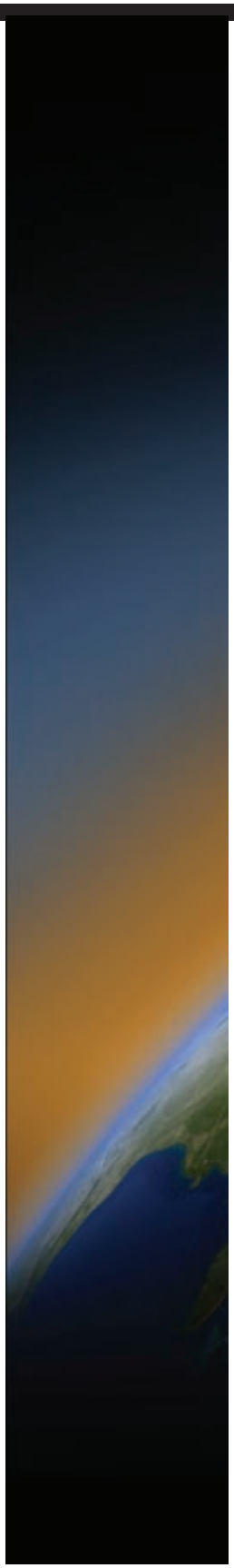
6th International

# Planetary Probe Workshop

**June 21-27, 2008**

Georgia Institute of Technology
Atlanta, USA

**PROGRAM**



# WELCOME

Welcome to the 6th International Planetary Probe Workshop. For the next four and a half days, we will explore the technological challenges and scientific opportunities associated with entry, descent, landing and flight in planetary atmospheres.

We are pleased to welcome such a large group of scientists, technologists, engineers, mission designers, students, and policy-makers, as together, we discuss and pursue planetary probe missions to solar system moons and planets with atmospheres.

Today through Friday, we hope you will:

- Gain insight into the current outlook for planetary probe missions
- Examine mission concept studies and historical perspectives
- Catch up with ongoing and proposed technology development activities
- Review sample return missions challenges
- Learn of recent advances in planetary entry science payloads
- Focus on the engineering and science of current planetary entry missions
- Discuss and build collaborative partnerships with otherworkshop participants
- Spend time meeting many of the participating students who are interested in a future career in this area

Please enjoy Atlanta while you are here. You will find a list of the city's more popular attractions in addition to local restaurants near Technology Square in this program.

Now, let's get started!

Best Regards,

Bernard Bienstock
Jet Propulsion Laboratory
IPPW6 International
Organizing Committee Chair

Robert D. Braun
Georgia Institute of Technology
IPPW6 Local Organizing Chair

**The 6th International Planetary Probe Workshop is being planned and implemented by members of the IPPW International Organizing Committee:**

**Jim Arnold, Al Seiff Award Chair**, University of California-Santa Cruz
**David Atkinson, General Chair**, University of Idaho
**Tibor Balint**, Short Course Co-Chair, Jet Propulsion Laboratory
**Andrew Ball**, IOC Co-Chair, Open University, United Kingdom
**Bernie Bienstock**, IOC Chair, Jet Propulsion Laboratory
**Bobby Braun**, Local Organizing Chair, Georgia Institute of Technology
**Neil Cheatwood**, Program Technology Chair, NASA Langley
**Ed Chester**, Student Program Co-Chair, CTAE
**Kristin Medlock**, IOC Student Member, Purdue University
**Jörn Helbert**, Program Science Chair, DLR Berlin
**Helen Hwang**, Long Range Planning Committee Chair, NASA Ames
**Bobby Kazeminejad**, Program Co-Chair, DLR
**Elizabeth Kolawa**, Short Course Chair, Jet Propulsion Laboratory
**Periklis Papadopoulos**, Student Program Co-Chair, San Jose State University
**Michael Wright**, Program Co-Chair, NASA Ames
**Sushil Atreya**, IOC Member at Large, University of Michigan
**Jean-Marc Bouilly**, IOC Member at Large, Astrium-EADS
**Neil Bowles**, IOC Member at Large, Oxford University
**Athena Coustenis**, IOC Member at Large, Observatoire de Paris
**Jim Cutts**, IOC Member at Large, Jet Propulsion Laboratory
**Rich Dissly**, IOC Member at Large, Ball Aerospace
**David Hash**, IOC Member at Large, NASA Ames
**Jean-Pierre Lebreton**, IOC Member at Large, European Space Agency
**Ralph Lorenz**, IOC Member at Large, APL
**Doug McCuistion**, IOC Member at Large, NASA Headquarters
**John McKinney**, IOC Member at Large, Boeing
**Curt Niebur**, IOC Member at Large, NASA Headquarters
**Suraj Rawal**, IOC Member at Large, Lockheed Martin-Denver
**Lutz Richter**, IOC Member at Large, DLR
**Anne-Marie Schipper**, IOC Member at Large, Thales
**Kelly Snook**, IOC Member at Large, NASA Headquarters
**Tom Spilker**, IOC Member at Large, Jet Propulsion Laboratory
**Roland Trautner**, IOC Member at Large, European Space Agency
**Oliver Witasse**, IOC Member at Large, European Space Agency

# Schedule at a Glance

## Extreme Environment Technologies Short Course
### Saturday, June 21

**8-8:30 a.m.** Continental Breakfast and Registration

**8:30 a.m.-Noon** Short Course Room 225

**Noon-1p.m.** Lunch on Your Own

**1-3:30 p.m.** Short Course Room 225

**3:30-3:45 p.m.** Break

**3:45-5:45 p.m.** Short Course Room 225

**Evening Open**

### Sunday, June 22

**8-11 a.m.** Short Course Room 225

**11-11:15 a.m.** Break

**11:15-12:30 p.m.** Short Course

**Noon-4 p.m.** Registration Social at Aquarium

**Evening Student Social**

## 6th International Planetary Probe Workshop
### Monday, June 23
### Session I: Current Outlook **Room 236**

**8-8:30 a.m.** Continental Breakfast and Registration

**8:30-9 a.m.** Welcome and Opening

**9-9:30 a.m.** NASA's Mars Exploration Program

**9:30-10 a.m.** Planetary Probes: An ESA Perspective

**10-10:10 a.m.** Break

**10:10-10:40 a.m.** NASA's Technology Investment Strategies for Planetary Exploration

**10:40-11:10 a.m.** JAXA's Space Exploration Scenario for the Next 20 Years

**11:10-11:45 a.m.** Open Mic, Q&A, Panel Discussion

**11:45 a.m.-12:30 p.m.** Al Seiff Award Presentation: Planetary Balloons

**12:30-2 p.m. Lunch** Atrium, Georgia Tech Global Learning Center

**Session II: Strategic Perspectives Room 236**
**2-2:30 p.m.** An Overview of EDL Technology Investments in the NASA Fundamental Aeronautics Program

**2:30-3 p.m.** The Future of Space Exploration: Relevance, Return and Relationships

**3-3:30 p.m.** History of the Discovery of Lightning on Venus and Looking for its Origin

**3:30-4 p.m.** Miniature Probes for Planetary Atmospheric Exploration: Where Less is More

**4-4:15 p.m.** Break

**4:15-5:30 p.m.** Evening Presentation: Investigating the Atmospheres of Exoplanets

**Evening Open**

**Tuesday, June 24**
**Session III: Probe Missions to the Giant Planets, Titan and Venus Room 236**
**8-8:30 a.m.** Titan/Saturn System Mission 2008: Exploring Titan on a Budget (and Without Aerocapture!)

**8:30-9 a.m.** Concept Overview for TITAN Probes Following CASSINI-HUYGENS

**9-9:30 a.m.** Physical & Computational Modeling of Heat Transfer for Titan Montgolfiere Balloons

**9:30-10 a.m.** Titan Bumblebee: A 1kg Lander-Launched UAV Concept

**10-10:10 a.m.** Break

**10:10-10:40 a.m.** Overview of Flagship Class Venus Mission Architectures

**10:40-11:10 a.m.** A Systematic Concept Exploration Methodology Applied to Venus In Situ Explorer

**11:10-11:40 a.m.** Research Activities on Venus Atmosphere Balloon Observation Mission

**11:40 a.m.-12:10 p.m.** Thermal Protection System Development, Testing and Qualification for Planetary and Aerocapture Missions

**12:10-12:40 p.m.** Aerocapture Mission Concepts

**12:40-2 p.m. Lunch** Georgia Tech Hotel

**Session IV: Historical Perspectives Room 236**
**2-2:30 p.m.** Pioneer Venus & Galileo Probe Development: Comparison/Assessment

**2:30-3 p.m.** Russian Missions to the Moon, Venus, and Mars in 1960s

**3-3:30 p.m.** Instrument Accommodation on the Pioneer Venus and Galileo Probes

**3:30-3:40 p.m.** Break

**3:40-4:10 p.m.** Acoustic Measurements on the Huygens Probe and Other Platforms: A Review and Future Prospects

**4:10-4:40 p.m.** Japanese Reentry/Entry Capsules: Past, Present, and Future

**4:40-5:10 p.m.** Perspectives on the Evolution of Mars Entry, Descent, and Landing Systems Development

**5:10-5:40 p.m.** Cone Angle Choices for Atmospheric Entry Vehicles: A Review

**5:40-6 p.m.** Group Photo Atrium Stairs

**6 -7:30 p.m.** Evening Poster Session and Reception Atrium

**Wednesday, June 25**
**Session V: Ongoing and Proposed EDL Technology Development Room 236**

**8-8:30 a.m.** The Phoenix Mars Landing: An Initial Look

**8:30-9 a.m.** Antenna Elements Integrated into the Parachutes of Planetary Entry Probes

**9-9:30 a.m.** Analysis of Temperature-Constrained Ballute Aerocapture for High-Mass Mars Payloads

**9:30-10 a.m.** Mars Entry Atmospheric Data System Requirements and Design for the Mars Science Laboratory

**10-10:10 a.m.** Break

**10:10-10:40 a.m.** Validation and Verification Approach for European Safe Precision Landing Guidance, Navigation and Control Technologies

**10:40-11:10 a.m.** Modeling of Lunar Dust Contamination Due to Plume Impingement

**11:10-11:40 a.m.** Avionics Architectures and Components for Planetary Entry Probe Payloads and Systems

**11:40 a.m.-12:10 p.m.** Arc-Jet Simulations of Ablators for the Mars Science Laboratory Program

**12:10-12:40 p.m.** Entry & Descent System for the Exomars Mission

**12:40-2 p.m.** Lunch on Your Own

**Session VI: Extreme Environments Room 236**
**2-2:30 p.m.** Radiation Hardened Electronics with Application to Science Missions

**2:30-3 p.m.** Engineering Considerations in Design of High Temperature Electronics for Planetary Probes

**3-3:30 p.m.** Cryogenic Characterization of Lateral DMOS Transistors for Lunar Applications

**3:30-3:40 p.m.** Break

**3:40-4:10 p.m.** A Laboratory System for Simulation of Extreme Atmospheric Conditions in the Deep Atmospheres of Venus, Jupiter, and Beyond

**4:10-4:40 p.m.** Assessment of PWT Conditions for the STARDUST Post-Flight Evaluation

**4:40-5:10 p.m.** Strategic Pressure Measurement System Characterization of the Mars Entry Atmospheric Data System

**5:10-5:40 p.m.** In-situ Cryogenic SEE Testing of High-Speed SiGe BiCMOS Devices

**6 p.m.-Midnight** Banquet, Sun Dial Restaurant

## Thursday, June 26

### Opening: Combined Session Room 222

- **8-8:30 a.m.** The Phoenix Mission Lands on Mars
- **8:30-9 a.m.** Mars Science Laboratory: The Next Rover
- **9-9:30 a.m.** ExoMars: ESA's Mission to Search for Signs of Life on the Red Planet
- **9:30-9:40 a.m.** Break

### Session VII: (Parallel Track) Planetary Entry Science Payloads Room 225

- **9:40-10:10 a.m.** ExoMars Entry and Descent Science
- **10:10-10:40 a.m.** A Robust Laser Diode Based Planetary Polarization Nephelometer
- **10:40-11:10 a.m.** Rescuing EDL Data
- **11:10-11:40 a.m.** Some Options for In Situ Geochemical and Geophysical Experiments in the Titan Environment by TandEM/TSSM
- **11:40 a.m.-12:10 p.m.** A 100-kg Class Titan Airplane Mission
- **12:10-12:40 p.m.** The International Lunar Science Network

### Session VIII: (Parallel Track) Current Planetary Probe Science and Technology Room 222

- **9:40-10:10 a.m.** The Challenges of Designing the MarsNEXT Network Science Probes
- **10:10-10:40 a.m.** ExoMars: The Enhanced Baseline Mission
- **10:40-11:10 a.m.** Exploring Venus with Balloons - Science Objectives and Mission Architectures for Small and Medium-Class Missions
- **11:10-11:40 a.m.** ExoMars Mission Analysis and Design from Mars Arrival to Landing
- **11:40 a.m.-12:10 p.m.** Ablation of Pica-Like Material: Surface or Volume Phenomenon?
- **12:10-12:40 p.m.** The Evolution of the MSL Heatshield

**12:40-2 p.m. Lunch Atrium, Georgia Tech Global Learning Center**

### Session IX: (Parallel Track) Sample Return Challenges Room 225

- **2-2:30 p.m.** Overview of the Mars Sample Return Earth Entry Vehicle
- **2:30-3 p.m.** Challenges for the Heatshield Development of Sample Return Missions —An Overview on European Sample Return Studies and Requirements
- **3-3:30 p.m.** Post-Flight Evaluation of Stardust PICA Forebody Heatshield Material
- **3:30-3:40 p.m.** Break
- **3:40-4:10 p.m.** CEV TPS Advanced Development Project Progress and Contributions to Current and Future NASA's Probe Missions
- **4:10-4:40 p.m.** SpaceX Dragon Re-Entry Vehicle: Aerodynamics and Aerothermodynamics with Application to Base Heat-Shield Design
- **4:40-5:10 p.m.** Multimission Earth Entry Vehicle Design Trade Space and Concept Development Strategy
- **5:40-6:10 p.m.** An Observing Campaign to Monitor the Reentry of the Automated Transfer Vehicle "Jules Verne" in August 2008

**Session X: (Parallel Track) Cross Cutting Technologies Room 222**

- **2-2:30 p.m.** Aerocapture Technology Developments by the In-Space Propulsion Technology Program
- **2:30-3 p.m.** In-Flight Research in Aerothermodynamics and TPS
- **3:10-3:40 p.m.** UAV Mission Design for the Exploration of Mars—ESA/EUROAVIA Design Workshop 2006
- **3:10-3:40 p.m.** Break
- **3:40-4:10 p.m.** Summary of Ultralightweight Ballute Technology Advances and Applicability to Planetary Probe Missions
- **4:10-4:40 p.m.** Utilizing Mars Global Reference Atmospheric Model to Evaluate Entry Probe Mission Sites
- **4:40-5:10 p.m.** The Program to Advance Inflatable Decelerators for Atmospheric Entry: An Overview of Results and Lessons Learned from Years 1 and 2
- **5:10-5:40 p.m.** Characterizing the Controllable Entry States and Reachable Sites for Planetary Landing
- **5:40-6:10 p.m.** Entry, Descent, and Landing System Design for the Mars Gravity Biosatellite

**Evening Open**
**Planning Dinner for IOC Members**

**Friday, June 27**
**Session XI: Closing Room 222**
**8-8:30 a.m.** 20 Minutes of Terror (And 10 Minutes of Questions)

**8:30-9 a.m.** Why Mars Sample Return Will Never Happen

**9-10 a.m.** Panel Discussion: The Future of Planetary Probe Partnerships

**10-10:15 a.m.** Break

**10:15-10:45 a.m.** Student Awards Presentation

**10:45-11:15 a.m.** Comments on IPPW7

**11:15-11:30 a.m.** IPPW Long Range Planning

**11:30 a.m.-Noon** IPPW6 Closing Remarks

**Noon Adjourn**

# Agenda

**Monday, June 23**
**Session I: Current Outlook Room 236**
Conveners: Jean-Pierre Lebreton, Ethiraj Venkatapathy

8-8:30 a.m.
Continental Breakfast
Registration

8:30-9 a.m.
Welcome and Opening

9-9:30 a.m.
**NASA's Mars Exploration Program**
***Doug McCuistion, NASA Headquarters***
The current decade for NASA's Mars Exploration Program has been a remarkable success with the Odyssey and Mars Reconnaissance Orbiter orbiters, twin rovers, Spirit and Opportunity, and the Phoenix lander. These missions have, and are, revolutionizing our thoughts and perspectives on the Red Planet. The program is poised to expand the discoveries of this decade through exciting missions that will lead us into an even deeper understanding of Mars. The Mars Science Laboratory is the "bridge" mission, from reconnaissance to large-scale intensive investigations on the surface. This presentation explores the approach and options, for setting the strategic framework for the future of Mars exploration by NASA. Ground truth has been critical to advancing our scientific understanding to date—how frequently do we need to go to the surface in the next decade? How likely is a Mars Sample Return mission by 2020? What international collaborations are developing, and how realistic will these be in light of budgetary and "partnership risk" pressures? What orbital science and infrastructure is desired, and what is needed? With heavy community involvement, and independent review and advice, these questions will result in a Mars Exploration Program that will engage the next generation, build on global partnerships, and advance our understanding of the solar system, Earth and Mars.

