JPL

2009 Space Grant Student Opportunities

(Great opportunities that lead to STEM careers)

This is now a year-round program. Students may come to JPL for Summer/Fall/Spring internships

The following pages contain actual abstracts prepared by the Space Grant interns at JPL for the summer of 2008. This document is intended to provide examples of the types of opportunities available for 2009 internships at JPL.

Application deadline for summer program: February 1, 2009, but deadline is flexible. Students should submit resumes to their state Space Grant consortium as early as possible. JPL can accept resumes for summer program up to April 1, 2009.

There is no deadline for students interested in Spring and Fall internships at JPL. Space Grants should just forward student resume and unofficial transcript to JPL.

Resumes may be sent electronically to Linda.L.Rodgers@jpl.nasa.gov, or addressed to: 4800 Oak Grove Drive, Mail Stop 180-109, Pasadena, CA 90019-8099

JPL managers will be able to fund many of the students!

Please direct any questions to Kelly Gaudet: Kelly.L.Gaudet@jpl.nasa.gov

The Opposition Effect and the Icy Moons of Saturn

It is well known that airless bodies covered in various types of surface material (known as regolith) exhibit a nonlinear "surge" in apparent brightness as they reach opposition, or approach phase angles (i.e., the sun-observerbody angle) of less than 1 degree. Outside of this region, for phase angles extending to ~10 degrees, linear brightness increases are seen to take place at greater rates than would be expected if only changes in illuminated surface area were taken into account. Below, we study the behavior of the five Saturnian satellites Rhea, Dione, Tethys, Enceladus, and Iapetus across these phase angles and across seven spectral bands as observed from the Visual Infrared Mapping Spectrometer (VIMS) aboard the Cassini probe. We present detailed phasecurves of each moon, comparing the shapes of their surges as a function of both wavelength and albedo, and attempt to justify the major theoretical models of photon backscattering and shadow hiding in the light of these new data and viseversa. Further, the behavior of different terrain types on both Dione and Enceladus is investigated using data from Cassini's Imaging Science Subsystem (ISS).

Opposition Surge Analysis of the Icy Satellites of Saturn

Planetary satellites covered in fine regoliths demonstrate a non-linear increase in brightness as the sun-satelliteobserver viewing angle, i.e., the solar angle, goes to zero. For many of these satellites, the region of linear increase dominates for solar phase angles greater than ~5 degrees. Within 5 degrees, a surge in the brightness takes place. Two models now exist to describe this behavior of reflected radiation for phase angles $1<a<5$ and for $a<1$: shadow hiding and photon backscatter. Phasecurves, demonstrating the phase angle dependence of radiance, and various other plots of phase coefficient, half-width at half-height of surge amplitude, and percentage amplitudes plotted against phase angle and/or albedo (a measure of the reflectance of the surface) show definitive trends in our data. In our analysis, we show the results for Rhea, Dione, Tethys, and Enceladus.

Algorithmic Cost Modeling for the Development of Flight Instrument Software

Predicting software development costs is often very difficult. Many times an inaccurate forecast of development costs can lead to a loss of functionality in the final product due to financial constraints. However, unacceptable opportunity costs arise when profitable development projects are lost due to overbidding. In the software development business, bids are usually based on comparisons to similar projects. These comparisons, done by either costing experts or the actual developers, are full of uncertainties since the necessary deviations from the functionality of the former projects cannot be fully accounted for in the bid. An alternative method uses an algorithmic cost model based on mathematical correlations between development factors and final costs. Models such as

COCOMO and SLIM give the institution templates to follow when they cost a project. These templates must be calibrated by analyzing the historical data of the institution to account for its unique development environment. This research analyzed ten instrument flight software projects and correlated various aspects of their software designs and development processes to their actual costs. The resulting model allows for estimates within 10% of the actual costs nearly 80% of the time. Opportunities for future improvement of the model are also discussed.

Landscape Scale Estimation of Canopy Height Using Light Detection and Ranging (Lidar)

The objective is to estimate forest canopy height at the landscape scale using sparse height measurements from lidar. Of specific substance is the development of computer software that interpolates sparse-sampled lidar to extend canopy height estimates to the landscape scale. Development of the software encompasses formulating an algorithm that estimates mean canopy height at any desired location. Given local estimates of height retrieved from lidar waveforms, the method interpolates using existing measurements weighted by the inverse distance. The software allows the user to specify a geographical region and outputs height measurements over the entire region with a specified resolution along with the associated error bounds for each estimate. Future progress will improve the quality of the interpolation algorithm using more intricate statistical techniques to minimize error bounds.

Acoustic-Structural Coupling in Acoustic Testing of Flight Hardware: Diffuse Field vs. Direct Field

During spacecraft lift-off and ascent, aerospace structures are excited by sound pressure waves. Acoustic testing is therefore required for many aerospace structures to attain flight qualification. To qualify, they are tested in a reverberant chamber that generates a diffuse sound field. More recently, acoustic testing has been performed with a direct acoustic field generated by a set of loudspeakers. In diffuse field tests, acoustic-structural coupling occurs at lower frequencies. In direct acoustic field tests, however, the structure may not experience these modal coupling effects. The objectives of this project were twofold: to assess the acoustic/structural coupling in diffuse field testing, and to develop an understanding of the underlying physical differences between diffuse and direct acoustic testing. A single test article was acoustically tested in both a diffuse field and a direct field. The vibrational responses of the test article to both tests were analyzed and compared using basic signal processing techniques. Preliminary data analysis shows evidence of structural coupling in the diffuse field acoustic testing that was absent in the direct field testing, supporting the acoustic chamber/structural coupling hypothesis.

Low Data Rate Transmitter/Receiver Pair for Optical Communications

A LASER-based optical communications transmitter/receiver pair was developed with the ability to transmit and receive low data rate communications. The system was developed to demonstrate the capability of the LASER link to transmit real-world data, such as voice communications from one end of the link to the other. This voice data must be clear enough to be recognizable on the other end of the link. The communications link must have a data rate of less than 50 kilobaud due to limitations of the LASER driver hardware. The system must utilize an avalanche photodiode as part of the optical receiver, due to sensitivity requirements. The transmitter/receiver hardware must be easily integrated into the currently existing support hardware used for the development of the optical communications link. The transmitter/receiver pair was developed and integrated into the currently existing LASER communications hardware, adding the ability to showcase the potential of the LASER-based link.

Systems Function Verification for MSL Entry, Descent, and Landing

Entry, descent, and landing (EDL) of the Mars Science Laboratory (MSL) is a complicated and critical system which requires careful integration of its components and subsystems. The purpose of a systems function-verification is to ensure various system functionalities by confirming that all documentation and conventions are consistent across several different working groups. In this project, the control of the Mars Lander engines (MLEs) during the powered descent stage of EDL is examined in depth. Function verification of MLE control is achieved by cross-checking all hardware drawings and software definitions between groups that may not be in regular contact, such as avionics, propulsion, flight software, and guidance, navigation, and control. Pin-outs, naming conventions, and current document revisions are all checked out, and considerable attention is given to MLE valve phasing. A summarizing document is delivered which describes the steps taken in verifying system interfaces. Function verification of MLE control is the start of a process that will eventually be performed on all EDL functions.

Communicating the Significance of Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2)

The Estimating the Circulation and Climate of the Ocean (ECCO2) project uses data from satellites like the Ocean Surface Topography Mission on the Jason-2 satellite (OSTM/Jason-2), launched on June 20, 2008, in combination with data from instruments in the ocean. These remotely sensed and in situ data constrain a numerical model to determine the time-evolving, three-dimensional ocean state. The high-resolution version of the ECCO2 project allows us not only to study ocean state or climate change but also

to provide the model's output to the wider research community. In this regard, it is important to simplify access to ECCO2's data for the scientific community and to communicate with clarity the significance of ECCO2 through a web interface for the public. The website has been newly updated with a consistent structure, working links, and additional instructions regarding the data content, data handling, and work in progress. The Concurrent Versions System kept track of code revisions made to the website.

Atmospheric Chemistry of Extrasolar Planets and Designing a Cavity for Use With a Piezoelectric Transducer

Extrasolar planets are planets outside of our own solar system, and they may or may not possess significant atmospheres. By looking at the absorption spectrum of a star before, during, and after a planet's eclipse, scientists are able to determine the molecular signatures of the gases that are present in a planets atmosphere. These absorption and emission spectra are directly related to the pressure, temperature, and chemical composition for a given planet's atmosphere. Next, by looking at the photoabsorption cross sections of different gases, we are able to determine the probability that a photon from the parent star will reach the surface of the planet. This is of great importance in determining the possibility of life on planets outside of our solar system. Frequency control and laser stabilization becomes very important when working with lasers. By making use of the Pound-Drever-Hall method, a Fabry-Pérot cavity, and a piezoelectric transducer, we can enable laser frequency locking and greatly enhance the sensitivity of laser measurements. We have been working on a design that will use these methods to enable frequency tuning of locked lasers, and as a result allow us to make better atmospheric measurements.

