losers. The application space will thus mature at a faster rate, with more data to support tangible directions for further funding.

Shift to Service-Based Models: NASA has been the main player – an overwhelming monopoly player – in this industry. But that is about to change with NASA looking to procure turnkey services from commercial vendors as one of many clients. Government acquisition of complex systems from prime contractors still survives, but actions like the RFP for Commercial Resupply Service to the space station are a strong indicator of changing tides. Another example is the Sabatier water production system being deployed to ISS. This shift to service-based models portends an increasing government role as guaranteed customer, which will greatly enhance the ability of business ventures to take market risks, provide insurance to investors, and promote entrepreneurship the way that early federal contracts supported the aviation industry.

Conclusion: Simple, reliable services competitive on cost, but dense with usefulness provided to multiple segments of buyers will alter the suborbital market. Next generation suborbital research is a logical stepping stone to a much larger pool of investment options in the nascent entrepreneurial space industry because it offers: (a) the flexibility to serve as a portal to an extremely wide array of microgravity research, even new ideas like "citizen science" using iPhones as research platforms, (b) the altered perception of access that accompanies low cost, quick answers, and frequent repeatability. With increased suborbital activities come reduced risk, and a broader investor base.

New Shepard Vehicle for Research and Education Missions

G. Lai, Blue Origins LLC

Program Overview

Blue Origin is developing New Shepard, a rocket-propelled vehicle designed to routinely fly multiple astronauts into suborbital space at competitive prices. In addition to providing the public with opportunities to experience spaceflight, New Shepard will also provide frequent opportunities for researchers to fly experiments into space and a microgravity environment.

Mission

Flight test of the prototype "Goddard" vehicle at Blue Origin launch site in West Texas

The New Shepard vehicle will consist of a pressurized Crew Capsule (CC) carrying experiments and astronauts atop a reliable Propulsion Module (PM). Flights will take place from Blue Origin's own launch site, which is already operating in West Texas. New Shepard will take-off vertically and accelerate for approximately two and a half minutes before shutting off its rocket engines and coasting into space. The vehicle will carry rocket motors enabling the Crew Capsule to escape from the PM in the event of a serious anomaly during launch. In space, the Crew Capsule will separate from the PM and the two will reenter and land separately for re-use. The Crew Capsule will land softly under a parachute at the launch site. Astronauts and experiments will experience no more than 6 g acceleration into their seats and a 1.5 g lateral acceleration during a typical flight. High-quality microgravity environments (<10-3 g) will be achieved for durations of 3 or more minutes, depending on the mission trajectory.

Experiment Accommodations

Blue Origin is soliciting input from investigators to help design research astronaut and experiment accommodations. Researchers will have the opportunity to provide their own racks to mount into the vehicle (subject to a safety review), or use standard racks and services to mount their experiments. Flight experiments may be autonomous, remotely operated, or operated manually by an accompanying researcher provided by the customer or by Blue Origin. The tables below show some of the preliminary accommodations and standard services Blue Origin anticipates will be available, along with a partial list of the types of investigations that can be performed.

Accommodation	Description
Capacity	3 or more positions to be used by astronauts or experiment racks
Experiment Mass Allocation	120 kg available per position (including rack)
Windows	One per position
Power	28 VDC provided
In-Flight Communications	Recorded voice communications with crew and ground; recorded low-data rate link for experiment telemetry and control
Data Recording	Experiment data storage provided for post-flight download with synchronized trajectory parameter measurements
Pointing Accuracy	+/- 5° per each of 3-axes during coast
Turning Capability	Available

Types of Investigations	Example Applications
Remote Sensing	Atmospheric science Earth observations
In-Situ Science	Atmospheric sampling, Magnetospheric measurements
Deployables	Under study
In-Cabin Science	Physiology, Gravitational biology, Microgravity physics
Instrument Test/ Demonstrations	Gain flight experience Raise TRL levels
Active Experiments	LIDAR, Coordinated operations with White Sands Missile Range launches

Social Networking Planetary Science: How to Bring the Public Along on Suborbital Flights

Emily Lakdawalla
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Social networks provide new ways to interact with, and excite, the public about science and technology. In the past, information has been transmitted to the public through formal processes like occasional press releases, which may (or may not!) be digested into news articles for a mass audience, or through articles in special-interest publications. Now, information about projects can be published to the Web where it may be picked up, discussed, and disseminated by members of special-interest forums or Facebook users, while rapidly-changing events such as launches become the topics of discussion on Twitter. These media are rapidly eroding the boundaries between traditionally separate groups like mission scientists and the general public. By participating directly in online discussions, scientists and engineers on space missions have elevated the quality of online conversation about space exploration and significantly increased the sense of involvement with space exploration among members of the interested public. In return, well-informed and creative members of the public serve as unpaid public information officers within their own communities, and have even shown a capacity for generating good ideas that can feed back into missions.

Airborne Astronomy: Launching Astronomers into the Stratosphere

Dan Lester, University of Texas, Next-Gen Suborbital Researchers Conference

Sending scientists into the sky to do what could otherwise only be done from space has a long and productive history in NASA's airborne astronomy program. For several decades, this program has provided hands-on real-time experience to space scientists and provided a fertile training ground for new generations of space science instrumentalists, as well as a test-bed for astronomical instrument technologies that would later be used in space. In addition, it has been a successful asset in STEM educational outreach. All of these functions are key for next generation suborbital work and the expeditionary spirit that it entails. Lessons from the LearJet Observatory (LJO), the Kuiper Airborne Observatory (KAO), and the Stratospheric Observatory for Infrared Astronomy (SOFIA), which is just coming on line, may well pertain to these new directions in suborbital science and technology that would put humans where the action is.

Ultraviolet Astronomy with the X-15 Rocket Research Aircraft: Lessons Learned for Next-Generation Suborbital Vehicles

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In the early 1960's , in response to a proposal from Professor Arthur Code at the University of Wisconsin, the X-i5-1 Rocket Research Airplane[1] made several flights to demonstrate the feasibility of obtaining observations of celestial objects in the ultraviolet spectral region. In this paper we describe the modifications made to the X-15 to enable these observations, the instruments flown, and the results of these observations. The lessons learned from these flights, and their application to flights with the next-generation of suborbital vehicles will also be discussed.

[1] http://en.wikipedia.org/wiki/North_American_X-15

Atmospheric Science Payloads for Suborbital Flights. C. Lockowandt and S Grahn, Swedish Space Corporation, Solna strandväg 86, 17104 Solna, Sweden, christian.lockowandt@ssc.se, sven.grahn@ssc.se

Introduction: The upcoming suborbital flights will offer a new possibility to perform experiments at an altitude around 100 km and in microgravity for approximately 3 minutes. The new concept also offers the possibility to repetitive flights, perhaps with two flights per day. The complexity of the experiment payloads could be compared with facilities used on parabolic flights and sounding rockets. Swedish Space Corporation is developing and operating experiment payloads for parabolic flights and sounding rockets since 30 years.

Atmospheric studies

Atmospheric physics studies from suborbital vehicles are nowadays often performed by optical means. Even the local environment is sampled by directing a beam of light (broadband or narrowband spectrum) into a volume outside the bow shock of the vehicle. A photometer or spectrometer on the vehicle then detects the response from the illuminated volume. In this way disturbing effects from the vehicle itself, including the inevitable out gassing from the rocket motor, can be avoided. Similar methods and precautions need to be taken when using piloted suborbital vehicles for atmospheric physics. The attitude of the vehicle needs to be controlled during the exoatmospheric portion of the flight to point the optical instruments in the appropriate direction.

These optical methods are often sensitive to sunlight or moonlight. Therefore measurements need to be taken during the night when the Moon is below the horizon. Aurora, if not the objective of the experiment, also needs to be absent. Mass spectrometers have successfully been flown on sounding rockets for atmospheric compositions studies and they are a good candidate to fly on piloted suborbital vehicles and are not as sensitive to illumination conditions as purely optical methods. However, mass spectrometers must still be protected from out gassing from the vehicle and be pointed along the direction of flight.

Synoptic atmospheric measurements at several places around the world will by definition require that the piloted suborbital vehicle can operate in all kinds of illumination conditions: night, day and twilight.

Studying short-lived phenomena in near-earth space

Using piloted suborbital vehicles for investigating very short-lived phenomena in the near-earth environment may present new challenges. Very often sounding rockets studying ionospheric or magnetosopheric phenomena are held in readiness for long periods awaiting the correct scientific conditions. Even so, the time-of-flight needed to reach the appropriate altitude may still be such that the phenomena of interest has vanished by the time the rocket reaches its target position in space.

Microgravity Science Payloads for Suborbital Flights. C. Lockowandt and S Grahn, Swedish Space Corporation, Solna strandväg 86, 17104 Solna, Sweden, christian.lockowandt@ssc.se, sven.grahn@ssc.se

Introduction: The upcoming suborbital flights will offer a new possibility to perform experiments at an altitude around 100 km and in microgravity for approximately 3 minutes. The new concept also offers the possibility to repetitive flights, perhaps with two flights per day. The complexity of the experiment payloads could be compared with facilities used on parabolic flights and sounding rockets. Swedish Space Corporation is developing and operating experiment payloads for parabolic flights and sounding rockets since 30 years.

Microgravity experiments

Microgravity experiments that could be flown on piloted suborbital vehicles could be similar to those flown on sounding rockets and parabolic flights. For the flight sequence perhaps two flights per day may be envisaged. Also, an accompanying operator onboard will be subjected to high physical stress (up to 4 g acceleration) immediately prior to entering microgravity and starting the experiment. An operator will also occupy valuable space that could be used for more experiments. It is therefore probably prudent to adopt some of the methods used in sounding rockets where "telescience" has been used even during short sixminute flights. The experiment often has a built-in sequence that its onboard computer controls, but telecommand intervention from the ground is possible. The scientist on the ground watches the process via a television link and can modify the performance of the experiment. For a microgravity experiment on a piloted suborbital vehicle there could possibly be three alternative control methods: pre-programmed, by intervention through the onboard operator or from the ground. It is probably helpful for the onboard operator to at least get assistance from specialists the ground who should be able to watch the progress of the experiment via telemetry and/or a video link.

Some microgravity experiments could be flown as self-contained experiments that do not require an accompanying operator. Actually, such experiments resemble the Get-Away-Special payloads flown on the Shuttle and also the 60-second flights in microgravity offered by NASA in the 1980's. Experiments were then placed in the back seat of a NASA Starfighter jet flying out of Edwards AFB in California, see figure 2.

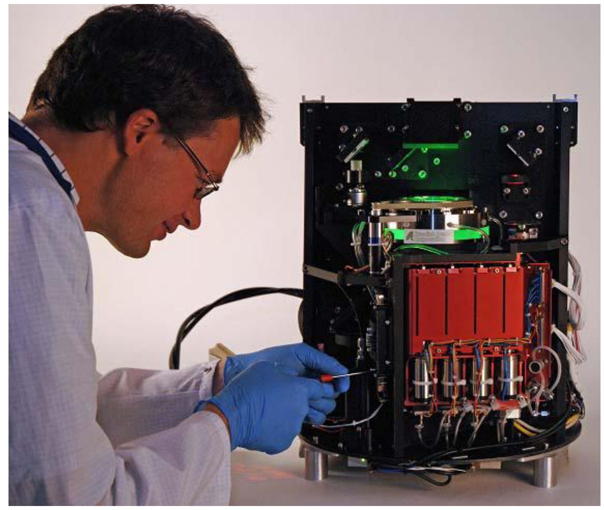


*Figure 1: Experiment module developed and flown on sounding rocket (MASER 11 May 2008 from Esrange) by SSC. Experiment by Dr T Podgorski (CNRS,
Grenoble, France) investigating blood cells flow motion in microgravity.*

Figure 2: Pore-formation experiment flown in NASA F-104 jet at Dryden Flight Research Facility February 1982. Experiment by Dr Hamid Shahani Royal Institute of Technology, Stockholm, Sweden. Experiment developed by SSC. Left to right: S Wallin (SSC), S Ishmael (NASA), V Horton (NASA), H Shahani (KTH).

The Canadian/Norwegian Student Sounding Rocket Program (CaNoRock)

I.R. Mann, D. J. Knudsen, K. A. McWilliams, K. Dahle, J. Moen, E.V Thrane, A Hansen

The Canadian-Norwegian Student Sounding Rocket (CaNoRock) program represents a collaboration between the Canadian Universities of Alberta, Calgary and Saskatchewan and the University of Olso, the Andøya Rocket Range and the Norwegian Centre for Space-related Education (NAROM). CaNoRock is proposed as a ten-year program which targets the training of undergraduate and graduate students in experimental space science, as well as the flight of research sounding rockets to study magnetosphere-ionosphere-atmosphere electrodynamics, including the generation of the aurora. The main parts of the proposed program comprise annual student sounding rockets from Andøya Rocket Range in Norway and a smaller number of scientific sounding rockets. The scientific rockets will provide research opportunities for active scientists from Canada, Norway and other countries but also opportunities for students from at least, and as a minimum Canada and Norway with a major focus on their training in campaign preparations, launch criteria decisions, payload integration, and data analysis. The proposed program will include university studies in physics, engineering and electronics as well as “hands on” instrument development, payload building and sounding rocket launches. The first four undergraduate students from Canada participated in the first CaNoRock student sounding rocket summer school in Andoya in November 2009; the same summer school also being used as a test of a new miniaturised magnetometer payload developed by a graduate from the University of Alberta. The proposed CaNoRock program is aimed to serve as a basis for a 10 year bilateral student sounding rocket program between Canada and Norway targeting the motivation of students to join space activities and acquire enhanced knowledge in physics, engineering and electronics for sounding rockets and stratospheric balloons. In the future the program may also include working with other scientific platforms such as Unmanned Aircraft Systems (UAS) which is a part of the business at Andøya Rocket Range.

THE CASE FOR HUMAN-TENDED SUBORBITAL PARTICLE-AGGREGATION EXPERIMENTS. J. R. Marshall[1] and G. Delory[2], [1]SETI Institute, 515 N. Whisman Rd. Mountain View, CA 94043, jmarshall@seti.org, [2]Space Sciences Laboratory, U.C. Berkeley, CA 94720, greg.delory@gmail.com.

It is planned to conduct suborbital particle-aggregation experiments as a follow up to Space Shuttle USML-1 and USML-2 activities. Electrostatic particle aggregation is a key process in the formation of planets, the behavior of impact palls and volcanic eruption plumes, the interaction of particulates in planetary rings, the behavior of aeolian dust clouds on Earth and Mars, and the formation of organic compounds in Titan's atmosphere. USML experiments showed that electrostatic dipoles are a strong influence on particle aggregation, not heretofore suspected. The discovery of complex aggregate structures (in the USML data) through image processing techniques not available at the time of the USML flights has reinvigorated our interest in the aggregation process. The USML hardware (Fig. 1) is still fully functional and would be employed in

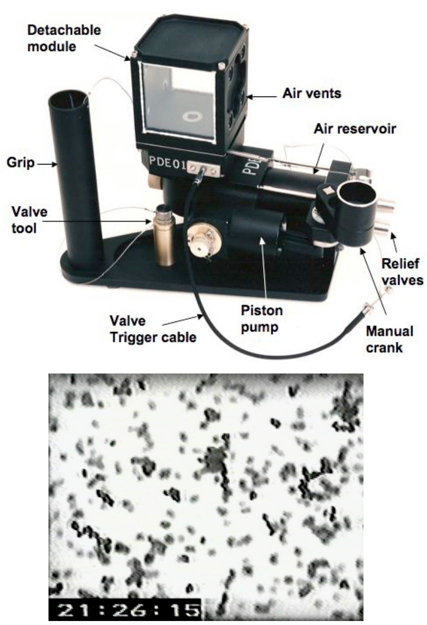


Figure 1: *USML hardware available for aggregation experiments. The detachable module is 5 x 5 x 5 cm. Lower image shows typical electrostatic chain structures generated in USML experiments (width of field = 1 cm).*

suborbital flights. It weighs <1 kg and requires no mechanical or electrical interfaces with the spacecraft. A choice of eight plug-in experiment modules is available.

We plan to use this or similar apparatus to investigate "pure" end-member states with regard to polarized interparticle forces in a particulate cloud. Specifically, the tests would include cases involving granular materials with 1) no electrostatic poles, 2) monopoles only, 3) monopole-dipole mix, and 4) dipoles only. This series of tests rigorously isolates the respective roles of monopolar and dipolar aggregation forces in particulate clouds. Additionally, a complementary series of force-spectrum tests would be conducted to separate the respective roles of electrostatic and mechanical (ballistic) forces in a dynamically active particulate cloud. Tests would include 1) no electrostatic forces, 2) no (effective) inertia/momentum using hollow glass spheres, and 3) no (effective) electrostatics or inertia/momentum using metal-plated hollow spheres. In combination, these experiments provide controls and separate all the force variables in an active particulate cloud.