9:30-10 a.m.
**Planetary Probes: An ESA Perspective**
***Jean-Pierre Lebreton, ESA/ESTEC, Noordwijk, The Netherlands***
The ongoing Cassini-Huygens science return at Titan demonstrates the great scientific complementarities between in situ measurements and remote sensing observations from an orbiter. ESA is currently developing the Exomars mission that plans to deploy both a rover and landed geophysical package on the surface of Mars in 2015. A joint ESA/NASA study of the Titan Saturn System Mission includes two Titan in situ elements, a montgolfiere and a probe/lander, in addition to a Titan Orbiter. TSSM is competing with the Europa Jupiter System Mission, jointly studied by NASA ESA and JAXA, for the next outer planet mission to be developed and launched in the 2010s. A new Mars mission is being studied by ESA, under the name Mars-Next, that includes an orbiter and a network of three landers to arrive at Mars in the late 2010s. Technology developments will soon be initiated for future missions to Venus that may include parachuted in situ elements. Planetary probes are now becoming an important tool for the implementation of ESA's planetary robotic and science missions.

**10-10:10 a.m.**
**Break**

10:10-10:40 a.m.
**NASA's Technology Investment Strategies for Planetary Exploration**
***Jim Adams, NASA Headquarters***
Significant investment has been made in years past on advancing the state of the art of technology to meet the demands of future NASA missions and initiatives. Recently however, NASA's investment pool has dwindled forcing a targeted approach to technology investment. This talk will discuss the changing face of technology investment strategies to assure a solid future for Planetary Science.

10:40-11:10 a.m.
**JAXA's Space Exploration Scenario for the Next 20 Years**
***Masato Nakamura, JAXA***

11:10-11:45 a.m.
Open Mic, Q&A, Panel Discussion

11:45 a.m.-12:30 p.m.
**Al Seiff Award Presentation: Planetary Balloons**
***Jacques Blamont, CNES***
In the 19th century, scientific use of balloons allowed for exploration of the Earth's atmosphere. The development in the 1950s of polyethylene aerostats led to the extensive use of these vehicles for atmospheric and astrophysical research with the development of new systems as super-pressurized balloons, infrared Montgolfieres, and aerodippers (floating on an ocean). Balloons offer the only possibility today of a long-duration voyage in the atmospheres of Venus, Mars, and Titan. Up to now, only in Venus' atmosphere have balloons been deployed; the story of this Soviet feat will be told with a view to the future exploration of Venus. With Titan being the best place for balloon deployment in the Solar System, it is hoped that they will form the backbone of the exploration of Saturn's satellite in the future. Mars offers a major challenge for ballooning. In this presentation, the ways and means to overcome the obstacles of flying over the red planet will be discussed.

**12:30-2 p.m.**
**Lunch**

**Session II: Strategic Perspectives Room 236**
Conveners: Carol Carroll, Bernard Foing

2-2:30 p.m.
**An Overview of EDL Technology Investments in the NASA Fundamental Aeronautics Program**
***Juan Alonso, NASA Headquarters***
The Hypersonics and Supersonics Projects of the NASA Fundamental Aeronautics Program have as one of their two key applications the High Mass Mars Entry System. As such, the two projects are pursuing fundamental technology investments in the general area of entry, descent, and landing (EDL) to make possible some missions NASA may want to pursue in the future but does not have feasible technical solutions today. The technology investments are principally focused on better entry systems, better prediction of the aero-thermal environment through the use/development of physics-based models and experimental databases, advanced materials for TPS, and decelerator concepts and ideas to go beyond the capabilities of the existing infrastructure. In addition, the projects have created a thriving NRA community that is pursuing many of the same topics being considered internally by NASA. This talk will briefly describe some highlights of these investments and discuss future perspectives for EDL work in the context of the Aeronautics Research Mission Directorate.

2:30-3 p.m.
**The Future of Space Exploration: Relevance, Return and Relationships**
***Scott Hubbard, Stanford University***
In this talk, I will present my view of the future of space exploration. My premise is that there will be three driving forces that shape the future beyond the current commitment to the Constellation Program. The first force is the relevance of NASA's investment to the American taxpayer. Of all NASA's programs only Earth science observations and aeronautics have demonstrable applications of obvious benefit to the public. As a nation, we will invest heavily in stewardship of this planet as climate changes. Both in situ and space-borne assets will allow us to think globally, predict regionally, and act locally. Next, both government and commercial space ventures will be seeking a return on investment. The world community has sunk perhaps $100 billion in the International Space Station. I will examine the prospects for "Sutter's Gold" in the form of new research using gravity as a variable that will draw researchers into space. In parallel, the commercial space sector will continue to grow as entrepreneurs seek to provide citizens, NASA and other entities with routine access to suborbital flights and low earth orbit. Finally, it will be international relationships that define the challenging and costly next generation of planetary missions. Mars Sample Return and Outer Planets missions will be used to describe the possible future collaborations.

3-3:30 p.m.
**History of the Discovery of Lightning on Venus and Looking for its Origin**
***Leonid V. Ksanfomality, Institute of Space Research of the Russian Academy of Sciences***
Studies of the atmosphere of Venus identified several minor gaseous components whose origin could involve electrical discharges, which produce high pressure and temperature in the discharge stroke. Measurements made by VENERA 11, 12, 13, 14 and PIONEER-VENUS (1978-83), as well as subsequent missions, indicated electrical activity of the atmosphere of Venus. Later electromagnetic pulses coming from the atmosphere of Venus were observed by instruments of the GALILEO mission (Borucki et al., 1996). The lightning of Venus is unusual. We consider its possible similarity with high altitude discharges. Taiwanese researchers discovered recently huge lightning discharges, which rise as clusters from storm clouds to the upper layers of the atmosphere (up to 100 km). In contrast to normal lightning, these sparkling streams are propagated in rarefied air, occurring in huge clusters, having a height up to 80 km. Their duration was less than one second. It is difficult to record these discharges. The researchers also found that four of these streams radiated radiowaves of extremely low frequency.

3:30-4 p.m.
**Miniature Probes for Planetary Atmospheric Exploration: Where Less is More**
***Tony Colaprete, NASA Ames Research Center***

**4-4:15 p.m.**
**Break**

4:15-5:30 p.m.
**Evening Presentation: Investigating the Atmospheres of Exoplanets**
***Mark Swain, NASA Jet Propulsion Laboratory***

**Tuesday, June 24**
**Session III: Probe Missions to the Giant Planets, Titan and Venus Room 236**
Conveners: Tibor Balint, Bobby Kazeminejad

8-8:30 a.m.
**Titan/Saturn System Mission 2008: Exploring Titan on a Budget (and Without Aerocapture!)**
***John Elliott, Kim Reh, Nathan Strange, and Tom Spilker, California Institute of Technology/NASA Jet Propulsion Laboratory***

Titan has been the topic of a number of mission studies in recent years, culminating in the 2007 Titan Explorer flagship mission study. This study, as with those previous, made use of the favorable conditions of Titan's atmosphere to allow aerocapture directly into Titan orbit, a technique which would provide over 6 km/s delta-V capability, greatly increasing delivered mass to Titan when compared to purely propulsive options. This year NASA chose to continue study of a Titan/Saturn System Mission with new ground rules that encourage a quick flight time to Titan while precluding the use of aerocapture. Further direction includes performing Saturn system science (including Enceladus) and purely Titan-focused investigations, as well as a requirement to provide accommodation for a European-provided in-situ vehicle that would be delivered to Titan by the orbiter spacecraft. The financial cap for the U.S. part of the mission is $2.1 billion (FY07). The sum of these constraints has resulted in a complete redesign of the Titan mission and flight system, the most notable changes driven by the necessity of providing a large onboard chemical delta-v capability to take the place of aerocapture. Responding to these constraints, the JPL-APL-ESA/ESTEC team has developed a concept that meets study ground rules and provides an extremely valuable post-Cassini exploration of Titan and the Saturn system. This paper presents an introduction to the challenges, the trades, and the resulting mission and flight system concept being developed for this potential outer planets flagship mission.

8:30-9 a.m.
**Concept Overview for TITAN Probes Following CASSINI-HUYGENS**
***Denis Lebleu, THALES ALENIA SPACE***
The NASA/ESA/ASI CASSINI-HUYGENS mission has renewed our view of the Saturnian system. Its potential promises to allow us to enhance our understanding of the evolution of the Solar System and eventual life beyond Earth. TITAN as revealed by HUYGENS and the CASSINI flybys will leave us with a long list of questions. In the U.S. and Europe, scientists and agencies are working to define a future mission to Titan and the Saturnian System. This paper proposes an overview of potential Titan probe concepts that achieve the objectives identified by the scientific community. In addition to a large mobility vehicle, a montgolfiere or balloon, lighter vehicles addressing specific science features are identified complementary to the primary mission.

9-9:30 a.m.
**Physical & Computational Modeling of Heat Transfer for Titan Montgolfiere Balloons**
***Julian Nott, Consultant Scientist to the NASA Jet Propulsion Laboratory***
***Tim Colonius, CalTech***
***Daniel Appeloe, CalTech***
Saturn's moon, Titan, is attracting intense scientific interest, leading to wide interest in exploring it with Aerobots, balloons or airships. Their function would be similar to Mars Rovers but instead of moving on wheels, they would float freely from location to location. A Montgolfier, "Hot Air Balloon" appears to be an attractive type of Aerobot for Titan. To design a Montgolfiere it is essential to know the temperature of the lifting gas. So, it is necessary to quantify heat transferred between the craft and its surroundings. Heat

transfer for existing balloons is well understood. However, Titan's gravity and atmospheric conditions are radically different from those in which balloons have ever been flown so there is great uncertainty in predictions of heat transfer rates. In particular, thermal radiation accounts for most heat transfer for existing balloons, but over Titan, heat transfer will be almost entirely by convection. The authors are conducting a two-pronged investigation of this heat transfer that includes making measurements on working physical model balloons at Titan temperatures, and developing detailed computational fluid dynamics models. The overall objective is to create accurate computational simulations of Titan balloon heat transfer. Once validated with data from experiments, these mathematical models will allow quick evaluation of any candidate design for a Titan balloon.

9:30-10 a.m.
**Titan Bumblebee: A 1kg Lander-Launched UAV Concept**
A concept for a small (~1kg) unmanned aerial vehicle (UAV) launched from a lander on Saturn's moon Titan is discussed. This battery-powered vehicle could survey an area of hundreds of square kilometers around the lander over a few hours, providing stereo imagery, boundary-layer meteorological profiles and other data. The cold, thick atmosphere on low-gravity Titan makes a fixed- or moving-wing vehicle easy to fly, but requires substantial energy to keep it warm, a situation similar to terrestrial bumblebees and a similar flight configuration may therefore be appropriate.

**10-10:10 a.m.**
**Break**

10:10-10:40 a.m.
**Overview of Flagship Class Venus Mission Architectures**
***Tibor Balint, James Cutts, Johnny Kwok, NASA Jet Propulsion Laboratory***
To assess the feasibility and potential technology needs of a future planned Venus Flagship class mission, NASA is funding a mission study in this fiscal year (FY08). Such a mission was recommended in NASA's 2006 Solar System Exploration Roadmap and in the NRC SSE Decadal Survey. The final mission architecture is required to be in line with the primary science goals and objectives, as defined in the Venus Exploration Analysis Group (VEXAG) White Paper, and enabled by suitable extreme environments technologies. To assist the Science and Technology Definition Team for this year's study, an initial assessment was performed at JPL during summer 2007, evaluating 17 potential mission architectures. Science requirements focused the architectures to near surface in situ missions only. Consequently, the studied architectures were bound by a New Frontiers (medium) class short lived surface mission concept at one end, working towards a future large Flagship class Venus Surface Sample Return (VSSR) mission at the other end In this paper, the findings of last summer's study are outlined, including the recommended three key mission architecture groups—landers, mobile platforms, and geophysical networks—and links from them to the final mission architecture from this year's study.

10:40-11:10 a.m.
**A Systematic Concept Exploration Methodology Applied to Venus In Situ Explorer**
***Jarret Lafleur, Gregory Lantoine, Andrew Hensley, Ghislain Retaureau, Kara Kranzusch, Joseph Hickman, Marc Wilson, Daniel Schrage, Georgia Institute of Technology***

A critical task in any design process is the initial conversion of customer or program objectives into a baseline system architecture. This task becomes particularly important for space exploration systems with unique requirements which, in many cases, have never been met. A useful tool to the space systems engineer would be a methodology that helps to make

this objectives-to-design conversion more systematic and efficient. In this paper, we present such a methodology frequently used at the Georgia Institute of Technology and apply it to initial concept formulation for a Venus In Situ Explorer mission to illustrate how systematic objectives definition, concept generation, and downselection methodology can be applied to advanced interplanetary missions. The methodology and tools presented here are shown as a helpful guide and addition to the toolbox of the space systems engineer during the advanced planning stages of design.

11:10-11:40 a.m.
**Research Activities on Venus Atmosphere Balloon Observation Mission**
***Tetsuya Yamada, Kazuhisa Fujita, Nobuaki Ishii, Institute of Space and Astronautical Science/JAXA***
A feasibility study of a small Venus entry capsule and the scientific observation by the water-vapor balloon are described. The atmosphere observation under the thick cloud on the Venusian surface is of great scientific interest. Because a super-pressure type of the balloon can travel long time over a wide area with strong winds on the Venus, it is considered to be a prime candidate for the atmosphere observations. A water-vapor super-pressure balloon is advantageous to obtain buoyancy force in the hot Venus atmosphere. A small entry capsule with the 20 m-long water-vapor balloon accommodated in it is separated from a 150 kg small spacecraft and carries out direct entry from the interplanetary transfer orbit at the velocity of 11.5 km/s. The capsule releases the balloon at the appropriate altitude after passing through the aerodynamic heating corridor. Total mass of the capsule is about 30 kg containing balloon and observation instruments with mass of 10 kg.

11:40 a.m.-12:10 p.m.
**Thermal Protection System Development, Testing and Qualification for Planetary and Aerocapture Missions**
***Bernie Laub, Joe Hartman, Ethiraj Venkatapathy, NASA Ames Research Center***
***Jim Arnold, University of California-Santa Cruz***
The science community is interested in planetary entry probe missions to improve our understanding of the atmosphere of Saturn, missions to Venus, and sample return missions from comets and asteroids. The In-Space Propulsion Program has completed aerocapture mission design studies that have defined requirements for the thermal protection system (TPS) to Venus, Mars, Titan, and Neptune. There have been investments in new TPS materials and to revive flight qualified materials such as PICA and Carbon-Phenolic, the TPS material of choice for Venus and Outer Planet missions. Qualification and certification of the heritage ablative materials, or the development of new ablative TPS materials is needed and the challenges are in testing, especially in the appropriate atmospheric gases. NASA Ames has nearly completed the construction of a small, low cost, 5 MW arc jet facility, called the Development Arcjet Facility that will permit testing of small models at high heat fluxes and in different gases. This paper will review the entry conditions from a collection of mission studies to various solar system destinations, the testing needs of both newer and heritage TPS materials for each destination, and provide the test and analysis approach needed.