Determination of Species Diversity in Atacama Desert Soil Samples Using Bacterial 16S Gene Sequences

NASA researchers consider the environmental conditions of the Atacama Desert of northern Chile to be analogous to Mars due to the extreme aridity, trace organic carbon content, and oxidizing conditions. This desiccated environment provides insight into how life could survive or how traces of past life could be preserved under similar conditions on Mars and gives an indication of the kinds of instruments needed to detect signatures of life. To further investigate the nature of life in hyperarid environments, subsurface soil samples were collected from the driest region in the Atacama Desert. This report describes the bacterial diversity derived from DNA extracted directly from these soils. Cells were removed from the soil matrix and the DNA was extracted and purified using a

CTAB extraction protocol. The 16S rRNA gene was amplified by PCR and cloned into E. coli. The 16S rRNA genes were sequenced from the clones and analyzed to determine the species of bacteria present in these soil samples. The diversity profiles of two different sites within the Yungay region of the Atacama Desert are described.

Opto-Mechanical Technologies for Deep-Space Optical Communication Proximity Links

In deep-space communications, proximity links are utilized to reduce the data transmission distance a spacecraft has to directly send and receive its information. Essentially, proximity communication links transmit information from the surface of a planet back to a ground-based communication station on Earth. While current space communication systems incorporate ultra-high frequency (UHF) links, it has been proposed that a transition to optical communication-based systems could increase the amount of broadcast data 10 – 100 times. In order for optical communication-based proximity links to become a reality, impediments such as laser beam co-alignment and opto-mechanical system design must be addressed. It has been proposed that by utilizing piezoelectric tube technology, it is possible to maintain laser beam co-alignment to a functional degree of accuracy and precision. Through testing a piezoelectric tube–based optical alignment system, one of the objectives of this project is to perfect a second-generation system capable of co-alignment to an accuracy of 100 microradians. To integrate an optical communication system such as this into next generation spacecraft, design analyses of current optomechanical structures must be performed. Another objective of this project focuses on redesigning current prototype opto-mechanical assemblies to achieve weight reduction, while maintaining structural integrity. As a method to further develop these designs, computational structural analysis (i.e., finite element analysis) and design integrity assessments will be performed on these prototypes. These undertakings are elements of the collection of technologies currently being developed for proximity communication links by JPL's Optical Communications Group that will hopefully be utilized in future NASA space missions.

Verification and Validation Activities for the MSL Flight Systems Team

With MSL's launching thirteen short months from now, the flight systems team is currently completely consumed in the verification and validation (V&V) activities. These activities include, but are not limited to, verifying the behavior of the fault protection system, testing the spacecraft's hardware and flight software capabilities to operate under nominal and extreme conditions, measuring the mechanical systems of the project and verifying they are within design tolerances, and testing the flight software for proper rejection of off-nominal commands. Each V&V activity is an integral part of the overall design of the MSL project and is important to complete. This partial list of V&V activities was worked on over the summer; the lattermost of the list is the main focus of

this paper. With currently over 1500 commands in the command dictionary, and more to come, it is desirable to have scripts that can read a command dictionary and do the off-nominal testing of all the commands and arguments for the commands. The scripts were written in Python and are designed to test each command in a command dictionary for each argument it has, then confirm that flight software rejected the command sent with an invalid argument value. The scripts also create a record file that can be easily understood and lets a reader see if there are any anomalies in the test. If anomalies present themselves, the user can study the record file from the script, the log file from flight software and the command itself to understand if flight software is working properly or not. Depending on how long the flight software takes to reject each command, running these scripts continuously can take from 4.5 hours to 21 hours each. The scripts have pauses built into them in which flight software can be shut down so that they do not have to be run continuously.

The Performance Evaluation of the Ultrasonic/Sonic Drill/Corer at Venusian Average Atmospheric Temperatures

The objective of this project was to demonstrate the operating capabilities of a specially developed Ultrasonic/Sonic Drill/Corer (USDC) at high temperatures. To do this, the USDC was placed in a variable temperature furnace and brought up to 500 degrees Celsius. The actuator resonant frequency, driving voltage, preload, power consumption, and drilling rate were monitored. The USDC operated at a slower drilling rate at the elevated temperature. Temperatures of 500 plus degrees also induced cracking of the piezoelectric material and fatigue stress in the bit interface. It was demonstrated that a higher tempering temperature for the bit prevented fatigue cracks. The details of the test performed and further possible design improvements are included in the full final project report.

Interannual Variability of the Global Distribution of Heavy vs. Light Precipitation

The launch of the Tropical Rain Measuring Mission in November 1997 marked the first time that a complete record of global land and ocean rainfall between 40° N and 40° S can be established. With ten years of precipitation data, this study analyzes major patterns of rainfall variability in the degree of anomalous heavy rain versus light rain, characterized by non-zero rainfall distributions matched to log-normal curves and evaluated against interannual rainfall distributions. By principal components analysis and method of empirical orthogonal functions, indices of the major modes of oscillation are found and compared to the El Niño-Southern Oscillation (ENSO), possibly indicating a correlation between interannual rainfall variability and the aperiodic event characterized

by an east/west oscillation in global winds, pressure, and oceanic subsurface temperatures across the Pacific Ocean.

Asteroid Astrometry

The ultimate goal of asteroid astrometry is to get a more precise calculation of the orbits of asteroids. To obtain this data, we use a 4K CCD camera and the 24-inch telescope at Table Mountain Observatory. The camera is focused using information for temperature, barometric pressure, and humidity in order to obtain clear images. We take two to three pictures of each asteroid, each with a different pointing, to ensure we have sufficient reference stars. Using the known positions of these reference stars in the picture, the position of the asteroid can be more accurately determined. We then run the images through a center-finding reduction program that uses the centers of the stars and asteroids in order to determine the asteroid's location. The results and information we obtain are then used by others who are able to update the asteroid's orbit. This technique allows for a more precise calculation of the orbit of an asteroid or satellite. To date, we have completed nine nights of observation and have obtained good data in seven out of those nine nights. There are six more observing nights planned, and we expect good results out of those.

Computational Modeling of Plasmas and Cathode Erosion: Simulating Hollow Cathode Life Tests in Ion Propulsion Systems

Ion propulsion systems (IPSs) typically produce very high specific impulse compared to conventional chemical rockets, with the result that significantly less propellant mass is needed to accomplish the same mission requirements. The life requirements of ion engines for NASA missions range in years. To qualify these engines it has been customary to perform life tests, which can be costly and very time-consuming. As mission demands increase, it is no longer cost effective or time feasible in many cases to perform such life tests. Computational modeling of these systems can significantly reduce the cost and time required by life tests. OrCa2D is a computational tool that models the plasma and erosion of hollow cathodes in IPS. Its purpose is twofold. First, OrCa2D helps us to better understand life-limiting processes inside a cathode. Second, once validated with short duration wear tests, OrCa2D can be used to predict the service life of these devices without performing the full life test. Presently, OrCa2D has only been used by its developers. The work performed under this task aims at improving the usability of OrCa2D for use by other researchers and for a variety of cathode geometries and operating conditions.

U.S. Rosetta Project: Understanding the Properties and Dynamics of Cometary Nuclei

Despite advancements in cometary science and the advent of the Space Age, the properties and dynamics of the cometary nucleus and its origins are still ambiguous. Opportunity to better constrain characteristics of cometary nuclei awaits the unprecedented mission, Rosetta, where a lander will be deployed on the surface of comet Churyumov-Gerasimenko. Several permutations of conceptual comet models since the conventional Whipple's comet model, the icy conglomerate model, have been proposed to account for the accumulating wealth of new evidence. Yet, results are still inconclusive. I will present preliminary results of an updated C. Alexander thermal model of the cometary nucleus to incorporate current ideas of actual structure, strength, porosity and density of various comets. Furthermore, the results will convey the model's implications in the context of the formation of the solar system.

Mid-Infrared Spectroscopic Observations of Saturn and Jupiter From the Subaru Telescope

In the study of the atmospheres of gas giant planets, spectroscopy is useful as a means to determine the pressure and abundance of chemicals in the atmosphere, together with other properties such as aerosol or cloud opacity and temperature structure. Mid-infrared spectroscopy, which is sensitive to thermal emissions, is particularly sensitive to the latter. Ground-based astronomical data from the Cooled Mid-Infrared Camera and Spectrograph (COMICS) instrument of the 8.2m ground-based Subaru Telescope were processed and reduced. The reduction process required developing instrument-specific code in the Interactive Data Language (IDL) to reduce and calibrate the raw data from COMICS. In their reduced form, these data provide information on the atmospheres of both Saturn and Jupiter, including latitudinal variation and properties of specific features, including both axisymmetric banded structure and discrete features, such as anticyclonic storms. Some initial work on scientific analysis of the data included comparisons with existing models. In addition, the developed procedures have been incorporated into a graphical software suite known as the Data Reduction Manager for simpler processing in the future, allowing userdefined choices between several options in COMICS as well as spectrometers at other observatories.