Clearly, the scope of this test matrix needs to involve a series of flights, but each test would be brief and simple to execute. This requirement is not met by cumbersome Space Shuttle or Space Station programs, nor is it met by zero-gravity aircraft flights or drop towers in terms of reduced-gravity duration. It is matched, however, by the possibility of rapid turnaround commercial suborbital flights involving several minutes of weightless conditions.

Suborbital flights offer the opportunity to conduct experiments with a human in the loop. The advantages are two-fold. Firstly, they remove the necessity to automate the experimental setup. For relatively simple particle aggregation experiments being planned, the cost and complexity of automation can easily be an order of magnitude greater than the experiment itself. Tasks such as detecting zero gravity, pressurizing and activating sequenced pneumatic systems, and mechanically agitating the test modules, are non-trivial to accomplish automatically. Such tasks, however, are quite trivial for a human operator.

Secondly, a human in the loop enables real-time adjustments to experimental procedures. Via uplink commands with USML, the astronauts were able to perform unscheduled variants to test procedures, and it was learned from this experience that direct human observation was important in determining the outcome of the experiments. Such real-time uplinks might not be feasible with suborbital flights, but USML nevertheless demonstrated how the presence of an interactive human operator can vastly improve the outcome of an experiment when curiosity and flexibility are introduced as experimental variables.

Beginning of a Student Experimental Space Science High Altitude Balloon Program at University of Alberta

M. L. P. Mazzino, D. Miles, T. Wood, J. Rae, K. Murphy, I. R. Mann

University of Alberta, Canada

Small payload high altitude balloon programs provide excellent opportunities to involve students in end-to-end training in the experimental space science. This can encompass grant proposal writing, planning and design, construction, calibration, integration testing, launch, data analysis, and publication of results, while at the same time generating high-quality scientific results. Since most large Space Environment programs extend longer than university degrees, students are often never exposed to the opportunity of learning valuable, practical experience related to the development of a complete mission. Therefore, this type of program is essential in the education of future experimental space scientists. In this presentation, we will share our efforts to develop such program at the University of Alberta, which is currently in its initial stage. In particular, we will present details on the planning of the logistic of launching, tracking and recovering latex sounding balloons at low cost, as well as the design and manufacture of low weight instruments that would measure magnetic field, plasma and energetic particle precipitation data at high altitudes.

SCIENCE WHEN FLIGHT RATE AND TURN TIME DON'T MATTER. Michael Mealling, Masten Space Systems.

Introduction: Masten Space System's line of suborbital vehicles is engineered to minimize operational costs and support high flight rates. Depending on payload integration times it will be possible to fly multiple times in one day every day. This greatly expands the range of techniques and processes available to a scientist.

Comprehensive survey based datasets. High flight rates and low per-flight costs allow measurements of changing phenomenon over long periods of time. Flights can happen every day at a certain time (high automobile traffic periods, day/night change, etc) or can take advantage of daily conditions (weather phenomenon in the area, upper atmospheric effects, solar events, etc) over a longer period of time. Increased data creates increased certainty in the outcome.

Targets of Opportunity. Fast vehicle integration and prep times allow for atmospheric and astronomical observations of fleating events such as hurricanes, supernova, and gamma ray bursts.

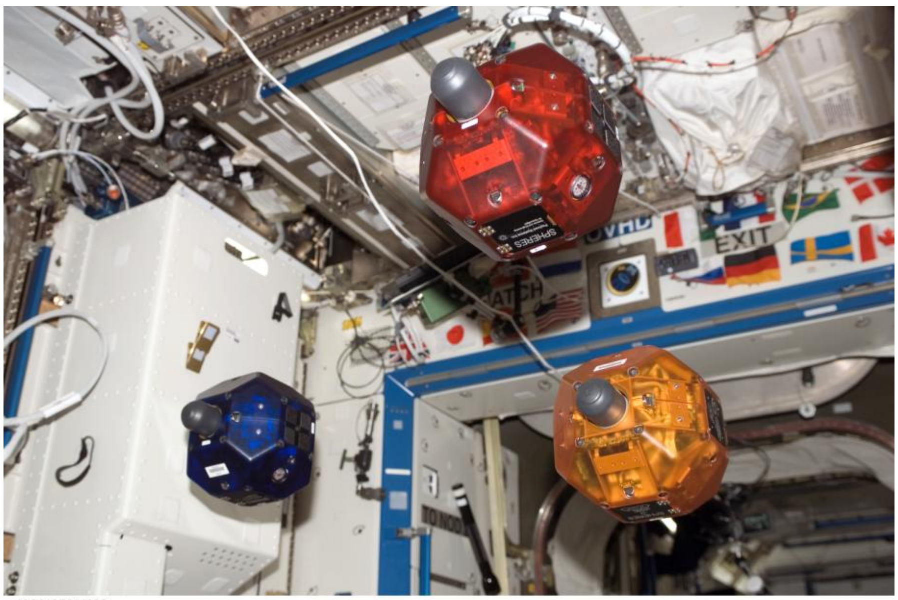
"What If" Science. With access to the environment of space costing just a few thousand of dollars it is possible to create programs where initial hypothesis or systems can be tested quickly and easily. Instead of lengthy analysis to determine if a flight is necessary the research can simply fly a payload to find out the answer. Instead of a space flight coming at the end of the research process it can be done much earlier and more often.

Additional Information: For more information please see http://masten-space.com or send email to Michael Mealling at mmealling@masten-space.com

Using the Shuttle, MIR and ISS for Operating Micro-Gravity Engineering Research Laboratories

David Miller

Prof. Miller has developed an extensive set of dynamics and controls (D&C) technology research laboratories on the Shuttle (MODE STS-40, 48, 62; MACE STS-67), MIR and ISS (MACE Expeditions-1 & 2 and SPHERES Expeditions 13 & beyond). Exploiting the long-duration micro-gravity environment that these carriers provide has presented challenges in creating the attributes of a research laboratory while simultaneously satisfying the unique safety and operational constraints of such carriers. This talk will discuss the design and operation of these laboratories as well as the research objectives and results. This sequence of laboratories is a pathfinder for one possible mode of technology research on ISS.



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ZERO-Robotics: a Student Competition Aboard the International Space Station

David W. Miller, Massachusetts Institute of Technology

As the International Space Station nears completion, it has gained importance by becoming a U.S. National Laboratory. ISS stands on the brink of having a substantial positive effect on the entire country through its new status, and education will play a major role in achieving the positive effect. The SPHERES program, led by MIT and Aurora Flight Sciences and supported by DoD DARPA/STP and NASA, has provided dozens of students unprecedented levels of access to microgravity for experimentation and analysis at the undergraduate and graduate levels. However, dozens is a very small number for a National Laboratory. "ZERO-Robotics" is envisioned as a robotics competition that will open the world-class research facilities on the International Space Station (ISS), specifically through SPHERES, to hundreds (potentially thousands) of students. By making the benefits and resources of the space program tangible to the students, it will inspire the future scientists and engineers, particularly to lead them back to working in the space program. In this way students, starting at the high school age group, will view working in space as "normal", and will grow up pushing the limits of space exploration, engineering, and development. Further, ZERO-Robotics also builds critical engineering skills for students, such as problem solving, design thought process, operations training, team work, and presentation skills.

The proposed program is aimed at high school, undergraduate, and graduate students, with age appropriate tasks. There are three main phases of ZERO-Robotics. Phase 1 is a software design competition that allows students to have their algorithms run in the microgravity environment on the SPHERES formation flight testbed aboard the ISS. Phase 2 is a hardware design competition that enables students the opportunity to design enhancements that use or add to the SPHERES satellites to accomplish complex tasks not possible with current hardware. By operating in the ISS, with SPHERES, the design of this hardware requires substantial engineering skills but is low risk. Phase 3 opens up the SPHERES program to by creating an open solicitation for unique ideas on an ongoing basis. All phases expose students to the challenges faced in the aerospace field, in a fun and safe learning environment.

Phase 1 - Software Design. This first phase is proposed to kick-start the ZERO-Robotics program by providing both high school and college students the opportunity to develop algorithms for SPHERES in the near future. Within a few months, the competition could have hundreds of students working on the design of software to accomplish complex tasks in space, such as docking, assembly, and formation flight. This first phase is low lead time because the SPHERES testbed is already operating successfully in the ISS. In the competition each team must complete a set of pre-determined tasks on which they are measured for performance. Tasks are age appropriate: high schools will have mission level tasks (determine the sequence of maneuvers), while college students' tasks may focus on controls and optimization. During all phases the students will be challenged not only with programming, but also with the development of documentation and presentations to add to their engineering communications skills. In all cases, the students will have to learn and practice successful teamwork skills as there will be minimum team size requirements. Four steps are proposed for the competition in this Phase, including proposal submission, algorithm simulation, ground testing on the MIT flat floor facility, and, for top teams, flight testing.

In this final step, the selected teams modify their algorithms for implementation in space. Tests are integrated and packaged to be run on ISS. This step includes at least one ISS test session, with live feed of the crew executing the tests. Students will have the opportunity to view their tests run in real-time. Data and telemetry will be downlinked to them a few days after the event so that they can perform data analysis and submit a final report.

Phase 2: Hardware Design. The goal of the second phase is to immerse students, including high school teens, in the complexities of developing space hardware. The second phase is based strongly on the successful "FIRST Robotics" competition (see sidebar). The concept of Phase 2 is based on making a comprehensive kit of components available to the teams; it is to be previously approved to operate safely aboard the ISS as an expansion of the SPHERES facilities. Students will write procedures for crew to assemble their satellite on orbit.

Phase 3: Ongoing Collegiate Competition. Once the ZERO Robotics program infrastructure is well established, the next goal will be to create an ongoing "open solicitation" for ideas to investigate unique robotics problems aboard the International Space Station. This outreach would be primarily geared at undergraduate collegiate teams (but possible other levels too) who wish to demonstrate their own robotics research using SPHERES. On regular intervals (multiple times a year), the team will evaluate the submitted proposals and choose a winner to demonstrate their unique research aboard the ISS. This will create a constant outreach to students, utilizing the Station as a National resource for education and space-robotics research.

Summary. In summary, ZERO-Robotics looks forward to leverage on three existing highly successful programs: the International Space Station National Laboratory, SPHERES, and FIRST, to create a unique opportunity to expose students to space flight experience very early in their educational career. By exposing students early on to the challenges of the space program, these students are better trained to solve these problems as they enter the workforce. By making this a fun learning experience, these students are more likely to continue to pursue math, science, and engineering as a career. The first phase, software development, can be started in the near future.

Flow Boiling for Thermal Management in Microgravity and Reduced Gravity Space Systems.

I. Mudawar[1], [1]Professor, School of Mechanical Engineering, Purdue University, West Lafayette, IN 47907

Significance: Advisory panels, such as at the 2004 "Workshop on Critical Issues in Microgravity Fluids, Transport, and Reaction Processes in Advanced Human Support Technology" recommend increased experimentation in low- and micro-gravity flow boiling physics and systems.

A plan for thermal systems and phase change processes is based on how the continuing need for improved energy-to-mass ratios suggests replacing present single-phase operations with two-phase systems. Future design of important thermal subsystems involves complex multiphase fluid flow and transport issues. Full understanding of these multiphase transport phenomena associated with operation of thermal and phase change subsystems in microgravity is needed for both the design and the safe and efficient operation of phase-change heat transfer systems in space.

The recommended approach for the above goal is to develop phenomenological understanding, accumulate empirical data, develop empirical correlations, theoretical models and scaling laws for two-phase flow in micro- and macro-geometries, boiling and condensation heat transfer, phase-distribution and phase-transition phenomena, and stability criteria for two-phase heat transfer loops in microgravity.

Motivation: Reduced gravity flow boiling heat transfer and critical heat flux data and models are all four virtually nonexistent. There is a dire need for such data to be acquired and for low-g boiling systems experience to be accumulated.

To understand the motivation, consider that phase change cooling is desirable in microgravity and reduced gravity space electronics because of its ability to enhance cooling performance and reduce weight of cooling hardware. The critical heat flux (CHF) is the key design parameter for heat-flux-controlled electronic devices. Thus, an ability to predict CHF is of paramount importance to both safety and reliability of two-phase systems.

Yet, the vast majority of reduced-gravity boiling studies have, and even now remain, focused on impractical *pool boiling* rather than the more-practical *flow boiling*. This has led to conflicting recommendations concerning viability of pool boiling in microgravity but flow boiling remains as the proven method for enhancing CHF relative to pool boiling in 1-g. Specifically, the bulk liquid motion increases CHF by flushing vapor bubbles away from the heated wall before they coalesce into an undesirable insulating vapor blanket. Thus, the flow also constantly replenishes the hot wall with new liquid.

It is simple to anticipate that a desire for minimal power expended on pumping will drive designers towards minimizing the liquid flow velocity in practical spaceflight boiling systems. Thus, the minimum liquid velocity which can adequately increase CHF and suppress detrimental effects of reduced gravity is therefore sought in low-gravity experiments.

Future Possibilities: It is anticipated that the experience gained from zero-gravity CHF experiments at Purdue (Fig. 1) can be applied to reduce experiment size so as to fit a number of the soon-to-be available commercial suborbital spacecraft. While a 5-second stabilization period has been achieved in parabolic flights, the much longer duration sub-orbital rocket flights will enable more creative research and more complete systems development. Important transient phenomena, such as start-up and shut-down in zero-gravity, can be explored during the rocket flights. If shared research flights become as inexpensive as some are projecting them to be, numerous additional geometries, flow characteristics, and similar would become affordable to address. The path from research to practical spaceflight systems will be shortened by more frequent access to low-gravity testing time.

References:

[1] NASA/TM-2004-212940: Workshop on Critical Issues in Microgravity Fluids, Transport, and Reaction Processes in Advanced Human Support Technology.

Figure 1. The Purdue “Flow-Boiling Critical Heat Flux in Microgravity” experiment for parabolic aircraft flights.

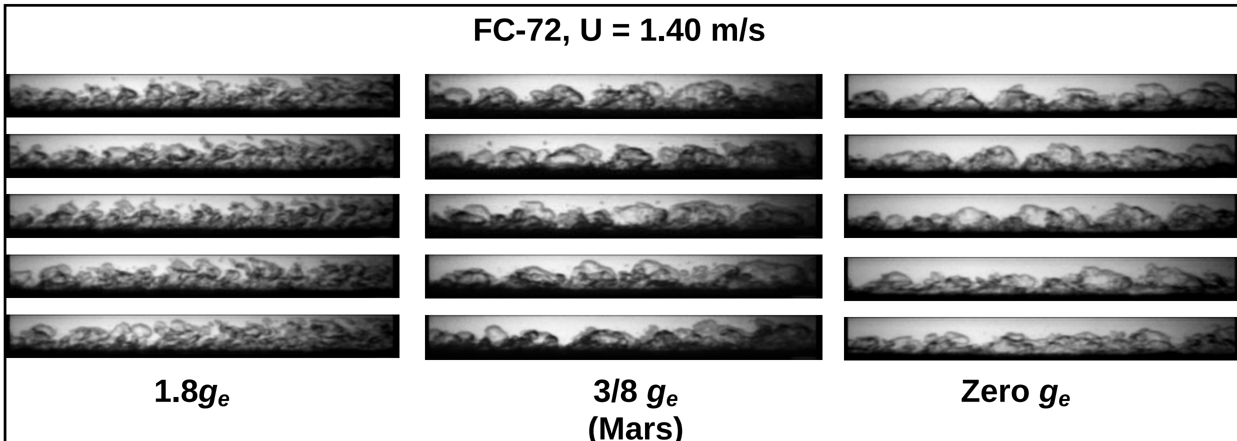

Figure 2. Example images of flow boiling during parabolic aircraft flight testing.

The SOAREX Sub-Orbital Flight Series
M.Murbach

Over the past several years, the NASA Ames Research Center has conducted a series of experimental sub-orbital sounding rocket flights called SOAREX (Sub-Orbital Aerodynamic Re-entry Experiments) . These flights were conducted over land and water test ranges, typically with a variety of means of data collection. Ejection techniques included the forward, rearward and radial direction with up to 11 ejected experiments. Individual flight experiments have included the testing of hypersonic decelerator designs, proto-type waverider concepts, and advanced Entry, Descent and Landing (EDL) systems for future planetary missions. The most recent flight was SOAREX-7 and was conducted from the NASA Wallops Flight Facility during May, 2009.

