

# **2007 Space Grant Student Abstracts**

**The following pages contain actual abstracts prepared by the 90 Space Grant interns at JPL for the summer of 2007. This document is intended to provide examples of the types of opportunities available for student internships at JPL.**

## **Improving Robotic Operations Experience Through Ergodex Keyboard**

The Maestro Team develops software to allow scientists and engineers to control robots. The software scales well, is easy to learn, but is limited to a standard keyboard, mouse, and joystick. To make rover operations more intuitive, the Ergodex input system was presented to allow users to freely reposition a set of wireless keyboard keys on a special keyboard surface. Collaboration with the Ergodex manufacturer provided necessary specifications to create a specialized Java driver for a Linux machine. Upon completion of the driver, user interfaces were prototyped and hooked to the driver. The system's features were then generalized for use on other USB devices. The Ergodex keyboard allowed scientists to configure, reconfigure and rearrange buttons to trigger a robotic action. The device improved user experience by allowing complex or repetitive commands to be issued very quickly and provided an intuitive system for scientists and engineers to operate in a way that is natural.

## **Beam Acquisition and Tracking System for Optical Communications**

An optical communications system depends on beam acquisition and tracking to reliably transmit data. An acquisition and tracking system has been implemented using commercial components. It is capable of quickly and accurately acquiring a communication beam low in the sky and tracking with a 1-milliradian tracking error. The system as a whole is able to track targets moving at speeds of one degree per second. It is able to acquire and track low-brightness contacts, including spacecraft illuminated by sunlight. The entire communications beam acquisition and tracking system is fully automated.

A fine-beam steering system based on a commercial piezoelectric tube and a commercial position sensitive device has also been implemented. This fine steering system is capable of correcting small instabilities caused by seismic motion or small errors in the tracking system. The fine-beam steering system is fully automated and independent of the coarse acquisition and tracking system.

## **Summer Work for Multi-Mission System Architecture Platform Integration and Test Team**

The purpose of the Multi-Mission System Architecture Platform (MSAP) project is to develop a standard avionics system for future JPL missions. My work this summer has consisted of several different operational tasks to assist the MSAP Integration and Test team. Three primary jobs are discussed in this paper. The first is to prepare for the installation of four Phase II upgraded testbeds, which will consist of roughly triple the amount of hardware as in Phase I. This will result in a significant increase in required floor space, cabling, and noise output. After considering several designs and reviewing them with the Ground Support Equipment lead, my final layout is being evaluated. My next job is to update the Verification and Validation matrix, which is maintained in a database program called DOORS. For several hundred items, I have assigned a test method, a manageable test group, and a test engineer.

Finally, I have run a regression test on a new Flight Software build. This involved following a procedure for testing the 1553 data bus, and reporting any anomalies I encountered.

### **Miniature Mars Science Lander Mission Study**

This project developed a 25-kg seismic science lander conceptual design that is to be delivered to the Martian surface by the Astrobiology Field Laboratory (AFL) rover in 2016. The Mars Program Office at JPL provided constraints for the payload and a team of 8 students developed a design satisfying the constraints. The lander is a completely self-sustaining and self-contained package with minimum interference to AFL. Roles were assigned to students on the team to cover the major systems including power, control and data handling, thermal, structures, telecommunications, science, and instruments. Additionally, a systems engineer manages the system interfaces, creates a management plan, and performed preliminary risk modeling.

The final product of this summer will be a baseline mission and lander concept described in detail with a 150–200page report as well as a final presentation to the leadership of JPL and the Mars Program Office.

### **Hydrogen Fueling Station for the ATHLETE Rover**

The ATHLETE rover is currently being developed as a multi-purpose mobility solution for the moon and general planetary missions. Three engineering models are constructed on site at JPL, with one rover (SDM-A) powered by a hydrogen fuel cell. The ATHLETE development group wants to demonstrate the rover's ability to autonomously dock and re-fuel so independent stations can be utilized on planetary missions. My project for the summer was to design, build, and test this fueling station along with the necessary fixtures on SDM-A. The station is designed to be remotely controlled through a Bluetooth connection with actuated valves, docking mechanisms, and solar panels. Energy collected from the solar panels splits de-ionized water and collects the hydrogen, which can be transferred to the rover.

### **High-Power Wireless Ultrasonic Feedthru**

The ability to transmit power and data wirelessly through a metallic wall is required for many terrestrial and planetary applications, including monitoring the seal of containers for planetary protection, power spacecraft or the Space Station or possibly recharging battery-powered instruments. The elimination of wires is critical to avoiding structural weakness and ensuring containers' ability to maintain pressure, vacuum, temperature or content of chemicals and gasses. For this purpose, a novel wireless acoustic-electric transmission method was developed using piezoelectric stack as means of generating ultrasonic stress waves that are transmitted through walls, and the received signal is converted by a symmetric piezoelectric stack to an electric signal. An analysis was performed on the device to find the optimal transmission frequency, and then an experiment was designed to test the efficiency and maximum power transfer of the device

at this frequency. A maximum power transfer of 1083W was achieved through a 5mm plate. Further analysis was performed on the thermal effects and losses associated with high-power transmission, and additional tests were devised for thicker and larger surface area walls.

### **The Design, Assembly, and Programming of a Volcano Monitor to Be Integrated With the Earth Science's Sensor Web**

The objective of the Volcano Monitor project is to show the autonomous capabilities of the Sensor Web. To do this, a sulfur dioxide-sensitive capsule has been built to be placed at the rim of Kilauea in Hawai'i. Data from the sensor will be collected every hour and transmitted to the Sensor Web through the Iridium Satellite Network once a day. A Basic Stamp was used to program the sensor's sampling frequency and its supporting electronics. Autonomous control of the sensor's sampling frequency is vital to the response speed of the Sensor Web network. When the threshold of change in sulfur dioxide is attained, the modem within the Volcano Monitor will send a signal to alert the Sensor Web. This alert will trigger other sensors in the area to take more frequent readings. In the event of a critical reading from other earth-based sensors, the Volcano Monitor is programmed to listen for commands from Sensor Web. With the speed of the autonomous system, information about volcano activity could be quickly compiled and made readily available to the scientific community.

### **Analysis of Stereoscopic Data From NASA's STEREO Mission**

Coronal mass ejections (CMEs) play a major role in the dynamics of Earth's geospace. However, the origin, magnetic configuration, and evolution of these solar manifestations are not well understood. The current twin-spacecraft mission, Solar Terrestrial Relations Observatory (STEREO), has provided images for stereoscopic analysis of coronal features to better understand mechanisms responsible for CMEs. In my talk, I will present findings from a catalog of May CMEs and their associated events in the low corona. I will report preliminary quantitative results using the Sunloop software tool, which uses a "tiepointing" method and triangulation for 3D reconstruction of coronal loops and prominences. Qualitative analysis of three-dimensional geometries of coronal features taken from Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI)/Extreme Ultraviolet Imager (EUVI) data will be presented using anaglyphs.

### **Terminal Descent Sensor On-Site Field Test Analysis Software**

In 2010, the Mars Science Laboratory (MSL) will begin its descent towards the Martian surface, and an onboard instrument called the Terminal Descent Sensor (TDS) will be used to detect the MSL's proximity to the ground. Prior to the mission's 2009 launch, the TDS needs to be verified and validated in the field through testing on a number of different aircraft at various altitudes and velocities. During a TDS field test, it is very important to have immediate feedback concerning the accuracy of the sensor to ensure efficient and useful data collection. To fill this need, a MATLAB program was written that combines data from onboard Global Positioning System (GPS) and Inertial

Measurement Unit (IMU) sensors. These values, along with appropriate digital terrain elevation data, is used to create a set of “truth” range measurements, which are then compared to corresponding TDS ranges to quickly determine the radar’s testing accuracy. Thus far, this software’s capabilities have been demonstrated and verified using a limited amount of past TDS field test data. The purpose of this presentation is to outline the developed set of in-field tools and demonstrate their integration into the rest of the TDS field testing procedure.

### **Analysis of Failure Mechanisms in Hollow Cathodes**

Electric thrusters are ideal for a variety of space applications such as interplanetary missions, spacecraft station keeping, and orbit raising maneuvers. As a result of the low thrust generation, electric thrusters are required to operate for tens of thousands of hours in order to provide the required total impulses. This operational requirement makes thruster lifetime essential and imposes substantial demands on component reliability. To address these needs, the goal of this project is to investigate the fundamental mechanisms that cause failure during hollow cathode operation in electric thrusters.