12:10-12:40 p.m.
**Aerocapture Mission Concepts for Titan and Venus Exploration**
***Michelle Munk, NASA Langley Research Center***
***Thomas Spilker, NASA Jet Propulsion Laboratory***
Aerocapture has been studied for decades as a mass-efficient way to deliver orbiting spacecraft to planets or moons that have atmospheres. NASA's In-Space Propulsion Technology program sponsored detailed studies of robotic exploration missions using Aerocapture at Titan and Venus, in 2002 and 2004, respectively. In this paper, the results of those studies are discussed in light of current Flagship mission studies to these same

destinations. Aerocapture is of enormous benefit for both missions, enabling multiplicative factors on delivered mass, compared to chemical propulsion or aerobraking capture techniques. The scientific return is significantly enhanced when aerocapture is used. Updates to our knowledge about Titan and Venus are included.

**12:40-2 p.m.**
**Lunch**

**Session IV: Historical Perspectives Room 236**
Conveners: Andrew Ball, Bernie Bienstock

2-2:30 p.m.
**Pioneer Venus & Galileo Probe Development: Comparison/Assessment**
***John Givens, NASA Ames Research Center (retired)***
This paper provides a comparison and assessment of the Pioneer Venus Large Probe and the Galileo Probe Development Programs. The Pioneer Venus Probe entered and descended through the Venus atmosphere measuring the characteristics of the atmosphere to the surface on Dec. 9, 1978. The Galileo Probe entered the atmosphere of Jupiter on Dec. 7, 1995 making measurements of the Jovian atmosphere to a pressure of 25 bars. Both missions were highly successful in meeting mission goals and requirements. Data collected by the science instrument payloads provided detailed information to increase our understanding of the planetary atmospheres (structure, composition, cloud makeup, wind characteristics, energy balance, etc.). The two probes were similar in overall size, shape and mass. However, the designs were significantly different because of differences in entry and descent conditions and mission requirements. There were also dramatic differences in the character of the development programs, driven primarily by decisions and events outside the control of the projects. This paper compares the major features of the two projects, including changes driven by outside events/decisions, the mission environments, and resulting designs. Design challenges and surprises, and major test issues encountered are described Lessons learned and general reflections are presented.

2:30-3 p.m.
**Russian Missions to the Moon, Venus, and Mars in 1960s**
***Vladimir Krasnopolsky, Catholic University of America***
Flights to the Moon, Venus, and Mars were a natural continuation of the Russian space program after the success of the first orbiters (Sputniks) in 1957-58. Sixteen spacecraft were sent to the Moon in 1959-1970 by the Soviet Union. Insufficient reliability of the forth rocket stage (which drove a spacecraft to interplanetary orbit from the orbit around Earth) and some spacecraft subsystems badly affected the Russian flights to Venus and Mars in the early 1960s though all later Russian missions to Venus were successful. In this paper, a summary of the early Russian missions to the Moon, Mars and Venus is provided.

3-3:30 p.m.
**Instrument Accommodation on the Pioneer Venus and Galileo Probes**
***Bernard Bienstock, NASA Jet Propulsion Laboratory***
Probe missions afford participating scientists the opportunity to perform in-situ measurements of atmospheric properties as well as planetary and satellite imaging. Extreme environments, limited volumes, modest levels of power, telemetry and command capability, and thermal control challenge the instrument design. The probe must be carefully designed to provide each instrument with the atmospheric and optical access required. Instrument accommodation on the Pioneer Venus Large and Small Probes and Galileo Probe was tremendously challenging. If you can imagine assembling a three-dimensional jigsaw puzzle, with the pieces changing shapes and each attempting to extend through the puzzle boundary, you get some idea of the difficulty the scientists and engineers had in

accommodating the many instruments on these early planetary entry probes. This paper will present the history and details of how the various instruments were accommodated on these two, seminal missions.

**3:30-3:40 p.m.**
**Break**

3:40-4:10 p.m.
**Acoustic Measurements on the Huygens Probe and Other Platforms: A Review and Future Prospects**
***Ralph D Lorenz, Johns Hopkins University Applied Physics Lab***
The Huygens probe at Titan recorded broadband sound levels during descent and on the surface with a passive microphone processed with a spectrum analyzer (part of the HASI experiment) as well as an active acoustic sounder (part of the SSP experiment). Some preliminary results of the SSP sounder near the surface have been reported previously: the present work examines data acquired during the descent and the light it may shed on atmospheric turbulence and possible precipitation. A major feature of any planetary acoustic measurement is noise due to ambient winds, or to the motion of the measurement platform through the air. Venera 13 and 14 recorded sound on the surface of Venus: the amplitude of the microphone signal was interpreted (by dynamic pressure scaling) to recover a windspeed. The Huygens SSP and HASI data are examined from this perspective. The paper reviews passive microphone measurements made on a rotating aerospace vehicle (an instrumented Frisbee), which show spin modulation and a variation with flight speed and angle of attack. The author used microphones as a crude wind sensor on an array of 20 meteorological stations to study dust devils in Arizona. Lessons learned and prospects and methods for microphonic anemometry (especially with limited telemetry bandwidth) on future missions will be discussed.

4:10-4:40 p.m.
**Japanese Reentry/Entry Capsules: Past, Present, and Future**
***Tetsuya Yamada, Nobuaki Ishii, Yoshifumi Inatani, Jun'ichiro Kawaguchi and Takashi Abe, Institute of Space and Astronautical Science/JAXA***
Japanese reentry and entry capsule missions together with related technology development in the past, present, and future are surveyed. EXPRESS was an international collaborative mission among Germany, Russia, and Japan, which was launched by M-3S-II rocket in 1995. DASH was to be a demonstrator for the high-speed reentry technology, and the technologies were later applied to Hayabusa sample return capsule. USERS capsule conducted reentry flight from LEO and was successfully recovered on the sea in 2003. Hayabusa spacecraft departed the asteroid Itokawa after the touch-down sampling and is planned to return to the Earth in 2010. Sample return of far extinct core of a comet is also investigated, in which the Earth reentry velocity exceeds 14 km/s and heatshield material for the corresponding high heatflux environment is now under development. The Venus entry probe and atmosphere scientific observation by a water-vapor balloon is now at the feasibility study phase.

4:40-5:10 p.m.
**Perspectives on the Evolution of Mars Entry, Descent, and Landing Systems Development**
***Erisa Hines, NASA Jet Propulsion Laboratory, California Institute of Technology***
NASA's history of Entry, Descent, and Landing (EDL)-dependent missions has its share of successes and failures. This paper focuses on the successes and failures as they unfold in the Mars exploration program, taking lessons from the Jet Propulsion Laboratory's experience. The Mars program's success has depended on work and partnerships shared among many entities that have elevated the challenges associated with the design and development of EDL systems for planetary spacecraft. Current EDL development is reliant on several

different organizations whether it's a specific analytical capability, unique facility, or the knowledge of how to design, build, and test a particular hardware component. As part of the developmental process, each of these organizations has influenced and been affected by evolutionary outcomes.

5:10-5:40 p.m.
**Cone Angle Choices for Atmospheric Entry Vehicles: A Review**
***Michael Tauber, Eloret Corp.***
***Michael Wright, NASA Ames Research Center***
The vast majority of past and proposed planetary atmospheric probes, landers and sample return vehicles have been blunted cones with cone angles ranging from 45 to 70 deg. Our objective is to explain the large variation of cone angle choices by examining the parameters that determine the configuration. The primary parameter is the manner in which the payload is housed, which depends on the atmospheric environment that it must withstand to meet the mission objectives. If the goal is to perform measurements under high pressures and temperatures, the instruments are housed in a spherical pressure vessel, typically. For a sphere the most compact, although not necessarily the lightest, blunted conical heat shield is a 45 deg cone. The blunted 45 deg cone also has anaerodynamic stability advantage. If a pressure vessel is not needed, the use of larger cone angles, producing higher drag, will permit using lighter heatshields by reducing the length of the heating pulse and the heat conduction time. Although it is desirable to maximize the drag, aerodynamic stability and heat transfer considerations effectively limit the cone angles to values that retain a straight shock, with the attendant thin shock layer, on the frustum. The thin shock layer requirement becomes especially important as a means of limiting radiative heating. However, when convective heating dominates, the largest practical cone angle that comes close to meeting the above requirements is used, generally.

**5:40-6 p.m. Atrium Stairs Group Photo**

**6-7:30 p.m. Atrium**
**Evening Poster Session and Reception**

**Penetration of Probes and Natural Cosmic Bodies into Planetary Atmospheres: Mathematical Interpretation of Observational Data**
***Maria Gritsevich, Lomonosov Moscow State University***
In the present report, an analytical model of the atmospheric entry is calculated using the altitude and rate of the body deceleration in the atmosphere from the data of actual observations. The main difference from previous studies is that the given observations are approximated using the analytical solution of the fundamental differential equations of the hypersonic flight of the body. The proposed general approach helps in understanding the extensive observational data of the deceleration of probes and natural cosmic bodies in the upper layers of the terrestrial atmosphere under conditions when the sizes, mass of a body and also aerodynamic flight regime are in advance unknown. The new model presented is applied to well-known impacts, including several famous meteorite-producing fireballs and the Stardust Sample Return Capsule (a hypersonic phase).

**Flood and Planetary Surface Management Satellite "HERMES"**
***Michael Dalmeir, Yunir Gataullin, Agung Indrajit and Volker Tesmer, Technical University Munich***
HERMES (Highly Enhanced Risk Management Emergency Satellite) is a potential European satellite mission for global flood management, being implemented by Technical University Munich and European Space Agency. With its main instrument, a reliable and precise Synthetic Aperture Radar antenna, and its orbit characteristics (covering the whole

earth surface in three days, low altitude), HERMES will provide stand-alone-data for: flood disaster monitoring, flood forecasting and flood prevention. Data obtained by HERMES can be used for commercial soil type maps (e.g. for optimized land use). As only highly effective and orbit proven hardware is used, HERMES is designed to be reliable, precise and of low cost. The project can be extended for use on other space bodies (planets) for rapid observation of the planetary surface.

**Tool for Planetary Probe Payload Sensor System Integration**
***Keith Schreck, Periklis Papadopoulos, Nik Djordjevich, San Jose State University***
Determination of instrumentation for interplanetary science mission is an involved, complex procedure. A final design solution is achieved at the end of this often lengthy process. The analysis methodology performed within this work investigates mission requirements and generates a mission sensor package using design engineering relations. In this investigation, a tool for in-situ measurements is developed using systems engineering design relations to deliver a sensor payload configuration starting from the initial mission concept and the specific measurement objectives.

**The Wirtanen Analysis and Surface Probe: Concept for a New Frontiers Comet Surface Sample Return Mission**
***Charles Miller, New Mexico State University***
***Matthew Smith, University of Washington***
***K. Block, University of Arizona***
***S. Byram, University of Michigan***
***B. Karpowicz, Georgia Institute of Technology***
***N. Lanza, University of New Mexico***
***J. Masiero, University of Hawaii***
***S. Singer, University of Maryland***
***B. Smith, Georgia Institute of Technology***
***A. Winfield, Auburn University***
***L. Wye, Stanford University***
***T. Balint, NASA Jet Propulsion Laboratory***
As participants in NASA's 2007 Planetary Science Summer School, we designed a New Frontiers class mission to extract a 0.5 kg surface sample from a cometary nucleus and return it to Earth. Comets contain primordial material from the formation of the Solar System (Morbidelli & Brown, 2004) and analysis of such material can answer fundamental questions regarding the composition of the early proto-planetary disk and the origin of water and possibly of life on Earth. Laboratory analysis of a comet nucleus sample addresses goals set in NASA's 2006 Solar System Exploration Roadmap and the NRC Decadal Survey. Our mission architecture, chosen to optimize science and the potential for a successful sample return within a New Frontiers budget, consists of a combined orbiter/lander craft designed for a nominal nine-year mission starting in 2015. In this poster, we outline the spacecraft architecture including instrumentation and spacecraft subsystems, overall trajectory, mission timeline, risk assessment, and cost considerations.

**Characterization of CO2 Plasma Free Stream Conditions for Atmospheric Entry Simulation**
***Sebastian Lein, Christoph Eichhorn, Michael Winter, Markus Fertig, Georg Herdrich, Monika Auweter-Kurtz, Institut fuer Raumfahrtsysteme***
With the increased interest in future space exploration missions to Venus and Mars, tools are needed to simulate atmospheric entry in CO2 dominated environments. These tools are represented on the experimental side by plasma wind tunnel facilities capable of generating high enthalpy CO2 plasma jets. In addition numerical tools are required to predict the expected convective heat flux. Additionally, numerical tools to simulate the

radiation heat flux are necessary especially for re-entry in CO2 dominated atmospheres as CO2 is known to be strongly radiating. The principal availability of ground test facilities to simulate atmospheric re-entry by generating high enthalpy CO2 plasma free streams will be described. A qualitative comparison of the measurement results with numerically simulated spectra is performed.

**Enabling Technologies for an In-Orbit Capture Mechanism for a Mars Sample Return Mission - Terminal Rendezvous Requirement**
***Alison Gibbings, Kingston University***
Any perceived Mars Sample Return (MSR) mission is of both scientific and technological importance. Under the proposed baseline architecture, the return phase is considered to be a logistical and technological challenge. This includes the Martian ascent, the rendezvous and Earth return. It is critical that the Martian samples are transferred effectively and correctly, ensuring that the critical geology and chemical composition of the samples are preserved. This paper formulates and presents issues contained within the terminal rendezvous sequence, allowing for a fully functional capture mechanism to be designed. All work has been performed in accordance to the MSR capture scenario, mission requirements and baseline architecture.

**Plasmatron Testing of Hybrid-TPS**
***George Vekinis, Galina Xanthopoulou, NCSR "Demokritos"***
During the previous two years, a "HybridTPS" thermal protection system has been under development at the NCSR "Demokritos" in Greece. The system exploits the synergy between a rigid, high refractoriness porous ceramic and a contained reinforced ablator as a heat-sink and is aimed at thermomechanical protection for high velocity atmospheric entries. The Hybrid-TPS project, funded by the European Space Agency, is expected to address some known problems with used ablative TPS, such as irregular recession of front surface leading to localised turbulence, disturbed shock wave, displaced centre of gravity and extremely brittle post-ablation char. The Hybrid-TPS has been characterised and tested under plasma-jet conditions in the Plasmatron at the Von Karman Institute in Brussels up to 2.5MW/m2 peak heat flux and for a maximum of 215 MJ/m2 integrated heat load. The areal density of the tested materials varied from 23 to 33kg/m2 and all specimens had a total thickness of about 25 mm. The results are promising. The Hybrid-TPS system is produced as tiles of various shapes and sizes, curved as well as flat, and may be side-bonded to each other in such a way as to minimize the effect of interfaces on a probe shield. Developments are aimed at adding a thin front-surface coating and at higher heat flux and integrated heat load capability. A 25 cm diameter heatshield model will be constructed and plasma-jet tested during 2008.

**New Trajectory Planner for Higher Elevation Landing**
***Josep Boada, Institut National de l'Aeronautique et l'Espace (ISAE)***
***Joel Benito, Kenneth Mease, University of California-Irvine***
A goal of Mars Entry, Descent and Landing (EDL) technology development is landing at higher elevation sites. To reach much of the Ancient Highlands requires landing at elevations as high as +3 km MOLA (Mars Orbiter Laser Altimeter). The entry guidance system has to deliver the lander accurately to the supersonic parachute deployment point within the parachute altitude, dynamic pressure, and Mach number constraints. The higher the required landing site elevation is, the lower the atmospheric density is that the lander must maneuver in during the final stage of entry and thus the lower the lift the vehicle can use to change the flight path. In previous work, the Evolved Acceleration Guidance Logic for Entry (EAGLE)has been adapted for low L/D vehicles. EAGLE is composed of trajectory planning and a trajectory tracking algorithms. It plans and tracks a drag acceleration profile, which makes EAGLE robust to modeling errors. This paper describes a new planning

algorithm intended to enable guidance of low L/D vehicles to higher final altitudes. The paper addresses the definition of the deployment altitude control authority. The paper also presents the development of a new trajectory planning algorithm The resulting planner generates feasible trajectories that deploy the parachute on the desired deployment point at high altitude and high control authority.