Fabrication in Microgravity Using "Wet Processes"

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This research explores the possibility of using "wet processes" to produce objects in microgravity that are impossible or extremely difficult to produce here on Earth. Taking weightlessness as an opportunity, and focusing on liquids as materials that are strongly affected by microgravity, computer simulations were executed to analyze the behavior of fluids and the way they interact with other objects (i.e. moulds, membranes, etc).

With increasing number of space travelers every year, there will be a higher demand for facilities and services that would accommodate the future travelers. This not only brings challenge for the private sector in facilitating them, but also creates a lot of opportunities for researchers, engineers, craftsmen and people in many other areas to question and examine their work in a new environment.

Benefiting from some of the physical properties of the liquids in microgravity such as surface tension and mixing properties, G° pouring and blowing processes were tested using resins that solidify relatively quickly.
G° blow molding was suggested in order to produce lightweight structures in various scales. The result demonstrated potentials for production of porous volumes with some degree of randomization in the distribution of air pockets.

The outcome of this research resulted in generating methods to produce low-weight structures using blow-moulding, and solidifying inflatables using fast cure epoxy resins and pouring processes over the surface of the membrane.
This research outlines a number of production techniques that would benefit from microgravity, discusses the feasibility of executing them in weightlessness and outlines the potential applications in future scenarios. Prospective utilization of the findings might vary from architecture to product scale. While the membrane rigidization could favor the production of large-scale structures for future setllers, the blowing process can be applied to fabrication of products and tools.

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[2] S.Jessen, E. Choi. (2004) Development Of A Space Manufacturing Facility for IN-SITU Fabrication of Large Structures. IAC.06-D3.2.

[3] Z. Zhang (1998) New Produt Development Using Experimental Design. University of Groningen Grauate School Research Institute System Organization

Figure 1 Blowing inside a sphere of resin in microgravity. What could be the future's space sourvenir?

Annular /Stratified Low-Gravity Internal Condensing Flows in Millimeter to Micrometer Scale Ducts

Amitabh NARAIN (Email: narain@mtu.edu), Soumya MITRA, Shantanu KULKARNI, and Michael KIVISALU

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Michigan Technological University
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This talk presents computational simulations and experimental results for internal condensing flows over a range of tube/channel geometries – ranging from one micro-meter to several millimeters in hydraulic diameters. Over the mm-scale, three sets of condensing flow results are presented that are obtained from: (i) full computational fluid dynamics (CFD) based steady simulations, (ii) quasi-1D steady simulations that employ solutions of singular non-linear ordinary differential equations, and (iii) experiments involving partially and fully condensing gravity driven and shear driven flows of FC-72 vapor. These results are shown to be self-consistent and in agreement with one another. The paper demonstrates the existence of a unique steady solution for the strictly steady equations for shear driven zero-gravity flows. Transient 0g simulation results show the stability of the steady 0g annular/stratified condensing flows provided the experimental setup allows seeking and holding (through a PID control) of the right exit condition (exit pressure or quality). For the micro-meter to mm-scale condensers, computations indentify a critical diameter condition (in terms of a non-dimensional criteria that depends on other flow conditions) below which the flows are less sensitive to the orientation and time history of the gravity vector - as the condensate is *mostly* shear driven. With the help of comparisons with 0g flow simulation results, the paper also discusses effects of transverse gravity and limitations of ground based experiments. It is argued that suitable system miniaturization will lead to requisite reduction in transient times that would allow a four-minute low-gravity experiment to provide us some critical scientific information on the functionality of condensers in space.

Stability of Evaporating Films in the Absence of Gravity - Isolation of Instability Mechanisms.

A. D. Narendranath[1], J. S. Allen[1] and J. C. Hermanson[2], [1]Michigan Technological University, Houghton, MI, USA (jstallen@mtu.edu), [2]Department of Aeronautics and Astronautics, University of Washington, Seattle, WA, USA (jherm@aa.washington.edu)

The stability of an evaporating film is of interest in a number of technologies and processes from coatings, paints, and food products to low-gravity systems such as water recovery systems. Physical mechanisms may stabilize or destabilize the films. Some of these mechanisms are gravity, surface tension and interface curvature, Marangoni stresses, buoyancy-induced convection, and vapor recoil. There is a need to understand under what thermal conditions each mechanism become important. In normal gravity with a stable upward facing, evaporating, thin liquid film, the destabilization mechanisms are difficult to isolate and study due to the overwhelming stabilization of gravity. Nonetheless, these destabilization mechanisms do affect the film in a terrestrial environment. A classic examples is the 'crinkling' of paint as it dries. Another example occurs in soft lithography processes in which surface waves are permanently left in a layer of photoresist after drying. In reduced gravity, the absence of a strong stabilization mechanism may result in a complete loss of a film, as has been observed in evaporation of sludge for water recovery. [ref]

The stability, convective structure and heat transfer of upward facing, evaporating, thin liquid films are being studied experimentally and modeled analytically. Various heating conditions, constant wall superheat, bulk superheat, and impulsive superheat, have been used to try and isolate destabilization mechanisms. Analytically, we are relaxing the periodic boundary condition normally used in order to investigate the effect of boundary geometry on film stability particularly in the absence of gravity where instability wavelengths may grow to the size of the boundary.

Access to quality, long-duration, (3-5 minutes) low-gravity environment would enable the isolation and study of destabilizing mechanisms on large-area liquid films.

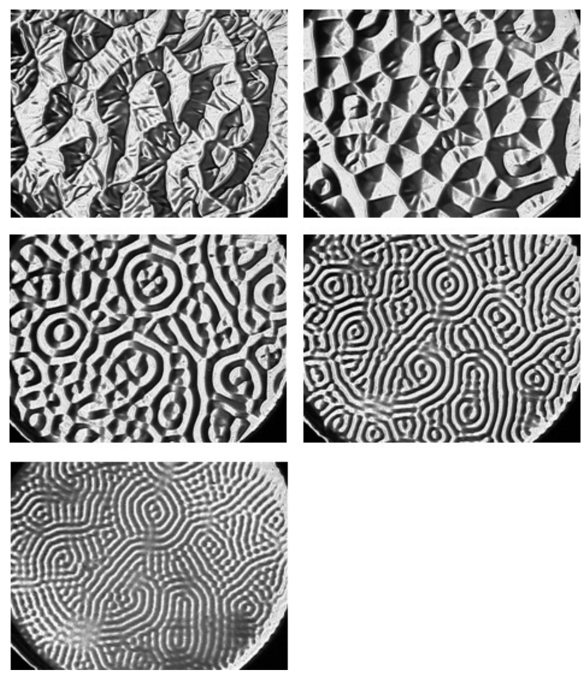

Figure 1: Progression of convective instability patterns as an evaporating liquid film thins. The images were acquired using double-pass schlieren imaging.

HIGH PRECISION SPECTROSCOPY FROM THE EDGE OF SPACE. S. N. Osterman[1], [1]Center for Astrophysics and Space Astronomy, University of Colorado, Boulder, CO, 80303, osterman@colorado.edu.

Abstract: The next generation of suborbital spacecraft represent a unique opportunity to the astronomical community with the promise of economical, high frequency access to space, and with the opportunity for researchers to accompany their payloads. These vehicles represent a new paradigm for suborbital research: At the same time that they relax many of the constraints on scientific exploration and instrument design, they place other, often more stringent limitations on what sort of science can be performed.

While it is challenging to conceive of missions that can produce high quality astronomical observations given the flight envelope and launch vehicle constraints, it is quite possible to imagine observations that demonstrate key technologies for more ambitious missions. A strawman mission demonstrating new technologies for high precision solar spectroscopy will be presented as an example of missions that can take advantage of this new launch opportunity.

Vulcan TP/PDA - A Modular Materials Processing System for Proprietary R&D. Ruel. A. (Tony) Overfelt, Executive Director, National Air Transportation Center of Excellence for Research in the Intermodal Transport Environment, Auburn University, 275 Wilmore Laboratory Building, Auburn, AL 36849, Tel: (334) 844-5940, E-mail: overfra@auburn.edu .

Introduction: Over the years, materials processing in space has generated both scientific and commercial interest due to the uniqueness of the low-g environment on many fluids-based processes. In September 2009, the Materials Science Research Rack was installed in the U.S. Destiny Laboratory. This new facility will provide the scientific community with significant new capability for advanced scientific investigations.

The entrepreneurial commercial community also needs access to the low-g environment of space to enable the development of high value data, processes and materials. Materials and process data that improves the competitiveness of manufacturing industries can have significant financial value. One area where basic materials data can be exploited to improve process design is in thermophysical properties of molten metals and alloys. Basic knowledge of properties like thermal diffusivity, viscosity, density, heat capacity, surface tension, etc. are important in the design of steel mills, casting plants, semiconductor crystal growth, welding processes, etc.

Various techniques for the measurement of thermophysical properties of materials have been developed over the years and recent research and development has focused on molten metals. Unfortunately, the standard earth-based techniques often cannot be confidently applied to high temperature, reactive melts due to contamination from the crucibles required to hold the samples in earth's gravity.

Flexible Space Hardware: Auburn University developed a modular research instrument to melt and test important industrial alloys in low-g. The Vulcan-TP/PDA integrated thermophysical property measurement device, shown in Figure 1, enables multiple thermophysical property measurements to be performed on containerlessly processed samples of a range of molten metals.

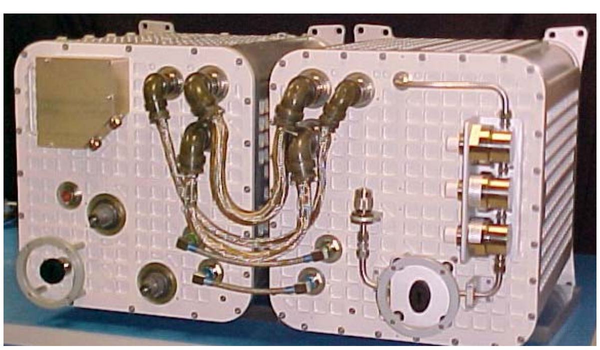

Figure 1. Vulcan-TP/PDA space experiment modules

The Vulcan-TP/PDA instrument carries 18 samples and can be controlled by scientists and engineers on the ground via teleoperation. The Vulcan-TP/PDA is comprised of two containers called Universal Small Experiment Containers (USECs) originally planned for operation in an ISS EXPRESS Rack. The USEC is a uniquely designed payload containment system of Wyle Corporation. The containment system is equivalent in size to two space shuttle mid-deck lockers. Vulcan-PDA (Power and Data Acquisition) contains the electronics for the experiment and provides the interface with the spacecraft/EXPRESS Rack for power, data and cooling. Vulcan-TP (Thermophysical Properties) contains the experiment hardware and provides the interface to the spacecraft/EXPRESS rack vacuum exhaust system.

The thermophysical properties experiment of Vulcan-TP is shown in Figure 2 and is comprised of an automated sample handling assembly, which transfers samples into an induction coil inside a vacuum chamber. A vacuum of $1x10^{-3}$ Torr is achieved via the vacuum exhaust system of an EXPRESS Rack and an internal turbomolecular pump further decreases the pressure to $1x10^{-6}$ Torr. As a sample is heated, data are gathered via video cameras, motion sensors and an infrared sensor attached to various ports on the vacuum chamber.

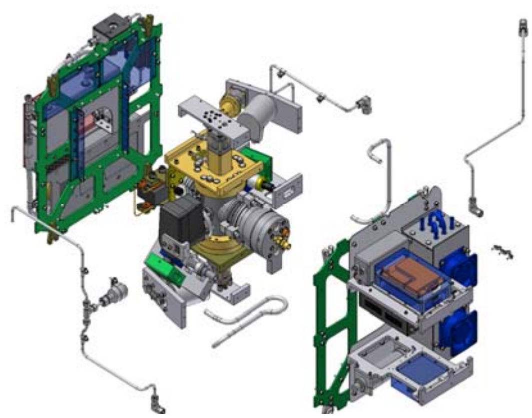

Figure 2. Exploded View of the Vulcan-TP Experiment Module

Video and data are recorded in Vulcan-PDA and downlinked to the ground via spacecraft/EXPRESS Rack data and video links. The Vulcan-TP/PDA uses two 500-watt power inputs and communicates with the ground via an Ethernet connection. See Figure 3. Required cooling, as currently designed, is provided by the ISS medium temperature water loop that interfaces with an internal water loop via a water-to-water heat exchanger inside Vulcan-PDA. Connections between the Vulcan-TP and Vulcan-PDA transfer power, commands, data and cooling between the containers.

Future Capabilities: The two separate container design of the Vulcan-TP/PDA Modular Materials Processing System enables new and considerably different material processing experiments to be developed quickly and at low cost. The dedicated thermophysical properties experiment in the Vulcan-TP module could be replaced with a wide variety of different experiments. For example, directional solidification experiments with metals and/or semiconductor materials or vapor crystal growth experiments could be designed and housed within a new experiment module powered and controlled by the existing Vulcan-PDA.

Acknowledgments: The author gratefully acknowledges the financial support and encouragement received from NASA over the years. In addition, special thanks are due to Charlie Adams, Steve Best, Henry Cobb, Mike Crumpler, Ron Giuntini, Barbara Howell, John Marcell, L.C. Mathison, Don Sirois, Deming Wang and Rick Williams for their many contributions to the development of Vulcan TP/PDA.

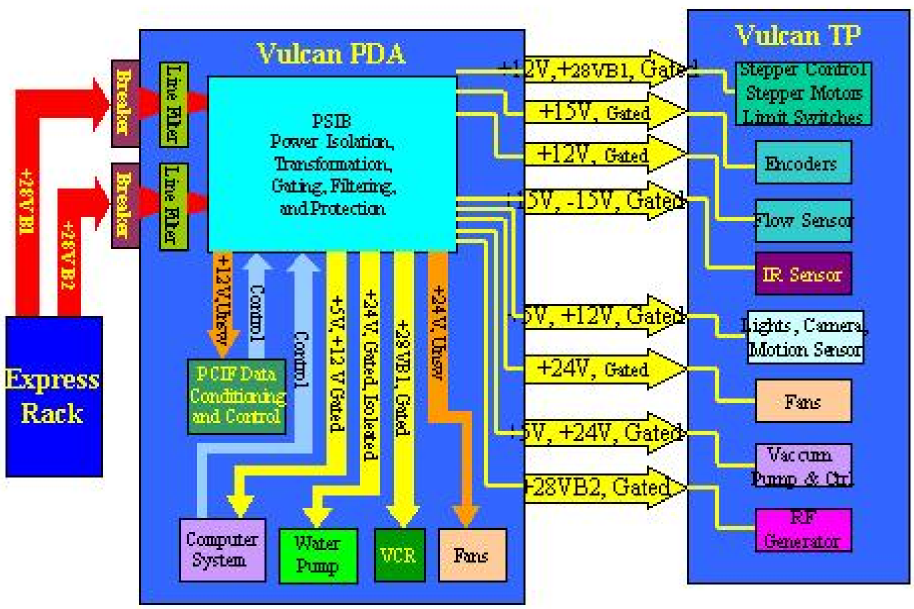

Figure 3. Schematic of the Vulcan-TP/PDA Instrument

EXPLORING THE LAST FRONTIER. Larry J. Paxton[1], The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd, Laurel, MD 20723: larry.paxton@jhuapl.edu.

Introduction: One region of the atmosphere remains as the last frontier – the region from 80 to 160 km – this transition to space, encompasses parts of the mesosphere, lower thermosphere, ionosphere or MLTI. The Earth's atmosphere has been explored by ground-based instruments, aircraft, balloons, satellites and sounding rockets (see Figure 1) but these instruments find it difficult if not impossible to address this region. There, the atmosphere is forced from above and below (see Figure 2). In this talk I will discuss a concept that is both powerful and flexible, and that can address key, urgent issues in our understanding of the MLTI. Due to the significant dearth of measurements of this region, we will be able to make significant advances in our understanding if relatively simple payloads are launched from either equatorial, mid-latitude or high-latitude sites. The observables and objectives remain the same – the factor that differs with launch site is the magnitude of the terms that drive the energy balance and, consequently, the temperature profile.

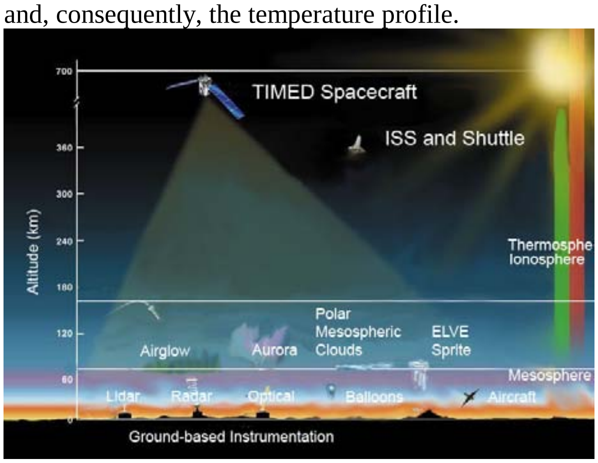

Figure 1. *This region, the lower thermosphere, E-region ionosphere and the upper mesosphere/mesopause is the ideal subject for human tended suborbital science. Orbital assets, such as TIMED, AIM and ground-based assets, such as lidars, radars, and optical instruments provide valuable collaborative science.*

The MLTI is literally the gateway to space. The key process is the transition from a well mixed atmosphere to one in which diffusive separation occurs. This transition is important to our own planet as it is here that the flow of hydrogen into the upper atmosphere, leading to eventual escape, is controlled by the eddy mixing coefficient and the temperature profile.