One of the mechanisms limiting emitter lifetime is damage to the emitting surface due to poisoning by reactive gases such as oxygen and water vapor. In order to quantify the sensitivity of the emitter to reactive gases, poisoning experiments will be conducted on the Xenon Ion Propulsion System (XIPS) cathode by varying the amount of oxygen present in the xenon propellant flow and measuring the resulting temperature distribution inside the cathode. The tests will be conducted for different current levels varying between 6 and 12.35 amps and will operate with oxygen at levels of 1 part per million, 10 parts per million, and 100 parts per million. These experiments will provide insight into what oxygen levels cause poisoning of the emitter surface.

### **Characterization of Inverted Pendulum Laser Beacon Source**

The system I am working on is a laser-mounted Inverted Pendulum, capable of seismic attenuation. The system was developed under contract by Yoichi Aso at Columbia University. The scope of my project is to characterize the system to make it user friendly and operational, and to measure the seismic environment of the laboratory, as well as to create a working coil driver for tilt stabilization. These tasks are performed by redesigning the IP controller with Simulink/MATLAB, using geophone seismometers to measure seismic activity, designing a circuit buffer and implementing it into the system. These tasks have been completed and the system is fully functioning, with the exception that the control system could be utilized more efficiently. Further work on this system can be done including beam wandering, temperature effects, and improving filtering for coil damping. Ultimately, the system will be used as a reference laser in another laser-guided acquisition project within the Optical Communications Group here at JPL.

**Sensor Web. With the speed of the autonomous system, information about volcano activity could be quickly compiled and made readily available to the scientific community.**

### **Mars Student Climate Lander (MSCL) Mission Proposal**

The Mars Student Climate Lander (MSCL) mission proposal is supported by NASA's Jet Propulsion Laboratory and the National Space Grant Student Satellite Program under the National Space Grant Consortia. The first student-designed, student-built mission to Mars, MSCL is a low-mass, low-volume, self-sufficient payload that will travel to Mars as a supplement to the Jet Propulsion Laboratory's proposed Astrobiology Field Laboratory rover (AFL). AFL will deliver MSCL to the Martian surface, thereby removing the challenges of launch, cruise, entry, descent, and landing. Once AFL establishes itself on the surface, it drops MSCL and continues its own mission. The MSCL mission will conduct high-priority Mars science and use the national network of Space Grant institutions to educate and inspire a generation of students over the mission's 10-year development.

The goal of this MSCL study is to demonstrate that a small, self-sufficient payload designed and built by university students can support an aggressive suite of instruments to conduct novel and meaningful science on the surface of Mars. Throughout this mission's development, the team created dynamic models of each subsystem so that the payload can quickly and easily adapt to different instrument suites that are representative of the current goals of the Mars Program.

### **BPSK Enabled Software Defined Radio**

Software Defined Radio (SDR) offers countless possibilities for the advancement of radio technology by allowing the radio's functionality to be dictated by software instead of hardware. The aim of this project is to implement binary phase shift keying (BPSK) modulation and demodulation capabilities into a reprogrammable FPGA embedded in a Universal Software Radio Peripheral. This project utilizes the free GNU Software Radio platform installed on an Intel MacBook Pro with a Mac OS X operating system. Use of this platform requires familiarity with C++ and Python programming languages.

Processes requiring substantial calculation and processing are written in C++, whereas routine operating procedures are written in Python. The integration of the two languages is achieved by using the Simplified Wrapper and Interface Generator (SWIG) program, which generates a Python wrapping of routine functions around the C++ code. This code is then implemented into an FPGA on the USRP. The actual transmission and receiving of the signal is done by daughterboards that can be directly connected to the "Receive" and "Transmit" ports on the USRP motherboard.

## **Evaluation of State Science Supervisors as Potential Formal Education Partners of the Space Place Program**

The Space Place Outreach Program, sponsored primarily by the NASA New Millennium Program, provides NASA resources and information to a variety of formal and informal partners and educators across the nation. So far, the Space Place has supported the formal education partners by providing standards-compliant classroom activity articles for publication in the International Technology Education Association's (ITEA) journals. However, the team wishes to expand its formal education reach, possibly through the science supervisor positions within each of the state departments of education. Thus, I developed, tested, and administered a survey to understand and evaluate whether the state science supervisors are a valuable contact to reach the teachers in the state. I created a brief and efficient script and phoned each of the state departments of education, asking to speak to the science supervisor or science consultant. The survey inquired about such issues as the degree of direct communication with teachers, available resources or materials for teachers, and communication with informal organizations and home schooling. After collecting and analyzing the data from a large sampling, I identified three major commonalities. Most of the science supervisors do have direct communication with teachers, do provide materials or resources, and do have some communication with informal education organizations. Preliminary findings show that the helpfulness of the state science supervisors in gaining access to classroom teachers varies widely. This paper describes the study process and findings, and presents the results in both detailed and summary charts.

## **Improving Terrain Simulations With GPU Hardware Shaders and Bump Mapping Techniques**

Simulating geographic terrain features typically involves using a digital elevation map (DEM) to produce a polygonal graphics object that can be visualized with a computer. This graphical object is built by sampling a DEM and then translating grid vertices to roughly correspond to a terrain's height. Many of these digital elevation maps are captured by satellite with resolution usually around 10 to 100m per pixel. This works well for most graphical applications but suffers from a loss of detail when visualizing the terrain surface at ground level. For the JPL Dynamics and Real-Time Simulation (DARTS) lab, which simulates vehicles such as rovers on planetary bodies, it is important that additional details are added to the terrain for additional context, even if these details are synthetic. Unfortunately, with large DEM data sets, generating a new DEM at a higher resolutions (such as 1cm) is both data and graphically intensive. Thus, a better technique is to render an existing DEM terrain and add higher resolution features dynamically. With many graphics cards today equipped with Graphics Processing Units (GPUs), it has become rather easy to add graphical details on the fly. Techniques such as bump mapping, normal mapping, parallax mapping, and relief mapping all give an appearance of additional terrain features without adding geometry. By manipulating lighting and terrain texture, this can create believable surfaces, such as rocks or sand. When coupled with a terrain, these techniques provide the necessary details at "ground level" while also preserving the underlying terrain with little performance cost. This

research explores these various techniques as well as other shader techniques such as reflective bump mapping and shadows.

### **COTS Products Study for the Workflow Manager Component of the DSAN Monitor and Control Service Management System: Survey and Preliminary Analysis Report**

The purpose of this paper is to survey COTS software applicable to the Workflow Manager (WfM) component of the monitor and control software system for the Deep Space Array Network (DSAN). The motivating questions were as follows: Are there suitable commercial off the shelf industry products applicable to the Workflow Manager component of the next-generation DSN monitor and control service management software system? If so, where do they fit within the various functional areas of the Workflow Manager component? What is needed to integrate the various offerings? The survey was conducted in the following phases: (1) Review of DSN monitor and control design model, especially focusing on the Workflow Manager component;(2) development of evaluation criteria based on review of DSAN monitor and control model and design;(3) identification of vendors with applicable products that could meet the required functionality;(4) information gathering, construction of a preliminary analysis, and the formulation of a survey questionnaire. Future development in this effort may include: Request for information (Questionnaire received from JPL), telecom follow ups, face-to-face meetings, creation of preliminary analyses, taking of final decisions and designation of the winner software vendor, COTS product integration of the Workflow Manager component into the DSAN Control & Monitor service management software system, and unit and system testing and solving of the remaining integration problems.

### **Beam Waveguide Arc Detector Upgrade**

The beam waveguide arc detector is designed to detect light or arc in the waveguide of the transmitter and quickly generate an interlock that will attenuate the drive signal to eliminate the arc and protect equipment. Existing detectors have a problem of causing an interlock (tripping) when no actual arc occurs. It was found that this false tripping was due to the high output impedance of the sensor circuit and the calibration of the voltage set point not being high enough above the trip point for sufficient noise immunity. The addition of a high speed, low output impedance driver chip to the sensor would correct these problems without adding any significant time delay. The arc detector also had problems with the failure of output driver chips that connect to the data acquisition and buffer amplifier assemblies. The chip failure was caused by current transients during a transmitter arc. The magnitude of the current transients can be reduced to an acceptable level by increasing the current limiting resistor value.