Powering the PLL Phase Detector for Optical Communication Applications

Tracking objects in space from Earth has various and wide-ranging applications. The velocity and position of near- Earth orbiting objects can be ascertained by measuring the Doppler shift created with respect to some fixed frequency emitted from the object. To ascertain smooth trajectory, the fixed and shifted frequencies must be obtained quickly

and accurately. This is achieved through use of a phase detector to create a phase-locked loop. Any error in frequency will depict abnormal speed and location; the phase-locked loop is susceptible to errors stemming from both input signal noise and thermal noise present in the circuit. As obtainable phase detectors have fixed noise characteristics, it is necessary to maximize the accuracy of the phase-locked loop by minimizing the noise present in the circuit. Multiple aspects of noise reduction in the circuit are considered from a design perspective. This begins by choosing the optimal components from leading manufacturers and measuring component characteristics for both noise and stability criteria via simulation in Simulation Program with Integrated Circuit Emphasis (SPICE). Design of the printed circuit board and integration of various noise-reducing materials are considered. Different layout techniques and materials, including connection interfaces, can be further explored for application-specific optimization.

Science Analysis Study for the HyspIRI Mission Concept

Using a Hyperspectral Visible-Near Infrared Imager and a Multispectral Thermal Infrared Scanner, HyspIRI is a mission scheduled for launch around 2015 that aims to detect detrimental ecosystem changes. This abstract is part of a team paper called "End-to-End Data System Design of the HyspIRI Mission." Our team's goal has been to expand development on the current HyspIRI mission concept by conducting studies of systems engineering, telecommunications design, command and data handling design and data processing and distribution. As part of that effort, I have defined the Science Analysis/Data Processing data levels for the HyspIRI mission, as well as determined what analysis needs to be done to the data in order to obtain the mission's desired science products. A series of calibrations, corrections, compression, packetization, depacketization and mapping processes will be applied to obtain space-time grids from raw data. I have also conducted an in-depth study of mission collaborations, determining what science products can be obtained from combining HyspIRI's science products with other data sets. Science products such as volcanic eruption, wildfires, landslides, natural resources, drought, soil and vegetation type, health and distribution maps can be of greater societal benefit if combined with past, present and future science product.

Seasonal Changes in Saturn's Clouds

Previous investigations indicate that Saturn's atmosphere consists of many hydrocarbons and trace chemical species such as methane (CH4), ammonia (NH3), and phosphine (PH3). NIR observations acquired from 1995 to 2006, equivalent to half a Saturnian year, are reduced and analyzed to study seasonal changes in the global distribution of these species in Saturn's clouds. The data was acquired from the NASA Infrared Telescope Facility with NSFCAM and NSFCAM2 (1995–2006) as well as the Cassini Visual and Infrared Mapping Spectrometer (VIMS, 2004–2006). Global cylindrical maps of reflectivity (or I/F) were created with software written in Interactive Data Language (IDL). IDL programs were also written to extract latitudinal and pole-to-pole profiles of the planet's albedo. In addition, Albert4, an atmospheric model algorithm, was run on the VIMS data to model the distribution and composition of clouds in Saturn's atmosphere. While time restrictions prevented further modeling, this project has developed the basic framework necessary. Further work involves adjusting the Albert4 input parameters to better match model output with observation, comparatively analyzing the NSFCAM2 data with VIMS, and then extending Albert4 to model the NSFCAM(2) observations. T. Momary, J. H. Kim and K. Baines provided assistance with VIMS data and Albert4 models.

Visual Aids for Robotic Navigation Systems

NASA rover navigation systems for Mars have been primarily based on dead reckoning using inertial measurement units (IMUs) and wheel encoder data. On the Mars Exploration Rover missions, the rovers evaluate possible paths through stereo vision, and then rely on dead reckoning to navigate to the next waypoint. However, wheels slip on the sandy Martian surface and errors accumulate, causing inaccurate distance and orientation estimates. By adding visual navigation, the wheel slippage can be compensated to give a more precise estimate to the waypoint. My project involved developing two tools to aid in visual navigation. The first part was to survey the Outdoor Mars Yard with a Lidar scanner, and then generate high-resolution 3D maps for computer simulations. The maps give a virtual representation of the Mars Yard that closely depicts the Martian surface and that should allow computer simulation and analysis of virtual rover navigation before implementation on the actual rover testbeds. The second part was to develop and demonstrate a monocular vision guided system that uses landmark tracking and visual steering on a rover testbed. Using Labview, a program was developed that analyzes streaming data from the camera, tracks a user defined target, and directs the robot towards the waypoint. These tools should allow simulation modeling to become a more realistic, and add an accurate and efficient way to travel the next point of interest.

Analysis of the Tensile Forces Experienced by the Axel Rover Tether

With previous rover designs it has been difficult to navigate steep terrain such as craters and caves on the surface of the moon and Mars. The Axel rover is a simple robotic design that could overcome these challenges. The rover consists of a two-wheel axle and an arm that extends from the center of the body. Movement is controlled by three actuators: one for each wheel and one for the pivoting motion of the arm about the body. Axel repels down steep slopes by means of a tether that connects to a larger lander or rover that would be positioned at the top of the crater. This tether is wrapped around Axel's body and extends through the arm. The goal of this project is to maximize the strength and durability of the tether while minimizing the mass and diameter. To do that, a Matlab program was designed to solve for the theoretical tensile forces experienced by the tether at varying slope angles and varying arm configurations. It was then necessary to check those values by obtaining experimental data through tests conducted with Axel. This data will be useful in the selection of an appropriate tether material and will help Axel to better manage situations that could create a sudden increase in tether tension.

Network Coding With Prioritization

Future communication scenarios for NASA spacecraft may involve networks with multiple paths from a sender to a destination, and the availability of individual links may be uncertain. The question of how to best utilize such a network can be addressed with network coding, a branch of information theory, in which coding at intermediate nodes is considered and the goal is to maximize throughput or to achieve robust data transmission under network unreliability. In this project, a network coding problem for priority-based data transmission is considered that expands on the usual robust data transmission scenario. The goal is to maximize the expected value of a probabilistic performance metric, which assigns more weight to successful transmission of data of higher priority (value). The simple network of multiple parallel links is considered first, with parameters such as outage probability and capacity for each link and priority and size for each data stream. Algorithms to maximize the expected value of the performance metric and simulation results are presented. Generalizations to more general networks are considered.

Determining the Rotational Period of Asteroid 1564 Srbija Through Light Curve Analysis

We imaged asteroid 1564 Srbija for three nights in the month of July 2008 using a remote connection to a private observatory in Idyllwild, California. The equipment used was a Ritchey-Chrétien 12.5" scope on a Paramount with a SBIG STL11000M camera. CCD Autopilot was used to automate the whole system to run robotically throughout the night. Red filter 2x2 binned exposures of the asteroid began as it rose 35 degrees above the

horizon and continued throughout the night until 4:00 a.m., except when the telescope slewed to SA112 Landolt field standard stars for calibrating exposures. After flat fielding and dark subtraction, the MPO Canopus software will be used to analyze the magnitude change over the course of the evening, revealing information about the shape of the asteroid, its rotational period, and possibly its composition. Additional data will be secured in August using the JPL Table Mountain Observatory 0.6 m telescope with an LN2-cooled camera.

Plume Mode Characteristics of the Neutralizer Hollow Cathode in the NEXT Ion Engine

Hollow cathodes are used as electron emitters in all Ion Propulsion Systems (IPS) flown or considered for flight by NASA, including NASA's Evolutionary Xenon Thruster (NEXT), which is currently undergoing a long-duration wear test at the Glenn Research Center with support by the Jet Propulsion Laboratory (JPL). A neutralizer hollow cathode (NHC) is the electron provider for the neutralization of the thruster's ion beam, but its operation can become unstable under certain conditions, such as fluctuations in the applied keeper voltage. Commonly known as "plume mode," cathode operation in this condition accelerates cathode wear, decreases cathode performance, and eventually leads to cathode failure. JPL has a continuing life modeling effort aimed at identifying the fundamental mechanism(s) that cause it, and the success of this modeling task strongly depends on the support of short-term experiments that provide data for model validation. The NHC was run at various NEXT operating conditions and different plasma diagnostic techniques were used to measure its plasma properties. These measurements were used to investigate plume mode operation and for comparison to life models.

Image Chain Analysis Technology for Space (ICATS)

The Jet Propulsion Laboratory (JPL) is developing the Orbiting Carbon Observatory (OCO), a polarization-sensitive sensor that will be launched in early 2009. Calibration and validation for this instrument require the ability to account for polarization properties of various surfaces and atmospheres. The primary resource for these calibrations will be VLIDORT, a vectorized multiple scattering radiative transfer model. This study will serve to confirm and validate VLIDORT results, as well as showing us more about the nature of polarized surface reflectance by examining various surfaces in the field with a polarization sensor.