**Proof of Concept of an Advanced Sun Photometer for Planetary Applications**
***Richard John Brill, Perikis Papadopoulos, San Jose State University***
***Anthony W. Strawa, NASA Ames Research Center***
A lightweight, compact, highly reliable instrument designed to measure gas phase and particulate concentrations has been developed that is suitable for use in planetary environments. Current efforts have focused on validating the direct aerosol optical depth measurements. Efforts have been primarily focused on characterizing the instrument angular response, as well as validating measurements of aerosol optical depth, and water-vapor columnar abundance. Recent work has been aimed at refining the analysis procedures. Comparisons of the Advanced Sun Photometer AOD measurements have been made with AOD readings taken with a commercial Microtops II handheld sun photometer

**Atromos: Mars Companion Mission, Mid-Size Polar Lander Investigation**
***K. Boronowsky, N. Fernandez, E. Hartman, E. Iskander, H. Lueng, R. Martinez, F. Ngo, N. Pham, S. Shah, and P. Papdopoulos, San Jose State University***
***M. Murbach, NASA Ames Research Center***
The polar regions of Mars offer a rich environment to search for signs of life. The Atromos probe was designed with the intent of investigating this polar region for evidence of life and to take atmospheric data in the harsh environment. The overall project was done as a proof of concept for a small and affordable planetary probe capable of collecting scientific data used in life detection. Several key instruments were included such as a mass spectrometer, methane detector, gas chromatograph, and atmospheric characterization equipment. System design, integration, testing and mock construction were performed on the various subsystems to determine feasibility and effectiveness. This poster shows the system layout, integration, and testing results for all the subsystems and equipment included on the probe. A mock model accompanies the poster to help visualize the scale and functionality of the probe.

**Key Features of the Entry, Descent, and Landing Repository**
***Elmain Martinez, NASA Jet Propulsion Laboratory***
This poster illustrates the key features of the Entry, Descent, and Landing Repository (EDL-R) Web application. Features of keen interest, such as security, multiple search methods, the submission process, and automatic notification, are highlighted. Also, the motivation for the task and future plans are summarized.

**Opportunities and the Position of Space Sciences in the Developing Countries**
***Babagana Abubakar, Kanuri Development Association***
Although the space program as a whole is a true reflection of the level of achievement in human history in science and technology, it is also important to note that there are a large number of communities and societies that are unaware of these great achievements. This poster presents research and recommendations to broaden the appeal of space science missions in developing countries.

**Wireless Multinodal Thermal Protection System**
***Brandy Holmes, John Sochacki, Jesse Pentzer, Lucas Wells, Chris Johnson, and Dave Atkinson, University of Idaho***
A spacecraft entering an atmosphere must have a thermal protection system (TPS) able to withstand the extreme heat developed during entry. The entry environment is extremely difficult to model and analyze. To better understand the conditions during entry and the performance of TPS, the University of Idaho and NASA Ames developed a prototype wireless sensor system that can be integrated into the TPS of entry vehicles. The data gathered from such a system would be instrumental in developing a more accurate model of the entry environment and the performance of the TPS, including mass loss. With a greater understanding of these conditions the TPS of future missions could be made safer and lead to a reduced TPS mass fraction. To demonstrate the robustness and modularity of the design, the prototype wireless sensor system was prepared for a flight on a high altitude balloon during which capsule and atmospheric pressure and temperature measurements were made.

**Optimizing the Landing Site Selection Process**
***Roderik Koenders, Delft University of Technology***
Selecting a landing site on another planetary body is not a trivial task. A site needs to be safe enough to land, whereas it has still to promise good scientific return. In this poster, we investigate how a semi-automated support system may be of benefit to the selection of a landing site for ExoMars.

**Post-Flight Aerothermal Analysis of the Stardust Sample Return Capsule**
***Kerry A. Trumble, NASA Ames Research Center***
***Ioana Cozmuta, Steve Sepka, Eloret Corp.***
***Peter Jenniskens, SETI Institute***
The Stardust Sample Return Capsule was launched in February 1999 on a mission to retrieve samples of interstellar dust from the tail of comet WILD-2. Stardust returned to Earth in January 2006 entering the atmosphere with a velocity of 12.6 km/s, the fastest Earth reentry of any artificial vehicle to date. Several optical instruments captured the reentry of Stardust through an observation campaign aboard the NASA DC-8 airborne observatory. Flow environments obtained from Computational Fluid Dynamics solutions are loosely coupled with material response modeling to predict the surface temperature of Stardust throughout the reentry. The calculated surface temperatures are compared with the data from two spectral instruments onboard the airborne observatory, the Echelle camera and SLIT telescope. The average surface temperatures resulting from the SLIT telescope analysis agree to within 5 percent with the average surface temperatures predicted by the material response. Surface temperature is one of the critical parameters used in the design of thermal protection systems since it is an indicator of material performance. The combined CFD/material response approach employed in the present analysis can thus be reliably used for future missions such as CEV Orion.

**Multinodal Wireless TPS Sensor System Integration**
***Justin Schlee, Greg Swanson,and David Atkinson, University of Idaho***
The University of Idaho and NASA Ames have prototyped and tested a wireless multinodal sensor system. A flight system integration analysis has been conducted to compare the integration of a wireless Thermal Protection System sensor network to a wired system. A case study of the LE-X sensor suite has been completed to compare and contrast the mass, power, cost and data requirements between wireless and wired technologies.

**Introducing PESST: A Conceptual Design and Analysis Tool for EDL Systems**
***Richard Otero, Michael Grant, Brad Steinfeldt, and Robert Braun,***
***Georgia Institute of Technology***
The Planetary Entry Systems and Synthesis Tool (PESST) has the capability to estimate the performance and mass of a hypersonic vehicle using user-defined geometry, hypersonic aerodynamics, flight mechanics, selectable guidance, thermal response and mass estimation. Earth and Mars atmospheres are preloaded with the ability to also use either user-defined or GRAM atmospheric models. Trade studies can be performed by parameter sweeps to gain an excellent understanding of the design space for conceptual studies. This framework is broadly applicable to conceptual studies of EDL, aerocapture and precision and/or pin point landing systems.

**Mass Advantage of Titan Aerocapture**
***Nathan Strange, Sarah Bairstow, and Thomas Spilker, NASA Jet Propulsion Laboratory***
NASA's 2007 Titan Explorer study employed Titan aerocapture to place a spacecraft in orbit around Titan, while NASA's 2008 Titan/Saturn System Mission study enters Titan orbit propulsively. These two studies may be used to develop a comparison of the mass advantage of aerocapture vs. chemical propulsion to achieve Titan orbit. This poster presents details of trajectories developed for the TSSM study and compares the dry mass achievable for Titan orbiters with these trajectories using both chemical propulsion and Titan aerocapture. Interplanetary trajectories using both chemical propulsion and solar-electric propulsion (SEP) are analyzed. The mass advantage provided by aerocapture could be used to improve a future Titan mission by: delivering a larger science payload, delivering additional vehicles, using a smaller (and less expensive) launch vehicle, or by using a higher DV interplanetary trajectory to achieve faster flight times to Saturn.

**DOTNET Framework Design Environment for System Integration of Planetary Probe Payload Sensors and Interplanetary Trajectory Optimization**
***Prabhakar Subrahmanyam, Keith Schreck, and Periklis Papadopoulos,***
***San Jose State University***
An engineering level system analysis based on the mission requirements and a web-based design environment has been developed specifically for planetary in-situ instrumentation. The software architecture is linked to a comprehensive instrumentation database via a middleware component that services the designer's requests through the framework. The framework also develops parametric trade studies at component architecture level for probes. A Mars Sample return test case is analyzed in this framework and presented in this poster.

**Student Project: International Offset—Interplanetary Probe Application**
***A. Baklashov, T. Le, and Periklis Papadopoulos, San Jose State University***
***J. Grady, Alliance of Commercial Enterprises and Education for Space***
Offset or industrial participation is a practice that is part of many large international transactions. In the event of a large international transaction involving the purchase of a product (e.g.: equipment or services), the company selling the product, is typically required to compensate the purchasing country for a perceived loss to the economy of the purchasing country. This compensation is called offset. Other terms for offset include industrial participation or industrial cooperation. Offset is a legal or formal requirement for many large sales by companies to most foreign governments. During the past 25 years, the number of countries practicing offset in international sales have increased tenfold to more than 150 countries. As estimated by offset associations (i.e.: GOCA, DMA, etc.) offset accounts for 10 percent to 15 percent of world trade, which translates to about $1 trillion in world trade per year. In this poster, the use of offset for interplanetary probe applications is explored.

**Thermal Protection Materials and High Temperature Composites for Planetary Entry Systems**
***John McKinney, The Boeing Co.***
The Boeing Co. has a long history in developing Thermal Protection Systems and designing and constructing high temperature aerostructures. Many space projects ranging from the first manned Mercury and Gemini missions through Apollo and continuing on with the Space Shuttle have been enabled through advanced research and development efforts. Advanced materials and construction techniques are being developed for applications beyond earth manned missions to include missions to Mars, the outer planets and their moons. This poster presents an overview of the various TPS Materials and High Temperature Composite structures in development and their intended mission design performance requirements.

**Autorotating Pararotor Decelerator Technology for Miniature Atmospherice Entry Probes**
***Austin Howard, University of Idaho***
Research has been conducted on the feasibility and modeling of a pararotor decelerator platform for atmospheric and planetary science. The specific application for pararotor technology, as presented, is miniaturized entry probes. A summary of research methods and results is presented. The research methods include developing a mathematical model for pararotor aerodynamics/dynamics to predict decelerator performance and to assist in pararotor design. The models developed as part of the research and other pre-existing models are validated in a series of small scale wind tunnel experiments. A full scale instrumented microprobe prototype is also being designed for the purpose of model validation in Earth's atmosphere.

**Honeybee Robotics Surface Science Tools**
***Kris Zacny, Honeybee Robotics***
Honeybee Robotics has been developing gas assisted excavation systems and drills/penetrometers for planetary exploration. These systems tend to be simpler and in turn more robust than similar devices powered by electro mechanical actuators. The principle lies in injecting of gas into regolith and creating high pressure cells. As gas follows the path of least resistance (back up) it carries soil particles with it. The mining tube can be positioned in such a way as to capture this dusty gas (regolith particles suspended in gas) for further processing (e.g. oxygen extraction) or diverted away from a hole and onto the surrounding ground.

**The SOAREX-VI Re-Entry Flight Test Experiment**
***Marcus Murbach, NASA Ames Research Center***
The experiment definition and development of the SOAREX VI (Sub-Orbital Aerodynamic Re-entry EXperiment) flight test is discussed. Scheduled for launch on the ATK X1 sub-orbital flight during July 2008, this flight test will permit one or more re-entry bodies to enter the atmosphere at approximately 4 km/s. The trajectory that is provided presents certain challenges, in that the launch site is the Wallops Flight Facility with a down-range splash point several hundred km north of Antigua (total downrange distance of 2037 km/1100NM). These included unique telemetry system choices and means of collecting accurate entry trajectory data due to the distance from any available land range. The principal entry experiment is the SCRAMP (Slotted Compression RAMP) probe, which is self-stabilizing and permits a simplification of the interface to the upper-stage/payload ejector system. Data from this experiment will be used to improve the understanding of this shock-shock behavior, provide design information for this class of highly stable re-entry probes, and streamline a capability of conducting comparatively inexpensive flight experiments at long down-range distances.

**Wednesday, June 25**
**Session V: Ongoing and Proposed EDL Technology Development Room 236**
Conveners: Jan Thornton, Denis Lebleu

8-8:30 a.m.
**The Phoenix Mars Landing: An Initial Look**
***Myron Grover, Erik Bailey, James Chase, Benjamin D Cichy, Daniel Eldred, Paul Laufer, Michael Lisano, and Eli Skulsky, NASA Jet Propulsion Laboratory***
Prasun Desai, Jill Prince, and Eric M Queen, NASA Langley Research Center
NASA's Phoenix Mars Lander landed on Mars on May 25, 2008. An initial look at the Phoenix landing will be presented, highlighting the high level events that occurred during EDL. Initial EDL flight reconstruction results will be presented, along with a retelling of the flight operations events that occurred on approach to Mars, and during the landing event itself.

8:30-9 a.m.
**Antenna Elements Integrated into the Parachutes of Planetary Entry Probes**
***Carlos Corral van Damme, GMV S.A.***
***Maarten van der Vorst, European Space Agency / ESTEC***
***Rodolfo Guidi, IDS Ingegneria Dei Sistemi S.p.A***
***Simon Benolol, CIMSA***
The canopy of the parachutes of planetary entry probes may be used to integrate elements of the antennas for communications with the orbiter spacecraft during the descent. The additional surface provided by the parachute may allow the implementation of higher gain antennas compared to more conventional solutions where the antenna is installed on the lander. For missions where the acquired scientific data needs to be transmitted during the descent through the atmosphere, the higher gain could improve the scientific return of the mission. In this paper, designs for a steerable S-band patch array antenna located on the canopy of a disk-gap-band parachute are presented. A retrodirective technique is used to point the antenna beam in the direction of the orbiter. The design concept is flexible and can be adapted to different mission requirements and constraints (frequency band, etc.). Different configurations are analysed in terms of the antenna performance, the aerodynamics of the parachute, the link budget, and the impact on the mission at system level. A system prototype is being built and will be dropped from a balloon for testing. Recommendations on the developments required for this technology as well as on its potential applications are provided, including the analysis of the possible use of these antennas for planetary exploration balloons.

9-9:30 a.m.
**Analysis of Temperature-Constrained Ballute Aerocapture for High-Mass Mars Payloads**
***Kristin Medlock, Alina Alexeenko, James Longuski, Purdue University***
We investigate trajectories and heating environments of ballute-assisted, low- to high-mass Mars aerocapture systems. Ballutes permit aerocapture at higher altitudes and allow for lower thermal protection system mass than traditional aeroshells. Trajectory calculations are presented for capture into a four-day parking orbit about Mars with varying vehicle masses (of 1-100 tons) and with a ballute temperature constraint of 500C. We note that, for the same ballistic coefficient, a higher mass payload will require a larger ballute and consequently will have a lower ballute temperature (due to a larger nose radius). Compared to a payload of 1 ton (requiring a ballistic coefficient of 0.76 kg/m2), a higher ballistic coefficient (of 3.45 kg/m2) can be employed for the high mass payload (of 100 tons) while satisfying the temperature constraint, thus allowing for capture of high-mass payloads with smaller ballutes than previously estimated. To substantiate these conclusions, which

are based on analytical heating calculations, we conduct a aerothermodynamic analysis at maximum heat flux conditions (for payloads of 1, 10, and 100 tons). We use the Langley Aerothermodynamic Upwind Relaxation Algorithm to analyze the ballute in the continuum flow regime where the Navier-Stokes equations apply.

9:30-10 a.m.
**Mars Entry Atmospheric Data System (MEADS) Requirements and Design for the Mars Science Laboratory (MSL)**
***Michelle Munk, Frank Novak, Mark Hutchinson, Michael Mitchell, and Peter Parker, NASA Langley Research Center***
Each vehicle that lands on Mars provides a unique opportunity to study the atmospheric entry environment. Taking measurements of this environment will enable a better understanding of vehicle performance and design margins. The Mars Science Laboratory Entry, Descent and Landing Instrumentation (MEDLI) experiment will measure pressure and temperature on the protective heatshield during the MSL entry. The pressure distribution and Martian atmospheric data measurements are required to accurately determine the vehicle attitude (angles of attack and sideslip), and the dynamic pressure on the windward surface of the MSL heatshield. The pressure measurements are also used to provide Martian environment data and support computational fluid dynamics code validation. This paper focuses on the pressure measurement system, known as the Mars Entry Atmospheric Data System (MEADS), which consists of a flush orifice configuration connected by tubing to a specially ranged and selected pressure transducer and a custom-built signal conditioner, known as the Signal Support Electronics. The MEADS design approach, manufacturing experiences, and testing results are discussed. As the system prepares for delivery in summer 2008, a key goal of the project is to serve as a pathfinder, such that every entry system of the future will be instrumented and will improve our knowledge of the critical entry environment.