### **Anaerobic Spore Detection by Use of Dipicolinic Acid-Terbium Luminescence**

Bacterial spores, also known as endospores, are known to be the toughest form of life. When spore-forming bacteria sense stressors in the environment, they transform through a process called sporulation from vegetative cells into endospores, a dormant state that

can withstand anything from UV radiation, to dehydration, to extreme temperatures. When spores return to their vegetative state through the process of germination, they release dipicolinic acid (DPA), the biomarker for bacterial spores, which can be detected by Tb-DPA luminescence. The luminescence intensity is correlated to spore concentration via a calibration curve, which is made by autoclaving spores with a range of concentrations and measuring the Tb-DPA luminescence intensity. Anaerobic spore-forming bacteria are of particular interest because of their applications in waste water treatment and food poisoning prevention, as bioweapons, and in the potential for extraterrestrial life detection. In this paper I will adopt a rapid aerobic bacterial spore detection technique and apply it to detect anaerobic *Clostridium* spores.

### **Battery Cooling and Instrument Purge on Mars Science Laboratory**

Several components on the Mars Science Laboratory (MSL) have strict humidity and temperature requirements. To accommodate these requirements, an instrument purge and battery cooling system must be implemented. On MSL, both battery cooling and instrument purge will be achieved with gaseous nitrogen (GN<sub>2</sub>) of minimum quality (MILP27401C, Grade B). Because only a single port to the internal rover exists, the same GN<sub>2</sub> source must satisfy both battery cooling and the instrument purge. This analysis discusses the requirements of each instrument for which a purge is necessary, as well as the requirements for battery cooling. Next, implementation of the purge/battery cooling system is discussed in terms of the flow and logistics of the Assembly, Test and Launch Operations (ATLO) timeline for the MSL project. Finally, the instrument and battery requirements are considered in combination with the constraints imposed by the ATLO timeline to develop a preliminary design for instrument purge and battery cooling on the ground. This design includes pipe flow analysis of the purge and battery cooling lines.

### **Autonomous Sample Caching for the Cliff-bot System**

The Cliff-bot system consists of three individual planetary rovers that work as a team to explore the surface of a cliff. Two of the rovers, designated “Anchor-bots,” assist the motion of a third repelling “Cliff-bot” down and along a cliff face using tethers. During successful field trials last year in Svalbard, Norway, a need arose to develop the ability to autonomously cache samples in order to reduce human risks as well as prevent sample cross-contamination. The software used to facilitate this task must be able to autonomously retrieve and store multiple sample collection scoops with mm scale precision, as well as open and close the storage containers. Due to the unpredictability of the terrain and inherent compliance in the manipulator, simplified force feedback was utilized to detect and compensate for various failure conditions.

### **Investigation and Characterization of Trans-Neptunian Objects**

An investigation of several Trans-Neptunian objects (TNOs) was performed. TNOs comprise some of the most distant objects in the solar system and are most likely the source of Jupiter family comets. Data taken from the Near-Earth Asteroid Tracking (NEAT) archive and observations from JPL’s Table Mountain Observatory were used so

that photometry could be performed on several TNOs. The process and challenges of conducting relative photometry on faint objects in database images will be described. The phase curves for each TNO were calculated. These results will be cataloged to provide additional statistics on TNO characteristics.

### **Force Control Implementation on Rover-Arm Coring With Slip**

Technology to enable core sample acquisition from a low-mass rover on slopes is being developed. Future planetary sample acquisition missions would benefit from a mobile low-mass rover with arm-mounted drilling or coring, where the rover may experience modest slippage during the operations. A force-torque sensor is used as feedback for reconfiguring the rover arm using a percussive coring tool. Sensor data is filtered using low-pass filters and fed into a standard proportional controller. This will be coupled with visual odometry to achieve continuous coring while slipping on a slope.

### **Development of Sample Caching Subsystem**

Sample caching is a concept NASA is pursuing for Mars missions in the near future. The subsystem must be small, lightweight, self-contained, and use the minimum amount of motors. It also must be able to interface with various coring tools. Our design uses a large amount of passive compliance so that only three motors are needed for the entire system. With the completion of our prototype demonstrable unit, NASA management will be able to see the concepts involved in the system and its overall simplicity.

### **Methods of 2.5D Mesh Generation for the Visualization of Terrains**

This paper describes methods of generating meshes from existing scientific data for terrain visualization. While these methods were generated using data from Mars, they can be easily extended to most terrain data sets. First, the problem of creating a usable mesh from a single XYZ-field or digital elevation model (DEM) is detailed with a decimation routine allowing arbitrarily large data sets to be visualized. Next, methods of co-registering meshes from different rover sites are presented, as well as methods of aligning these meshes to a mesh from a DEM generated by overhead satellites. This technique allows the creation of a nearly seamless terrain, incorporating high-resolution rover data, to be built into a global terrain map.

### **Empirical Solar Linelist for the Near Infrared and Visible**

The spectrum of sunlight contains thousands of narrow absorption lines (Fraunhofer lines) due to atoms and molecules in the solar photosphere. Knowledge of the depth and position of these lines is important for remote sensing of the Earth's atmosphere using sunlight: to be able to separate solar and telluric absorptions.

We have been extending an empirical solar line list from the near infrared to the visible. This involves fitting a modeled solar spectrum (calculated from the solar linelist) to spectra measured from the Earth's surface. This is achieved by looking at plots of the measured and modeled spectra, determining which absorptions are caused by our

atmosphere versus the Sun, and then adjusting the solar line frequencies, strengths and widths in the linelist to improve the match. Using this approach we have extended the solar linelist from 15,271 to 17,000  $\text{cm}^{-1}$  (654nm to 588 nm), adding 516 additional lines in the process.

### **Mass Spectrometer ASIC**

A mass spectrometer applies RF power ramps to an ion trap to create a spectrum of mass-charge ratios, which are used to identify the trace organic species in a sample of air. An application specific integrated circuit (ASIC) converts and amplifies a digital signal from a field programmable gate array into the RF power ramps. One of the converters in the ASIC is a 12-bit R-2R digital-to-analog converter (DAC) and another converter is a 12-bit successive approximation analog-to-digital converter (ADC). The 12-bit R-2R DAC has 12 current mirrors that reflect a reference current into a set of 12 switches. When the switches are turned on, they allow current to flow into the R-2R resistor ladder. The output voltage increases as more switches are turned on and more current flows into the ladder. The switches are controlled by the digital signal that is being converted into an analog signal. The 12-bit successive approximation ADC uses a 12-bit shift register, a successive approximation register (SAR), a 12-bit DAC, and a comparator. The ADC creates a digital signal by adjusting one bit of the signal at a time and comparing it to a sample of the analog signal being converted. At the end of the conversion the final digital signal is read from the SAR.

### **Discovering Relationships and/or Patterns Between Risks**

Every aspect of life has a certain degree of risk associated with it. Risk management is used to try to reduce the implications that may be associated with a particular risk. The intent of this project is to determine if patterns exist among risk items, and to review the risk management implementation practices across a multitude of projects and programs at the Jet Propulsion Laboratory. Through the examination of information presented in the monthly and quarterly reports, correlations were found between some of the identified problems, concerns, and risks. These correlations will hopefully indicate the effectiveness of the risk management process in understanding and mitigating problems, concerns, and risks. Comparison of the observed items will be used to develop recommendations for uniform implementation standards for risk management across all Jet Propulsion Laboratory processes.

### **Harpoon Device for Long Range Sampling From a Rover**

This paper describes the initial design, fabrication, assembly, and testing of long range in-situ sampling device to be fitted on a research rover. The design was determined (by trade study) to be a crossbow mounted to a base, with tooled steel bolts projected at high velocities into various rock samples to determine sample acquisition feasibility. Proof of concept was validated and the subsequent empirical data compared to penetrometer formulas where design viability was determined to be practical or not.

## **Qualification and Characterization of Thermal Cycle Resistant Electronics for Surface Missions to Venus and Mars**

Traditional in-situ missions require significant shielding of electronics from extreme environmental conditions found on other planets, which include extreme temperatures, large temperature ranges, and high levels of radiation. This shielding takes up mass and consumes energy, which are both critical resources in any interplanetary mission. To avoid or reduce the use of shielding, electronics must be designed to withstand extreme environments. The scope of this experimental research involves Venus and Mars. For Venus, exotic semiconductor materials are being characterized at temperatures as great as 500 degrees Celsius for eventual use in amplifiers and digital circuits. The Mars component begins to qualify an operational amplifier that could be used on a shaft encoder circuit that would track Mars Science Laboratory's wheels without thermal control. The analysis and testing of these parameters show that it is possible to design and build electronics for long-term, robust performance in extreme environments.