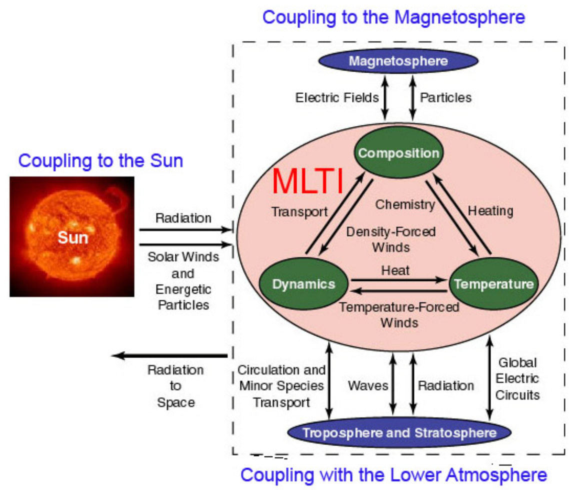

Figure 2*. The Mesosphere/ Lower Thermosphere / Ionosphere or MLTI is forced from above and below. Atmospheric waves propagate from below and deposit their energy in the MLTI. Wave forcing from below is captured in the eddy diffusion coefficient. At high latitudes auroral particles heat the upper atmosphere through particle deposition and Joule heating. Figure Courtesy of TIMED mission.*

One of the key questions that we must understand is: what is the temperatue structure of the MLTI region? The temperature structure in the upper atmosphere of all planets is controlled by the balance between cooling and heating terms. These terms demonstrate both global and local variability and they vary in response to solar output changes with the solar cycle, geomagnetic storms, and, quite possibly, possibly, anthropogenic influences. For example, the mesopause, the temperature minimum, is the coldest place on Earth with a temperature of around 172 K. This is due to the combination of the strong CO_2 cooling and the relatively low amount of absorption of solar radiation. The altitude of the mesopause shows some variation but is generally at about 85 km. The summer mesopause is colder than the winter mesopause – a consequence of gravity-wave dissipation which sets up a circulation pattern that results in downwelling at the winter pole (leading to adiabatic warming) and an upwelling at the summer pole (leading to a cooling).

These processes, and others, constitute the lower boundary conditions of the MLTI. Variation in many if not all of the physical parameters that characterize the MTLI is approximately equal to the mean of that parameter. In other words, if the mean electron number density at a particular location is $1x10^{11}$ electrons/m^3 the “one sigma values” measured will be about $1x10^{10}$ to $2x10^{11}$ electrons/m^3, at best. This variation is driven by forcing from above and below, and transport of energy, momentum and mass within the system as well as electric fields that may be internally generated or externally imposed.

Global circulation models make a number of parameterizations of subgridscal processes. The most important of these are the parameterization of the eddy mixing coefficient, K. Others include the auroral Joule heating. Suborbital experiments will provide the opportunity to test those parameterizations. An associated science analysis program could evaluate the impact on the first principles models.

This work is urgent as it directly impacts our ability to predict and/or model the solar cycle variability of the E-region ionosphere and lower thermosphere and supports the ongoing AIM and TIMED program. AIM – the Aeronomy of Ice in the Mesosphere – is characterizing the distribution of PMCs and their physical properties. TIMED is studying the dynamics and energetics of this region. There is a strong synergy possible with the AIM and TIMED missions.

In the likely event that TIMED and AIM are cancelled before the first of the next generation of suborbital vehicles can fly, this will be the US ITM community’s only access (aside from traditional sounding rockets) to this region.

In addition to understanding our own home and the transition from an atmosphere to space, we will also have important insights into the processes that lead to the evolution of other terrestrial planets – especially the escape of hydrogen and how that shapes the amount of water on a planet like Mars and Venus and how increasing CO_2 shapes the hydrogen budget in the upper atmosphere.

In this talk I will provide more detail on the pressing problems in MLTI science and how these can be addressed by suborbital platforms.

Integrating Education, Research, and Design-Build-Fly: Perspectives from AggieSat

Helen L. Reed
Texas A&M University

The prospect of the next generation of commercial suborbital vehicles providing opportunities for the community to attract students and instill cognizant engineering practices and systems-level perspective in our students, is incredibly exciting. In providing a real experience for students with real deliverables, quality assurance checks, documentation, and organization, a university environment features some interesting challenges, including minimal resources, continuity of "workforce", time management (classes, …), varying levels of experience on the team, and so forth. Our lab integrates research, design-build-fly, and education with multidisciplinary teams of freshmen through graduate students, and has gained many lessons learned over the years in launching three satellites, two payloads on an Orion sounding-rocket out of NASA Wallops, payloads for several high-altitude balloons, and four KC-135 microgravity experiments.

Reducing the Complexities of Integrating Suborbital Capabilities

Berni G. Reiter, Michael A. Schmidt, Sovaris Aerospace, LLC, Boulder, CO 80302

Managing the complexities of suborbital systems is among our most daunting challenges. One of the key features of reducing complexity and facilitating integration of systems is a vast simplification of the software architecture. A novel, object-oriented programming language (COOP-ER™) can reduce the application footprint from, for example, 50 to 100 megabytes down to roughly one (1) megabyte. This reduced application footprint allows for sharply reduced power consumption, greater program stability, greater ease of integrating system components and new devices, and reduced development times. In addition, this platform is extremely front-end friendly. It can be taught to investigators in as little as 8 weeks, so that programming can more easily enter the hands of those with the core knowledge in their respective discipline

This new programming language is coupled with a novel database structure called Omnidex™, which is a robust search/find engine that enables more efficient parallel management of high dimensional data. It is a hybrid of capabilities that integrate traditional database structures and retrievals, combined with free-text and the inclusion of massively large numeric data fields. Another feature of this database architecture is the capacity to “report out” the variables most responsible for the change under various conditions, which can be used to augment traditional data reduction techniques like principal components analysis (PCA).

When integrated with a paired photon-based communication network (optical multiplexing), this synthesis of technologies allows for cross-platform applications that can address numerous challenges within the ground-based and flight-based suborbital environment. The footprint of all underlying technologies is highly compact, taking a fraction of the space compared to any conventional technology and associated applications, while delivering extraordinary sophistication. As such, it is possible to deliver state-of-the-art software on computers the size of an iPhone.

EMPLOYING ONBOARD VIDEO FOR ENHANCING SUBORBITAL RESEARCH. R. W. Ridenoure, Chief Executive Officer, Ecliptic Enterprises Corporation (Pasadena, CA, and Moffett Field, CA, rridenoure@eclipticenterprises.com).

Introduction: For any of the emerging human-rated aerospace systems designed for flight operations in the suborbital regime, selective placement and use of onboard video systems promises to enhance overall situational awareness and flight documentation, and ultimately the effectiveness of suborbital research conducted during such flights.

Motivation: Capturing activities and events onboard human-rated aerospace systems has been integral to the civil U.S. human space program since the Mercury launches, first using exclusively conventional film technologies and later film and video. This practice continues to this day on Shuttle and International Space Station.

Video systems first developed in the early and mid-1990s to provide onboard views for various uncrewed U.S. launch systems (Pegasus, Atlas, and Titan IV) were eventually adapted for use on Shuttle External Tank during its (suborbital) ascent phase, with the first launch in late 2002. No further Shuttle launches with this onboard video system were firmly planned as of early 2003, but the *Columbia* orbiter breakup during reentry precipitated a series of decisions at NASA which made such onboard video systems standard equipment for providing enhanced onboard situational awareness on all Shuttle launches, starting with the Return-to-Flight launch in mid-2005.

During the post-*Columbia* Shuttle hiatus, similar onboard video systems captured multiple dramatic views (live and recorded) of the pioneering, privately developed *SpaceShipOne*/*White Knight* suborbital aerospace system as it captured the X-PRIZE (see photo).

The experiences and lessons learned from these two examples and other less visible ones provided most of the impetus for treating onboard video systems not as discretionary capabilities, but required.

Key Factors to Consider: Suborbital researchers contemplating the use of onboard video during their flights should consider various key factors, which will be highlighted.

Provider. Does the host vehicle come with onboard video capability, or does the researcher have to provide it? Or Both?

Control. To what degree does the video system need to be manually controlled by the researcher or host vehicle crew, via commanding by ground-based operators, or via autonomous means? Are there important operational constraints to factor in?

Sensor Suite. How many cameras are required, and where should they be placed? What types of sensors, lenses and optical characteristics are needed? Are lights needed? How about supporting engineering data?

Data Transport. How many live video feeds are required? How many recorded? Is data compression an issue? Playback? Editing? What's the downlink frequency and allowed bandwidth? What sort of ground-based assets are required to receive the downlink, capture it and display it?

Architecture. Does the system support a series of research flights? Can it work on different host platforms? Is it integrated with the researcher's equipment, the host platform or both? How is it tested before the flight? Does it scale (up or down)? Is it modular enough to accommodate technology modifications and advances? Is it easily maintainable?

Programmatic. What does the system cost (non-recurring and recurring)? Does it have any flight heritage? How long does it take to acquire and integrate with the host platform? Can intellectual property be protected? Are there any licensing, policy or ITAR issues?

Near-Term Prospects: Examples of how onboard video can be employed to enhance suborbital research will be discussed, using likely near-term host platforms and research objectives as "case studies" for consideration. The current state of technology and important trends will also be addressed.

HIGH-ALTITUDE BOUNDARY-LAYER TRANSITION - PROSPECTS FOR RESEARCH

William S. Saric & Helen L. Reed

Texas A&M University

The use of re-usable vehicles with significant instrument payloads (70- 100 kg) can provide the means to obtain transition data at high-altitudes and Mach number. Various techniques will be discussed to acquire these data. Atmospheric measurements are a key element to this endeavor since the randomness of high-altitude transition may be due varying concentrations of particle and ice crystals.

Work supported by the AFOSR/NASA National Center for Hypersonic

Research in Laminar-Turbulent Transition

XPC –A Novel Platform for Suborbital Research.

Paul Schallhorn[1], Curtis Groves[1], Charles Tatro [1], Bernard Kutter[2], Gerald Szatkowski[2], Mari Gravlee[2], Tim Bulk[3], and Brian Pitchford[3], [1]NASA Launch Services Program, KSC, FL, [2]United Launch Alliance. Denver, CO, [3] Special Aerospace Services, Boulder, CO.

Abstract: High altitude, suborbital research payloads are typically restricted to small packages (in terms of both volume and mass) due to the delivery platform employed. Typically, sounding rockets providing these services have payload capacities which severely limit the scope of the research which can be performed. A new research platform is currently under consideration for both large payload microgravity suborbital payloads seeking access to these regimes. The EXternal Payload Carrier (XPC) utilizes an open solid rocket motor position on the Atlas V vehicle and aerodynamically mimics the outer contour of a solid rocket motor. This paper will detail the current conceptual design and capability of XPC for potential future users.

Scientific Opportunities Enabled Via Affordable Suborbital Access

John Schmisseur, Air Force Office of Scientific Research

While ground test and numerical simulation remain the foundation for research addressing aerothermodynamic flows associated with reentry bodies and air-breathing space access, scientific flight research represents a critical opportunity to focus and provide guidance to such efforts. While many aspects of the flowfield around a hypervelocity body can be simulated in ground test facilities, no facility can match the exact flight environment. As a result, progress in the development of technologies critical to planned hypersonic capabilities is often paced by the ability of researchers to extrapolate scientific results from ground test to flight conditions using computational solutions to guide scaling. While flight research provides a means to circumvent such challenges, the cost associated with such an approach is prohibitive within the scope of a basic science program. This presentation will address the scientific opportunities enabled by affordable access to suborbital systems. Examples will be presented within the context of contributions to planned future DoD capabilities. The joint Air Force - Australian DSTO HIFiRE flight research program will be discussed along with efforts to coordinate contributions from several flight research programs.

DESIGN OF ADVANCED VERY HIGH RESOLUTION RADIOMETER FOR SURFACE TEMPERATURE ANALYSIS AND CHLOROPHYLL CONTENT INCORPORATING NANO/PICO SATELLITES. Rishitosh Kumar Sinha[1], Dr. R. Sivakumar[2], Department of Remote Sensing & GIS, SRM University, Chennai, INDIA , Email[1]: rishisrmice@gmail.com

Abstract: The collection of accurate, timely information of the chlorophyll content and temperature of the sea surface will always be important. The collection of such information using in situ technique is expensive, time consuming and often impossible. An alternative method can be done by analyzing the multispectral image. The design of this miniaturized non imaging radiometer enables the development of very high resolution data for surface temperature analysis. This advanced radiometer is capable of acquiring a wide swath of 960 km, at a high resolutions level, thereby providing surface temperature analysis in the visible and infrared regions of the spectrum in various selective channels. An appropriate choice of the materials for the radiometer optics and the coating of nano materials on the lens are achieved so as to absorb 98% of the optical radiations. The design of nano bolometer with a coating of LaB_6 onto the silicon sheets in the nano regime after ensuring 93% of absorptions produces an instantaneous signal generation system by exciting the surface plasmon electrons. An insulation layer of vaccum is developed for ensuring cooling of the nano bolometer. The output from the nano bolometer is given to the silicon temperature sensor, where the output from the sensor is incorporated to develop the temperature for that particular region for which there is a difference in the input and output signal for the sensor. The output signal from the sensor is given to an analog to digital converter from where a high resolution data is recorded for determinations of chlorophyll content and also an improved understanding of circulations and distributions of phytoplankton population in water masses can be achieved. The revisit time or period & the inclination angle of the radiometer have also been taken under considerations so as to maintain the preciseness of the data. The very low power consumptions (<10 watts) capability and the overall volume of the system enable it to be fit as the payload of a nano satellite.

Keywords: multispectral image, resolution, radiometer, sensor, optics, bolometer, signal, silicon, temperature sensor, chlorophyll, nano satellite.

Problems in the MLT Region of the Atmosphere Which Need a new Approach

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Introduction: The mesosphere-lower thermosphere (MLT) region of the atmosphere (80-120 km) is important as the boundary between the terrestrial environment and the ionospheric/space weather regime. It is the region where gravity waves break, where meteors ablate and where the atmosphere changes from well mixed to a heterogeneous composition. It also represents the base of the ionosphere. Despite its importance, it remains relatively unexplored both due to the difficulties in accessing this region for in-situ observations and in interpreting remote sensing data.

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Discussion: Several key observables have resisted our attempts at quantification. Here I summarize some of these problems with an emphasis on how reliable, in-situ access to the MLT region might solve them. Specific examples include the problem of imaging the products of meteoric dust ablation, measuring the carbon dioxide abundance and measuring the wind shears which seem to be relevant for the surprisingly rapid, world-wide transport of space shuttle plumes. With the advent of global meteorological models of the entire atmosphere, from the surface to the thermosphere and ionosphere, the need for reliable MLT data to feed assimilation systems is likely to increase in coming years. An example from a current prototype system, NOGAPS-ALPHA (Navy Operational Global Atmospheric Prediction System- Advanced Level Physics High Altitude) is shown in Figure 1[1].

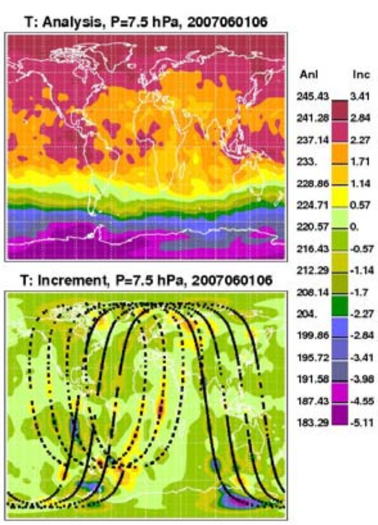

Figure 1: Sample of a temperature field from a middle atmosphere data analysis system. The top panel is an analysis field for 7.5 hPa (about 35 km). The bottom panel shows the temperature increments caused by the injection of temperature data from the AURA/MLS instrument (orbit is the solid black curve which goes pole-to-pole) and the TIMED/SABER instrument (dashed black curves which go from 50S to 80N).