**10-10:10 a.m.**
**Break**

10:10-10:40 a.m.
**Validation and Verification Approach for European Safe Precision Landing Guidance, Navigation and Control (GNC) Technologies**
***Christian Philippe, Alain Pradier, European Space Agency***
***Alain Pradier, European Space Agency***
Autonomous safe precision landing is an important capability required to ensure mission success for future robotics exploration landing missions. The landers will be able to automatically identify the location of the desired landing site while detecting hazardous terrain features within it during the final powered descent to the surface, to designate an alternate safe landing site, and to maneuver to the selected safe site. In this respect, the European Space Agency has supported the preparation of European solutions for autonomous safe precision landing systems. GNC technologies under development include autonomous vision-based and LIDAR-based navigation systems (image processing, autonomous navigation algorithms, APS camera and imaging LIDAR breadboard), terminal descent algorithms encompassing onboard capabilities for terrain relative navigation, hazard map generation, re-designation of safe target during powered descent. These technologies are at different maturity level and are developed to support primarily safe precision landing missions to Mars and Moon. The suite of simulation tools and ground test facility for the performance validation and verification of autonomous safe precision landing GNC systems will be presented with special emphasis on the high fidelity end-to-end Entry, Descent and Landing Simulator and the Precision Landing GNC Test Facility.

10:40-11:10 a.m.
**Modeling of Lunar Dust Contamination Due to Plume Impingement**
***Michael Woronowicz, SGT Inc.***
Historical data from the Apollo missions indicate the ubiquitous presence of lunar dust caused a number of troubling performance issues with mechanisms, optical devices, and thermal control devices,. Consequently, NASA Constellation program managers are interested in developing designs, techniques, and procedures to mitigate the deleterious effects of this material when men and women return to the Moon. One particular scenario involves Altair lander descent operations, where the lander's engine plume will disturb electrically charged lunar regolith particulates that may be attracted to the lander or equipment and habitats already on the surface nearby. Of special concern is that enough of these particles may find their way to thermal control surfaces to degrade their function to unacceptable levels. A model was developed to study the influence of such effects as engine height above the Moon's surface, effect of thrust level, and thrust vector angle during descent and ascent operations as well as local electrical fields. Lunar dust size distribution and other properties are considered to determine the fraction of particles of a given size transported to critical vertical and horizontal surfaces relative to the engine.

11:10-11:40 a.m.
**Avionics Architectures and Components for Planetary Entry Probe Payloads and Systems**
***Roland Trautner, Martin Suess, and Agustin Fernandez-Leon, European Space Agency/ESTEC***
Like all complex spacecraft, planetary entry probes require reliable, performant and resource-efficient avionics to successfully fulfill their mission. Due to specific mission constraints and targets, high integration as well as power and mass efficiency are particularly important. An important focus of avionics development work continues to be standardization of interfaces, protocols and algorithms in order to facilitate re-use and compatibility of individual building blocks. An overview of the ongoing developments on avionics architectures is presented. State-of-the-art network and processing node types and their elements, such as SpaceWire, SpW Router, Remote Terminal Controller, and Scalable Multi-channel Communication subsystem are introduced. New types of interfaces and components under development like SpaceFibre, Next Generation Multipurpose Processor, Spacecraft Controller On-a-Chip, and related technology developments are presented. The ESA IP core service is introduced, and other ongoing and planned developments in the avionics area that are of particular interest for planetary entry probes and their systems and payloads are discussed.

11:40 a.m.-12:10 p.m.
**Arc-Jet Simulations of Ablators for the Mars Science Laboratory Program**
***Todd White, ELORET Corp.Chun Mail, NASA Ames Research Center***
The NASA Ames team working with the Mars Science Laboratory (MSL) project has recently been involved in arc-jet tests to characterize the material response of candidate ablators to the high heat flux and high shear stress conditions that the MSL probe is likely to experience during entry into the Martian atmosphere. These tests have been conducted at the NASA Ames Aerodynamic Heating Facility, the NASA Ames Interaction Heating Facility (IHF), and the H2 arc-jet at Arnold Engineering Development Center (AEDC). New techniques have been employed for the pre and post test analysis of the arc-jet aerothermal environments. Specifically, these methods address the modeling of non-uniform enthalpy and mass profiles in the arc-jet facilities, and the coupling of the nozzle flow with the test articles. Simulations of inclined wedges at AEDC H2 test conditions and swept cylinder at IHF test conditions using the DPLR code will be presented. In

particular, computations of the thermal response of SLA and PICA will be compared with experimental data. These comparisons will highlight some of the uncertainties that exist in correlating the measured recession with the numerical predictions.

12:10-12:40 p.m.
**Entry & Descent System for the Exomars Mission**
***Frederic Beziat, Patrick Arfi, Thales-Alenia Space FRANCE***
Within the Aurora Exploration Program, ESA initiated the design phase of the development for the ExoMars mission, scheduled for a 2013 launch. Thales Alenia Space-France led consortium was awarded the contract for design, development and manufacturing of the Entry and Descent System under Thales Alenia Space-Italy mission prime. ExoMars has the technical objective to demonstrate critical technologies of a Mars surface mission, including the critical Entry Descent and Landing phases and the scientific objective at establishing whether life ever existed or is present on Mars. The EDLS functions are to ensure the entry, descent and landing phases of the descent module. This presentation focuses on the main functions of the entry and descent system . The major trades and optmization performed are outlined to provide a better insight of the EDS design approach and the challenge of designing a robust and flexible EDS. An accurate and detailed end-to-end EDL trajectory modeling & simulation tool has been upgraded by the TAS-F Entry Descent and Landing System team. A Monte-Carlo tool is used to assess the robustness of the EDS end-to-end sequence to off-nominal operational conditions to assure that all EDS requirements and constraints are satisfied.

**12:40-2 p.m.**
**Lunch on Your Own**

**Session VI: Extreme Environments Room 236**
Conveners: Jean-Marie Muylaert, Steve Ruffin & Bernard Marty

2-2:30 p.m.
**Radiation Hardened Electronics with Application to Science Missions**
***Andrew Keys, NASA Marshall Space Flight Center***
The Radiation Hardened Electronics for Space Environments (RHESE) project endeavors to expand the current state-of-the-art in radiation hardened electronics by developing high performance devices robust enough to withstand the extreme radiation and temperature levels of the space environment. The individual tasks that comprise RHESE are diverse, yet united in the common endeavor to develop electronics capable of operating within the harsh environment of space. This paper describes each RHESE technology development task and reviews how each task could support the extreme environmental needs of the planetary probe community.

2:30-3 p.m.
**Engineering Considerations in Design of High Temperature Electronics for Planetary Probes**
***Leora Peltz, The Boeing Co.***
Low weight and high reliability are primary goals in scientific exploration space missions. Many mission concepts involve probes operating at high ambient temperatures for various lengths of time. In these cases, high-temperature electronics can simplify the system design and reduce overall mass, resulting in higher reliability of the overall system. High temperature electronics can be improve performance measuring instrumentation for Thermal Protection Systems, integrated in embedded sensor plugs, to perform front-end signal conditioning and acquisition during atmospheric entry and descent. Thermal Protection System thickness and material characteristics affect the thermal exposure seen

by such embedded electronics. Our presentation focuses on two technologies applied in our group: SiGe (silicon-germanium) for TPS applications, and GaN (gallium nitride) toward a Venus Lander. GaN electronics for high temperatures are being developed by HRL. These two technologies, together, are capable of spanning a range of temperatures of over 700C. Examples from our recent validation tests in harsh environments illustrate the performance of the electronic components and modules. In addition to the SiGe or GaN-based semiconductor material, the characteristics, reliability and viability of the electronics is affected by constituent materials (metallization, dielectric layers) and by the packaging (die attach, wire bonding).

3-3:30 p.m.
**Cryogenic Characterization of Lateral DMOS Transistors for Lunar Applications**
***A. Kashyap, M. Mudholkar, and H. Mantooth, University of Arkansas***
***T. Vo, M. Mojarradi, NASA Jet Propulsion Laboratory***
LDMOS devices are increasingly gaining attention as they aid in easier integration with existing CMOS technologies. They are especially useful in applications requiring higher operating voltages such as power management circuits and high power amplifiers. The Jet Propulsion Laboratory has developed LDMOS transistors using the existing IBM 5 AM technology to be used primarily in high voltage current mirrors in sensor interface circuits. This paper reports results on the breakdown, transfer and output characteristics of the JPL LDMOS devices as temperature decreases and attempt to explain the observation with physical reasoning.

**3:30-3:40 p.m.**
**Break**

3:40-4:10 p.m.
**A Laboratory System for Simulation of Extreme Atmospheric Conditions in the Deep Atmospheres of Venus, Jupiter, and Beyond**
***Bryan Karpowicz, Paul Steffes, Thomas Hanley, Georgia Institute of Technology***
A new atmospheric simulator, in operation and developed at Georgia Tech, offers a flexible platform for simulating deep planetary atmospheres. The laboratory system has been designed to simulate the deep Jovian atmosphere and measure the microwave opacity of key atmospheric constituents. The primary motivation for this system is to provide reliable microwave opacity models for use in interpreting data from the Juno microwave radiometer (MWR). The Juno-MWR will be capable of sensing centimeter-wavelength emission from the very deep atmosphere of Jupiter at pressures exceeding 100 Bars. To date, only a very limited number of measurements have been made of the microwave absorption of ammonia or water vapor at such high pressures, and none of these measurements were conducted at wavelengths greater than 3.3 cm. While our primary motivation is to provide this critical information, this is not the only function our system may perform. This system could easily be adapted to provide a test platform for instrumentation and hardware that must withstand some of the harshest atmospheric conditions, including those of Venus which has a surface pressure up to 100 bars. While the Venus surface temperature exceeds our maximum simulator temperature (616 K), it would certainly be a sufficient test platform for a variety of entry probe hardware for Venus, Jupiter or any other planetary atmosphere which reaches 100 bars pressure.

4:10-4:40 p.m.
**Assessment of PWT Conditions for the STARDUST Post-Flight Evaluation**
***Georg Herdrich, IRS Stuttgart***
On Jan. 15 2006, the STARDUST capsule re-entered Earth's atmosphere after its almost seven year journey with a re-entry speed of 12.8 km/s. Due to the nature of the mission,

no diagnostics for the re-entry phase were installed on the capsule. Nevertheless, this was the fastest re-entry of a human-made space vehicle ever and data on heatshield erosion and plasma characterization is considered to be very valuable for further missions since the entry conditions are typical for hyperbolic re-entries for sample return missions e.g. from Mars. Therefore, an observation mission was initiated by NASA aboard the NASA DC-8 airborne observatory. Among experiments conducted, a conventional spectrometer in a Cerny Turner configuration was fed by fiber optics with light collected by a small mirror telescope. The paper provides a short summary of the obtained spectra for different flight altitudes of the STARDUST capsule. A comparison of said spectra to the results of numerical simulations of the plasma emission with PARADE and URANUS radiation/flow field simulations is presented. To further interpret the obtained data, ground testing is discussed.

4:40-5:10 p.m.
**Strategic Pressure Measurement System Characterization of the Mars Entry Atmospheric Data System (MEADS)**
***Peter Parker, NASA Langley Research Center***
A primary flight science requirement of the Mars Science Laboratory (MSL) entry descent and landing instrumentation (MEDLI) project is the direct measurement of pressure at seven locations distributed across the heatshield during the entry and descent phases of the MSL mission. These direct pressure measurements, coupled with other sources of data, enable an estimate of the vehicle's orientation and of the atmospheric density. Estimating these parameters in flight reduces the uncertainty in the design and validation of a robust Mars entry system for future missions. A critical component to achieve these objectives is the experimental characterization of the pressure measurement system over the extreme environmental conditions to support rigorous estimates of pressure measurement uncertainty. The integrity of the mission results can be ensured by the experimental methods and analyses employed in the characterization. In this paper, we propose a systems engineering framework for the pre-flight experimental testing necessary to obtain an estimate of total measurement uncertainty; a framework that is broadly applicable to other instrumentation systems. This systematic approach translates project requirements into the statistical design of a series of experiments that efficiently characterizes the pressure system uncertainty and stability and requires minimal resources.

5:10-5:40 p.m.
**In-situ Cryogenic SEE Testing of High-Speed SiGe BiCMOS Devices**
***Vishwanath Ramachandran, Michael Alles, Robert Reed, Jeffrey Black, Jonathan Pellish, and Greg Walker, Vanderbilt University***
We present details of a first-of-a-kind system that was custom-designed to enable in-situ single-event testing at cryogenic temperatures. The system is capable of using either liquid nitrogen (LN2, 77K) or liquid helium (LHe, 4K) as cryogens and includes a heating plate for fine adjustment of temperatures. This enables emulation of combined temperature and radiation environments such as those on the surfaces of the Earth's moon and those of other planets like Jupiter (Europa) and Saturn (Enceladus), where surface temperatures fluctuate from 50K at night to 400K during daytime. As part of the NASA Exploration Technology Development Program, this project aims to aid future NASA missions to the above planets and/or moons by providing both qualitative and quantitative insights into the SE response of high-speed SiGe BiCMOS devices at cryogenic temperatures. This work also establishes excellent synergy with other NASA efforts such as the Radiation Hardened Electronics for Space Environments and NASA Electronic Parts and Packaging programs.

**6 p.m.-Midnight** **Banquet, Sun Dial Restaurant**

**Thursday, June 26**
**Opening Combined Session Room 222**

8-8:30 a.m.
**The Phoenix Mission Lands on Mars**
***Peter Smith, University of Arizona***
Phoenix landed on the arctic plains of Mars on May 25. The team of the University of Arizona, the Jet Propulsion Lab, European Space Agency, and Lockheed Martin have spent a considerable effort in orchestrating a robust approach, entry, descent, and landing sequence of events. Contingency maneuvers were planned for every critical event such that the team could respond rapidly with tested procedures to any potential anomaly. Panoramic images and the results of the analysis of the first surface samples of soil should be available for presentation at the workshop. In addition, the weather patterns will be monitored during the active summer season. The mission will continue for several months while we dig down to the ice boundary and sample both ice and soil to understand the mineralogy, chemistry, and the potential for habitability of this unexplored region of Mars.

8:30-9 a.m.
**Mars Science Laboratory: The Next Rover**
***Michael Meyer, NASA Headquarters***
The Mars Science Laboratory rover represents firsts in many aspects for interplanetary exploration. To get the rover to the planet's surface, the rover is winched down from the thrusters, substituting wheels for the usual platform, legs (or air bags) and off-ramp. The mass savings have afforded a larger rover and accompanying instrument payload. The landed platform, which is the rover, will carry an analytical laboratory with two instruments of unprecedented capability, a Gas Chromatograph/Mass Spectrometer, which includes a Harriet cell Tunable Laser System, and X-Ray Diffractometer, an instrument type not flown since the Viking landers in 1976. In addition, the other instruments represent innovative improvements with significant increases in capability. Of particular note, an instrument new to planetary exploration, is ChemCam, a laser induced breakdown spectroscope for remote sensing of chemistry and micro-imaging. This enables elemental/chemical composition to be measured at a meters distant, greatly expanding the survey capability. The details of MSL's approaches and the implications for future missions will be discussed.

9-9:30 a.m.
**ExoMars: ESA's Mission to Search for Signs of Life on the Red Planet**
***J. L. Vago, G. Kminek, A. Haldemann, P. Baglioni, R. Trautner, A. Elfving, D. McCoy, G. Gianfiglio, B. Gardini, European Space Agency***
Establishing whether life ever existed or is active on Mars today is one of the outstanding scientific questions of our time. To address this important goal, within the framework of its Aurora Exploration Program, the European Space Agency plans to launch the ExoMars mission in 2013. ExoMars will deploy a rover carrying a comprehensive suite of analytical instruments dedicated to exobiology research. The rover will travel several kilometers searching for traces of past and present signs of life. It will do this by collecting and analyzing samples from within rock outcrops and from the subsurface, down to a depth of 2 m. The powerful combination of mobility and access to subsurface locations, where organic molecules may be well-preserved, is unique to this mission. The ExoMars rover mission will be complemented by the Humboldt instruments on the lander, dedicated to environment and geophysics investigations. This paper will briefly describe the mission's science content and current level of definition.