## **Advanced Concept Validation for Hyperspectral Imaging Instruments**

Two tasks related to advanced concepts for hyperspectral imaging science will be presented. Advanced concepts, such as Observing-Systems Simulation Experiments (OSSEs) and on-board instrument-based processing, have the potential to greatly increase the quality of science return from proposed missions. We have applied OSSE methods to characterize the science return from a proposed hyperspectral instrument design. In our model, we have simulated leaf reflectance, as determined by leaf composition characteristics, propagated this reflectance through the atmosphere, and added errors associated with instrument sensing. The resulting leaf characteristics as seen after post-processing were then compared to those initially entered into the model. Additionally, on-board image classification through the use of field programmable gate arrays (FPGAs) promises to support future high data rate instrument designs and advanced algorithm needs. To this end, we validated an image classification algorithm for implementation on an FPGA.

## **Variability of Spring Thaw in Relation to Vegetation Productivity: Investigation With GRACE Gravity Field Measurements, Microwave Remote Sensing, and Integrated Hydrologic Data**

Rising global temperature has caused many changes in terrestrial ecosystems. The northern latitudes (above 40 degrees) are specifically vulnerable to climate change. Climate warming has caused earlier thaw dates, longer growing seasons, deeper seasonal soil thaw, and changes in vegetation growth and carbon dioxide exchange. These changes, along with an increase in precipitation and water storage, led to an increase in photosynthetic activity and net primary productivity (NPP) in the 1980's and 1990's. However, beginning in the mid 1990's, there has been a decrease in mid-season photosynthetic activity and NPP in some high latitude regions. Vegetation with a shallow root depth dominates many of these areas and leads to the hypothesis that this decrease in NPP is caused by less plant available moisture and the boreal ecosystem's inability to

provide necessary water under the changing climate. This investigation examines the relationships between northern vegetation productivity, seasonal processes affecting the productivity, and changes in terrestrial water storage as inferred from GRACE measurements. Inter-comparative analysis of data products derived from remote sensing and modeling are employed to examine correlative relationships between these parameters.

### **Extending the Internal Charging Code NUMIT: Simulating Energy and Charge Deposition From 10-100 keV Electrons in Thick Elemental Slabs**

High-energy electrons pose a substantial hazard to sensitive electronics on board spacecraft. These electrons can penetrate the surface of the spacecraft, leading to a buildup of high electrical potentials (several kV) that can cause damaging arcing. The internal charging code NUMIT (NUMERical INtegration) can simulate the charge deposition from electron radiation in various materials to a high degree of accuracy for electron energies over 100 keV. However, due to a high-energy approximation used in the program's dose-depth algorithm, it cannot reliably include the effects of electrons of lower energies than this. In order to extend NUMIT so that it may include electrons in the 10-100 keV energy range, we have run several hundred simulations using the TIGER/ITS3 1-D Monte Carlo code, producing dose-depth curves for every elemental solid in the periodic table between Li and Pb. We then fit a curve to this energy deposition data with respect to the atomic number of the absorber, the energy of the impacting electrons, and the depth of the material. Finally, we built a module for NUMIT in the FORTRAN 90/95 programming language to represent this contribution to internal charging.

### **Acquisition and Pointing for Optical Space Communication**

We consider communication systems utilizing beams with optical wavelengths near infrared for studying 1) the probability of spatially acquiring an optical beam and 2) pointing. 1) The probability of acquiring correctly (PAC) an optical beam with a focal plane array (FPA) is simulated and verified with a basic theoretical model for when all the signal photons are collected by a single pixel in the presence of background signal. The simulation is then extended to where the signal spot on the FPA covers an  $M \times M$  array of pixels. For both a uniform distribution and a symmetric bi-variate normal distribution of signal, algorithms are developed for the acquisition of such a beacon signal and their PAC is simulated (PACs up to 100% are simulated). For a uniformly distributed signal, it is demonstrated that pixel binning yields a larger PAC through simulation and mathematical proof. 2) For fast steering of an optical beam, a Piezo-electric tube (PZT) is modeled as a possible replacement for fast steering mirrors. The results of discrete frequencies and frequency sweeps applied to the PZT, ranging from .2Hz to 2kHz, are presented. The resulting PZT feedback from the direction perpendicular to the direction of motion is also modeled.

### **Analysis of Particle Velocities Due to Dust Entrainment at Mars Science Laboratory Touchdown/Flyaway**

At touchdown, the Mars Science Laboratory (MSL) rover will be lowered from a descent stage via tether to the surface of Mars. The four descent stage thrusters, which support both the descent stage and rover until touchdown, must throttle up just after touchdown to near 100% thrust for descent stage flyaway. This work assesses the danger of dust entrained into the thruster plume flow “sandblasting” the rover, which could damage white thermal control paint on many rover surfaces. Dust particles are treated as spheres of SiO<sub>2</sub> which interact with the plume flow based on a Reynolds-number-dependent drag coefficient. The work attempts to determine bounding cases on velocity for various particle sizes. A test plan is then outlined to describe a method for testing whether the velocities analytically pose a threat to white paint. The test will also aim to determine a cutoff velocity where damage to paint samples begins to occur.

### **The Construction of a Laser Communications Receiver**

Laser communications could allow data to be sent from space at rates which are orders of magnitude faster than current broadband antennas achieve. An in-lab test of high data rate laser communication using large optics was recently completed. The next step is an outdoor test to observe the effects of atmospheric turbulence and background light. This project involved the construction of a manually portable and pointable receiver for this test. The frame is about 30 inches square and 6 feet long. It houses a 24 inch primary. The secondary collimates the beam and sends it to an attached optics and sensing package. Elevation and azimuth adjustment resolution is about 1  $\mu$ Rad with a range of about 45 mRad. The apparatus is flexible enough to accommodate changes in both primary and secondary optics. The frame may also be suited, with some modification, to mounting to a large gimble or some other automated tracking system.

### **Miniature Mars Science Lander Mission Study**

This project developed a 25 kg seismic science lander conceptual design that is to be delivered to the Martian surface by the Astrobiology Field Laboratory (AFL) rover in 2016. The Mars Program Office at JPL provided constraints for the payload and a team of 8 students developed a design satisfying the constraints. The lander is a completely self-sustaining and self-contained package with minimum interference to AFL. Roles were assigned to students on the team to cover the major systems including power, control and data handling, thermal, structures, telecommunications, science, and instruments. Additionally, a systems engineer manages the system interfaces, creates a management plan, and performed preliminary risk modeling. The final product of this summer will be a baseline mission and lander concept described in detail with a 150-200 page report as well as a final presentation to the leadership of JPL and the Mars Program Office.

### **Miniature Mars Science Lander Mission Study**

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The final product of this summer will be a baseline mission and lander concept described in detail with a 150-200 page report as well as a final presentation to the leadership of JPL and the Mars Program Office.

### **Development of Sample Caching Subsystem**

Sample caching is a concept NASA is pursuing for Mars missions in the near future. The subsystem must be small, lightweight, self-contained, and use the minimum amount of motors. It also must be able to interface with various coring tools. Our design uses a large amount of passive compliance so that only three motors are needed for the entire system. With the completion of our prototype demonstrable unit, NASA management will be able to see the concepts involved in the system and its overall simplicity.

### **Development of a Parameterized Linear Analytical Longitudinal Airship Model**

In order to explore Titan, a moon of Saturn, airships must be able to explore its surface autonomously. To achieve this, an accurate model and accurate control of the vehicle must be developed so that it is understood how the airship will react when given a set of commands. This paper explains how aircraft stability derivatives can be used with airship parameters to create a linear model of the airship solely by collecting its geometric and aerodynamic data from the airship. This method does not require system identification of the vehicle, as all of the required data can be derived from computational fluid dynamics and wind tunnel testing. The independence from system identification reduced time and cost in creating models for airships. The results are compared to other stable airship dynamic models to validate the methods employed. Future work revolves around creating a lateral airship model using the same methods.

### **Active Stabilization of Laser Beam Pointing**

Optical beam stabilization is directly related to the signal strength of an optical communication link. To guarantee a stable, efficient, and accurate communication link, fine and coarse stabilization (from spacecraft and natural disturbances) of an optical emitter is required. With the recent technological advancements in Piezoelectric Tubes (PZT), cost effective stabilization techniques are now possible. We propose a project design and implementation to test the possibilities of using a PZT with a collection of tilt

and angular rate sensors. We also propose a solution for natural disturbances on an inverted pendulum system. We select a collection of tilt and angular rate sensors to detect major and minor natural disturbances. Our design and implementation method includes the use of a feedback control methodology known as a Proportional-Integral-Derivative (PID) controller. These techniques allow for control and stabilization of the systems from the disturbance frequencies in the range DC to 300Hz, with most common frequencies between 0 and 1Hz.