The data requirements for future versions of these analysis/forecast systems will be discussed along with suggestions for meeting these anticipated needs.

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Implementing the NASA CRuSR Program. M. G. Skidmore[1], D. C. Maclise[2], Y. D.Cagle[3], R. C.Mains[4], L.Chu-Thielbar[5], [1]NASA Ames Research Center (NASA ARC, MS240-10, Moffett Field, CA 94035_Mike.Skidmore@nasa.gov) , [2]NASA ARC (Douglas.C.Maclise@nasa.gov), [3]NASA ARC (Yvonne.D.Cagle@nasa.gov), [4]Mains Assoc. (rmains@mainsgate.com), [5]SETI Inst. (Lisa.Chu-Thielbar@nasa.gov).

Introduction: With the advent of a new class of Commercial Reusable Suborbital spacecraft, NASA is developing a new program to respond to policy guidance and to facilitate access to "Near-Space" by NASA-sponsored researchers, engineers, technologists, and educators. The goal of the Commercial Reusable Suborbital Research Program (CRuSR) is regular, frequent, and predictable access to the edge of space at a reasonable cost with easy recovery of intact payloads.

Background: Extensive guidance concerning Commercial Space has been delivered by Congress:

• 1958 National Aeronautics and Space Act
• Commercial Space Act of 1998
• NASA Authorization Act of 2005
• NASA Authorization Act of 2008

And the White House:

• White House Space Policy (2004)
• White House Space Transportation Policy (2006)

Goals: The CRuSR Program has been developed to respond to the guidance referenced above and intends to implement this guidance in the following specific ways:

- Educate the scientific and technological (user) community about the opportunities presented by this new access to space
- Facilitate user access to Near-Space through the emerging Commercial Reusable Suborbital community
- Work with FAA and other regulatory agencies to achieve safe and effective access to Near-Space
- Facilitate the operations of a commercial payload integration industry that will work to move experiments safely and effectively from the laboratory onto Near-Space platforms
- Work to transfer NASA technologies and processes critical to the transition of experiments from laboratories onto Near-Space platforms
- Work with established spaceports to encourage commercial activities that facilitate the growth of suborbital space research
- Work with government (DoD & other agencies) and industry to leverage resources across the R&D community to develop access to Near-Space
- Work with the government's administrative infrastructure to define strategies and approaches that will facilitate research access to Near-Space
- Engage the education community to integrate their expertise and creativity into Near-Space research so that the integration of Scientific, Technical, Engineering, and Mathematical (STEM) educational assets and Near-Space are mutually beneficial and self sustaining
- Facilitate the development of an open interactive website where:
    • the research community can exchange information and ideas to facilitate development of an active and knowledgeable user community
    • the launch provider community can share information to develop common community responses to items of interest, develop standard payload interfaces, and communicate capabilities to potential users
    • the broader Near-Space community (launch providers, users, service providers, & government) can exchange information and develop innovative collaborations

The CRuSR Program is soliciting input from the user, provider, regulatory, and commercial infrastructure communities so that it may better support the utilization and development of a robust and vibrant Near-Space community.

The Atsa Suborbital Observatory: using crewed suborbital spacecraft for a low-cost space-borne telescope.
L. S. Sollitt[1] and F. Vilas[2], [1]Department of Physics, The Citadel, 171 Moutrie Street, Charleston, SC 29409, luke.sollitt@citadel.edu, [2]MMT Observatory, P.O. Box 210065, University of Arizona, Tucson, AZ 85721-0065, fvilas@mmto.org.

Introduction: We discuss a suborbital flight program supporting NIR observations, suitable for a variety of Solar System targets. A suborbital platform gives an observatory two distinct advantages over a ground-based system. First, a suborbital telescope, at 60-100 km altitude, is above telluric water in the Earth's atmosphere, allowing access to the complete IR spectrum of an object. Second, an inexpensive telescope can observe inside the solar exclusion angles of robotic orbital telescopes. For example, the solid angle excluded for the Hubble Space Telescope is 50^{o}[1]; for Spitzer Space Telescope, it is 82.5^{o}[2]. Observations of the Aten and Apohele asteroids, Vulcanoid searches, Sun-grazing comets, comets reaching perihelion at heliocentric distances < 1 AU, and the planets Mercury and Venus, all must be made in the vicinity of the Sun.

Instrument Concept: The Atsa Suborbital Observatory ("atsa" is the Navajo word for eagle) system would consist of a Schmidt-Cassegrain telescope, potentially a ruggedized commercially-available Celestron tube with an aperture of 356 mm and a focal length of 3.97 m ("telescope"), along with a commercially-available Silver 220 SWIR infrared camera at the focal plane (a FLIR Thermovision SC4000 is also possible) ("camera"). The camera accomodates a filter wheel, and is sensitive to the spectral range of 0.8-2.5 µm with a quantum efficiency over 70%. The telescope is attached to a gimbal system and drive motors. The exact configuration will depend on the vehicle used: in the case of Virgin Galactic's SpaceShip2, the gimbals would be attached to the front aperture of the telescope, and attach, via a frame or bracket, to the SS2 porthole. The aperture opening is kept very close to the porthole. Gross telescope steering would be provided by the spacecraft; fine steering is provided through the gimbal system. This telescope would have diffraction-limited resolution of about 2.6 km/pixel on the Moon near 2.0 µm for lunar observations. Actuation might be motor-driven, potentially with a steadicam-like system to track the target through perturbations of the spacecraft (similar systems currently fly on Air Force Predator and Reaper drones). The initial target acquisition would be done manually by the operator. Control of the telescope, including data acquisition, would be done with a ruggedized laptop computer.

Observations with Atsa require a judicious selection of filters. For asteroids, the filters should concentrate on defining the existence and characteristics of the mafic silicates having absorption features near 1.0 and 2.0 µm (pyroxene, olivine), or the existence of water of hydration by observing OH and H_2O near 1.4 and 1.9 µm, and the overall trend of the slope of a featureless spectrum. A possible suite of filters to use with these asteroid observations includes medium-band (200 Å FWHM) filters centered at 0.9 µm, 0.93 µm, 0.96 µm, 1.00 µm, 1.10 µm, 1.25 µm, 1.40 µm, 1.90, 2.00, 2.30 µm, in order to identify and discern spectral features of pyroxenes or olivines or both near 1.0 µm (shape of M1 mafic silicate feature for pyroxenes and olivines), pyroxenes near 2.0 µm, plagioclase at 1.25 µm, the water of hydration combinations and overtones at 1.4 and 1.9 µm, and the overall shape of the spectrum. As the object gets closer to the Sun, the thermal component in the spectrum dominates at shorter wavelengths in the near IR, and will need to be characterized and removed from the photometry.

Heritage and development status: The telescope and focal plane components are all commercially available. The parts that must be custom fabricated include the interface between the telescope and the camera, the mounting system (gimbals, bracket, etc.), the drive system, and specified filters. Depending on available spacecraft, a simple, hand-steered first iteration of the telescope could be ready in as little as a few months.

Size, mass, power, data: The notional telescope diameter is 14 in, length is 31 in. The tube weight is 45 lb. The camera is ~ 6.5 lb, and ~ 8 in long. The computer is 5.1 lb. Truss and drive motors are loosely estimated here at 50 lb. Total mass is ~ 100 lb. The camera uses a power source that accepts 80-240V AC, and would either need a power from the spacecraft, or an on-board battery. Likewise, the camera can be battery-powered. The duration of the flight is short enough that battery power should be sufficient for both devices. The gimbal drives might similarly be battery-powered, but this is subject to power availability on the vehicle and current draw of the gimbal drives. All data would be stored on the computer hard drive using commercially available software. There would be no real-time data streaming from the instrument, and no data storage requirements levied on the vehicle.

Requirements on a suborbital spacecraft: Use of a suborbital spacecraft for astronomical observations may impose new requirements on vehicles that might be planning for tourist flights. Some targets may require a night launch, which might require upgrades to the craft's avionics to allow for night flight. It may be necessary for a single experiment to take up an entire launch: in the case of SpaceShip2, instruments would be restricted to looking out of portholes, and unless the instruments are looking at the same target (and are in coplanar portholes), it is unlikely that two different instruments could be accommodated on the same flight. An observatory flight would likely not be suitable for flying tourists. On the one hand, the spacecraft may have to fly in an attitude which is disadvantageous for Earth viewing in order to accommodate pointing at the target; on the other hand, pointing stability requirements of the telescope will likely necessitate all participants remaining seated, and not hitting the side of the spacecraft (as they would do if free-flying), even if the telescope were isolated from passengers.

Flight planning and training requirements. As the period of time above the atmosphere is mere minutes, effective time management is critical to mission success. This will require choreographing the mission beforehand, and understanding the timing of critical events, such as maneuvers and deployments, to the second. Flight training for the crew should include NASA-like practice of the mission profile, with plenty of simulated missions run before the real thing.

Window. The spacecraft window must have good transmissivity across the desired spectral range (tentatively, 0.4 – 2.5 μm for the infrared telescope concept). It could be that a special window must be fitted to the craft (as is planned for XCOR's Mk 2 Lynx vehicle [3]); also, provision must be made in the craft to accommodate the instrument (attachment points, etc.). The ideal location for an instrument would be on the exterior of the spacecraft to avoid all issues with window tranmissivity.

Stray light. Accommodation for stray light issues will depend on the spacecraft configuration. In the case of SpaceShip2, this may include essentially turning off all lights inside the cabin to avoid reflections from the window, and optically shielding the data acquisition station from the telescope. Scattered light from the spacecraft exterior must also be accounted for: this may mean using a certain attitude to put the telescope in the spacecraft shadow, or even altering the spacecraft exterior to minimize reflected light. Given that one of the great strengths of a low-cost suborbital system is its ability to observe close to the Sun, thorough understanding of and planning for light reflected from the spacecraft will be critical to mission success. Accomodation issues should be worked with spacecraft designers early in their process.

Pointing requirements: The drift rate should be less than perhaps 20 seconds for the target to cross the FOV; overall spacecraft pointing control needs to be within the field of regard of the telescope, which will depend on the window size versus the telescope diameter, etc. One important point is that if we are using a pre-existing window, which ostensibly has a constant thickness, we will want to limit the movement of the telescope so that we do not see time-dependent effects due to seeing a changing transmission coefficient at different angles (at different points during the observation).

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SPACEX DRAGONLAB: A PLATFORM FOR LONGER DURATION MICROGRAVITY EXPERIMENTATION. Erin Spengler and Max Vozoff, Space Exloration Technologies Corp. (SpaceX), 1 Rocket Road, Hawthorne, CA 90250

Introduction: In the coming few years microgravity will become a commercial product offered by a diverse list of providers. These environments are already commercially available through companies offering atmospheric parabolic flight. While this is an acceptable environment for some types of scientific investigation, and an excellent proving ground for longer duration experiments, many fields of science require microgravity environments with duration measured in hours, days or months rather than in seconds.

Starting in 2010, suborbital platforms will offer several minutes of high quality microgravity. In early 2011, the first mission of SpaceX's DragonLab spacecraft will carry up to 6000 kg of microgravity payloads and other in-space experiments into Low Earth Orbit, marking the dawn of regular, frequent, commercial microgravity services for durations up to two years, including recovery and return of payloads at the end of the mission.

Dragon and DragonLab: Microgravity experimentation and utilization are of interest to many fields of scientific research, engineering development and commercial manufacturing. Although many flown payloads have yielded highly successful and promising results, infrequent flight opportunities and irregular reflight options have impeded the development of sustained research programs or plausible commercial business models.

The SpaceX Falcon 9 launch vehicle and Dragon spacecraft are both slated for inaugural flights in 2009 with multiple missions annually thereafter. Flights will be to the ISS and also as commercial free-flyer missions, dubbed "DragonLab", specifically for in-space experimentation. Both pressurized and unpressurized payloads can be accommodated with recovery of pressurized payloads as a standard service. DragonLab's flexible capability and launch rate will make access to microgravity significantly more frequent and affordable. The prospect of routine access to space will enable researchers in a variety of fields to expand their microgravity research while fostering the growth of new industries and research possibilities.

Microgravity Applications: SpaceX has added to its manifest two free-flying missions of its "DragonLab" spacecraft. This improvement in access to the orbital microgravity environment has piqued the interest of the scientific community as microgravity research opportunities abound in both the physical and life sciences. Potential areas of physical science research include the material, fluid and combustion sciences among others. Crystal growth and metallic deposition are examples of specific material science fields where significant possibilities are known to exist with crystals grown in microgravity exhibiting more diverse structures with fewer defects and inclusions than otherwise possible. Vast life science research possibilities include fundamental biology, biotech and space medicine. Many of these processes have been found to be modified or enhanced in a microgravity environment and may be critical to manned missions to the moon and beyond.

Aside from fundamental microgravity research, DragonLab also serves as a platform for research in material sciences and radiation effects, especially space environment effects on surfaces and coatings. DragonLab offers both recoverable and non-recoverable payload accommodations with exposure to the space environment.

DragonLab will also be capable of carrying instruments and sensors into space for on-orbit testing, verification and the attendant accumulation of flight heritage.

This paper emphasizes the value of DragonLab as an on-orbit scientific platform for microgravity research and manufacturing by outlining and discussing the various known and potential areas it will make available.

IMPROVING MISSION FLEXIBILITY WITH THE HIPPOGRIFF PROPULSION MODULE. Robert C. Steinke[1], [1]SpeedUp, LLC (2207 Rainbow Avenue, Laramie, WY 82070, rsteinke@bresnan.net).

Introduction: SpeedUp, LLC is developing a hydrogen peroxide hybrid rocket propulsion module called the Hippogriff. The primary benefit of the Hippogriff will be to improve flexibility in mission planning by allowing incremental increases in the propulsion capability of a launch system. The Hippogriff will be able to increase the apogee and/or payload mass of a suborbital launch. Hippogriff modules are intended to be clustered with additional modules easily added to accommodate payload weight growth.

Technology: The Hippogriff is based on our hydrogen peroxide monopropellant rocket entered in the Northrop Grumman Lunar Lander Challenge. A hybrid rocket is a straightforward evolution from a monopropellant rocket providing the most bang for the buck: medium performance at low cost.

The Hippogriff will use a catalyst based ignition system where the oxidizer and fuel ignite on contact. This provides extremely high ignition reliability, similar to a hypergolic system, but with much easier to handle and more environmentally friendly propellants.

The Hippogriff provides simplicity, reliability, and low cost while giving mission planners the flexibility to tailor the performance of a launch system to their payload.

Performance: The Hippogriff is still under development so all performance numbers are projected. The Hippogriff will have a gross mass of about 130 kg, and be approximately 230 cm long by 45 cm in diameter. Table 1 gives the payload mass to an apogee of 100 km and the apogee of a 100 kg payload assuming a nominal first stage that can lift 100 kg to 100 km and a variable number of Hippogriffs.

Number of Hippogriffs	0	1	2
Payload to 100 km	100 kg	145 kg	165 kg
Apogee of 100 kg payload	100 km	150 km	180 km

Table 1: Using the Hippogriff to increase payload mass or apogee

Planetary Science from a Next-Gen Suborbital Platform: Sleuthing the Long Sought After Vulcanoid Asteroids. S.A. Stern[1] , D.D. Durda[1], M. Davis[1], and C.B. Olkin[1]. Southwest Research Institute, Suite 300, 1050 Walnut Street, Boulder, CO 80302, astern@swri.edu.

Introduction: We are on the verge of a revolution in scientific access to space. This revolution, fueled by billionaire investors like Richard Branson and Jeff Bezos, is fielding no less than three human flight suborbital systems in the coming 24 months. This new stable of vehicles, originally intended to open up a space tourism market, includes Virgin Galactic's SpacesShip2, Blue Origin's New Shepard, and XCOR's Lynx. Each offers the capability to fly multiple humans to altitudes of 70-140 km on a frequent (daily to weekly) basis for per-seat launch costs of \$100K-\$200K/launch. The total investment in these systems is now approaching \$1B, and test flights of each are set to begin in 2010.

We have been funded to conduct a multi-flight next-gen suborbital series of imaging experiments to search for the Vulcanoids, a long sought after putative population of small asteroids orbiting inside the orbit of Mercury.

Background: Among the few stable dynamical niches that are still largely unexplored is the region interior to Mercury's orbit (i.e., orbits with aphelia <0.25 AU; see Fig. 1), where a population of small, asteroid-like bodies called the Vulcanoids is hypothesized to reside. This reservoir likely contains valuable samples of condensed material from the early inner solar system, of which we have no current information, but which could be spectroscopically studied in the future. It also bears relevance on our understanding and the interpretation of Mercury's cratering record, and thus Mercury's surface chronology.