**9:30-9:40 a.m.**
**Break**

## Session VII: (Parallel) Planetary Entry Science Payloads

Conveners: Doug McQuistion, Roland Trautner

9:40-10:10 a.m.

**ExoMars Entry and Descent Science**

***Andrew Ball, Francesca Ferri, Open University***

The entry, descent and landing of ExoMars offer a rare opportunity to perform in situ investigation of the Martian environment over a wide altitude range. We present an initial assessment of the atmospheric science that can be performed using sensors of the entry, descent and landing system (EDLS), over and above the expected engineering information. This is intended to help fulfill the concept of an Atmospheric Parameters Package. Mars' atmosphere is highly variable in time and space, due to phenomena including inertio-gravity waves, thermal tide effects, dust, solar wind conditions, and diurnal, seasonal and topographic effects. New data from different site, season and time period are essential to investigate the thermal balance of the surface and atmosphere of Mars, diurnal variations in the depth of the planetary boundary layer and the effects of these processes on the martian general circulation. A better understanding of the Martian environment and meteorology is also essential for refining and constraining landing techniques at Mars and to evaluate the possible hazardous to machines and humans in view of future Martian explorations. As the ExoMars project definition proceeds, the entry, descent and landing sequence may offer further science opportunities. We are interested in exploring these and welcome additional members to the consortium.

10:10-10:40 a.m.

**A Robust Laser Diode Based Planetary Polarization Nephelometer**

***Adam Saltzman, Don Banfield, Cornell University***

We are developing a polarization nephelometer using reliable, low power-consumption laser diodes, for use on future planetary decent probes. The laser diodes provide a polarization modulated illumination source that enables simultaneous collection of scattering intensity and polarization phase functions. Our device will be a significant upgrade to previous planetary nephelometers. The addition of polarization information greatly increases our ability to constrain the number density, size distribution, shape and chemical composition of atmospheric aerosols. We have succeeded in building and characterizing a polarization modulated laser source. In addition we have developed a numerical model of our full instrument, including optical losses, and a variety of scatters. Testing is under way, using a small glass cylinder as a well-known scattering source, to confirm the choice of optical components, and verify our simulations. Following this, we will test our device using known distributions of water droplets, which better simulate the range of expected atmospheric aerosols. Our progress indicates that we will be able to provide a prototype nephelometer for terrestrial field deployment or balloon missions at the end of 2009.

10:40-11:10 a.m.

**Rescuing EDL Data**

***Elmain Martinez, NASA Jet Propulsion Laboratory***

After 50 years of spaceflight, a tremendous amount of information has been written and published about the entry, descent, and landing discipline. While there are holdings, with individuals and partial collections at various NASA web sites, there is no central repository or portal for this critical information. This paper discusses an initiative for archiving and preserving technical EDL material, which aims to provide a single resource for archiving and preserving EDL material from recent missions and older data at risk of being lost. Background information is presented establishing the rationale and charter for the repository along with a description of the scope and intended users. Plans for future capabilities, expanded repository content, and maintenance are described.

11:10-11:40 a.m.
**Some Options for In Situ Geochemical and Geophysical Experiments in the Titan Environment by TandEM/TSSM**
***Andrew Ball, Open University***
We present concepts for in situ instrumentation for Titan aerial platforms, probes, landers and penetrators, in the context of the TandEM mission proposal in ESA's Cosmic Vision Program and TSSM in NASA's New Frontiers Program. These include 1) geochemical instrumentation for aerosol analysis, GCMS of surface materials, stable isotope analysis and trace gas detection, and 2) geophysical/meteorological instrumentation for studies of atmospheric science and energy balance. These concepts draw upon heritage and lessons learned from the Huygens Surface Science Package and Atmospheric Structure Instrument, the Beagle 2 Gas Analysis Package and the Ptolemy evolved gas analyzer on the Philae comet lander.

11:40 a.m.-12:10 p.m.
**A 100-kg Class Titan Airplane Mission**
***Lawrence Lemke, NASA Ames Research Center***
The combination of low gravity and high density of Titan's atmosphere makes powered, aerodynamic flight on that Saturnian moon energetically more favorable than at any other known location in the Solar System. Titan also possesses a relatively transparent atmosphere below 10 km altitude, which suggests regional or global scale imaging of Titan's surface could be conducted by a small Unpiloted Aerial Vehicle (UAV). This paper discusses the engineering details of a point-design autonomous UAV for performing this mission capable of being delivered to Titan via an atmospheric entry probe. The probe payload consists of a 100 kg UAV with an L/D of 15. Such a vehicle could fly at 8 km altitude on Titan on 50 W of aerodynamic power (steady state). Taking into account reasonable allocations for propeller and electric motor efficiencies, such a vehicle could fly on the output of NASA's next generation radioisotope power generator, the Advanced Stirling Radioisotope Generator (ASRG). An ASRG powered Titan UAV could fly for an indefinite period and map the equivalent ground track of 20 circuits around Titan's equator. Alternatively, an aircraft of this type powered by stored chemical energy may have a lifetime of one or two days and fly a path of more than 1,000km. In addition to normal aircraft design requirements (lift/drag-weight/thrust equilibrium, weight and balance, etc.) UAV's intended for flight in the atmosphere of a celestial body other than Earth must be folded to fit into the shape and volume of an entry probe and must have provision for autonomous, mid-air unfolding prior to beginning of flight. Conceptual UAV-entry vehicle design and supporting engineering calculations are presented.

12:10-12:40 p.m.
**The International Lunar Science Network**
***Thomas Morgan, Kelly Snook, and Jim Adams, NASA Headquarters***
NASA's Science Mission Directorate (SMD) is leading a new program of lunar robotic orbital and landed missions to address key lunar science measurements. A major element in this new SMD program is the US contribution to a recently proposed International Lunar Network (ILN). This is a network of small geophysical nodes on the lunar surface designed to accomplish lunar surface and interior science uniquely enabled by the availability of simultaneous multiple sites. NASA's contribution to the International Lunar Network is two small landers that will be launched in the 2012-2013 time frame. These two landers will provide two nodes for the proposed International Lunar Network. The U.S. is actively seeking international partners to provide their own landers equipped to utilize the unique science that can be accomplished with simultaneous seismic and thermal measurements from a distributed lunar network. NASA hopes to have three to six additional nodes in the network. NASA SMD is considering a possible second pair of US nodes in 2016. NASA

has initiated engineering studies of these micro-landers. A Science Definition Team has been formed to work in tandem with the engineering studies.

**12:40 p.m.-2 p.m.**
**Lunch**

**Session VIII: (Parallel) Current Planetary Probe Science and Technology Room 222**
Conveners: Lutz Richter, Wayne Lee

9:40-10:10 a.m.
**The Challenges of Designing the MarsNEXT Network Science Probes**
***Kelly Geelen, EADS Astrium***
***Philippe Tran, Astrium Space Transportation***
In the European Space Agency's Aurora Program, Europe has clearly identified the exploration of Mars as a main objective to contribute to the international effort on the exploration of the solar system. With the ExoMars mission due for launch in 2013, and the Mars Sample Return mission foreseen for the 2020 timeframe, the agency is considering the opportunity between these two events for an intermediate mission—the so-called NEXT (Next Exploration Science and Technology) mission. One of two mission concepts considered for NEXT is a Mars mission demonstrating aerobraking and rendezvous/capture in Mars orbit and to deliver a network of science probes. The surface mission aims to deploy a network of three identical landers in the 100-125 kg range, which will perform simultaneous measurements to study the internal structure, sub-surface, and atmosphere of Mars. Each network science probe comprises two main subassemblies: the surface module, and the entry, descent and landing system. The EDLS is based on a parachute system, retro-rockets and unvented airbags. When the network science probe is released from its cocoon of gas-filled bags the impact onto the Martian surface could be in any orientation. Therefore, the surface module will be similar to the clam-like structure of Beagle 2. Once opened, one half of the shell will deploy the solar panels, while the other half will contain the instruments and electronics. Most of the electronics are kept in an insulated box with an RHU to ensure thermal survival during the Martian night, as well as throughout the Global Dust Storm Season. Communications are nominally via an orbiter spacecraft, but for contingency a direct link to Earth is implemented. This paper describes the science that can be achieved with this type of mission and how such a system will be designed to survive a year on the Martian surface. It also includes a description of the EDLS, thermal architecture, power system, communication systems, operations and planetary protection.

10:10-10:40 a.m.
**ExoMars: The Enhanced Baseline Mission**
***Carlo Cassi, Thales Alenia Space-Italy***
ExoMars is the first mission of the ESA Exploration Program-Aurora, which will demonstrate the feasibility of several key technologies that are necessary to support the European ambitions for future human exploration. The mission configuration foresees the launch of a Spacecraft Composite by means of an Ariane 5 launcher lifting from Kourou. An optimal launch window has been established from Nov. 23 to Dec. 13, 2013. The mission and the SC will be designed to be compatible with a back-up launcher, Proton –M from Baikonur. An alternative launch date is foreseen in January 2016. The PFM campaign will be completed within February 2013 with the Flight Acceptance Review which authorises the SC shipment to Korou for the starting of the launch campaign. The Flight Readiness Review is placed mid-November 2013.

10:40-11:10 a.m.
**Exploring Venus with Balloons—Science Objectives and Mission Architectures for Small and Medium-Class Missions**
***Kevin Baines, Jeffrey Hall, NASA Jet Propulsion Laboratory***
***Sushil K. Atreya, University of Michigan***
***Sanjay Limaye, University of Wisconsin-Madison***
***Kevin J. Zahnle, NASA Ames Research Center***
Following the trailblazing flights of the 1985 twin Soviet VEGA balloons, missions to fly in the skies of Venus have been proposed to both NASA's Discovery Program and ESA's Cosmic Visions and are being planned in response to NASA's New Frontiers Mission opportunity. Such missions would address key questions of Venus's origin, evolution, and current state, including detailed measurements of (1) trace gases associated with Venus's active photo- and thermo-chemistry and (2) measurements of vertical motions and local temperature which characterize convective and wave processes. As an example of what can be done with small and medium class missions (less than $900 million and $500 million, respectively), the Venus Aerostatic-Lift Observatories for in-situ Research (VALOR) Discovery and New Frontiers mission concepts will be discussed.

11:10-11:40 a.m.
**ExoMars Mission Analysis and Design from Mars Arrival to Landing**
***Rodrigo Ramos, Juan Cano, DEIMOS Space***
***David Gittins, David Northey, Tessella***
***Stefano Portigliotti, Alberto Anselmi, Thales Alenia Space - Italy***
ExoMars is ESA's next mission to planet Mars. The project is currently undergoing Phase B2 studies under ESA management. In that context, DEIMOS is responsible for the mission analysis support to Thales Alenia Space Italy as ExoMars prime contractor, covering all mission phases, including launch, interplanetary, Mars orbit injection and orbiting, down to entry, descent and landing (EDL). Tessella supports DEIMOS in the area of Descent and Landing Analyses. The current mission baseline is based on an Ariane 5 launch in 2013 of a spacecraft Composite made up of a carrier module (CM) and a descent module (DM). This paper's objective is to present the current design of the EDL phase of the ExoMars mission, focusing on the Mars Orbit Insertion targeting up to the touchdown. This paper also addresses the detailed evaluation of the performance of the mission in selected landing sites through detailed end-to-end Monte Carlo analyses (from DMTM to touchdown). Multibody simulations for the descent phase have been also run to verify the stability of the system and the sensitivity to perturbations (gust). These results serve not only as a verification of the mission design but also as a validation of the design methods and tools.

11:40 a.m.-12:10 p.m.
**Ablation of Pica-Like Material: Surface or Volume Phenomenon?**
***Jean Lachaud, Nagi Mansour, NASA Ames Research Center***
The ablation of the char layer in ablative material is usually described in term of recession velocity of the overall surface. This description is valid for dense materials. However, the recession of the average surface in porous materials may not recede uniformly, but the individual fibers may progressively vanish. In the second regime, ablation is no longer a surface phenomenon, but is volumetric. Seen from a surface point of view, three important consequences follow this volume ablation regime: (1) the effective reactivity of the material is significantly in-creased, (2) the material weakens in volume and is subject to strong mechanical erosion (spallation), and (3) the ablation enthalpy distributed in volume modifies the thermal response of the material. In this regime, surface ablation models should be replaced by volume ablation models for a more accurate description of the outer layer of the material. In the presentation, a first attempt to couple volume ablation with pyrolysis is done using a multiscale approach. A parametric study shows that ablation is either a surface

or a volume phenomenon depending on the value of Thiele number (reaction/diffusion competition inside the porous media), when advection due to pyrolysis and thermal gradients are neglected. A macroscopic model for volume ablation is derived analytically using homogenization (averaging). The model is a set of partial differential equations, similar to traditional pyrolysis models. Simulations of coupled pyrolysis and volume ablation are presented. The possible spallation of PICA due to volume ablation during Stardust re-entry is discussed under the light of this model.

12:10-12:40 p.m.
**The Evolution of the MSL Heatshield**
***Robin A. S. Beck, NASA Ames Research Center***
The MSL entry vehicle will be experiencing aerothermal environments that no previous Mars entry vehicle has seen, and as such, will require a heatshield that no previous Mars entry vehicle has flown. Early assessments of the environments led engineers down the path to "fly as we've always flown," with the heritage Mars heatshield material, SLA-561V. Screening tests in arc jet facilities in stagnation model configurations substantiated the claims that the SLA-561V could survive high heating rates expected on the heatshield, albeit, with a melting surface. However, due to the size and mass of the vehicle, along with the need to reenter at angle of attack, high heating and high shear in turbulent flow was predicted on the leeward side of the vehicle. Testing in shear showed that the SLA-561V exhibited catastrophic ablation which led to the abandonment of the material for this application and the fast-tracked development of a tiled PICA heatshield design, for a 2009 launch.

**12:40-2 p.m.**
**Lunch Atrium**

**Session IX: (Parallel) Sample Return Challenges Room 225**
Conveners: Jim Arnold, Jean Marc Bouilly

2-2:30 p.m.
**Overview of the Mars Sample Return Earth Entry Vehicle**
***Robert Dillman, James Corliss, NASA Langley Research Center***
NASA's Mars Sample Return project will bring Mars surface and atmosphere samples back for detailed examination. The MSR Earth Entry Vehicle is a core part of the mission, protecting the sample container during atmospheric entry, descent, and landing. Planetary protection requirements demand a higher reliability from the EEV than for any previous planetary entry vehicle. An overview of the EEV design and preliminary analysis is presented, with a follow-on discussion of recommended future design trade studies to be performed during the next several years in support of an MSR launch in 2018 or 2020. Planned topics include vehicle size for impact protection of a range of sample container sizes, outer mold line changes to achieve surface sterilization during re-entry, micrometeoroid protection, aerodynamic stability, thermal protection, and structural materials selection.

2:30-3 p.m.
**Challenges for the Heatshield Development of Sample Return Missions—An Overview on European Sample Return Studies and Requirements**
***H. Ritter, A. Santovincenzo, L. Walpot, ESA/ESTEC***
The atmospheric entry of the Earth return capsule of sample return mission is one of the most critical phases of sample return missions. The Earth return from extraterrestrial bodies (e.g. Mars, comets or asteroids) involves a hyperbolic entry with entry velocities typically above 12 km/s, resulting in peak heat fluxes in the order of 10 MW/m2 and heat loads up

to 200 MJ/m2. The paper provides an overview on the main challenges involved in the development of the heatshield for the Earth re-entry capsule of sample return missions, based on the results of different ESA studies to Mars and asteroids. This will include system aspects, the choice of the TPS material and its qualification, flight path stability and reliability. Preliminary technology roadmaps will also be presented.