Extreme Temperature Pulse Width Modulation of a DC/DC Power Converter

Pulse width modulation of a DC/DC power converter for use in a distributed motor controller at extremely low temperatures is described. The power converter takes a 30-volt input signal and steps it down to 5 volts for use in the motor controller's electronics assembly. The power converter is known to fail at temperatures below -180 degrees Celsius, where the desired result is for the assembly to start-up and operate at -230 degrees Celsius. The cause of low temperature failure is thought to be due to the breakdown of bipolar transistors, which are used in the existing pulse width modulation controller. A potential replacement has been developed and will be tested in an attempt to further understand the cause of low temperature failure.

In-Situ Instruments for the Study of Wind and Melt Water Patterns in the Polar Regions of Earth

As of late, the scientific community has been marked with a piqued interest in the polar regions of Earth. Exploration of areas such as Greenland and Antarctica can provide valuable information about the changing global climate and what can be done to prevent further negative change. In addition, extreme environments on Earth can serve as a testing ground for the exploration of other solid bodies of interest in our Solar System, such as Mars, Titan or Io. Two instruments that can facilitate such research are under development at the Jet Propulsion Laboratory. The Tumbleweed Polar Wind Rover is a large, inflated, spherical rover capable of traversing great distances and relaying GPS coordinates and elevation data in order to track wind patterns and map out the terrain of the region. The Tumbleweed is designed to be simple and inexpensive so that one could feasibly release a larger group of the devices and track wind patterns more thoroughly. The Moulin Explorer Probe will travel through the moulins of Greenland while collecting data to describe the paths taken by melt water as it flows from the Greenland ice sheet to the ocean. Both instruments will be deployed in fall 2008.

Assessment of GHRSST Level 4 Sea Surface Temperature Products in the Gulf of Mexico and Gulf Stream Regions

The global ocean data assimilation experiment (GODAE) high-resolution sea surface temperature (GHRSST) project has produced several sea surface temperature (SST) products based on a variety of infrared and microwave sensors. It is necessary to assess the accuracy and validity of these data in the regions of interest by comparing the Level 4 merged multi-sensor products with in situ data. In this investigation, we analyze four GHRSST Level 4 products over a one-year period (June 2007–June 2008) in the Gulf of Mexico and Gulf Stream regions. Twentytwo buoys from the National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center were used for daily comparisons with each Level 4 product as well as an overall mean ensemble product. The

spatial variation of the buoys allowed us to discriminate between nearshore and offshore regions where oceanographic conditions can be dramatically different. Initial comparisons indicate that the Level 4 products performed very well with mean differences less than 0.5 degC for most regions, but the regions of high ocean variability showed a significant disparity between the in situ buoy SST values and the Level 4 products. More specifically, in the winter months, dynamic regions produced larger biases and mean RMS greater than 1.0 degC.

Development of a Miniature Laser Spectrometer for Measuring Carbon Dioxide Isotopomers in Earth's Atmosphere

Global climate change has been one of the most discussed topics in Earth science for the past few years. Understanding the global carbon cycle can aid in predicting future climate change and help us to better know the world around us. The main focus for this project is to develop a miniature in situ laser spectrometer that will measure the concentrations of two different isotopomers of carbon dioxide in the atmosphere: 12CO2 and 13CO2. With the data that these spectrometers collect, scientists will be better able to profile the vertical distribution of carbon dioxide above carbon sinks and quantify carbon flux. Development includes implementing a real-time fitting non-linear least squared fitting algorithm based on Voigt line profiles, reducing electronic noise in the measured data by improving the analog circuitry, and integrating a telemetry system to track and receive data from the spectrometer once airborne. These devices will be tested in the field to determine if other redesigns are necessary.

Creation and Organization of the Phoenix Visualization Products

In support of the Phoenix Mission, the Solar System Visualization (SSV) team has been processing vast amounts of image data acquired and returned by the lander. Visualizations have been created using these images. These products enhance the scientific discovery process as well as help the general public to get a better understanding of the mission. A major component of this task is the creation of pan and zoom animations, and organizing the production of animation movies. The animations are created using Shake software and they are shared/released to other NASA centers and the general public via the Image Products Release Website (IPRW). This paper presents the following: 1. The procedure involved in creation of the pan and zoom animations. 2. The import and testing of the animations in PowerPoint format. 3. The selection of a php framework to enhance the usability of Phoenix's IPRW. 4. The imitation of the existing IPRW features and functionality using the selected framework to make the site easily extensible. 5. The automation of the cumbersome process of manually converting the animations to PowerPoint format.

Characterization of Voltage Drop in Mars Science Laboratory (MSL) Engineering Camera Power Supply Circuit and Recommended Modifications to Non-Volatile Memory/Camera Board

Due to the extreme environments the Mars Science Laboratory (MSL) Rover will experience, narrow margins of voltages are required for specific components. The engineering camera system interfacing with the Rover Compute Element [RCE] is a thermally isolated system that must receive a minimum/maximum voltage. Because of unforeseen issues with a larger rover and longer cable runs, higher-than-expected resistance between the power supply and camera created worst-case situations where the voltage would drop below the requirement. Predictions based upon temperature, maximum load, multiple cameras operated simultaneously, realistic trace resistances and other factors helped create schedule-critical recommendations and haywire solutions for reduction of voltage drop in the MSL Flight Spare RCE Non-volatile Memory/Camera [NVMCAM] board. These recommendations will carry over to future flight hardware awaiting fabrication.

Comparison of AR4JA and C Code Performance Usin 2 g Phase Shift-Keying Modulation

Forward error correction (FEC) coding is a method of reducing the power needed, at the cost of bandwidth expansion, to achieve a specific transmission error rate in a communication channel. Information is protected by an error-correcting code before transmission. Original information is recovered from corrupted received data through decoding. In this project, we experiment with the performance of the Accumulate Repeat-4 Jagged-Accumulate (AR4JA) family of codes, developed at the Jet Propulsion Laboratory, when used together with higher-order phase shift-keying (PSK) modulations. This project aims to compare the performance of 7156 bit, rate 7/8 C2 code with two rate 4/5 AR4JA codes (1024 and 4096 bits long), with the overall goal of determining the best code and modulation scheme given mission constraints. Because of spectral crowding, future NASA near-Earth missions are considering basic higher-order modulation schemes paired with a modern error-correcting code in order to support more power-efficient space communications. We analyzed, simulated, and compared uncoded binary (BPSK), quaternary (QPSK), and eight (8PSK) PSK modulation using MATLAB. AR4JA coding was added to the BPSK, then the 8PSK modulation schemes by using the C-language hardware encoder and decoder implementations. After the simulations are verified, the AR4JA-coded 8PSK simulations will be compared to a C2-coded simulation.

Aerodynamic Modeling of an Aerobot for Exploration of Titan

The use of an autonomous, lighter-than-atmosphere robot, or aerobot, for the exploration of Saturn's moon Titan is currently under serious consideration and scrutiny for a potential future mission. A robust, aerodynamic model of an aerobot is an essential tool required for accurate feasibility assessment and mission planning. Part of the work conducted was to help make the existing model a more functional computer simulation as well as to validate the underlying physics. Data was collected through a combination of in-lab experimentation and flight tests performed in the field with data recording instruments outfitted to the aerobot. For example, an apparatus was built to measure the static thrust of the propeller and motor in use. Also, some planning of the flight test was required to ensure all the data collected is usable for analysis. This data was used primarily for better identifying the aerodynamic characteristics of the airship. The conglomeration of all this work will help bring the mission into the next stages of development.

Characterization Studies of Boron- and Gallium-Substituted Li(Li(1/3-2x/3)Mn(2/3-x/3)Nix)O2 Cathodes

Lithium-ion batteries have made it possible for the portability of a great deal of devices. Continued demand for batteries with higher energy densities has lead to the advancement in the Li-ion battery chemistry. This same demand is prevalent in NASA’s interest in reducing spacecraft launch mass by incorporating very high specific energy Li-ion batteries. The jump from traditional state-of-the-art LiCoO2 cathodes to LiMnNiO2 cathodes has already exhibited nearly double the specific capacity. This capacity increase however, came with a sacrifice of degraded rate capability and cycle life. To aid in NASA’s endeavor, we investigated and characterized the effect of gallium and boron substitution as a function of stoichiometry for a series of cathodes built on the LiMnNiO2 family. This was done by chemically synthesizing group III substituted transition metal oxide sol-gels and then spraying coating them onto aluminum substrate electrodes. Coin cells were then fabricated and cycled. X-ray diffraction was also employed to aid in characterization. We reported on the effect of the boron and gallium substitutions into the family of LiMnNiO2 cathodes in terms of cathode specific capacity, rate capability, and cycle life.