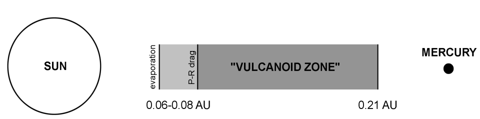

Figure 1. The Vulcanoid zone (VZ) interior to the orbit of the planet Mercury.

Although a modest population of Vulcanoids may exist, they are particularly challenging to detect due to their angular proximity to the Sun and relative faintness compared to the twilight sky. Viewed from Earth, the Vulcanoid Zone (VZ) lies between just 4º (0.08 AU) and 12º (0.21 AU) of the Sun. This means it can only be observed near twilight (with difficulty, we note) or with spacecraft coronagraphs that block the disk of the Sun. High sky brightness, short observation windows before sunrise or just after sunset, and atmospheric haze and turbulence are among the daunting challenges faced by ground-based observers searching for objects near the Sun at twilight. Consequently, only a few visible-wavelength ground-based searches for Vulcanoids have been conducted.

Experiment: We will conduct a large area search for Vulcanoids using our SWUIS imager developed for Space Shuttle and high altitude F-18 flights. We will conduct our Vulcanoid search experiment at altitudes of 100-140 km near twilight so that the Vulcanoid region is seen above a dark Earth with the Sun below the depressed horizon. In this way we will eliminate the scattered light problems that have dogged all ground-based Vulcanoid searchers.

The Vulcanoid search is an extension of the same observing strategy we followed for our NASA-funded investigation at high altitudes in the F/A-18B aircraft. The limitations that have plagued past ground-based visible-wavelength searches for Vulcanoids can be greatly alleviated by reducing or removing the various observing problems (clouds, variable hazes, turbulence, scattered light, high airmass, etc.) associated with the atmosphere. From above the Earth's atmosphere, in deeper twilight than is *ever* possible from the ground for objects so close to the Sun, we will be able to detect Vulcanoids down to at least magnitude V = 12.5, corresponding to p_v = 0.14 (i.e., Mercury-like) objects only 8 km across at the outer boundary of the Vulcanoid zone. Covering ~100 square degrees to limiting magnitude V=12.5-14.0, this effort will result in the most comprehensive, constraining Vulcanoids search yet conducted.

Some Issues in Mesosphere-Lower Thermosphere Chemistry that can be address with Measurements from Next-Generation Suborbital Vehicles, Michael E. Summers, Dept. of Physics and Astronomy, George Mason University, 4400 University Drive, Fairfax, VA, 22030, msummers@gmu.edu.

Introduction: The region of the atmosphere encompassing the mesosphere and lower thermosphere (50-120 km altitude) is possibly the least sampled and least understood region of the Earth's atmosphere. This region of the atmosphere is impossible to sample by balloons and spacecraft, and only briefly sampled by rockets. To date the primary means of studying this region is through the use of either ground-based or satellite remote sensing. Remote sensing by satellites is a powerful means of monitoring this part of the atmosphere, but has its own drawbacks, such as poor vertical and horizontal resolution determined by instrument weighting functions, and highly constrained sampling locations determined by the satellite's orbital geometry. Several issues in mesospheric photochemistry are particularly impacted by lack of high spatial resolution measurements of key reactants and trace gases.

.

Discussion: Several key mesospheric trace gases, such as water vapor, methane, and carbon monoxide have chemical lifetimes comparable to their dynamical transport timescales. As such, these species are especially useful as tracers of dynamical processes. However, in order to characterize dynamic aspects of the atmosphere from the distributions of these tracers it is important to understand their respective chemical production and loss processes to high accuracy. This is very important for using these species to understand the transition region known as the turbopause which is the region where the atmosphere undergoes a transition from being controlled by dynamics to diffusive control. In addition, this region is the atmosphere is where solar influences (e.g. solar UV variability) are expected to maximize.

There are a variety of observations of these important trace gases which suggest that we don't yet have a sufficiently complete understanding of mesospheric photochemistry to be confident in using them as pure tracers of dynamical processes. For example, water vapor exhibits layers of enhanced mixing ratio both at low latitudes and high latitudes which cannot be accounted for by gas phase chemistry [1]. Mesospheric ozone above the mesopause shows evidence suggestive of enhanced mixing rates, presumably from gravity wave breaking, that are as yet not sufficiently characterized to determine the relative role of mixing and chemistry in the control of the ozone profile. There are a variety of dynamical processes which act on both small and large scales, which should lead to observable effects on trace gas distributions in the upper mesosphere, yet are not well understood due to critical observations [2].

High spatial resolution measurements of these and a variety of other trace gases and radicals from the next generation of suborbital vehicles could provide a new window on understanding the details of the balance between chemistry and dynamical processes in the mesosphere and lower thermosphere. The ability to directly sample the environment, i.e., measureing the concentrations of both long- and short-lived chemical species at high spatial and temporal resolution, and at a varity of latitudes and seaons, would provide the necessary information to test the completeness of our photochemical theories and at the same time test our understanding of the dynamical processes controlling this region of the atmosphere. In this talk we will discuss several examples where such measurements might provide a much-needed new approach to mesospheric-lower thermospheric science.

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National Space Biomedical Research Institute and Space Life Science Research
Sutton, J.P.

Established in 1997 through a NASA competition, the National Space Biomedical Research Institute is working on countermeasures to the health-related problems and physical and psychological challenges men and women face on long-duration missions. The research consortium's primary objective is to ensure safe and productive human spaceflight. Projects also address key technologies required to enable and enhance exploration. In particular, NSBRI scientists and physicians are developing technologies to provide medical monitoring, diagnosis and treatment in the extreme environments of microgravity, the moon and Mars. NSBRI discoveries impact medical care on Earth. While solving space health issues, the Institute is transferring the solutions to patients suffering from similar conditions, including osteoporosis, muscle wasting, shift-related sleep disorders, balance disorders and cardiovascular system problems.

This talk will focus on the opportunities for suborbital flights and NSBRI, highlighting areas of scientific and technical interest with application to both spaceflight and Earth-based medicine.

eSpace NSRC Abstract

Scott Tibbitts
Executive Director
eSpace: The Center for Space Entrepreneurship

Space is fertile ground for entrepreneurs with its own unique characteristics and peculiarities. Since opening its doors in January of 2009, eSpace: The Center for Space Entrepreneurship, a 501 c 3 organization formed from a partnership of academia and industry, has been active in this domain, helping to create entrepreneurial space companies, commercialize their technologies and develop a passionate workforce to fuel their growth.

Next generation Suborbital Research is a new frontier that is expected to spawn new entrepreneurial opportunities by providing access to space at a fraction of the cost. The subject talk will present key elements of successful space entrepreneurism and their applicability to this new frontier, with criteria for a successful suborbital space venture presented. Emphasis will be placed on describing opportunities for university students, with suborbital and orbital space entrepreneurship being presented as an alternative to traditional aerospace careers.

DYNAMIC MICROSCOPY IN SUBORBITAL FLIGHT. P. Todd[1], M. A. Kurk[1], J. C. Vellinger[1] and R.E. Boling, II.[1]
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Introduction: Suborbital low-gravity flights to the "edge of space" open new opportunities for laboratory research in low gravity utilizing the capabilities of the forthcoming generation of crewed space ships. There is an expected demand for rapid execution of low-gravity experiments, especially those in which fluids, biological cells or model organisms are involved. A portable, robust microscope will be a vital component of a wide variety of research designs. Two configurations of light microscopy systems are presented here as potential tools for crew members aboard suborbital space ships.

Discussion: The technology described herein had its origins in a completed Phase II SBIR project conducted by Techshot , Inc. for NASA Glenn Research Center. The project culminated in two deliverable models of the product, which was named "Dynascope". One of the instruments consists of a platen equipped with four reservoirs and valves, two piezo pumps, a hollow slide for samples, and three selectable dynamic elements: electric field, magnetic field and heater (Figure 1).

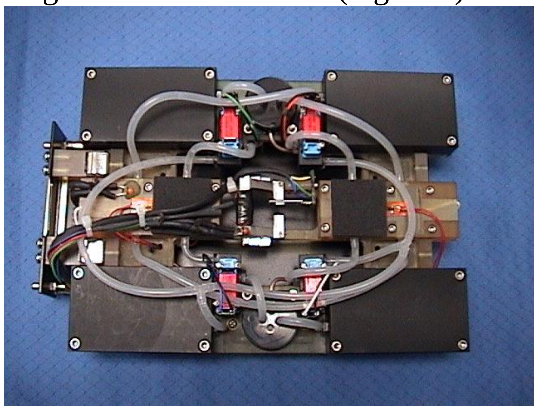

Figure 1. Dynamic microscope platen designed to fit the geometry of standard microscopes. It can be used to apply electric and magnetic fields to samples, thermal control and real-time fluid changes. The platen is 176 mm x 127 mm (6.9" x 5.0").

This device includes a controller for the platen components that controls hardware and software interfaces (Figure 2).

Figure 2. Electronics interface for fluidics controls and image acquisition. The dynamic microscopy platen is seen on the far right. The software environment provides users with opportunities to design, optimize and operate their experiments.

The other instrument (Figure 3) is a self-contained microscopy unit capable of recording time-lapse images of particles or cells or interfaces under dynamic investigations, such as applied magnetic or electric fields, moving interfaces, self-assembling systems or living cells.

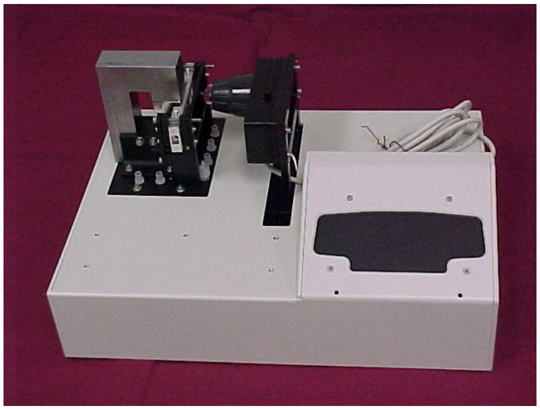

Figure 3. Self-contained version of dynamic microscope for video recording of hydrodynamic, gravitational, magnetic, electrokinetic, interfacial and swimming motion, built into a small-footprint housing.

The mounted USB video microscope is focused and scanned by computer-controlled stepper motors. Fluidics and control circuits are located in the housing.

Hollow slide. At the heart of the technology is a hollow glass slide. Commercial rectangular extruded glass (borosilicate or fused silica) with a 4.0 x 0.4 mm cross section is ideally suited for most anticipated applications. Figure 4 shows an exploded view of a version of a holder for hollow slides. Considering their composition and their shatter characteristics, the hollow slides are embedded in a protective holder that still allows the close approach of a high-magnification microscope objective. The hollow slide is an exchangeable, disposable element of the platform. Its own reservoirs are fed from the four reservoirs on the platen (Figure 1) or within the self-contained unit using two micro pumps and four microvalves.

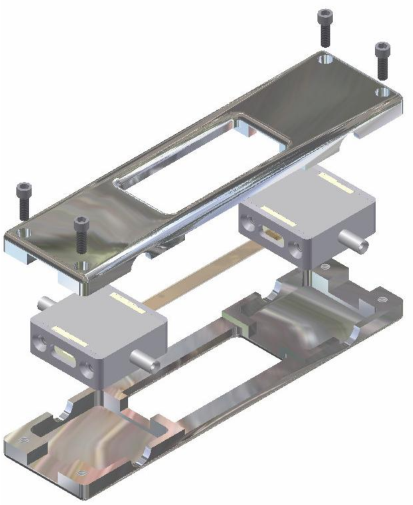

Figure 4. Hollow slide holder. Exploded view of components showing fluid reservoirs "headers" at each end of the hollow slide and embedded into stabilizing holder. Each header has an inlet and an outlet.

Application example. Figure 5 is a photo taken with the device. It shows the interface between two immiscible liquid phases and suspended particles undergoing extraction from the right phase into the left phase. Interfacial experiments represent one category of microgravity science served by microscopy.

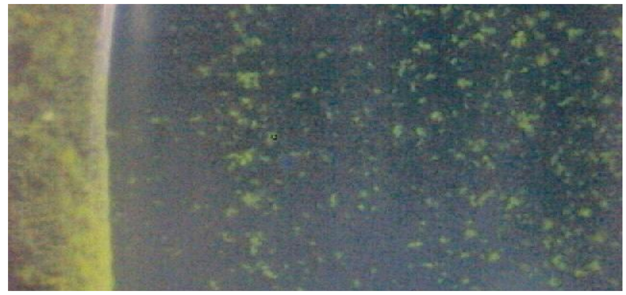

Figure 5. Video micrograph of a two-phase system in the hollow slide showing dynamics of extraction of particles from the right phase into the left phase.

Summary Comments: The technology is especially applicable to life sciences experiments in brief low-gravity episodes. The ability to change fluids in cultures of living cells under the microscope, suitably enough, originated with Charles Lindbergh [1, 2], and today, low-cost, temperature-controlled perfusion units for observing living cultures by microscopy are readily available commercially for ground-based observations (for example: Bioscience Tools, San Diego, CA). Typically such systems are observed using an automated camera and time-lapse microscopy, which we prefer to call "dynamic microscopy" because in most experiments the experimental system is subjected to temporal modifications by the investigator (robotically) and not just passively observed by the microscope, and a suitable name for the instrumentation would be "Dynascope".

Acknowledgments: The development of these two technologies was sponsored by NASA Glenn Research Center via NASA SBIR grant NAS3-02085.

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SLIDING CAVITY ACCOMMODATIONS FOR LIQUID-LIQUID AND THIN-FILM EXPERIMENTS IN LOW GRAVITY. P. Todd[1], J. C. Vellinger[1], M. S. Deuser[1] and R.E. Boling, II.[1]

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Introduction: Suborbital low-gravity flights to the "edge of space" open new opportunities for laboratory research in low gravity utilizing the capabilities of the forthcoming generation of crewed space ships. There is an expected demand for rapid execution of low-gravity experiments, especially those in which fluids are involved. Sliding-cavity accommodations can provide a very rapid means of bringing pairs of liquids into contact, mixing them and either capturing the result or making a video record of the action [1-5]. This technology has been applied to low-gravity fluids experiments on low-g aircraft [6,7], sounding rockets [8] and the U. S. space shuttle [2,5, 8]. Cassettes that have flown have contained biphasic liquid separation, multistage extraction, immiscible fluid contacting, particle diffusion, drug microencapsulation, protein crystallization, uniformity of crystallization, and cell culturing experiments.

Discussion: Cavities can be brought into and out of contact on opposite plates that either slide or rotate. Several very interesting questions can be asked using this simple approach. *How it works:* Figure 1 (top) is a schematic diagram showing how two liquids are brought into contact, allowed to react with or without mixing, and captured during brief exposure to low gravity by sliding to the uncontacted position. Figure 1 (left) shows a pair of plates with a peripheral ring of sliding cavities being loaded with samples. Figure 1 (right) is an exploded view of two plates being assembled into an enclosed cassette so that up to 44 experiments can be performed per cassette. Several categories of low-gravity fluid physics and transport experiments are feasible, some of which are presented here.

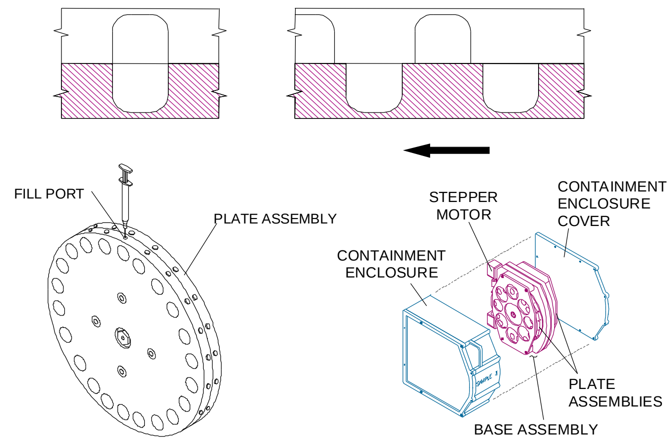

Figure 1. Top: Plates are launched with cavities in the "half-stepped" position (right figure); the lower plate moves in the direction of the arrow to contact fluids in upper and lower cavities (lower cavity may contain a magnetic stir bar). Lower left: Each of 22 cavities per plate is filled with the desired liquid by the investigator. Lower right: Two plates are assembled into each cassette for motorized operation during flight.

Separation methods. Mixing, demixing and transport in liquid biphasic systems and associated interfacial phenomena in biphasic liquid systems can be analyzed on the basis of post-flight capture or in-flight video imaging [2,4,5,8]. Particle migration and aggregation in electrophoresis can be studied using the electrokinetic version of the hardware [9]. Migration of magnetic particles in a variety of magnetic fields and gradients can be studied, and magnetophoretic mobilities can be estimated [10,11]. .