3-3:30 p.m.
**Post-Flight Evaluation of Stardust PICA Forebody Heatshield Material**
***Don Ellerby, Joseph Lavelle, Frank Milos, Dean Kontinos, NASA Ames Research Center***
***Mairead Stackpoole, Ioana Cozmuta, ELORET Corporation***
***Jim Arnold, University of California at Santa Cruz***
As a result of its low density (~ 0.27g/cc) and efficient ablative capability PICA is an enabling technology for the Stardust mission. Three cores at key locations were extracted from the forebody heatshield of the Stardust Sample Return Capsule post flight and evaluated. Core locations include a near stagnation core, a flank core and a segment taken from the shoulder of the heatshield. Evaluation included density profiles, recession determination, thermal analysis profile, PICA bondline examination, strength of remaining virgin PICA, emissivity profile, chemical analysis profile and microstructural analysis. Comparisons between experimental density profiles and profiles derived from FIAT, a tool used to predict ablative performance, are in good agreement. Recession comparisons from measured values and FIAT predictions are being obtained. In addition a laser scanning tool developed at Ames is being used to evaluate recession measurements and compare to experimental and predicted values. In general, the PICA material examined in the cores is in good condition and intact. Impact damage is not evident and the main degradation observed was that caused by heating on entry. A substantial amount of "virgin" PICA was present in all cores examined. It is noted that the post-flight analysis of the Stardust heatshield is especially important since PICA is baselined for both the Orion (CEV) and Mars Science Laboratory vehicles.

**3:30-3:40 p.m.**
**Break**

3:40-4:10 p.m.
**CEV TPS Advanced Development Project Progress and Contributions to Current and Future NASA's Probe Missions**
***Ethiraj Venkatapathy, James Reuther, NASA Ames Research Center***
The Orion (CEV) thermal protection system (TPS) advanced development project (ADP) was initiated in late 2006 to reduce developmental risk by significant investment in multiple heatshield architectural solutions that can meet the needs both the Low Earth orbit (LEO) and Lunar return missions. At the same time, the CEV TPS ADP was also charged with developing a preliminary design for the heatshield to meet the PDR requirement and at the time of the PDR, transfer the design to Lockheed-Martin, the prime contractor. In this paper, we plan to present the significant progress achieved in the past three years and highlight the contributions the CEV TPS ADP Project has made to advance the state of the art in Thermal Protection System technology that has and will continue to benefit future entry probe missions.

4:10-4:40 p.m.
**SpaceX Dragon Re-Entry Vehicle: Aerodynamics and Aerothermodynamics with Application to Base Heat-Shield Design**
***Loretta Trevino, SpaceX Co.***
The purpose of SpaceX is to improve the reliability and cost efficiency of access to space. The NASA COTS procurement provides the mechanism to accelerate the timing of human

orbital transportation development. SpaceX's orbital transportation system is tailored to the requirements of NASA for both cargo and crew transport to the International Space Station (ISS), while allowing for its future applicability to other markets. This development is known as COTS and consists of the Dragon crew/cargo spacecraft, the Falcon 9 booster, and the Ground Segment. The goal of COTS is to provide continuing crew/cargo transport to the ISS once the Shuttle is retired. The Dragon spacecraft design is structurally identical for both cargo and crew configurations. With a nominal internal or external cargo mass of 2550 kg of cargo, Dragon has a gross liftoff weight of 8750 kg. The design is based on a traditional re-entry capsule: A body of revolution with 0.78 height-to-diameter ratio. With a radially offsetcenter-of-mass, Dragon is designed for a canonical lifting re-entry at a "low" 12 º trim angle of attack with a 0.18 L/D. The 12 º sidewall angle represents a compromise between internal volume, TPS mass and L/D ratio and minimizes sidewall heating. In this paper, the aerothermodynamic design of the Dragon spacecraft is described.

4:40-5:10 p.m.
**Multimission Earth Entry Vehicle Design Trade Space and Concept Development Strategy**
***Robert Maddock, NASA Langley Research Center***
In recent years the sample return mission concept has gradually grown increased favor over in-situ missions. The successes of the Stardust and Genesis missions have highlighted the advantages of bringing samples back to Earth where they can be studied in much greater detail by more powerful instruments, examined by a much wider scientific community, and preserved over an extended period of time. This paper outlines an approach to be taken to develop a flexible Earth Entry Vehicle (EEV) design concept that can be utilized by multiple sample return missions. The multimission EEV concept is based on the Mars Sample Return (MSR) EEV design, which is driven by minimizing risk associated with sample containment. However, not all sample return missions will need to meet the rigorous planatery protection requirements of MSR. The goal of this study is to provide a foundation by which individual missions can build upon to optimize an EEV design which meets their specific needs while preserving as many common elements as possible. This multimission EEV concept could then provide a platform by which technologies, design elements, processes, etc., can be developed and even flight tested prior to implemention on MSR. This approach could not only significantly reduce the risk and associated cost in development of the MSR EEV, but also by leveraging common design elements, all sample return missions will benefit.

5:10-5:40 p.m.
**Marco Polo: A Sample Return Mission to a Primitive NEO**
***David Agnolon, Jens Romstedt, Detlef Koschny, Diego Escorial, and Peter Falkner, European Space Agency***
***Antonella Barucci, LESIA - Observatoire de Paris-Meudon***
Marco Polo is a Near-Earth Object (NEO) sample return mission being studied by the European Space Agency in collaboration with the Japanese Aerospace Exploration Agency. It has been selected as a medium-class mission candidate for a one-year competitive assessment study within the Cosmic Vision 2015-2025 program of ESA. The primary goal of Marco Polo is to return to Earth samples of surface material from a primitive NEO (e.g. D or C-type). At this early stage many design options are being assessed, including the NEO target which is one of the primary mission drivers. A number of them have been identified based on their scientific interest and analyses are ongoing to determine which ones are most compatible with the technical, cost and programmatic requirements. Due to the stringent mission cost and programmatic requirements simple and robust technologies with a high technology readiness level will be favoured throughout the assessment study. This paper presents the study status and an overview of the mission scenario with a focus on

the key enabling technology areas involved in the NEO landing and Earth re-entry phases. These can efficiently build upon the expertise of ESA acquired in sample return mission studies (e.g. Mars Sample Return) and JAXA who has tremendous development and flight experience from the ongoing Hayabusa mission.

5:40-6:10 p.m.
**An Observing Campaign to Monitor the Reentry of the Automated Transfer Vehicle "Jules Verne" in August 2008**
***Peter Jenniskens, SETI Institute***
***Jason Hatton (ESA-ESTEC)***
The next great opportunity to investigate aspects of entry and descent dynamics is the reentry of ESA's Automated Transfer Vehicle (ATV) called "Jules Verne". This first in a series of ATVs was launched on March 9. It has a function similar to that of the Russian Progress, a re-supply ship for the International Space Station. It was scheduled to dock with ISS in April, then undock in early August. An observing campaign is being organized to monitor the reentry of the 15-ton ATV-1 over the South Pacific Ocean on Aug. 8. An international team of researchers from governments, universities, and private institutions will deploy from NASA Ames Research Center in California, travel to the staging area, and field a wide range of imagers and spectrographs to record the manner in which ATV breaks during entry. This data is expected to constrain the model uncertainties in the size of the debris footprint and help ensure future safe returns of ATV.

**Session X: (Parallel) Cross Cutting Technologies Room 222**
Conveners: Joern Helbert, Chester Ong & Walt Engelund

2-2:30 p.m.
**Aerocapture Technology Developments by the In-Space Propulsion | Technology Program**
***Michelle Munk, NASA Langley Research Center***
This paper explains the investment strategy, the role of detailed systems analysis, and the hardware and modeling developments that have resulted from the past five years of work on aerocapture technology under NASA's In-Space Propulsion Technology (ISPT) Program. Accomplishments include improved understanding of entry aerothermal environments, particularly at Titan, demonstration of aerocapture guidance algorithm robustness at multiple bodies, manufacture and test of a 2-meter Carbon-Carbon "hot structure," development and test of evolutionary, high-temperature structural systems with efficient ablative materials, and development of aerothermal sensors that will fly on the Mars Science Laboratory in 2009. Many of NASA's programs are benefiting from the sustained ISPT support for aerocapture, component technologies are mature enough to be infused on entry missions, and the aerocapture system technology is ready to be validated in flight.

2:30-3 p.m.
**In-Flight Research in Aerothermodynamics and TPS for Space Transportation Systems**
***J. Muylaert, H. Ritter, and G. Ortega, ESA/ESTEC***
***V. Danilkin,SRC-MDB***
***C. Park, KAIST***
This paper addresses a strategy to perform in flight research on Aerothermodynamics and Thermal Protection Systems taking advantage of the low cost VOLNA and SHTIL class of launchers. A series of flight test beds will be addressed and their relevance discussed as to the gathering of critical Aerothermodynamic and TPS related data for design tool qualification and associated physical model validation. Four initiatives are reviewed, all of the class of flying test beds launched by the VOLNA launcher. It is concluded that these low cost class of flight research initiatives are the way forwards to improve the tools to be used for design of future re-entry space transportation systems.

3:00-3:30 p.m.
**UAV Mission Design for the Exploration of Mars**
***Lisero Perez Lebbink, Technical University of Delft***
This paper describes three different mission concepts for the exploration of Mars by means of a UAV (Unmanned Aerial Vehicle). These concepts have been proposed after a three-week workshop held by the European Association of Aerospace Engineers EUROAVIA and the European Space Agency ESA. The UAV designs have been a combined effort of a total of 30 European engineering students. The students had to transfer broad ESA requirements into a mission statement, specific requirements and a clear scientific mission goal. All three designs will be addressed in this paper up to a subsystems level detail. In addition, the design implications of the Martian environment, specifically on UAV design, will be addressed.

**3:30-3:40 p.m.**
**Break**

3:40-4:10 p.m.
**Summary of Ultralightweight Ballute Technology Advances and Applicability to Planetary Probe Missions**
***Jim Masciarelli, Reuben Rohrschneider, Kevin Miller, Ball Aerospace***
Ultralightweight ballutes offer the potential to provide the deceleration for entry and aerocapture missions at a fraction of the mass of traditional methods. Significant technology advances have been made in the areas of ballute materials, aerothermal analysis, trajectory control, aeroelastic modeling, hypersonic test, and overall ballute system design processes. The results show that ultralightweight ballutes provide excellent performance and packaging benefits aerocapture, de-orbit, entry, descent, and landing missions to planetary bodies with a sensible atmosphere. This paper discusses ultralightweight ballutes, the technology advances made by the team, and applicability of the technology to planetary probe missions.

4:10-4:40 p.m.
**Utilizing Mars Global Reference Atmospheric Model (Mars-GRAM 2005) to Evaluate Entry Probe Mission Sites**
***Hilary L. Justh, NASA Marshall Space Flight Center***
***C. G. Justus, Stanley Associates***
The Mars Global Reference Atmospheric Model (Mars-GRAM 2005) is an engineering-level atmospheric model widely used for diverse mission applications. An overview is presented of Mars-GRAM 2005 and its features. The "auxiliary profile" option is one new feature of Mars-GRAM 2005. This option uses an input file of temperature and density versus altitude to replace the mean atmospheric values from Mars-GRAM's conventional (General Circulation Model) climatology. Any source of data or alternate model output can be used to generate an auxiliary profile. Auxiliary profiles for this study were produced from mesoscale model output (Southwest Research Institute's Mars Regional Atmospheric Modeling System (MRAMS) model and Oregon State University's Mars mesoscale model (MMM5) model) and a global Thermal Emission Spectrometer (TES) database. The global TES database has been specifically generated for purposes of making Mars-GRAM auxiliary profiles. This data base contains averages and standard deviations of temperature, density, and thermal wind components, averaged over 5-by-5 degree latitude-longitude bins and 15 degree Ls bins, for each of three Mars years of TES nadir data. The Mars Science Laboratory (MSL) sites are used as a sample of how Mars-GRAM could be a valuable tool for planning of future Mars entry probe missions. Results are presented using auxiliary profiles produced from the mesoscale model output and TES observed data for candidate MSL landing sites. Input parameters rpscale (for density perturbations) and rwscale (for wind perturbations) can be used to "recalibrate" Mars-GRAM perturbation magnitudes to better replicate observed or mesoscale model variability.

4:40-5:10 p.m.
**The Program to Advance Inflatable Decelerators for Atmospheric Entry: An Overview of Results and Lessons Learned from Years 1 and 2**
***Charles Player, NASA Langley Research Center***
The Program to Advance Inflatable Decelerators for Atmospheric Entry (PAIDAE) is jointly funded by NASA's Fundamental Aeronautics Supersonics and Hypersonics Projects. The purpose of PAIDAE is to engage in the research, ground testing, and analysis necessary to mature Inflatable Aerodynamic Decelerator (IAD) technology for both a hypersonic atmospheric entry application and a supersonic deceleration application. Over two years, PAIDAE has executed three wind-tunnel tests, a set of ballistic range tests, and a number of analyses and trade studies. This presentation reviews some of PAIDAE's results and lessons learned, and discusses the future activities of the program.

5:10-5:40 p.m.
**Characterizing the Controllable Entry States and Reachable Sites for Planetary Landing**
***Joel Benito, Kenneth Mease, University of California-Irvine***
Future Mars missions requiring increased landing accuracy, higher landed mass, and higher elevation landing are driving the development of entry, descent and landing (EDL) technology. Understanding the envelope of trajectories of which a lander is capable of flying is important for mission analysis and design. In this paper, trajectory optimization is used to characterize the envelope of entry trajectories and in particular to evaluate the impact of the vehicle aerodynamic performance (low or mid lift-over-drag ratio (L/D)) and the parachute deployment velocity (Mach 2 or Mach 5) on the envelope. Two characteristic are the focus of our attention: (1) the landing footprint (LFP), or more generally, the reachable set of parachute deployment states from a given entry state, and (2) the set of controllable entry states (CES), set of entry states from which there exists a feasible trajectory to a given parachute deployment state. We are especially interested in using this information in entry guidance development. This paper addresses the computation and interpretation of the LFP. Trajectories are optimized to have maximum deployment altitude and are constrained to have high control authority to compensate for the dispersions due to modeling errors for the atmosphere and the vehicle aerodynamic performance. For a given nominal EDL mission, the study of the LFP qualitatively indicates the difficulty of the nominal mission. The paper also addresses the computation and interpretation of the CES. The CES directly shows the allowed dispersions on the entry state. As with the LFP, the trajectories used to find the boundaries of the CES are constrained to have high control authority. It is shown how the CES can be used to provide the target for the skip phase guidance algorithm in a skip-entry guidance system. The target (for the end of the skip phase and beginning of the entry phase) is chosen from the CES so that the margins for errors both in the skip phase and the entry phase are large, ensuring high parachute deployment accuracy in the presence of large uncertainties. In both parts, a Viking- type capsule (low L/D) and an ellipsled-type vehicle (mid L/D) are considered, with deployment speeds of Mach 2 and Mach 5. Entry capability is studied from a guidance point of view, evaluating the performance of the guidance algorithms provided the LFP and CES. Lateral as well as longitudinal motion is considered.

5:40-6:10 p.m.
**Entry, Descent, and Landing System Design for the Mars Gravity Biosatellite**
***Ashley Korzun, Christine Hartzell, Brandon Smith, Scott Martinelli, Kyle Hott, Laura Place, Chi-Yau Yu, and Robert Braun, Georgia Institute of Technology***
Mars Gravity Biosatellite is a novel program aimed at providing data on the effects of partial gravity on mammalian physiology. A collaboration between MIT and Georgia Tech, this student-developed free-flyer spacecraft is designed to carry a payload of 15 mice into low Earth orbit, rotating to generate accelerations equivalent to Martian gravity. After 35 days, the payload will re-enter the atmosphere and be recovered for study. Having engaged more than 500 students to date in space life science, systems engineering, and hardware development, the Mars Gravity Biosatellite program offers a unique, interdisciplinary educational opportunity to address a critical challenge in the next steps in human space

exploration through the development of a free-flyer platform for partial gravity science with full entry, descent, and landing (EDL) capability. Execution of a full entry, descent, and landing from low Earth orbit is a rare requirement among university-class spacecraft. The EDL design for the Mars Gravity Biosatellite is driven by requirements on the allowable deceleration profile for a payload of de-conditioned mice and maximum allowable recovery time. The 260 kg entry vehicle follows a ballistic trajectory from low Earth orbit to a target recovery site at the Utah Test and Training Range. Reflecting an emphasis on design simplicity and the use of heritage technology, the entry vehicle uses the Discoverer aeroshell geometry and leverages aerodynamic decelerators for mid-air recovery and operations originally developed for the Genesis mission. This paper presents the student-developed EDL design for the Mars Gravity Biosatellite, with emphasis on trajectory design, dispersion analysis, and mechanical design and performance analysis of the thermal protection and parachute systems. Also included is discussion on EDL event sequencing and triggers, contingency operations, the deorbit of the spacecraft bus, plans for further work, and the educational impact of the Mars Gravity Biosatellite program.