Atmospheric Conditions in Jupiter’s Great Red Spot and Oval BA

The colored, banded appearance of Jupiter is probably best well known for the Great Red Spot (GRS), a large, anticyclonic storm system in the southern hemisphere. Until late 2005, the GRS had the distinction of being not only the largest and oldest known storm in the solar system, but also the only long-lived, red-colored storm on Jupiter. Then, in December of 2005, Oval BA, a white anticyclone that had formed through the merger of

three smaller storms began to turn red. Though it was predicted that the Oval would lose this coloration and possibly disperse following the close passing of the GRS, this did not occur, and the Oval remains red. It has, in fact, increased in size and strength, making it the second red-colored, relatively long-lived storm currently active on Jupiter, and the second largest in the solar system. As the unique properties and distinct coloration of the GRS have never been thoroughly investigated or explained, the appearance of this new storm provides a singular opportunity to test current hypothesis. This project provides analysis of infrared images of Oval BA and the GRS in the time from before December 2005, when Oval BA was white, to the present. We will present new information regarding the temperature structure of the Oval and its environs, as well as the distribution of NH3 and aerosols in the 100 to 400 mbar range. These data will be compared with those from the GRS in the same time period in order to provide constraints on long-standing questions and assumptions about the cloud properties and dynamics of Jupiter. We will also present serendipitous observations of a smaller red anticyclone that drifted between the GRS and Oval BA while they were near their closest approach.

Moulin Explorer: Examine Melt Water Flow Through Glacier Mills

The Greenland ice sheet has been melting at an accelerating rate over the past decade. Current climate warming understanding does not predict the ice thinning and subsequent decrease in surface elevation. The meltwater flows from the surface of the glacier to the bedrock by draining into tubular crevasses known as moulins. Scientists believe these pathways converge to the ocean. The Moulin Explorer Probe traverses autonomously through the moulins. It uses in-situ pressure, temperature, and three-axis accelerometer sensors to log data. Retrieved via helicopter, the probe will surface in the ocean and send GPS coordinates using Iridium satellite network. Highdefinition stereoscopic cameras are equipped on a tethered unit to extract volumetric images. We can use this information to map the pathways and water flow rate through the moulins and help us quantify the rise in sea levels.

Qualification of XIPS Neutralizer Cathode for NASA Missions

During this project, work has been done in the field of electric propulsion to qualify commercial electric thrusters for use on NASA missions to reduce the cost and schedule risk of using seldom-built NASA-developed thrusters.
The focus of the work was to characterize the XIPS (Xenon Ion Propulsion System) neutralizer cathode by taking the necessary measurements so that a life test can be conducted on it. Characterization was accomplished by measuring the plasma parameters of the discharge from the cathode along with the voltage and current characteristics of the cathode at many different operating conditions. Additionally, a vacuum system was set up in order to conduct the life test in. To do this, an out-of-commission vacuum system

was used as a starting point, and all of the necessary components were added, including a new chamber control system, power supplies, a new flow system, and many other parts. At this point in time, the cathode is mostly characterized and the new vacuum system is almost ready for the life test in the future.

Exploring a Test Automation Framework: Using STAF/STAX to Perform a System-Level Test of MPCS and Matis

To reduce labor and improve efficiency of testing, many software testers seek to automate their tasks. The Software Testing Automation Framework (STAF) and its programming language, STAX, are open-source products created to support testing automation. This study seeks to evaluate the effectiveness of STAF/STAX as a supplementary testing tool through a sample test between two software products, MPCS and Matis. The test uses STAF/STAX as the primary tool for initializing, monitoring, and verifying communication between MPCS and Matis, in an effort to exercise its core features relative to the testing environment. Experience shows STAF/STAX to have significant automation benefits despite its complexity. Its learning curve is comparable to that of learning a new programming language. However, the strengths STAF/STAX exhibits in remote execution, parallel operations, and extensibility are well worth the effort.

Effect of Damping on Extreme Peak Occurrences in Random Vibration and Acoustic Testing of
Aerospace Structures

Aerospace structures are typically designed to withstand three times the RMS loading (i.e., three sigma). However, the most recently measured responses from acoustic and random vibration testing of flight hardware have indicated a sigma value exceeding five. Extreme peak occurrences present a particularly stiff design penalty for brittle structures. Under investigation is the effect of viscoelastic damping on extreme peak occurrences in acoustic and random vibration testing. Simple test articles with inherent structural damping and added damping have been subjected to random vibration testing. Data analysis from simple test hardware and flight hardware qualification tests have shown that the peak distribution follows a Rayleigh distribution and that extreme peaks are weakly dependent on damping.

Broad-Band Imaging of Titan's Atmosphere Using Cassini ISS Narrow-Angle Camera Pictures From the CURE/Cassini Imaging Project

In order to build a Monte Carlo (MC) model of Titan's atmosphere, the variation of the single-scattering albedo in the atmosphere must be determined. The data includes UV1, UV3, and IR4 filter images at a phase angle of 53o from the Consortium for Undergraduate Research Experience (CURE)/Cassini Imaging Project. These used the Cassini Narrow-Angle Camera. Horizontal banding, vertical banding, and cosmic ray hits were removed using National Optical Astronomy Observatory Image Reduction and Analysis Facility procedures and custom processing scripts; this was followed by registering the images. DN scans were plotted using diameter vectors at angles from 0° to 179°. These coordinates were fitted by an ellipse to find a more exact center. The scans were plotted again with the new center. To calibrate the data, the products of the given transmission percentages and quantum efficiency were integrated over each filters' waveband; this was used to correct the DNs to fluxes. The scans were repeated. Plots showing the loci of Titan's detached haze layers will be presented. This will constrain the scattering properties assumed in the MC model.

Polymer Fiber-Reinforced Composites Structurally Enhanced Through a Nanowire Interphase

Fiber-reinforced composites are extensively used in the aerospace industry due to their high strength and stiffnessto-weight ratios. However, Kevlar-reinforced materials display a weakness in their compressive strengths due to a weak matrix-to-fiber bonding interface strength. An enhancement process has been developed to strengthen this interface by growing zinc oxide nanowires to the fibers. The nanowires enable the fibers to essentially act like rebar in concrete. Various mechanical property characterization tests are being performed on regular and enhanced composite specimens. The tests consist of compression tests, shear tests, and fracture toughness tests. The results are projected to show improvement in strength and stiffness properties for the enhanced specimen. Preliminary compression tests have shown increased stiffness of the enhanced specimens. Further testing is expected to show other improved mechanical properties.

Automated Processing of 3D Meshes From Stereo Imagery

This paper presents an automated pipeline for stereo image processing with a focus on applications for Mars missions. Using a pre-existing pipeline of stereo correlation, xyz-fields are generated for every stereo pair. We first identify and separate connected components within each stereo pair, using a combination of distance metrics and connectivity within the range image for each stereo pair. Connected components are then Delaunay triangulated and smoothed to create watertight models. Models can then be run

through an optimization algorithm to produce small, high-quality meshes. As a final step, we uv-map for a variety of image products, ranging from single eddy dissipation rates (EDRs) to mosaics comprised of 100s of EDRs. Finally, we present methods based on the iterated closest point algorithm of aligning meshes from different stereo pairs, allowing the correction of errors in the camera pointing and spacecraft positioning data. We demonstrate the success of our algorithms by presenting a full 3D color model of the entire Phoenix worksite.

Geological Interpretation of the Region in and Around Mawrth Vallis, Mars

Mawrth Vallis is one of the seven remaining candidates for the landing site of the Mars Science Laboratory rover. The existence of hydrated minerals in and around it has been known since 2005. This work aims to map the extent of the occurrence of these minerals using spectroscopic data from CRISM and to propose a geologic interpretation by incorporating HiRISE and CTX data. We find that clay-bearing units are found up to 1200 km away from the mouth of Mawrth Vallis. The stratigraphy observed in the studied observations show a consistent relationship between 1) a dark-toned capping unit, 2) an aluminum-rich clay-bearing unit, 3) a ferrous iron-rich layer, 4) an iron-rich clay-bearing unit, and 5) a second, dark-toned unit confined to lower elevations. Evidence suggests that the two dark-toned units formed independently and that intermingling of loose debris from distinct units may have resulted in an overestimate of the number of actual units present. We interpret the remarkable consistency of the thicknesses of the observed units as support for the hypothesis that their formation is the result of regional alteration.

Space Interferometry Mission Mass Properties

The search for Earth-like planets continues and will be carried out by the Space Interferometry Mission (SIM). There are various methods available to detect Earth-like planets. One such method, astrometry, precisely measures the position of the parent star relative to a background of more distant stars. Interferometry, a type of astrometry, is implemented on SIM. SIM uses an arrangement of mirrors, some of which are articulated and cause SIM's body to respond by rotating in the opposite direction due to conservation of momentum. Additionally, when the spacecraft slews to a new orientation, such as targeting a new star, the amount of force needed to make the turn (and the amount of propellant required) is determined by the moments of inertia. In order to properly predict the performance of SIM, and hence properly design SIM, it is important to know the masses and moments of inertia of all the component parts. Keeping track of mass, moment of inertia, and center of mass for all of SIM's parts was done using NX and the Excel Mass Property application, created at California Institute of Technology, Jet Propulsion Laboratory.