### **Mars Science Laboratory System Testbeds Cabling Project**

Modern spacecraft are becoming increasingly complicated. Complex cabling needs to support all of this new functionality. In addition to the flight harness, cabling is also required in the System Testbed. The cabling inside testbeds are more complex, however, as they need to have the added flexibility to integrate real or simulation hardware. The Mars Science Laboratory System Testbeds also need to support the movement of hardware and their respective cables between each of the testbeds. Before this project, the testbed architecture was comprised of well over a hundred unique cable diagrams. This made it difficult for personnel in the testbed to determine how boards, boxes, and custom test equipment are connected. The goal of this project was to develop a high level cable block diagram that will encompass all of the Mars Science Laboratory System Testbed cabling and hardware. This will simplify the complexity of the cables by augmenting the many unique drawings with a single usable one.

### **Market Research: An Analysis of JPL's Competitive Position Through Surveying Relative Marketplace on Student Compensation and Degree Funding Programs**

Employees aging and the retirement of the baby boomer generation is a question of major importance within organizations today. This research analyzed differences between compensation programs offered to recruit and retain students and current employees in degree funding programs. A survey was designed and conducted to capture information on student and degree funding compensation programs for peer organizations. Fifty FFRDCs, high-tech, and aerospace organizations were identified as peer organizations and contacted to participate in the survey. Twenty-two organizations completed the survey, providing information on their compensation practices, and were analyzed to define market practices. This survey was compared to JPL practices to determine its competitive position for student and degree funding programs. Trends have been recognized from the analysis of this survey in terms of salary offered to students across different fields of study. This analysis has shown the unique features of the program at JPL that concentrates on students and focuses on creating incentives for recruiting them. The overall participation of organizations in this survey suggests an interest among organizations in compensation issues concerning student programs. Overall, JPL offers unique opportunities that seem to be lacking in many other organizations.

## **Power System Upgrade for A.T.H.L.E.T.E. Lunar Rover Software Development Models**

Two software development models (SDMs) of the A.T.H.L.E.T.E. (All-Terrain Hex-Limbed Extra-terrestrial Explorer) lunar rover are currently in use at JPL. The power systems on these models are in a non-optimized state and are difficult for the operator to use. Both models can run off of standard 110/220 AC wall power, a hydrogen fuel cell (as is the case on SDM-A), or gas-powered generators (SDM-B). The rovers also incorporate the use of Cyclon sealed lead-acid batteries and power transformers. The purpose of this project is to develop a more efficient way to switch between these sources of power, as well as to perform a general reorganization of the models' power systems to make them safer and easier to use.

## **Using Cassini Imaging Data to Determine Relative Surface Roughness Through Radiative Transfer Analysis of the Optically Active Regolith on Iapetus**

The nature of the albedo asymmetry exhibited by the Saturnian satellite Iapetus is still unclear and has been a mystery since its discovery in 1671. Ground based observations and Voyager spacecraft data have established that the albedo of the bright trailing side is ~0.6, while the dark leading side is reddish in color and has an albedo of less than 0.03. (McCord et al. 1971, Murphy et al. 1972, Zellner 1972, Smith et al. 1982, Buratti and Mosher, 1995). In an attempt to further clarify this dichotomy, we apply photometric data from Cassini's January 1, 2005 flyby of Iapetus to a crater roughness model originally developed by Buratti and Veverka (1985). Since macroscopic features of topography alter the scattering properties of a planetary surface (Schoenberg, 1925; Hameen-Antilla et al., 1965; Hapke, 1966, 1984; Veverka and Wasserman, 1972; Lumme and Bowell, 1981; Buratti et al., 1985), this model uses the observed scattering behavior to provide a depth to radius factor  $q$  describing the roughness of the surface. Our preliminary findings are that there are differences in macroscopic roughness between the bright and dark areas. These differences enable an estimate of the depth of the low albedo deposit.

## **SPACES Instrument Test Bed Development**

The Submillimeter Planetary Atmospheric Chemistry Exploration Sounder is a prototype high-sensitivity spectrometer for orbital planetary atmospheric analysis. Data collected by this new technology will allow chemistry and dynamics of planetary atmospheres to be mapped. One application of the instrument is to localize emissions of water vapor from possible geothermal "oases of life" on Mars. Water and other chemicals can be detected by spectral analysis of their molecular resonance emission and absorption. The detector will use a heterodyne receiver front end operating in the 520-600 GHz range. The test signals converted down using key JPL submillimeter components to the range of 0-10MHz, where they are digitized. The spectral power density is calculated using Fast Fourier Transform and then integrated (up to 3 seconds) to pull the weak signals out of the noise. This project includes software and hardware. I am writing software to interface the prototype instrument to a control/data computer and to collect and analyze the data

from the microwave downconverter and digitizer I have assembled to verify that the instrument can be operated and collect valid data.

### **Experimental Testing of the Angular Resolution of Ion Energy Diagnostic Instruments**

Probes that measure ion energy are essential tools in the study of Hall thruster plumes. By focusing on different areas of the plume, they can reveal how its composition evolves with distance from the emitting plane. The angular resolutions of these instruments are critical to determining which part of the plume they are observing. While theoretical angular resolutions for these instruments are known, they lack experimental verification. This presentation will discuss the effect of incident ion angle on the measurements taken with different ion diagnostic measurements, specifically a hemispherical analyzer and aligned and nonaligned grid retarding potential analyzers. The instruments will be tested in a beam chamber with a monoenergetic ion source. A rotation stage will allow the instrument to change its azimuthal angle and pitch with respect to the ion beam, while the entrance aperture does not translate. This data will more accurately determine the angular resolution of existing instruments and aid in the design of future instruments.

### **The Design of a High Power Amplifier**

An L-band high power amplifier has been designed for Synthetic Aperture Radar applications. The amplifier is expected to produce an output power of 250W and a power added efficiency of greater than 50%. Compact couplers are employed to combine power from two high power transistors. The amplifier uses a pair of silicon bipolar junction transistors.

### **Validation of the LSpec Autonomous Vicarious Calibration Facility**

The LED Spectrometer (LSpec) test facility is located at Frenchman Flat, Nevada, where it records surface reflectances, measured by Light Emitting Photodiodes (LED), and atmospheric properties. These data can be accessed by an analyst via a website and used to compute top-of-atmosphere (TOA) radiances. The purpose of this study was to validate data from this site. The first step was to confirm the process and software used to create the LSpec database. Once the process was updated, missing data could be populated in the database. Next, TOA radiances were computed using data from the facility. These LSpec radiances were then compared to those measured by the Multi-angle Imaging SpectroRadiometer (MISR), a NASA sensor on-board the Earth Observing System (EOS)/ Terra spacecraft. The radiance comparison between LSpec and MISR showed a data agreement within 10%. The differences in the TOA radiances stem from a lack of surface bi-directional reflectance function (BRF) adjustments in the radiative transfer calculations and an incorrect algorithm that adjusts voltages for temperature change. Future work will provide updates to the LSpec processing algorithms to include sensor view-angle adjustments and LED temperature effects.

## **Mars Science Laboratory: Automating the Production of the Command and Telemetry Dictionary**

Flight and ground software for the Mars Science Laboratory (MSL) are anticipated to manage the communication of approximately 250 commands and upwards of 1,000 different telemetered channels throughout launch, flight, descent, and surface operations. A master dictionary containing all parameters and properties for each command and channel is frequently updated during mission design. It is crucial that the dictionary accurately represents the information provided by Functional Design Document (FDD) authors. In this project, the flow of data was reexamined and standardized in order to automate the creation of the Systems XML document. Major improvements include the integration of real-time validation of the XML against its schema, creation of a test system to insure that all delivered documents are consistent with the original FDDs, and finally the incorporation of versioning into the Systems XML document. These changes eliminate human interaction with the data during the process and fix all known idiosyncrasies in the pre-existing dictionary generation code. Feedback time is also substantially reduced so that errors do not propagate as far into the process. Further research is suggested in the user interface so that authors themselves can catch their own mistakes before submission of the FDD.

## **Experimental Investigations of High-Power Bismuth Hall Thrusters**

Experiments were performed to demonstrate high-power (25-36 kW), high-specific impulse (6000-8000 s), bismuth-fueled Hall thruster operation in the condensable propellants vacuum facility at JPL. Owing to the stringent requirements imposed by high-discharge voltage and power, a significant effort was put forth to ensure safe and reliable operation of the thruster and vacuum facility. Of principal concern was the overall quality of the vacuum system. Initially the vacuum level of the condensable propellant facility was inadequate to meet the operational requirements, so a systematic leak check procedure was performed using a residual gas analyzer that improved the vacuum level. A liquid cooled beam dump was also installed in the facility in order to collect the high-energy exhaust plume from the thruster. A data acquisition system was interfaced with the power electronics and vacuum facility, enabling automated and unattended operation. Experiments were performed with the thruster to characterize the thermal characteristics of the thruster due to heating from the electromagnets, feed system heater, and anode heater. Additional experiments were performed demonstrating gas flow of bismuth and thruster operation at high voltage. Steady-state operation at 5 kV, 25 kW was achieved that demonstrated high-power, high-specific impulse, bismuth-fueled Hall thruster operation for the first time in the United States.