Microbiology and model organisms. Swimming and interaction transport of bacteria, flagellates, nematodes, and various cells can be analyzed on the basis of post-flight capture or in-flight video imaging.

Interfacial reactions, crystallization. Most reactions, especially including phase separation in crystal growth, are considered too slow to study in the 3-6 minute time frame; however, judicious selection of concentrations (which can be varied because many cavities are available) can lead to rapid interfacial crystal growth. In addition, rapid mixing is possible with a mixing version of the sliding cavity device [12,13].

Polymer thin-film casting. The phase-inversion process involved in forming a polymer thin film associated with solvent evaporation is a process ideally suited for study in brief low-g episodes [14-16]. Figure 2 is a schematic diagram of a device that has been used for the study of polymer thin film casting on low-g aircraft.

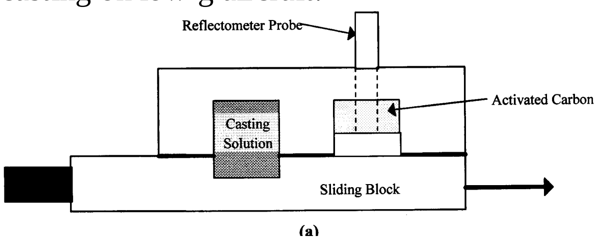

Figure 2. Sliding-cavity method for evaporative thin-film casting. Lower block slides to right bringing casting solution under a chimney of activated carbon that rapidly absorbs solvent.

Summary: Sliding-cavity technology can be applied to a wide variety of experiments during brief low-gravity periods such as are expected on forthcoming crewed suborbital space flights.

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Next-Generation Modular Recovery Systems

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Introduction: Recovery systems perform a critical role in the execution of many suborbital missions and atmospheric research programs where high value payloads and vehicles containing personnel or experimental equipment and data must be safely and reliably retreived. A recovery system could comprise a mixture of subsystems, ranging from a parachute, an integrated guidance system, flotation airbags, impact attenuation devices, mid-air retrieval techniques, location and identification aids.

These subsystems can be combined to provide location accurate recovery of time critical experiments, or to ensure a soft landing for sensitive components. Identification beacons and locational aids offer a means of consistently retrieving the payload. For systems landing on water, flotation airbags can keep the payload encapsulated and above water until recovery personnel arrive.

Guided parachute delivery systems have made significant technology advances in recent years and now provide a reliable means of recovering payloads ranging from tens of pounds up to forty thousand pounds. These recent advances have been required to resupply US forces in Afghanistan and Iraq. The Joint Precision Airdrop System (JPADS) technology has been utilized since early 2007 as an alternative to land based convoy resupply. Substantial DoD investment in this technology coupled with driving requirements for high reliability and low cost has resulted in the development of precision recovery capabilities readily extensible to suborbital vehicles and payloads

Airbag technology for flotation and impact attenuation have also matured rapidly in recent years. Advances in transient finite element analysis have enabled rapid assessment of an entire operational envelopes for these components. Airbags that encompass both landing attenuation and flotation technology can be combined with non-guided parachutes to offer reliable soft-landings.

In addition to recovery of the primary capsule that may contain suborbital experiments, recovery systems have also been assessed for the ability to recover equipment used for external atmospheric research.

Mid-air retrieval is a technique available for recovery of payloads that cannot be subjected to any landing loads. Such systems utilize a helicopter to hook a parachute and payload in flight. This approach was routinely used in the 1960s to recover film during the Corona-Discoverer missions.

This purpose of this paper is to review the current state of the art of recovery systems and discuss how a combination of leveraging emerging technologies and applying a modular approach to selection and design of recovery subsystems has the potential to provide unique, superior, and reliable solutions to the recovery of next generation suborbital vehicles.

SOLAR SYSTEM ASTRONOMY WITH SUBORBITAL CREWED SPACECRAFT: ADVANTAGES AND CHALLENGES.

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Introduction: Observational astronomy has benefited greatly from the advent of spaceflight. Space-based observatories have the advantage of being able to study astronomical targets without atmospheric losses caused by ultraviolet (UV) absorption in ozone layers at 50-km altitude above the Earth. Absorptions due to the telluric water content beginning in the near infrared (NIR) at 0.73 µm, and extending non-uniformly through the mid-IR with increasing absorptivity, are also eliminated above 100 km. Major advances across all fields of astronomy have been made with space-borne telescopes in Earth orbit (e.g., Hubble Space Telescope, Spitzer Space Telescope).

Existing space-borne robotic telescopes cannot, however, observe near the Sun (for example, the solid angle excluded around the Sun for HST is 50^{o} [1]; for SST, it is 82.5^{o} [2]) A unique need exists to observe Solar System objects remotely from Earth orbit, using telescopes that can point within that solid angle excluded for most of the robotic telescopic spacecraft. From Earth's heliocentric distance, observations of the Aten and inner-Earth asteroids, Sun-grazing comets, comets approaching the Sun through perihelion, and the planets Mercury and Venus, all must be made in the vicinity of the Sun. Observations of these objects provide clues to the existence, composition and physical structure of Solar System materials, which in turn teach us about Solar System evolution and the attributes of populations of objects that threaten the Earth through impact. Ground-based observations of these objects are often constrained to twilight observations with the resulting interference of stray sunlight and effects of a high, rapidly-changing air mass on the observations. In addition, they still fail to eliminate the attenuation of light at different wavelengths caused by the Earth's atmosphere.

Suborbital robotic rockets and balloons have carried instrumentation to high altitudes in the past to study some of these astronomical targets in inaccessible spectral regions. These experiments are likely to be single or limited flights. If something fails to operate properly, the results can range from a nonproductive to catastrophic flight.

Aircraft ranging from fully equipped observatories such as the Kuiper Airborne Observatory, to NASA F/A-18 aircraft outfitted with portable photometers and data recorders, have been used in the past to conduct astronomical observations. These experiences offer many "lessons learned" about structuring and executing astronomical observations during a flight. But, although they offered platforms that were flexible - able to be positioned away from clouds or in the line of a planetary occultation, for example - the service ceilings of these aircraft limit their altitudes: the advantages of observing above ozone absorption in the UV at 50 km, or any higher altitudes, cannot be met.

Human-tended observations on suborbital flights can observe spectral regions inaccessible from the Earth's surface, while limiting the developmental expense and maximizing the flexibility of the flight hardware. Simply by inserting "human-in-the-loop", real-time adjustments and decisions about the functioning and execution of the experiment are also possible. A reusable equipment suite that can be reflown multiple times maximizes investment in equipment cost.

Telescope System Needs and Challenges: For Solar System observations, a crewed suborbital system comprises the telescope/detector/data recorder instrumentation, the suborbital spacecraft (including the pilot), and the human in the loop. Robust designs for the hardware incorporated in the spacecraft advance planetary sciences use of these suborbital spacecraft, and must address these considerations (and probably more):

What hardware is required? Equipment mass, volume for both the stowed position and during operation, power requirements for operation, power sources for all hardware (e.g., camera, gimbal systems). What can be obtained commercially (e.g., ruggedized commercial optics and cameras)? What must be custom fabricated (e.g., mounting systems including gimbals, brackets, etc.)?

How should data be recorded? Commercially-available software for data acquisition should be available for use; no real-time data streaming from the spacecraft should be required, and no data storage requirements should be levied on the vehicle.

How can the suborbital flight environment be optimized? A single experiment likely will take up an entire flight. Pointing and spacecraft stability requirements probably limit the number of experiments requiring pointing on a flight, and are likely not suitable for flying tourists. Night launch could be required for some temporally-driven experiments. What safety constraints exist?

What special requirements are levied by reusable suborbital spacecraft? A telescope system probably is mounted to observe through a window on the spacecraft. Transmissions requirements could require a custom window. Degradation of the window with reflight must be considered. Creative means of light and heat shading from sunlight are required.

Solar System Study Example: Target acquisition and tracking for faint, moving point sources represents the greatest observational challenge. Solar System targets that could benefit from the scientific data provided by human-tended suborbital spacecraft, and the design challenges presented by them, illustrate the utility of these types of observations. As an example, consider an inner-Earth asteroid mentioned above:

From ground-based telescopes, these asteroids require twilight observations through high atmospheric air masses for both asteroid searches and photometric or spectral characterization. These objects are also point sources. These asteroids are, however, compelling to observe and study both scientifically and operationally. They are likely representative of daughter asteroids that moved to near-Earth space following the collisional destruction of a main-belt asteroid, but could be extinct comets or comet fragments. Near-Earth asteroids do not have stable orbits; they survive a few Myr before crashing into the Sun, a terrestrial body, or being ejected from the Solar System [3], [4]. We benefit scientifically from observing these objects as they represent asteroids that were disrupted during recent Solar System history, and can be windows into the interior composition and formation conditions that occurred in the inner main asteroid belt, much less affected by surface alterations due to exposure in space ("space weathering").

The near-Earth asteroids also represent the population of objects most likely to produce the next major impacting body to the Earth. An impactor has the capability of wreaking major damage to the Earth's living occupants. For the first time in human history, we have the technological ability to address mitigating this issue. Designing this technological capability requires an inventory of the number and physical characteristics of NEAs. As well, an imminent impactor on its final approach to the Earth with limited time for study could also be a good candidate for rapid response observations by suborbital human-tended spacecraft.

Asteroid reflectance spectra are governed by the crystal structure of surface materials. Most NEAs have reflectance spectra similar to those of iron-bearing mafic silicates (e.g., olivines, pyroxenes, plagioclases), consistent with the S-class asteroids that dominate the inner main asteroid belt. Other NEAs, however, have characteristics similar to the C-class asteroids that dominate the outer main belt, many of which have reflectance spectra similar to aqueously-altered rocks (e.g., phyllosilicates, iron alteration materials). Physical properties of these different minerals vary, suggesting important differences among asteroids of these classes. Two examples here show the need for knowledge of the different properties possible for asteroids.

(1) Different mineralogical composition suggests a different grain density (object mass divided by volume occupied only by mineral grains). Asteroid densities measured are bulk densities (object mass divided by volume of material grains and pore spaces) [5]. Bulk densities of asteroids divided into the two broad classifications of C (1.4 gm/cm^3) and S (2.7 gm/cm^3) vary by almost a factor of 2. Bulk density differences will affect mass calculations needed for mitigation efforts. The mineralogical composition of the asteroidal material is one factor in understanding the bulk density of the asteroid.

(2) The geometric albedo (percent reflected light) among asteroids can vary through a range of 0.03 to 0.5. A factor of 10 difference in albedo translates to a factor of 3 difference in diameter of the object. The size difference will affect the design of NEO strike mitigation techniques for a given object. Visible photometry provides one means of estimating geometric albedo through assumptions about absolute magnitude, H, from photometric measurements [6]. Thermal IR radiometry coupled with visible photometry provides an extremely accurate measure of the albedo.

Characterizing asteroid compositions, size, and structural state requires both visible photometry and thermal infrared radiometry. Narrowband filters at specified wavelengths would elucidate the surface mineralogy well. A camera with a sufficiently wide field of view would be able to capture a known asteroid in its FOV; stable tracking allows for longer integration times which allows us to acquire photometry of fainter objects.

Visible and NIR spectral region photometry should include filters to define the existence of iron-bearing silicates and phyllosilicates, and the overall trend of the slope of a featureless spectrum. Thermal infrared radiometry requires mid-IR observations made at a wavelength near 10 μm. Measuring temperature from observations at two different thermal IR wavelengths permits a measurement of albedo. Background signal for thermal IR observations is greatly reduced, and affords better detection of a faint NEA.

The equipment described here can be used for short-notice targets of opportunity, or objects for which space-based observations provide significant advantage. Other examples covering the range of possible Solar System targets will be presented.

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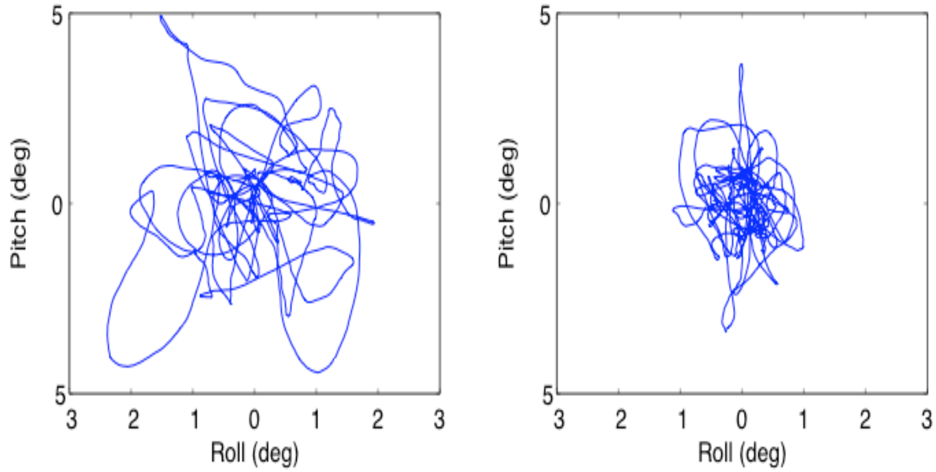
Use of Suborbital Flight to Elucidate the Role of Tonic Otolith Stimulation Due to Gravity in Balance Testing and Orientation Tasks. C.Wall, Harvard Medical School and Massachusetts Eye & Ear Infirmary, Boston MA 02114, cwall@mit.edu.

Introduction. Suborbital fight provides an opportunity for further understanding of tests for the clinical evaluation of otolith function, the tonic effect of gravity upon certain tests of oculomotor function, as well as a better understanding the use of tactile cues for spatial orientation. Each of these three ideas will be briefly explored.

Clinical evaluation of otolith function. The vestibular evoked myogenic potential or VEMP uses sound to stimulate the saccules that are the portion of the otolith organs exposed to a tonic 1 g field on Earth. The saccular response to sound activates the vestibular nucleus and generates a reflex in the sternocleidomastoid muscle in the neck. This almost completely unilateral reflex is measured using electromyography (EMG) and is usually an averaged response to a succession of tone bursts. Abnormalities are commonly detected as a change in the amplitudes of certain parts of the averaged response. The vestibular afferent nerves are characterized by spontaneous activity whose amount depends somewhat on the diameter of an individual nerve fiber, but also upon the strength of the gravity field. How much the average EMG response depends on the latter is not well studied. Suborbital flight, with moderate exposure times to altered gravity, is a way of better understanding the effect of tonic gravity upon the VEMP. The test procedure and apparatus could both be quickly adapted for use in suborbital flight experiments. One factor that is crucial for taking VEMs is the correct loading of the sternocleidomastoid muscle itself. In some cases, the weight of the head is used to load the muscle. This would obviously not work in suborbital flight, but it is not difficult to have the subject apply a known force against a pad to accomplish correct loading. Experiments would likely start with subjects having normal 1 g VEMP responses, then progress to subjects with saccular lesions.

Oculomotor function tests. While the effect of gravity on responses to optokinetic stimuli such is moving striped patterns is well known, the gravity effects on certain volitional tasks is not as well-studied. Saccades or voluntary quick eye movements from on target to another have been studied in parabolic flight, but the emphasis has been on so-called “reflexive” saccades. Making a movement to a target that is no longer visible – a so-called “memory” saccade is less well studied, and may very well be influenced by g level, since g level effects the sense of orientation. For this test, the subject must look back to the site of a *previously* shown target using memory of where that target had been. A sound cue then prompts the subject to shift gaze back to the site of the memorized target. The accuracy and timing of the memory saccade would be recorded. These non-reflexive saccades are thought to be sensitive to mild brain disorders, including mild traumatic brain injury (TBI) that could have an effect on cognitive function. Thus, it may be possible to see whether the exposure to microgravity on suborbital flight has an subtle effect on brain function. Both the test protocol and the eye movement response measurements for these tests should be quickly adaptable to suborbital experiments.

Tactile Cues for Spatial Orientation. Vibrotactile cues have been successfully used for pilot orientation, and recently have been shown to help those with balance disorders better maintain their balance while standing and walking in a 1 g setting. One interesting finding is that the spatial resolution of the vibrotactile display needed to maintain postural stability is unexpectedly low. Using tactile vibrators placed on the cardinal body orientations (forward, right, backward, and left), a spatial resolution of 90 degrees does as well as using 16 directions with a spatial resolution of 22.5 degrees. The figure shows typical responses with and without vibrotactile feedback of body position This result may be attributed to the idea that there are really only two postural control systems in humans while standing in 1 g: an anterior-posterior one and a mediolateral one.



Vibrotactile feedback reduces the degree of wavering while standing on a moving surface. Left figure shows subject wavering with vibrotactile belt turned off. Right is with belt turned on.