Upgrading the 70m DSN Gearbox Suspension

Each of the three 70m Deep Space Network (DSN) antennas uses four 22000 lb. gearboxes to control the elevation angle of the antenna main reflector, a 4 million lb. structure. On each of these gearboxes are three struts that are used to position and stabilize the gearbox and its pinion gear relative to a bull gear that articulates the dish. These three struts function as 1) vertical tension, 2) vertical compression, and 3) horizontal compression/tension struts respectively. They must operate to keep the pinion and bull gear aligned to eliminate binding so that during operation there is 0.040 in. of backlash between the two gears, allowing the main reflector to be positioned very accurately for deep space signal transmission and reception. Efforts this summer have been focused on a complete redesign of the compression strut, as well as changes to the tension strut to replace the currently used Belleville spring system with a more reliable and consistent coil spring system. These struts, once approved through the process of a critical design review, will be manufactured and installed at all DSN locations, replacing the outdated hardware with a dependable, low-service alternative.

Piercing the Dust Around Supermassive Black Holes

Active galactic nuclei (AGN) are high-energy phenomena, thought to be caused by interstellar gas and dust accreting around a supermassive black hole. In some AGN, relativistic jets emerge from the region of the disc/black-hole system along the rotational axis. Apparent differences between AGN can occur since the orientation of the obscuring dusty structure and the relativistic jets can result in different views of similar objects. In order to check some of the basic predictions of this orientation-based model, we investigate a sample of 126 powerful radio sources from the Spitzer archive. Compiling photometry from the Multiband Imaging Photometer and extracting low-resolution Infrared Spectrograph data, we construct spectral energy distributions for each object in the sample. This will allow us to compare the thermal luminosity for different classes of AGN at a wavelength where the effect of orientation is much reduced.

Database Migration and Integrating Radar Image Data Into Google Maps

NASA/JPL's Airborne Synthetic Aperture Radar, AIRSAR, flew missions on the NASA DC-8 aircraft from 1988 to 2004 and collected valuable data from a variety of different sites around the world. This radar image data is of great value to the scientific community, but it is currently only accessible through an internal AIRSAR website. The main goal of the project is to transform the internal AIRSAR website into a public website with more sophisticated visualization tools. Using Perl and SQL scripts, the radar data that was stored in an Oracle database was migrated to a MySQL database, and the backend of the website was updated to support the change in software. The radar image

data was then integrated into Google Maps, enabling the general public to easily browse the data through an interactive interface.

Structure and Properties of Ferrous Sulfide Membranes in Relation to the Origin of Life

Ferrous sulfide membranes, precipitated at hydrothermal springs on Hadean-era Earth, are of central importance in Michael Russell's (JPL) origin of life hypothesis as compartments in which pre-biotic chemistry matured into protolife. Here we examine the surface topology of ferrous sulfide membranes by growing chimney-like structures from the injection of 10 and 20 mM concentrations of sodium sulfide into similar concentrations of ferrous chloride at 50oC. We examine the precipitates under an environmental electron scanning microscope (ESEM) looking for micropores, capillary tubes and other structures that could contribute to the compartmentalization of organic compounds. We have found evidence that the surfaces of precipitated membranes are varied and rich in topography with pockets and channels that could serve to collect and focus organic materials. We have also begun preliminary investigations into the conducting properties of the iron sulfur membranes in order to gauge their capability to hold a proton gradient in a manner comparable to modern phospholipid membranes.

Mapping the Dark Matter Halos of Galaxy Clusters Through Strong Gravitational Lensing

Dark matter is matter that is thought to exist (and account for ~83% of all matter in the universe) but so far can only be detected by its gravitational effect. One of the observable effects of dark matter is gravitational lensing similar to the effect of glass lenses bending light through refraction. When the projected surface density is above a certain threshold, this gravitational lensing effect can result in multiple images of the same object, and this phenomenon is called strong lensing. In this paper, the galaxy cluster MS1358 has been analyzed and its dark matter halo mapped through strong lensing. The mass map fit was computed by using basis functions at the images and then using direct matrix inversion to find their magnitudes as implemented in the LensPerfect software written by Coe et al. The resulting mass distribution has been fit to a radially decreasing profile and some attempt has been made to quantify its substructure. The results of the mass map fit can be compared to the results from simulations to check for the validity of current theories concerning dark matter.

Fine-Tuning the Command and Data Storage Unit 2

The performance of the Mars Science Laboratory (MSL) Terminal Descent Sensor (TDS) must be verified against requirements, and the CDSU2 is essential to the verification process. As the name implies, the CDSU2 stores device data and relays telemetry and user commands. All of this functionality necessitates a complex software architecture involving modified device drivers, custom user-interfaces, and frequent TCP/IP communication. Additionally, the Unix-based operating system must be carefully managed in order to avoid catastrophic system failure. The CDSU2 is currently in its final phases of development, and the team is confident that it will be ready for the upcoming Mini China Lake Field Test, the first of numerous field tests to verify TDS performance.

Determining the Efficiency of the Mars Science Laboratory (MSL) Rover's Sample Acquisition and Sample Processing and Handling (SASPaH) Subsystem

The primary operation of the Sample Acquisition and Sample Processing and Handling (SASPaH) subsystem, as used by the Mars Science Laboratory (MSL) rover, is to acquire samples from the interior of Martian rocks through the use of a percussive drill, which is attached to the rover's robotic arm. The drill mechanism bores a hole into the rock and then transfers the ground rock sample to the rover's analytical instruments. This paper will discuss two development tests run on the drill in order to determine the efficiency of the assembly design at transferring sample with minimal contamination. By comparing the mass of the original sample to the mass of the sample collected after passing through the assembly, it can be determined how efficient the drill is at collecting and transporting usable samples. The contamination of the sample, due to the sample acquisition process, can be determined by running multiple sample transfer cycles through a model of the drill assembly using samples with different bond lengths. The process of X-ray diffraction is then used to determine the amount of contamination in the final sample. The results of these development tests will determine what changes, if any, are necessary to fulfill SASPaH's flight requirements.

HyspIRI Science Data Distribution and Archive Architecture

The Hyperspectral Infrared Imager [HyspIRI] Mission is one for the top ten missions described in Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (National Research Council, The National Academies Press, 2007). HyspIRI consists of two instruments with a combined raw data collection rate that exceeds 2 TB/day and nearly 2 PB/year. The raw data ingest rate alone would increase the current Earth Observing System Data and Information System daily archive growth by 57%, not including the storage of science products. The HyspIRI Adaptive Data Processing System [HIIAPS] is a student-proposed data processing architecture based on

the MODIS Adaptive Data Processing System [MODAPS]. HIIAPS would handle the challenge of archiving, processing, and distributing such an immense amount of data while keeping costs low. The paper also covers the issues encountered in reaching scientists and decision makers unfamiliar with remote sensing data. This is a part of a larger work entitled End-to-End Data System Design for the HyspIRI Mission, a student-led investigation concerning the HyspIRI mission currently being studied by Team X at the Jet Propulsion Laboratory of the California Institute of Technology.

Aeolian (Wind-Blown) Processes on Earth and Mars: Analysis Through Wind Tunnel Experiments

Aeolian processes are the primary erosional force on Mars under current climatic conditions. This project seeks to determine the kinetic energy that is transferred from saltating basaltic sand to a basaltic target rock upon impact under different environmental conditions. These objectives were executed by performing wind tunnel experiments at the NASA/Ames Research Center Planetary Aeolian Facility. The experiments were conducted at terrestrial conditions (STP at wind speeds of 5.5 and 11 m/s) and Martian conditions (10 mbar at wind speeds of 30 and 60 m/s), with the target rock oriented at 6 different angles (0, 15, 30, 45, 60, and 90 degrees to the horizontal). The experiments were recorded with high-speed video, transferred to VHS, and viewed with Motion Analysis software. Individual grain trajectories were documented. From these data, the numerical modeling of velocities and the restitution coefficient will be manually calculated, providing the information necessary to compute the kinetic energy lost upon impact and transferred into the rock. Previous studies with quartz grains showed the kinetic energy loss is proportional to the target angle, with a greater amount of energy going into steep faces. This project will provide an improved understanding of the primary erosional force on Mars.

Process Automation Software Development: Issues, Solutions, and Consequences in the Modern Working Environment

As collaborative efforts increase linearly in required workforce, communication overhead increases much more rapidly, both in volume and complexity. For the Cassini project, this overhead typically involves gathering data across various systems and checking its consistency, certifying results via administrative forms, ensuring adherence to established interface protocols, and distributing and processing bulk notifications. Since such mundane processes usually exhibit simple, repetitive structures, they are prime candidates for automation with custom software. Automation frees time for more substantial work, boosts productivity, reduces operating costs, increases the accuracy of inspections, and reduces human input errors. Care must be taken in undertaking software process

automation, however, to prevent over- or under-engineering that may end up wasting time by producing unmanageable, inflexible, or outright useless software.