## **High Redshift Galaxy Clusters: A View of the Earlier Universe and Galaxy Evolution Through Galaxy Clusters in the Boötes Field**

Galaxy clusters at redshift greater than 1 provide one of the most straightforward means of studying the universe when it was less than half its current age. Each cluster contains a large number of galaxies at a common distance or lookback time, and therefore their colors and morphologies can tell us how their stellar populations and structures evolve. By measuring the flux of each individual galaxy in several different color bands, we can see a relationship between the color of a galaxy within the cluster and the luminosity or magnitude of that galaxy. By comparing the color-magnitude relationship in distant galaxy clusters to the nearby Coma cluster ( $z \approx 0$ ) we can understand how the characteristics of these galaxies change with time. This study focuses on the color-magnitude relation and scatter of one specific galaxy cluster at redshift 1.11 in the Boötes field. The study will continue and extend to the other  $z > 1$  galaxy clusters, one hundred of which are contained in our sample.

## **Active Lens Low Order Wave Front Correction**

Atmospheric and lens aberrations lead to degradations in optical communication as well as imaging systems. The system we wish to consider utilizes two actively moved lenses to correct low order deviations in the wavefront due to atmospheric turbulence or physical changes in the telescope mirrors due to heat or gravity. The proposed system is an alternative to the industry standard using deformable mirrors to correct for the aberrations due to atmospheric and lens imperfections. The Active Lens Adaptive Optics (ALAO) method allows for whole aperture wavefront phase correction without the need for calibration and local irregularities removal found in standard adaptive optics methods. A MATLAB model of the system has been created to numerically model and determine the characteristics of the optical system. In addition, a manual translation stage model of the system will be utilized to fully model the system. The active lens adaptive optics system is to be prepared for on-Earth operation focusing on atmospheric as well as lens imperfection correction. The main application is for Earth to space communication, but another application may be in lowering the cost of low order adaptive optics for small astronomy telescopes.

## **Development of Precision Aiming Capabilities of Deployable Structures**

Satellite components that are backed by deployable structures often times require precision aiming at the nanometer scale. As a result, systems that are able to accomplish nanometer precision aiming, as well as characterizing systems at the nanometer scale, are required. A parametric model of a space truss backing a composite hexagonal panel was utilized as a system to develop these characterization efforts. As part of the project, housings to support the aiming actuators were designed, as the actuators are very sensitive to shear, bending, and torque loads. Additionally, a laser metrology system was installed to measure the system at the nanometer scale and a method of taking these laser measurements and translating them into the piston and rotation of the panel centroid was developed. A third task included measuring vibrations in the system at the nanometer

scale. By accomplishing these three tasks, further research in developing control loops to position the panel with nanometer accuracy can be undertaken.

### **Mars Rover Visualization and Animation**

The Multi-Mission Image Processing Laboratory (MIPL) supports NASA/JPL space flight missions by creating images and animations. MIPL engineers work to make this data useful and accessible to the science community and the public. The panoramic mosaics created from images returned from the Mars Exploration Rovers (MER), Spirit and Opportunity, are often too large to be easily processed by computers. Additionally, when merged into a panoramic mosaic consisting of many smaller images, the mosaic loses the detail inherent in each image in the overall view. The Shake program is used to create visualizations of these MER mosaics. These visualizations zoom into and then pan across these large mosaics, demonstrating the surface detail of various parts of the mosaic in very high resolution. These accessible visualization movies allow easy access to the points of interest inherent in each large image. The animations are not only useful to the science community for examining a particular area of interest, but also useful for presenting the work of NASA/JPL to the American public.

### **Automation to Reduce Cassini Instrument Operation Risk and Cost**

The Navigation Team notifies the Instrument Ops Team periodically with the latest update information, as Cassini-Huygens transmits data to Earth through Deep Space Network. The accuracy of the updates is critical for Science and Navigation Team for post processing of public data. This process is currently performed manually and is subject to the human errors. The main goal in this task was to automate the update process; and it has been accomplished using an object oriented approach. This design currently uses only for Planetary Constant Kernel files for update. The secondary goal is to reflect the update on the Space Planetary Instruction Camera-Matrix Events (SPICE) website. The website is under redevelopment to meet the current World Wide Web Consortium Hypertext Markup Language standards using Hypertext Preprocessor and Structured Query Language.

In addition, a design is underway for the maintenance of Science Operations Personal Computer (SOPC) accounts. SOPC Account Requests are originated, circulated and stored in hardcopy form. Distributed Operations Teams around the world FAX or hand deliver the paper requests. Creating an online system is expected to reduce the time and resources used to generate and approve account requests as well as eliminate storage of multiple paper copies.

## **Quantifying the Effect of Gravity-Dependent Aberrations on Palomar's AO System at the Hale 5.1m Telescope**

As an upgrade to Palomar Observatory's current adaptive optics (AO) system on the Hale 5.1 m telescope, the newly implemented PALM-300 system will consist of new wavefront sensors and a deformable mirror (DM), comprised of approximately 3000 actuators. Capable of achieving wavefront error of less than 50 nm, the effect of gravity-dependent aberrations within the wavefront sensor is of concern to the overall performance of the AO system. To quantify this effect, DM position will be locked and applied to various positions from zenith on the telescope. Values of residual RMS wavefront error will be measured as a function of the gravity vector by method of phase retrieval on the PHARO science camera. Results of the study will contribute to the knowledge of current AO system performance as well as the definition and design of future wavefront sensor systems.

## **Investigating Saturn's Rings Using CIRS Data**

The rings of Saturn, one of the most beautiful features of our solar system, are highly complex. The three major rings (A, B, and C) have different temperatures, emissivities, and colors. Although it has long been known that the rings are primarily composed of water ice, the identities of the trace constituents—which provide subtle color to the rings and could shed light on their origin and formation—remain poorly understood. These trace constituents could affect the thermal infrared part of the rings' spectral signature. Previous observations have not observed any such effects. However, they have been hindered by three major problems: 1) the inability to observe the entire wavelength interval through the Earth's atmosphere, 2) low spectral resolution, and 3) a limited wavelength range. Data obtained with the Composite Infrared Spectrometer (CIRS) instrument on the Cassini spacecraft circumvents these difficulties. Using CIRS data, we place constraints on the identities of ring trace constituents.

## **Identification and Characterization of Uncertainty for Component Structures Within a Precision Environment Test Enclosure**

Observatories planned for future NASA missions will involve reliable design of large precision deployable apertures where sensitivities to uncertainties affecting their performance must be characterized a priori. For systems that cannot be fully ground tested before flight, models that can correctly characterize the behavior of component subsystems to extremely small and known tolerances must be developed. This presentation will detail the identification of uncertainties in component-based models and measurements related to a precision metrology reflector test performed within the Precision Environment Test Enclosure (PETE) laboratory. We will describe the method used to determine error bound estimates for the reflector experiment models that were produced. We performed a sensitivity analysis using a design of experiment to determine uncertainty source contributions to the estimated total uncertainty present within the model. This process is important to the community, as it provides guidance regarding

sources of uncertainty for precision models and measurements related to large aperture design.

### **Planetary Data System Archiving Update**

The Planetary Data System (PDS) archives and distributes scientific data from NASA planetary missions, astronomical observations, and laboratory measurements. The Imaging Node of the PDS is the curator of NASA's primary digital image collections from past, present and future planetary missions. The node provides the digital image archives, necessary ancillary data sets, software tools, and technical expertise necessary to the NASA planetary science community to fully utilize the vast collection of digital planetary imagery. This paper will provide details of a data decompression task describing the data used; the processing applied to the data to update its format for the PDS; the amount of decompression applied to the data and why the decompressed data was uploaded into an SQL database.