**Evening Open Planning Dinner for IOC Members**

**Friday, June 27**
**Session XI: Closing Room 222**
Conveners: Jim Cutts, Bernie Bienstock

8-8:30 a.m.
**20 Minutes of Terror (And 10 Minutes of Questions)**
***Rob Manning, NASA Jet Propulsion Laboratory***
Starting with the valiant attempts by the USSR to land the Mars 2 & 3 landers in 1971 through last month's Phoenix landing, Manning will review the wild history of Mars landing attempts.

8:30-9 a.m.
**Why Mars Sample Return Will Never Happen**
***Mark Adler, NASA Jet Propulsion Laboratory***
The ongoing quest to bring to Earth selected samples of the surface of Mars has repeatedly run into what appear to be insurmountable obstacles. The mission continues to be delayed at rates greater than one year per year. Though it is the highest priority objective for Mars exploration, it is the least likely mission to be mounted. So what's the problem here? We will discuss the many hurdles, both technical and programmatic, that a successful Mars Sample Return mission will have to overcome.

9-10 a.m.
**Panel Discussion: The Future of Planetary Probe Partnerships**
**Moderator: Jim Cutts, NASA Jet Propulsion Laboratory**
Rob Manning, NASA Jet Propulsion Laboratory
Doug McCuistion, NASA Headquarters
Bernard Foing, European Space Agency
Andrew Ball, Open University

**10-10:15 a.m. Break**

10:15-10:45 a.m.
Students Awards Presentation Periklis Papadopoulos, San Jose State University

10:45-11:15 a.m.
Comments on IPPW7 Ed Chester, CTAE

11:15-11:30 a.m.
Long Range Planning Helen Hwang, NASA Ames Research Center

11:30 a.m.-Noon Closing Remarks

**Noon Adjourn**

## Thank You to Our

# SPONSORS

NASA

Georgia Institute of Technology

esa

BOEING

LOCKHEED MARTIN

ELORET CORPORATION

Europlanet European Planetology Network

University of Idaho

San José State UNIVERSITY

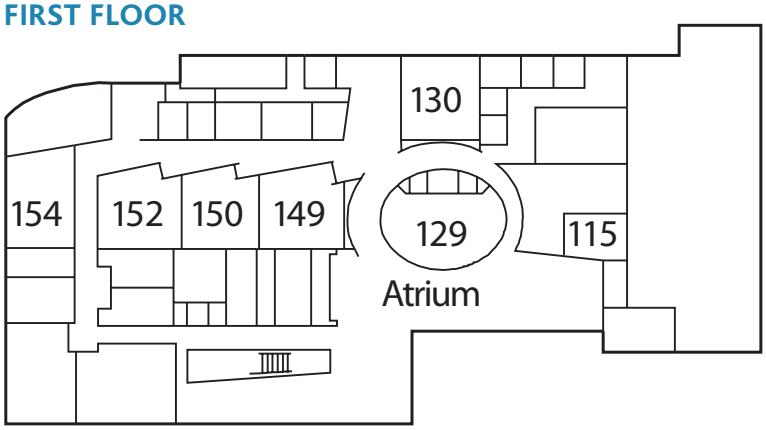
The Open University

ARA

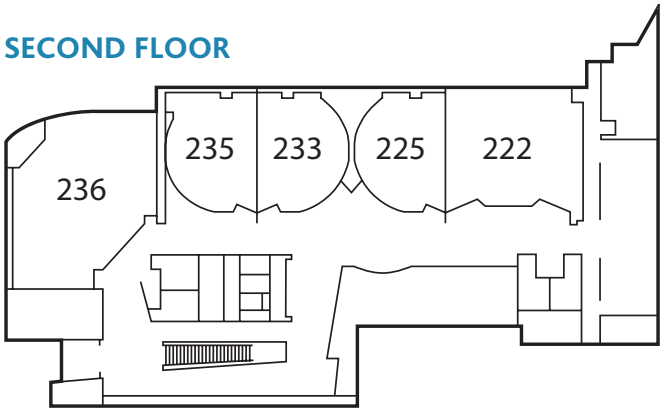
UC SANTA CRUZ

Georgia Tech
Global Learning Center

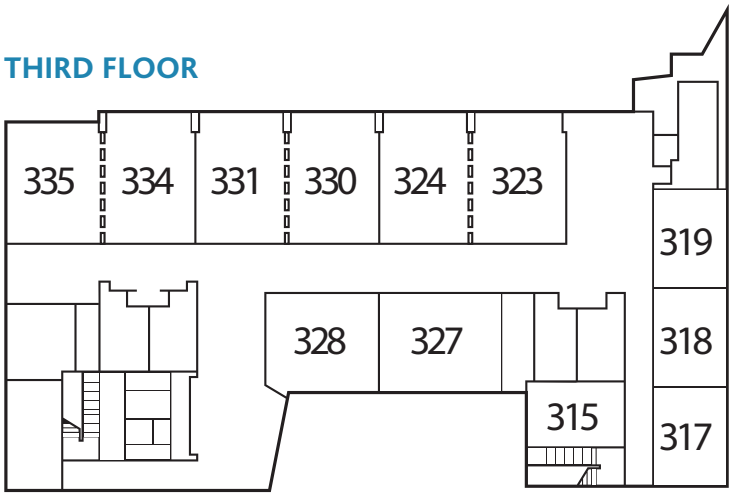
## FIRST FLOOR




## SECOND FLOOR




## THIRD FLOOR




- Our business concierge staff provides the support you need to stay connected while you are away from the office.

### Working Spaces

The Center includes convenient working spaces to charge your laptop, take a phone call, and keep connected to the day's business. Throughout the facility, you will find comfortable chairs and sofas to meet informally during breaks.

### Wireless Environment

The Center offers an 802.11B Wireless Network by Biltmore Communications FAST PASS. If your laptop is wireless ready, you can purchase a FAST PASS from our concierge desk for only $10 for the entire day.

### Concierge Staff

The Center's concierge staff is ready to provide you with superior customer service.

We offer traditional fax and copy services and free local calls. In addition, the concierge staff can help you by providing information about area restaurants and shopping, ordering tickets to local sporting and cultural events, reserving tee times at area golf courses, and much more.

# Things to Do within 20 Minutes of Technology Square

## Short Walks

**Federal Reserve Bank of Atlanta, 0.7 miles**
Atlanta Fed's Visitors Center and Monetary MuseumSelf-guided tours. 1000 Peachtree St. N.E., Atlanta, GA 30309-4470
404-498-8777

**Fox Theatre, 0.7 miles**
660 Peachtree St. N.E.
Atlanta, Georgia 30308
404-881-2100
www.foxtheatre.org

**High Museum, 1.3 miles**
1280 Peachtree St. N.E.
Atlanta, GA 30309
404-733-HIGH
www.high.org

**Margaret Mitchell House & Museum, 0.7 miles**.
990 Peachtree St. Atlanta, GA 30309
404-249-7015
www.gwtw.org

**Woodruff Arts Center, 1.3 miles**
1280 Peachtree St. N.E. Atlanta, GA 30309
404-733-4200
http://www.woodruffcenter.org/wac/index2.asp

## Longer Walks

**Centennial Olympic Park, 1.6 miles**
265 Park Ave. West N.W. Atlanta, GA 30313-1591
www.centennialpark.com

**Center for Puppetry Arts, 1.4 miles**
1404 Spring St. N.W.
at 18th Street
Atlanta, GA 30309-2820
www.puppet.org

**CNN Center, 2.0 miles**
One CNN Center
Atlanta, GA 30303
404-827-2300
or 877-4CNNTOUR
www.cnn.com/StudioTour/

**Georgia Aquarium, 1.2 miles**
225 Baker St.
Atlanta, GA 30313
404-581-4000
www.georgiaaquarium.org

**Imagine It! The Children's Museum of Atlanta, 1.1 miles**
275 Centennial Olympic Park Drive N.W.
Atlanta, GA 30313-1827
404-659-KIDS (5437)
www.imagineit-cma.org

**World Of Cola-Cola, 1.1 miles**
121 Baker St. N.W.
Atlanta, GA
404-676-5151
www.woccatlanta.com

## Restaurants

**5th Street Ribs n Blues**
Barbeque ribs, chicken, and pork
86 Fifth St. N.W.
Atlanta, GA 30308
404-249-8808
www.ribsnblues.com/5th Street/info.htm

**The Globe**
**Urban bistro**
75 Fifth St. N.W.
Atlanta, Ga 30308
404.541.1487
www.globeatlanta.com/

**Lexington Chocolatier**
Original chocolate treats, cookies, and homemade ice cream
68 Fifth St. N.W.
Atlanta, GA 30308-1031
404-875-0111

**Marble Slab Creamery**
Gourmet ice cream and frozen yogurt
85 Fifth St. N.W.
Suite B
Atlanta, GA 30308
404-279-1000
www.marbleslab.com

**Moe's Southwestern Grill**
Southwestern burritos, tacos, nachos.
85 Fifth St. N.W., Suite C
Atlanta, GA 30308
404-541-9940

**Ray's Pizza/Cedar's Mediterranean**
Pizzas, salads, and calzones
26 Fifth St. N.W.
Atlanta, GA 30308
404-888-9911

**St. Charles Deli**
Deli-style sandwiches, salads, and burgers
22 Fifth St. N.W.
Atlanta, GA 30308
404-249-7733
www.stcharlesdeli.com

**Starbucks**
48 Fifth St. N.W.
Atlanta GA, 30308
404-894-1858

**Tin Drum Asia Cafe**
Thai and Vietnamese
88 Fifth St.
Atlanta, GA 30308
404-881-1368

**The Varsity**
61 North Ave.
Atlanta, GA 30308
404-881-1706

## ATMs and Banks

**RBC Centura Bank**
Corner of Fifth and Spring streets
Atlanta, GA 30308
Barnes & Noble@Georgia Tech Bookstore
Corner of Spring and Fifth streets
Atlanta, GA 30308

**SunTrust (ATM)**
Biltmore Hotel
817 W. Peachtree St.
Alanta, GA 30308

**SunTrust (Branch & ATM)**
West Peachtree Branch
760 W. Peachtree St.
Alanta, GA 30308
404-870-3120

**Nearby Banks:**
**Bank of America ATM**
(walk-up only)
Georgia Tech Student Center
350 Ferst Drive
Atlanta, GA 30313

**Bank of America (Branch & ATM)**
Midtown Operations Center
715 Peachtree St.
Atlanta, GA 30308

**SouthTrust**
One Georgia Center
600 W. Peachtree St.
Atlanta, GA 30308

**SunTrust (Branch & ATM)**
West Peachtree Branch
760 W. Peachtree St.
Alanta, GA 30308
404-870-3120

**Wachovia (Branch & ATM)**
Midtown Office (corner of 10th
& Peachtree streets)
999 Peachtree St.
Suite 100
Atlanta, GA 30309
404-865-3010 and 404-865-3012

**Wachovia**
(Branch & ATM)
Tech Parkway Office (across from Georgia Tech campus)
645 State St. N.W.
Atlanta, GA 30313
404-853-1960
& 404-853-1971

## Nearest Grocery Store

**Publix**
The Plaza Midtown
950 W. Peachtree St. N.W.
Atlanta, GA 30309-3846
Main: 404-253-3544
Pharmacy: 404-253-3547

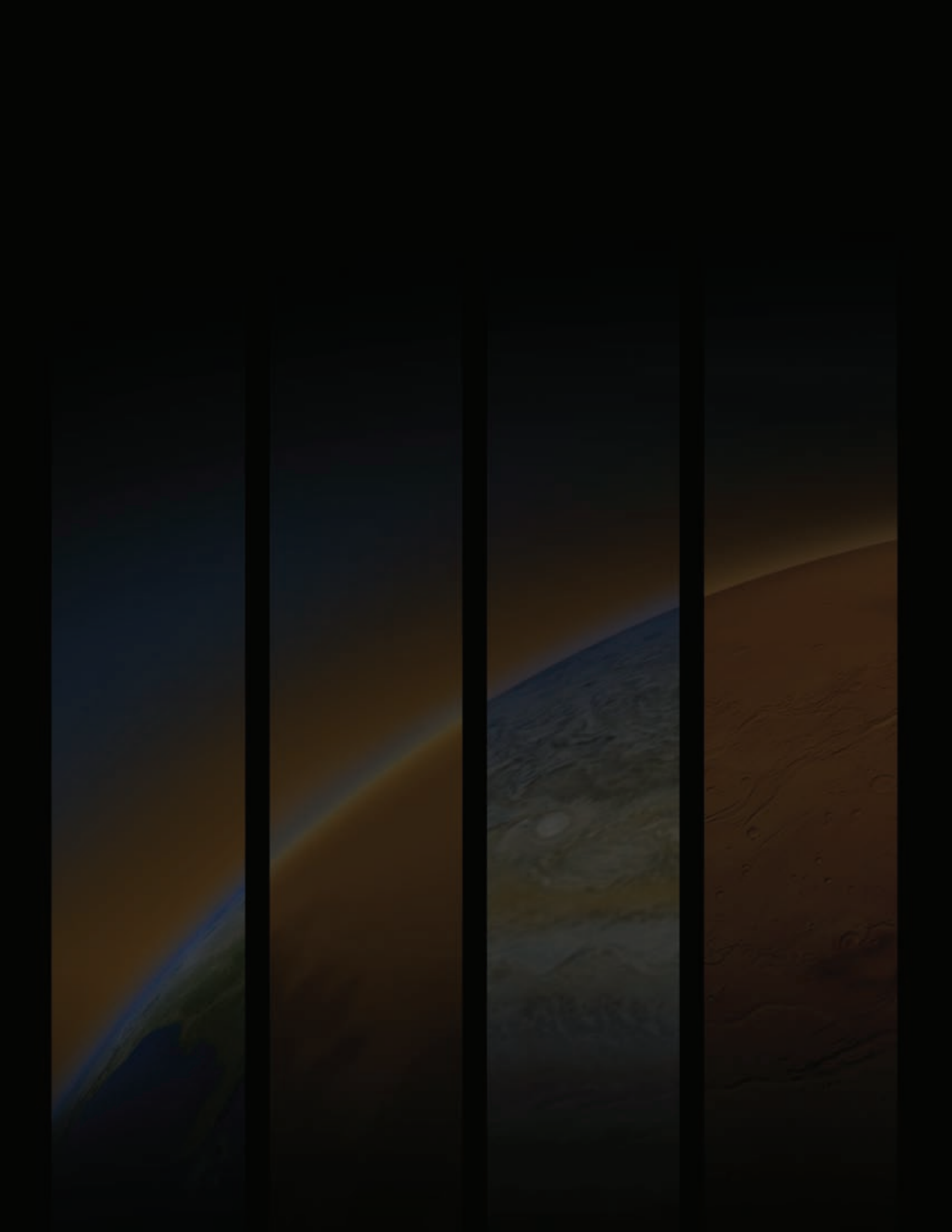
## Nearest Drug Stores

**CVS**
842 Peachtree St. N.E.
Atlanta, GA 30308
Phone: 404-881-1605
Pharmacy: 404-892-8468

**Walgreens**
595 Piedmont Ave.
(at North Avenue)
Atlanta, GA 30308-2480
Phone: 404-347-9997
Pharmacy: 404-685-9665

## Nearest Hospital

**Emory Crawford Long Hospital**
550 Peachtree St. N.E.
Atlanta, GA 30308
404-778-7777
1-800-753-6679

# NOTES

# CD