The Extension of the Data Reduction Manager (DRM) to Support Spectrum Reduction

Dr. Glenn Orton and his colleagues in the Earth and Planetary Atmospheres Group at the Jet Propulsion Laboratory study the structure and composition of the atmospheres of Jupiter, Saturn, Uranus, and Neptune. In the course of this work, they have made mid-infrared observations of Jupiter and Saturn from the COMICS spectrometer on the Subaru Telescope. These data include some of the first ground-based spectra of planets to come from large (8-m class) telescopes with high spatial resolution and will provide information about the abundances of gasses such as methane and ethane in the atmospheres of Jupiter and Saturn. Before these important data can be analyzed, however, the spectra must be reduced. Partial support for the reduction of COMICS spectra has been added to the Data Reduction Manager (DRM), a GUI-based code that Dr. Orton and his team use for the routine reduction of astronomical data. This support includes facilities for preprocessing the data and for preparing the dark and flat images needed for the reduction of spectra. The ultimate purpose of this work is to provide full support for COMICS spectrum reduction for DRM.

C++ Implementation of Active Optics Elements Interface

Prior research in the field of free-space Optical Communications shows that use of active optics elements such as deformable mirrors or spatial light modulators for compensation of aberrated optical systems will help test precision re-collimation. Signal distortions on a laser beam traversing the optical system can be captured as an image using a wavefront sensor, which is an input to the program interface. The goal is to correct this signal from the input and encode instructions to the output device in real time. The program should interface the devices, which requires modifying the data format from input to output. A high-speed algorithm computes resolution dimensions and specifications for the image. Open Graphics Library loads the image from power of two resolution into the source formatting desired. A 24-bit bitmap is formatted for the spatial light modulator, which reads these as instructions and corrects the laser beam path. After further testing, converting the input format for the program, and setting the format for output will complete the software interface.

Automatic Image Position Offset Correction and Annotation of International Space Station EarthKAM Images

For over a decade, EarthKAM (Earth Knowledge Acquired by Middle school students) has been taking cloud-free images of the Earth from the International Space Station to provide to middle school and high school students to enhance student interest in space exploration and technology. However, the method by which these images are currently annotated is a completely manual process that is both time consuming and inconsistent. The objective of the summer work is to correct for systematic image position offsets using cartographic software that is capable of aligning images using geographically interesting features to serve as control points. Additionally, the work entails creating an automated process to annotate the images using coordinate data from the GeoNames database, which contains data for geographic features such as lakes, cities, and mountains throughout the globe. Image software such as ImageMagick will also be used to assist in the process of actually labeling the geographic features of the EarthKAM images.

Thin Films for Use in UV Detector Design

A typical CCD will absorb any ultraviolet (UV) light that impinges on it. How then does one make a CCD-based detector for a telescope designed to look at the universe in UV wavelengths? Thin films offer a solution. By modifying a standard silicon CCD using delta-doping (~25 Angstroms of highly doped silicon) and adding layers of various materials (MgO, MgF, etc. in thicknesses of a few hundred Angstroms), it is possible to increase the transmission of UV light into a detector up to nearly 75%. Contrast this with micro-channel plates (another option for detectors in the UV), which have at best a quantum efficiency of only 5%. My summer work has focused on thin film deposition techniques, and in constructing a vacuum chamber to characterize their reflectance. Theoretical predictions indicate that the transmission in the UV will be greatly boosted, and the films should present low reflectance when tested. We hope to confirm this and make recommendations for optimizing delta-doped CCDs for use in the UV.

Temperature Dependence of Microbial Growth of Greenland Ice Core Isolates

As part of the characterization of ten strains of Clostridium—recently isolated from ice core samples from the Greenland ice sheet—a growth rate analysis, including the temperature dependence, was performed on each strain. Growth was measured by optical density at 630nm—methodology validated by microscopy of representative samples. The doubling times were calculated using exponential regression to fit the data. Ideal growth temperature was determined by considering which temperature minimized the doubling time, reached the highest maximum optical density, and gave the shortest lag phase. Ideal growth temperature fell between 37°C and 45°C for most of the strains, depending on

how the criteria were weighted. For all of the isolated strains, tolerable temperature ranges—temperatures at which there was appreciable growth in the period of a month—were from 18°C to 45°C for these strains. Knowledge of the ideal growth temperatures of these strains will be used in experiments requiring sub-optimal growth temperatures as a possible condition for sporulation. This project is also part of a larger project to quantify probability of growth in Mars special region conditions.

Data Handling System Design for a Hyperspectral Imaging Mission

Due to advances in imaging spectrometry, future Earth science spectrometry missions will generate increasingly large amounts of data. A feasible data handling system design was created for a large data volume Earth-observing mission carrying two spectrometers. Focus areas included reducing the downlink data volume through cloud detection and compression, downlink communications options, and ground-based data handling. The cloud detection algorithm and its relation to the compression scheme are presented. More advanced pixel classification schemes were also considered, which could allow the spacecraft to autonomously detect disturbance events such as volcanic eruptions. Additionally, the impact on the attitude control system of slewing to increase the observation of these events are presented. These results are presented as part of a larger work entitled End-to-End Data System Design for the HypsIRI Mission.

Baseline Effects on Interferometric Maps Using UAVSAR Data

The Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) project is based around an L-band SAR that has been designed to collect data through two different transmission modes, polarimetric interferometry and polarimetric tomography. By collecting tomographic data, it is possible to get detailed information of the vertical structure of a forest, which can lead to more accurate biomass calculations. These biomass calculations can determine the carbon content of the observed forest. However, since SAR tomography relies on different baselines, the effects that these variations have on the correlation between the interferometric pairs must be studied. Using recently gathered data, this paper analyzes the relationship between the theoretical correlation parameters and how these parameters affected the acquired UAVSAR data.

Terahertz-Wave Imaging for Through-Clothes Concealed Weapons Detection

Concealed weapons detection at standoff ranges of 4 and 25 meters has been demonstrated by Siegel et. al. using a submillimeter-wave frequency modulated continuous-wave (FMCW) radar operating at 576–605 GHz. The present system is capable of imaging a torso with 1 cm lateral resolution in about five minutes. As the technology advances, fast, high-quality image processing algorithms will be necessary to achieve near real-time refresh rates. Imaging for weapons detection generally demands that the body of an imaged target be made as smooth as possible so that concealed objects are not lost in surface imperfections. One of the challenges in performing a heavy background blur is ensuring that foreground objects are not smoothed over and lost. Since most foreground objects hidden on a smooth surface such as skin will exhibit a steep slope at the object's edge, I show experimentally that a Sobel gradient can be used to detect the edges of a concealed weapon. I also demonstrate how the gradient can be used to create a map of different image regions using dilation and erosion, which can be smoothed independently to ensure a heavy background blur with a minimal effect on the contrast of foreground objects.

Automated Preload Optimization for an Ultrasonic/Sonic Driller/Corer

The Ultrasonic/Sonic Driller/Corer (USDC) consists of three main parts: an ultrasonic transducer (piezoelectric stack, a backing element, and a horn), a free-mass, and a drill bit. The vibrations of the horn tip excite the freemass, causing it to bounce between the horn tip and the top of the drill bit. The USDC requires some preload while drilling. There is a relationship between how much preload applied and how often the free mass bounces. A closedloop program setup that samples and analyzes the current going through the USDC can control a voice coil, which applies the optimal preload. Every time the free-mass hits the horn, there is a sudden decrease in the current. This program adjusts the preload until the number of impacts per second of the free-mass is at the most efficient average. If there is too much preload, then the impacts are too frequent and do not have as much power in each impact. If there is not enough preload, then there are fewer impacts, which mean the USDC is wasting energy by being in resonance without impacting. Therefore, there is an optimal preload where impacts occur just as the USDC reaches resonance.

Safety Assessment of Landing Site Selection for the Mars Science Laboratory (MSL)

The radar on the Mars Science Laboratory (MSL) rover entry, descent, and landing (EDL) system has constraints regarding surface topography at different length scales (baselines). As an example, engineers have put an upper limit of ~40 meter elevation change on the landing ellipse at a baseline of 900 meters. Relief above ~40 meters could potentially be dangerous to MSL at this baseline, and rover safety is an important variable in selecting a landing site. I created elevation and relief maps containing data from the Mars Orbiter Laser Altimeter (MOLA) that display relief at 300, 600, 900, 1200, 1500, 1800 and 2100 meter baselines. Raw MOLA data are converted into elevation maps through GIS programs: ArcMap and ArcCatalog. The slopes are color coded from 0 to 40 (green), 40 to 80 (yellow), 80 to 120 (orange) and 120 and above (red) in order to make quick comparisons between different sites. The MOLA elevation and relief data were also used to generate statistics about the topography for each site. The maps and statistics will assist the team of scientists that will decide the future destination of MSL on Mars. MOLA data is considered to be the most accurate topographic data, so other data, such as HiRISE digital elevation models (DEMs), will be checked against it for accuracy

Rehearsal: Lightweight Rover Mission Simulator

This project, titled Rehearsal, focuses on developing a method for the testing and development of Maestro, the award-winning ground software tool that Mars Exploration Rover (MER) scientists utilize to plan the day-to-day operations of the MER robots. Rehearsal aims to simulate all aspects of this planning cycle, keeping Maestro unaware that it is not interfacing with a virtual rover. This simulation will allow for valuable testing of Maestro at a time when the real robots are undeployed and unable to provide test data. To implement Rehearsal, a virtual rover has been created complete with a virtual martian environment and set of executable commands similar to those used by the MER rovers. Rehearsal is more than a rover simulation, though; Rehearsal contains functionality allowing it to receive plans constructed by Maestro. Rehearsal is capable of sending the results of those plans back in a fashion mirroring the way MER data products are sent back, keeping Maestro 'in the dark' to the fact that it is interfacing with a simulation. The fact that Maestro is unaware that it is dealing with a simulation paired with Rehearsal’s mimicry of the MER processes makes the testing that will be done with Rehearsal highly valuable.