But what about using vibrotactile displays to orient people in microgravity? Would a spatial resolution of perhaps 45 degrees be sufficient for self-navigation in microgravity? Another related question is whether it is possible to give a person their own “artificial horizon” in microgravity using a vibrotactile display. Limited data from subjects with Mal de Debarquement Syndrome suggest that such a display can help a person who subjectively feels they are walking on a downward sloping ramp, but logically knows they are not on a slope be able to use the vibrotactile display to “cancel out” the illusion of the slope. Thus, experiments with vibrotactile displays in suborbital flight would be helpful in evaluating this type of device for more prolonged flight.

Conclusions. Suborbital flight would seem to provide a micro gravity environment of a sufficiently long duration so that the effect of gravity upon these three approaches to vestibular/balance testing and potential spatial orientation could be evaluated in a time- and cost-effective way.

MY-ASTRONAUT.ORG: VOTE FOR AND FUND SUBORBITAL SPACE HEROES. E. F. Wallace, Giraffe 'n' Ant Productions (EPO), 7516 Holly Avenue, Takoma Park, MD 20912, efwallace@aol.com

Introduction: "We did it!" cheered crowds worldwide as Apollo 11 crew members toured their home planet. WE put men on the moon. Not just Americans, but the world did it! First we were all glued to the TV and then we threw ticker tape parades. We gave them a hero's welcome.

Through the portal of suborbital space tourism, we have the chance to rally enthusiasm worldwide for earth stewardship through e*mpowerment:* WE can do it! Given a chance to choose our new heroes, we will follow their epic journeys and welcome them home with huge crowds—as their grassroots sponsors. For the industry to prosper, we each need to feel that space tourists are My Astronauts, that we have a synergistic and personal relationship with our NextGen heroes.

Hero's Journey: What suborbital space tourism needs now is not just a memorable logo or tag line, but a unifying and compelling story—a transcultural monomyth, a One Story. Monomyths require heroes, according to Joseph Campbell, who "venture forth from the world of *common* day into a region of supernatural wonder: fabulous forces are there encountered and a decisive victory is won: the hero(es) come back from this mysterious adventure with the power to bestow boons on (their) fellow man.*"* Sounds like a suborbital spaceflight to me, but the operative word is "common."

Elitism—Deterrent to Suborbital Enthusiasm: "One of the discouraging messages that I get from kids is that they feel that the space effort is intangible. They feel that it is elitist and there's no part in it for them," according to Lonnie Schorer, author of *Kids to Space: A Space Traveler's Guide*.

Initially space tourism looks like it will belong to the economically advantaged—as did airline travel in its early years. But would Henry Ford's workers have succeeded in transforming transportation with such vigor 100 years ago if it had not been for the fact that those who worked on the line could also afford a Model T?

Recently students at a magnet middle school for aerospace technology near Washington DC watched a Virgin Galactic flight animation. They were spellbound. Their courses don't cover the advances in commercial spaceflight. But the spell was broken when they heard the $200,000 price. However, when asked to consider the possibility of going into space as a reward for community service, smiles returned to their faces and faraway looks of adventure to their eyes.

Mission: Stewardship: Some young students say the coolest thing about suborbital spaceflight is that it is a "humongous roller coaster ride" that goes "super speedy fast." The most important aspect of space tourism, however, is the ability to view Earth from space, according to over 60 percent of respondents to the Futron Space Tourism Market Study.

Ah Ha Moment. "A Chinese tale tells of some men sent to harm a young girl who, upon seeing her beauty, become her protectors rather than her violators," says Astronaut Taylor Wang. "That's how I felt seeing the earth for the first time. I could not help but love and cherish her."

Similarly a 10-year-old African student imagined how she might feel. "I'd say it was amazing from up there, but I would think in my head…we can make it more beautiful if we take more care of it."

Sharing the Vision. While one may be weightless peering through portals for only a few minutes in space, an ah ha! moment of inspiration takes just a fraction of a second. Multiply the number of flights by the number of passengers who are willing to take the risk to see the precious curvature of the Earth…..The ripple effect of possibilities has no bounds.

Social Experiment. Only about 500 astronaunts have been in space. With frequent flights, full human payloads and a long term goal of including at least two persons from each nation, could space tourism facilitate environmental consciousness to reach a critical mass faster? A social experiment of an unprecedented magnitude awaits.

Social Activism Needs Humans: When I asked students whom they would want sitting next to them in a suborbital space flight, none of them mentioned a scientific instrument.

There is much to be learned from instruments that detect images invisible to the human eye, for example, but humans have the ability not just to see but to *view* Earth's landscape: its dimensions, textures, colors and materials. "The human brain understands scenes, places and events quickly and effortlessly, outperforming the most advanced artificial vision system," asserts Dr. Aude Oliva, Associate Professor of Cognitive Neuroscience at MIT. This is done in fractions of a second because the human brain has at least 250 million miles of wiring—long enough to reach from the earth to the moon! And back to the heart. What boons will be bestowed on mankind based on a shift in space tourists' perceptions, their stories and resultant commitments?

My Astronaut—Drawing From The Pool of Heroes: In order to create the possibility of a monomyth to arise from the global culture, I propose that a non-profit organization named My Astronaut be created.

It would be dedicated to an all nation, cross-disciplinary experience of space tourism for the purpose of Earth's stewardship.

Now, not later. Knowledge without compassion could wreak havoc in a solar system that is already hostile to human life. All the more reason My Astronaut is necessary to contribute to the solar system's care. Even our children understand that there are still lessons to be learned before we migrate.

Stepping onto the Hero's Path: My Astronaut would be open to all candidates who take a stand to live a life of inspiration as Earth stewards before, during and after the flight. The synergy of popular support could precipitate an unprecedented worldwide shift away from the dangers of global warming.

Telling the Story. Candidates would include the great communicators of our culture—musicians, visual artists, dancers, video game designers and filmmakers—so that their stories and those of fellow astronauts could be told in multiple ways.

Physical Challenges. Extreme sports enthusiasts such as urban skateboarders and breakdancers would be encouraged as well as those with careers in the most dangerous occupations such as fishermen, loggers, steelworkers and waste management workers.

Global Understanding. Multinational groups of astronaut candidates would be formed to support each other to promote international cooperation and teambuilding as well as education and public outreach.

Structure. My Astronaut would be a voting and fundraising system built both on social networking via the internet and personal contact.

Modeled on Obama's successful fundraising strategies, My Astronaut would be developed simultaneously in countries with easy access to the internet as well as geographic and economic areas without it. It would bypass the well-worn circuit of traditional big donors and lottery sytems The selection process would be placed in the hands of voters inspired by the environmentally and socially responsible lives of the astronaut candidates.

Efforts of team leaders in remote areas would be facilitated by donations of proper equipment to ensure communication with and connection to the global effort. Twitter, podcasts and You-Tube clips would keep the synergy alive.

Donations would be limited to small amounts over time. Donors would be encouraged to fund more than one astronaut candidate.

Preparing the Hero's Way: When asked whom they would like to be accompanied by into space, middle school students' answers included doctors, lawyers, physical trainers, and "a really good insurance guy." Perhaps answers were based on a combination of fear of the risk involved as well as living inside the Beltway, but they also underscored the fact that many diverse professions are necessary to support this developing industry.

Space Education is "Higher" Education. Every 9 seconds in the United States, another high school student drops out. A large percentage of the world's population need to believe in space tourism to inspire a sufficient number of people to staff it and its ancillary services—whether or not they personally want to leave Earth's atmosphere. Students in middle school need encouragement *now* to finish high school and to choose higher education if only to support the 15,000 projected tourists in 2020.

According to Schorer, "It's hard for regular teachers who are overloaded with required curriculum…to convey to children the information they would need to know to be able to choose one of these trades, professions, or careers….We need International Space High and Middle Schools." Perhaps the ISU in France could be a model.

Other than School. My Astronaut would collaborate extensively with existing community organizations which offer programs ranging from curriculum supplement to encouraging teenage entrepreneurs. We would actively make connections between space tourism and a myriad number of professions: hospitality, business administration, urban planning, and communications as well as the sciences.

Mentoring the Dream. In centuries past apprentices spent years under the tutelage of master craftsmen. Those who are actively engaged in suborbital tourism and research must now step up to the plate as long term mentors to K-12 as well as college students.

A Hero's Welcome Home: Before the first My Astronaut ship launches, spaceports will need to prepare for the thousands of supporters who will see Earth's stewards off and hail their heroes home.

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Applied Low-Gravity Fluids Research: Potential for Suborbital Flights.
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Abstract:

Significant challenges remain for the designers of multiphase fluid systems for spacecraft: liquid fuels and cryogens storage and handling, phase change temperature control systems, and various life support systems requiring water processing. Such challenges are acute for such strongly gravity-dependent phenomena that cannot be thoroughly tested on the ground. Frequent and affordable suborbital flight opportunities provide the potential to gain key knowledge and experience not possible using either shorter duration ground-based facilities or longer duration orbiting spacecraft. Examples of applied fluids research employing drop towers and low-gravity aircraft are highlighted that touch on high performance cooling systems and phase separations for waste water collection and circulation. Such studies are significantly limited to 'subscale' or 'subsystem' levels at best and the potential for dramatic increases in designer confidence and technology readiness are discussed in light of increasingly competitive suborbital flight opportunities. In particular, for high speed flow phenomena, the possibilities for applied research relating to system level tests (start-up, shut-down, transients, etc.), technology demonstrations, and scale-up are addressed.

Convergence of Space Tourist Processing and Suborbital Payload Processing in Spaceport Facility Design.

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Introduction: New spaceports to service the commercial spaceflight industry are in development with either new construction, refurbishment of existing facilities, or at the proposal stage for various locations around the globe. Functional requirements for design concepts for these facilities have mostly been centered on servicing the needs of the space tourist experience and processing the spacecraft for rapid turnaround. The advent of an expanded market for spacecraft operators offering suborbital payload services places additional unique requirements on facilities for functional design that optimizes operational concepts for processing either the tourist and/or the scientific payload.

Tourist or Payload Specialist Operations: Operational considerations from a facilities point of view very widely between accommodating the tourist experience including family and friends, and the payload specialist experience overseeing a scientific payload. Spacecraft operators flying each category of passenger either together or as separate dedicated flights should consider the operational impact on their pre and post flight processing operations and implication for facilities design.

For the space tourist, many of the activities and processes within the building will be centered on the astronaut journey that progresses from initial reception through training, food service, launch and celebration. A segregation and hierarchy of users is likely integrated into facility design layout to maintain varying degrees of access and exclusivity. Meanwhile in the hangar area spacecraft flight prep and overhaul activities strive to progress at a sufficient pace to maintain a turnaround schedule for more than one flight per day. A sample of key systems and hardware requiring routine checks and flight prep for flight turnaround may include:

- Installation/change-out of rocket motors
- Fueling
- Change-out/charging of batteries
- Thermal Protection System (TPS) cleaning/ overhaul
- Decal re-application
- Oxygen servicing
- Environmental Control System (ECS) servicing
- Replacement of nose skid shoe
- Seat widgets
- General cleaning & interior/cabin overhaul
- Data download
- Placement of protective covers for vehicle windows and other miscellaneous

By contrast, payload processing for scientific suborbital flights adds to the above list with requirements for example, of clean room protective spaces for scientific payloads, additional degree of spacecraft resources and ground support equipment for payload integration into the spacecraft. These impact storage, floor space, work area and functional adjacency requirements, which in turn may influence processing turnaround timelines. Environmental implications may include new accommodations for hazardous waste management. Typical functional maintenance areas competing for floor space allocation include:

- Flight Prep and Overhaul
- Engineering & Maintenance
- Bench Testing/ Backshops
- Tools and Support Equipment
- Storage Operations
- Breathing Oxygen/ Liquid Oxygen
- NDI/ XRAY
- Cables/ Wiring
- Hydraulics
- Washing of Spacecraft
- Rocket Motors

Due to the sophisticated and complex nature of sensitive payloads, it may be necessary to accomplish the final prelaunch payload processing in a specially designed facility located close or adjacent to the main staging area. The requirements and characteristics of specific payloads will vary. Design of Class 10,000 or even Class 100,000 clean room bays, or something as simple as a clean tent area for payload processing are considerations for the facility design. A standardized payload container system may be employed, adding additional facility accommodation and spacecraft integration requirements.

Conclusions: A payload operations concept for science flights may be at odds with the flight profile for a typical tourist flight. The preferred concept of operations for science flights and integration of science passengers with other spaceflight participants (space tourists) may impact ground pre and post flight processes and flight turnaround scheduling. The degree of convergence of these two operational scenarios for space port and spacecraft operators should be considered in spaceport facility design and operations.

Life Science Opportunities in Suborbital Flight

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ABSTRACT

Microgravity effects on biological systems occur from the cellular level to the organ level, and effect the whole body as well. The best known ones are those which affect the human astronaut, including bone and muscle, cardiovascular and sensori-motor systems. Some of the influences require days to weeks to observe, whereas others occur within moments of weightlessness. Sub-orbital flight represents an opportunity to make frequent and inexpensive repeat measurements – on animal and cellular preparations and on the flyers themselves, to complement and prepare for orbital studies. In particular, the opportunity to make frequent observations during the transition periods from hypo-g to hyper-g will fill a gap between the short parabolic flights and the highly constrained orbital missions.

BRAIN HEMODYNAMIC CHANGES MEASURED WITH NEAR-INFRARED SPECTROSCOPY DURING ALTERED GRAVITY.

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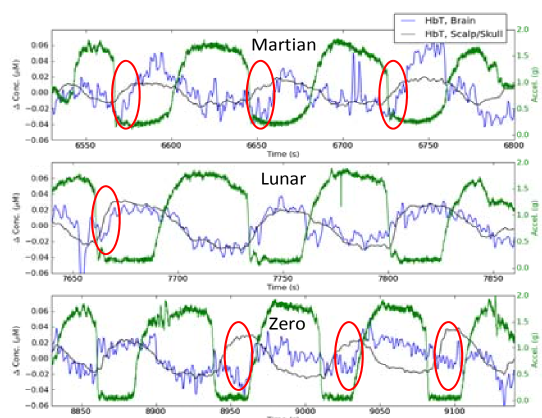
Introduction: During suborbital flights, rapidly changing gravitational forces are expected to significantly challenge the capabilities of the neurovascular system to sustain normal neurophysiological operations. While the brain has robust autoregulatory mechanisms to maintain stable perfusion, the degree to which exposure to hyper- or microgravity (μG) may compromise these mechanisms has not been extensively investigated and is not well understood. Prolonged μG is known to reduce hydrostatic gradients and cause cephalad fluid shifts that could interfere with accurate brain activity monitoring. These changes not only induce adaptive hemodynamic responses by the systemic circulation, but also influence cerebral perfusion pressure and blood flow. Our aim was to determine whether acute changes in gravity, and the attendant changes in brain perfusion, would permit sensitive detection of brain hemodynamics measured using near-infrared neuroimaging (NIN).

Methods: Using a novel mobile NIN device fabricated in our laboratory, we recorded continuous scalp and brain hemodynamic changes during a flight consisting of 20 parabolas, including simulations of Mars gravity, Lunar gravity and microgravity. Each parabola consisted of approximately 30 s of climb and 30 s of freefall. During the flight, the participant was seated upright, facing forward, with his head immobilized with a cervical collar for the first 16 parabolas, then floating freely for the final 4 parabolas.

Results: We recorded eight physiological data channels at 250Hz throughout the flight, including acceleration (Gx and Gz), cardiac electrical activity, respiration, and both peripheral and brain hemodynamics from dorsal prefrontal cortex. Hemodynamic changes associated with gravity alterations were similar in magnitude to those observed in our ongoing ground analog head-down tilt experiments. Following gravity transitions, we also observed differential regulation of brain relative to scalp blood volume.

Discussion: Gravitational variation over a range encountered during spaceflight resulted in clearly detectible modulations in human cerebral blood volume. Although these are the first such measurements accomplished in microgravity, mobile NIN may prove to be a practical means to achieve continuous monitoring of cerebral physiology during suborbital spaceflight. Its use could provide information pertaining to the integrity of cerebral autoregulation mechanisms in the face of phasic gravitational variations and could be of great practical value in routine physiological monitoring of individuals participating in commercial suborbital flights.

Participant wearing our NINscan mobile brain monitoring system during a period of microgravity. Successful continuous measurements of brain hemodynamics were made during 20 periods of reduced gravity.



Total hemoglobin (proportional to blood volume) for the near detector (black; sensitive to scalp and skull) and far detector (blue; additionally sensitive to brain tissue) plotted as a function of gravity loading (green). Red circles indicate periods where brain blood volume exhibited a lag relative to the blood volume of the scalp.

NOTES