### **Shaping Titan: A GIS Spatial Analysis of Landform Distribution and Process on Saturn's Largest Moon**

Since its arrival at Saturn, the Cassini spacecraft has used high-resolution synthetic aperture radar (SAR) to image over 20% of Titan's surface. Analysis of these images has revealed a complex world with a young surface extensively modified by cryovolcanism, fluid flow, impact events, tectonic activity, aeolian processes, and atmospheric deposition. To better understand the interplay between the various processes that have shaped this world, a geospatial analysis of the distribution of these landforms across Titan's surface was undertaken using the tools in the ArcGIS software package. The extent of obvious features was outlined, both manually and through contours of equal return, and subsequently layered on a cylindrical projection of processed SAR swaths. Statistical analysis of the resultant maps shows that at high latitudes, fluvial processes are the primary means of landform modification, while at lower latitudes, aeolian processes are dominant. This analysis further enables a derivation of temporal relationships between these processes at local scales.

### **Reception and Handling of Photographic Data From in situ Camera for Extreme Terrain Rovers**

Cameras are necessary to capture visual images of the extreme terrains explored by autonomous and/or unmanned in situ instruments. Because these instruments may not be retrievable, or may take years to retrieve, this photographic data must be transmitted mid-mission to data terminal equipment (DTE) at a base station. This transmission is done wirelessly over an Iridium modem. However, the transmission of data is limited to 512 bytes by the low capacity of the miniature camera, which measures only an inch end-to-end. Therefore, the image must be transmitted in smaller packets of data (of which the default size is 64 bytes) padded on both ends by commands and data markers. When received sequentially by a computer at the base station, a Java program developed this

summer filters out communication commands and concatenates, or reassembles, the data into the original JPEG image.

### **Surface Mount Technology Assembly Processes for Low-Temperature Electronic Circuit Boards**

Electronic circuit boards are becoming more complex with greater densities of components on each board. As the number of components on each board has increased, so has the difficulty of the board assembly processes. Additionally, the circuit boards being built for MSL must be able to withstand low-temperature thermal cycling fatigue stresses without experiencing failure due to coefficient of thermal expansion (CTE) mismatch between various materials. This presentation will discuss the surface mount technology processes involved in assembling electronic circuit boards. Additionally, common failure mechanisms and difficulties with low-temperature electronics will be presented. Lastly, a new type of printed circuit board (PCB) with carbon composite laminate layers will be discussed. These carbon composite laminate layers have the potential to drastically reduce the stresses induced by CTE mismatch as well as to spread heat much more efficiently than current PCBs, allowing for even denser component packaging.

### **Development and Testing of a Thruster Erosion Sensor**

While the majority of the atoms emitted by a Hall thruster exit along the thruster axis, those on the low end of the energy spectrum may be discharged with slower velocities and at much higher angles. These atoms are in a position to damage spacecraft components by eroding away their specialized coatings. This presentation will discuss the fabrication and testing of an erosion sensor designed to quantify the number of thruster ion collisions at a given angle. The device measures the increase in the resistance of a small wire as it erodes due to exposure to a thruster plume. The logic behind details such as choice of materials, basic construction techniques, and testing strategies will be analyzed. Recommended modifications to the next-generation model that will improve performance and durability will be presented as well.

### **Electronic System Design for Mars Driller**

JPL is working on is a maneuverable drilling device capable of long-distance subsurface exploration on Mars. One element of this concept is to have replaceable coring bits that can be moved to the front of the drill. The focus of this summer project was to test and enhance an electromagnetic bit transport system that uses solenoid windings actuated in sequence to exert substantial forces on the steel bits to move them in a controlled way through a transport tube. A major part of this effort was to complete an initial control circuit, debug it, test it, and make enhancements. Testing and analyses showed that the circuit prototype worked with minor changes, and a new circuit design will provide for these modifications. Other areas of research included an overall analysis of the electronic controls and system power requirements.

## **Advancements in Imaging and Animation**

The animations created in the JPL Digital Image Animation Laboratory (DIAL) for the Mars Exploration Rover (MER) mission are created with images obtained from the MER rovers—actively collecting data from the surface of Mars since 2003. The images returned from the panorama cameras (PANCAM), two of the cameras on a rover, are  $n$  pixels \*  $m$  pixels in size. Since these images are so large, working with an entire image at a time is inefficient and difficult. Therefore, the animators break up the image into individual tiles. Maps, like infrared elevation maps, are used to provide terrain features. When these two pieces of information, elevation and the actual image, are combined, they give animators accurate 3D terrain objects with which to work. This paper will describe 1) the computer program written to sort PANCAM tiles, 2) the graphical user interface tutorial, and 3) the Pan and Zoom animations created using Flash.

## **Experimental Investigation of Magnetic Field Effects on Flush-Mounted Langmuir Probes**

Hall thruster lifetime models being developed by NASA would greatly benefit from experimental studies of the non-neutral sheath layer formed along the channel walls. This layer is responsible for many plasma-wall interactions that affect performance and lifetime. Langmuir probes mounted flush with the channel wall are currently being considered as a way to experimentally interrogate the sheath. While use of such probes within the channel has been previously demonstrated, interpretation and analyses of the resulting data can be difficult and is usually simplified by neglecting magnetic field effects and the complex sheath structure. This study aims at experimentally investigating the effect of the magnetic field on such probe data. A one-inch boron nitride disk imbedded with a planar Langmuir probe was immersed within a cathode plume assumed to have uniform properties. The probe was rotated with respect to a uniform magnetic field generated by a Helmholtz coil, such that the effects of both the relative angle and magnitude of the magnetic field could be confidently studied. Further analytical and computational investigations would complement the data presented in order to determine an accurate, practical way to account for magnetic field effects when implementing such probes within the thruster channel.

## **SmartLand: Multi-Sensor Hazard Assessment and Safe Site Selection**

The selection of safe landing sites for planetary exploration spacecraft, such as NASA's Spirit and Opportunity rovers, is crucial to the success of these missions. Safety is always the dominating concern in any space exploration mission. The task of selecting a suitable site that is both scientifically interesting and meets the necessary safety requirements is not only daunting but time consuming. SmartLand has developed a means of fusing orbital data from a variety of heterogeneous sensors in order to construct safety maps that cover a broad span of terrain from which a suitable landing site can be selected. By using intelligent reasoning techniques, a high-resolution and high-fidelity hazard map is generated based on images and other information; the hazard map is used to identify terrain features such as rocks and craters. A Bayesian Network is used to statistically

determine the probabilistic relationships between all variables of interest and estimate a true probability of safe landing for each point on the terrain. The SmartLand approach enables a fast and accurate evaluation of safety probabilities for a large number of landing sites.

### **Test Bed Percussion Drill and Thwack Testing**

My research has been performing tests on the test bed percussive drill and sieve thwacker mechanisms designed for the Mars Science Laboratory. The objective of these tests was to determine certain criteria and variables that apply when designing the flight models of these mechanisms. The drill has many variables that can alter its performance, including drill speed, weight on bit, impact energy, drill angle and more. Time limited me from testing all of these variables. Because of this no definite conclusions can be drawn at this time. The variables for the thwacker were spring energy and sample rock. Some of the rocks would easily get clogged in the sieves; however, some rocks hardly got clogged at all. By using the worst-case rock, the spring size was selected. From the vast number of samples that were put through the sieves and then thwacked, I determined that thwacking is a plausible form of cleaning the sieves as long the right power of spring is used.

### **Filament Monitor Circuit Modifications, 20kW X-Band Transmitter (HEF Sites)**

New X-band klystron tubes for the Deep Space Network's High-Efficiency (HEF) antennas require a lower filament operating voltage than previous tubes. After operating the new tubes at the original voltage level and encountering reduced tube lifetime an engineering change was requested to provide adjustability to the filament voltage. After this change was made it was observed that the filament current metering, a parameter vital for determining the tube condition, was not reading correctly. The filament monitor circuit was analyzed to determine an effective solution. It was determined that a solution could be obtained through the use of a properly tuned gain stage followed by an adjustable stage which made use of a potentiometer. Using standard circuit analysis a design was determined which provided for adequate adjustment of the metering while not exceeding meter inputs at the nominal value. The design was completed, parts were procured, and a surface mount (SMT) printed circuit board (PCB) fabricated to replace the existing wire wrap board. The completed SMT PCB will be installed at HEF antenna sites for use on the 20kW X-band transmitter system.

### **Characterization of Amino Acids in a Martian Analog Environment**

The investigation of amino acids in extreme planetary milieus is an attractive prospect, owing to their ubiquity in organisms on Earth. Efficient analysis of amino acids requires a compound-catered sample preparation protocol to optimize detection ability. Ion-pairing chromatography was utilized to develop an efficient method for the quantification of amino acids in solvent-extracted soil samples, eliminating the need for amino acid derivatization. Using high-pressure liquid chromatography (HPLC) with electrospray ionization mass spectrometry (ESI-MS), this method enabled the separation and quantification of 20 biologically relevant amino acids at sensitivities below 0.1

ng per amino acid. The developed procedure was applied to the analysis of amino acids in soil samples from Haughton crater (Devon Island, Canadian High Arctic), an extreme terrestrial environment that acts as an analogue for potential Martian sampling sites. Efficient quantification of underivatized amino acids in relevant soil samples demonstrates the utility of HPLC-MS for the detection of biomarkers in planetary environments and provides a promising outlook for future in situ astrobiological analyses.

### **Designing a Rover Simulation Experiment Using Orbital Imagery**

Science Operations on Planetary Surfaces (SOOPS) has been very effective in combining multiple technologies to test new rover-mounted instruments and on-board processing capabilities in an operations setting. SOOPS is a simulation-based system that integrates ground science operations tools with on-board rover software controlling a simulated rover in a virtual terrain. This project takes the versatility of SOOPS one step further by designing an experiment that combines orbital imagery and possibly a new subsurface rover instrument to have scientists and engineers better understand the complex operations of searching for subsurface water and ice. Having this type of experiment available to both scientists and engineers allows them to try a number of different scenarios in different terrains, making it more cost-effective than physical testing. This experiment will then help the users of SOOPS improve rover operations and maximize science output for future missions looking to locate and study sub-surface water/ice.

### **An Examination of Martian Topographical Dichotomy Using SHARAD Data and Analyzing Martian Gullies for Future Campaigns**

The Martian dichotomy boundary divides the southern highlands from the northern lowlands and is believed to have extended through gravitational relaxation. Topographic shelves and the disappearance of topographic “knobs” parallel to observed normal faults provide evidence of buried extensional faults. Mars Reconnaissance Orbiter's Shallow Subsurface Radar (SHARAD) ground-penetrating radar data is able to observe subsurface features, including faults. A program was written to map the SHARAD orbits over the Ismenius region, and the radargrams were analyzed with topographical data, Mars Orbiter Laser Altimeter data, as well as clutter simulations and examinations of RBG spectra in SHARAD data to judge possible remnant faulting and subsurface discontinuities. Potential subsurface faults are being examined. The next step is to simulate the radar backscatter due to topography to distinguish surface “clutter” from subsurface features.

Many hypotheses have been suggested to explain Martian gully activity, including the presence of leaking subterranean aquifers. To date, relatively few gully regions have been investigated using SHARAD data. Because of SHARAD's sensitivity to certain conditions, the SHARAD Team has produced a map detailing the probability of high quality SHARAD data from any given region. Code was written to map the gully locations onto this map, and an analysis of the best targets for future campaigns is underway.

## **Evolutionary Robotics: Creating and Restoring Functions Through Genetic Algorithms and Adaptive Reconfigurable Hardware**

A modular design paradigm has proven to ameliorate issues of reliability, portability, maintainability and efficiency in both software and hardware applications. Use of reconfigurable hardware provides the opportunity to migrate certain software algorithms to hardware, thereby decreasing computational load on a central processing unit and, consequently, lowering overall power requirements—a key consideration in the development of exploration robotics. Additionally, through the use of genetic algorithms and field-programmable transistor arrays, restoration of function can be achieved in devices damaged by external sources such as radiation. This in situ self-healing ability provides invaluable redundancy and life expectancy, especially in hostile environments not amenable to human intervention. This project proposes the application of field-programmable transistor arrays in conjunction with genetic algorithms in robotics to create modular fault-tolerant components.

## **Simulations of High-Angle Ions in Hall Thrusters**

Hall thrusters emit a small but significant amount of high-energy ions at large angles away from the exit plane. This presentation outlines the results of applying HPHall, a widely used near-field Hall thruster simulation code, to understanding the presence of these high-angle ions. HPHall is used to examine ion velocity distributions at various angles away from the exit plane. Graphs of HPHall's predicted ion distribution density peaks at various angles are presented and shown to be the effects of the primary discharge, electric field acceleration, and atomic collisions. Comparisons of observed velocity distributions to simulation data are made to comment on which physical aspects of HPHall are functioning adequately. New code additions to HPHall are explained, and the new Matlab data processing code is outlined. Simulation changes that effect the distribution of ions to high angles are suggested.

## **UV Life Detection Instrument: Working Towards Efficient Life Detection Through Fluorescent Light**

The search for life in extreme environments on Earth, or on other planetary bodies/moons, has been an ongoing challenge for the scientific community. Through the use of rovers and satellite imagery, we have learned much about other planets that could have supported life. Despite all this effort, signs of life or organics on planets such as Mars have yet to be observed. Enter the UV life detection instrument. This instrument was designed in the hopes of finding a more efficient way of detecting trace amounts of organics. It is dependant on 248nm UV light that, when directed on a living or once living specimen, will make it emit in a unique manner. This “Christmas tree” effect is caused by fluorescence and can be further substantiated by Raman scatter. The effect has great appeal in that it allows for insight into where a rover should look for life during its critically short life searching planets.

Currently, a new prototype instrument was created that was small enough to be mounted to the JPL Cliffbot for an August 2007 deployment in the Arctic (Svalbard, Norway). In addition to the design, build and testing, a rugged wireless communication system was developed.

### **Interplanetary Overlay Network (ION) Monitoring and Control Framework**

The Interplanetary Overlay Network (ION) Monitoring and Control Framework is an intranet-based software tool supporting experimental tests of the ION protocol. ION is poised to develop into NASA's next-generation, packet-switching network protocol in space, and this software tool works towards this goal by helping to evaluate ION experiments. Currently, the experiment results consist of a swarm of unorganized packet-related data that lack a cohesive storage and retrieval facility. This presents two fundamental problems for ION research: the first being the difficulty of discerning the status of network experiments in real-time, and the second being the possibility that research data may be unutilized. ION Monitoring and Control Framework seeks to mitigate these problems. It provides scalable storage for packet data, and an asynchronous method for accessing experiment-related data, including ION-specific bundle path data, packet information, and topological node configuration data. The control framework is composed of back-end packet retrieving software, an SQL (Structured Query Language) database, and an AJAX (Asynchronous JavaScript and XML)-based web-interface. Combining these technologies, the control framework seeks to help researchers perform more informative and useful ION experiments.

### **Measuring Optical Properties of Aerosols**

Planetary climates and habitability, including global warming, is a major topic in current scientific research. A main goal is to study and characterize every aspect of global warming to predict future scenarios that will happen to our climate. Aerosols in the environment play a key role in this discussion, as they have the ability to either reflect or absorb sunlight, potentially cooling or warming the surface. The optical properties of aerosols, however, are one of the least known forces that relate to global warming. Because of this relative high uncertainty, researchers have been trying to develop better tools and instruments that measure the optical properties of aerosols. An in situ instrument developed by Pin Chen, which uses a method known as NICE-OHMS, is used to measure the refractive index and extinction of atmospheric aerosols by measuring the complex forward-scattering of the electromagnetic field. A device built this summer that is used to transport atomized and dry aerosols into the instrument will be discussed. The key goal is to attain results that verify the usage of using NICE-OHMS as an excellent means of measuring aerosol optical properties.

### **Monitoring and Control Framework for Interplanetary Overlay Network Testbed**

Interplanetary Overlay Network (ION), an implementation of Delay Tolerant Networks (DTN), aims to bring networking to environments where extreme conditions limit the

usefulness of standard networking protocols such as TCP/IP. Interplanetary and ad-hoc mobile military networks are two of the major drivers for this technology.

Working in the research and test-bed group, my goal was to create an application suite, named ION monitoring and control framework (IMCF), which collects data from ION simulations and provide a clear, concise web interface to display and analyze the data. Besides collecting data from ION nodes in our simulation, we also collect data from simulations of channels between nodes and Consultative Committee for Space Data Systems (CCSDS) File Delivery Protocol (CFDP), a central application to space networking. IMCF provides both live monitoring of DTN simulations and the ability to trace data across the network. Use of this suite will be very important in both internal simulations and external presentations of the DTN network architecture as ION gets closer to launching.

### **Testing Procedures**

For large teams of software developers, such as the Maestro software team, having a full-time software tester increases the efficiency and productivity for the overall project. The MaestroMER science-planning graphical user interface (GUI) is being developed by twelve software engineers and must work properly across several different platforms (Mac, PC, Linux). Since changes are being made to the software several times a day, it is imperative that the software testing keeps up with the software modifications. A full-time tester will focus his or her time on trying to break the software rather than checking if the code modifications are working correctly. Having a full-time tester also allows the developers to focus more of their time on what they are the best at, programming software. By having a full-time tester more bugs are caught before software release, which improves the overall credibility and usability of the software and is beneficial to the entire software team.