Error Analysis of Spatial and Spectral Data From Imaging Spectrometers

Imaging spectrometers can produce an abundant amount of spatial and spectral data of a given scene, which is useful for a variety of applications that require the identification of the chemical composition of a surface. In order to fully understand the data, it is necessary to diagnose the errors inherit in the process of acquiring the spatial and spectral data. These errors may originate from photon noise from external sources, or flaws within the instrument design. On MATLAB, simulated data from a computed tomography imaging spectrometer (CTIS) was used to investigate errors in spatial and spectral data. The results of this project will provide a better method of interpreting the data and evaluating the performance of imaging spectrometers. This will be beneficial to a variety of JPL missions, such as the Mars Reconnaissance Orbiter (MRO), AVIRIS (airborne earth observer), and the Moon Mineralogy Mapper.

Low-Frequency Vibration Isolation Platform

Deep space optical communications satellites must have a stable platform to transmit data. Due to the noisy environment of spacecrafts, it is necessary to attenuate high-frequency vibrations from the control thrusters, reaction wheels or any other types of perturbation. To attenuate high-frequency vibrations, a spring for a sub-hertz mechanical oscillator that behaves as a second-order low pass filter was designed and tested. The spring had to have two important qualities, the first of which being that it had to be as small as possible while demonstrating the ability to perform. Second, the spring had to have a stiffness to produce a resonance frequency less than half a hertz to obtain the required attenuation properties. A solid model of the spring was designed and modeled using a finite elements of analysis program to study problems such as stress concentrations, spring constants, fatigue failures, buckling, and harmonic resonance modes. After modeling, the spring was prototyped and will be tested to validate the simulations to determine its properties and verify its ability to provide the required vibration attenuation.

Team X: Prototyping a CDS Subsystem Design Tool Upgrade

As hundreds of millions of dollars are spent on projects like Phoenix and Mars Science Laboratory (MSL), it becomes increasingly important to deliver accurate cost assessments of future missions in the earliest phases of design. The Jet Propulsion Laboratory's Team X functions to create rapid designs and cost estimates of future and potential missions for customers in a critical early design period. As missions evolve and become increasingly complex, the capabilities of each subsystem's design tool must evolve to facilitate these increasingly complex designs. Through extensive use by the

Flight Systems Avionics Section, limitations in the current command and data subsystem (CDS)—like the restriction to multi-mission support, complicated debugging, detached databases, and cost-model shortcomings—will be addressed through the prototyping of a new CDS design tool. Maintaining integration with all of Team X is paramount so data inflows and outflow will be left unchanged. The tool will remain in Excel format. The new CDS design tool will have a highly simplified new architecture, expediting the process of adding additional capabilities and debugging in future generations of the CDS design tool.

Full-Dome Planetarium Presentation of STEREO

An important part of part of the work done at JPL is to make the results of various missions available to the public. My research will allow the public to experience the results from the Solar TErrestrial RElations Observatory (STEREO) mission, which studied the sun in new and exciting ways. It is a vital component of scientific research to communicate it to others and find new ways to bring the information to people. Development of a full-dome planetarium presentation with the STEREO mission data will make it possible for scientists and the public alike to experience the Solar System and the Sun in new and exciting ways. This paper details the process of creating a DigitalSky2 planetarium presentation using STEREO sun images, video sequences, and 3-D models of the two STEREO spacecrafts.

Statistical Modeling of Discrete Features on Jupiter

My project for this summer was to develop programming tools in order to perform Principal Components Analysis (PCA) on discrete features on Jupiter and to examine how well PCA can reproduce its results as white noise is added to it. To do this, I wrote a program using the statistical programming language R, which adds computer simulated white noise in various percentages to data sets containing the Great Red Spot, The Little Red Spot, the Northern Temperate Belt Outbreak, and a featureless region of Jupiter. Then I ran PCA on each of those different cases and compared the results to the original data. This comparison showed that although PCA tends to reveal thesame trends for lower amounts of white noise, it reverses these trends as higher percentages of white noise are added. Also, I examined whether it is possible to use PCA as a compression method in order to remove the white noise. I wrote a program to do this and compared that to the white noise–added data as well as the original data and found that, although it is impossible to use PCA as a compression method in order to get the same pre-white noise–added data back, it is possible to use the compression method to get closer results to the original data then the white noise added data.

Electron Density in the Solar Corona From the Cassini 2006 Solar Corona Experiment

The Radio Science Systems Group at NASA's Jet Propulsion Laboratory measured frequency fluctuations in S-band, X-band, and Ka-band signals as the ray path transmitted from the Cassini spacecraft and received by the Deep Space Network passed through the solar corona. Although range and range-rate (Doppler) observations are available, only the range-rate or phase velocity data are available at two wavelengths (e.g., S- and X-bands). The observed frequency fluctuations are used to determine the change in total electrons. This dual-frequency Doppler data is used to determine the change in electron density along the columnar signal path as a function of solar offset from a heliocentric reference point. The year 2006 is near–solar minimum in the 11-year solar cycle.

Deep Impact Flyby Spacecraft Fault Protection Parameter Gathering

The Deep Impact flyby spacecraft has several thousand fault protection parameters that monitor the state of the spacecraft. These parameters rarely change, but when they do they are not tracked or documented. On February 17, 2008, the spacecraft entered safe mode because several of the fault protection parameter values were inconsistent with spacecraft team expectations. Tools to track these parameters could prevent future events. This task is challenging because few engineers understand how the fault protection system works. There are 4303 parameters on board the spacecraft, requiring 52 sequences totaling 4526 commands to telemeter them all from the spacecraft. A sequence of this magnitude has never been developed before and the commands have never been used in this manner. Tools to automatically generate sequences from flight software code and process the downlinked telemetry have been developed. Large parameters were partitioned to fit in the fixed-size telemetry packet. Numerous executions of these sequences were required for debugging and testing on the Deep Impact test bench. The spacing between commands was adjusted to ensure the parameter downlink would be able to run in parallel with science images. Ground tools have also been developed to reassemble parameter data from hexadecimal packet dumps and stored to display their values in a database. The process for getting parameters from the spacecraft and updating the database on the ground is easily repeatable and has been fully documented for the spacecraft team.

Modeling Radiative Transfer in Protoplanetary Disks

The characteristics of bodies in a given planetary system depend on the protoplanetary disk from which they form. Understanding planets and their formation requires observing such protoplanetary disks and modeling their behavior. This task is complex, since chemical and thermal processes are involved. Also, the disk is generally not in local thermodynamic equilibrium (LTE). A program has already been developed that can accurately simulate radiative transfer of water rotational excitation in comets. The program uses a standard internal model for these processes and produces a map of emission from the disk, including dust emission and absorption. It also accounts for the fact that the gas and dust in the disk are not in LTE. Using a Monte Carlo simulation, the program is able to generate outputs of spectra and temperature profiles comparable with infrared measurements made by deep space telescopes. Modeling protoplanetary disks requires adapting code used in the comet model to fit in with basic geometry, absorption by dust, and the rudiments of non-LTE source functions. The successful implementations of such numerical models assist with a larger JPL effort as a means to understand the origins of the solar system.

Plasma Characterization and Analysis of High-Frequency Oscillations in the Xenon Ion Propulsion System Neutralizer Cathode

Ion thrusters are a highly efficient form of space propulsion that rely on the emission of heavy atoms at high speeds to produce thrust. Because of their small level of thrust, ion engines are often used for deep space propulsion, requiring them to remain operating for extremely long periods of time. There are several modes of failure present in modern thrusters that prevent them from reaching their full lifespan potential. Understanding the failure modes requires a combination of theoretical modeling of the effects of the plasma on the thruster components along with actual experimental life tests. By comparing the acquired life test data to the predictive models, failures can be diagnosed and changes made to the thruster design to optimize longevity. An array of plasma diagnostic measurements was taken to fully characterize the Xenon Ion Propulsion System [XIPS] cathode in order to prepare it for life testing and also for use in current modeling efforts. Furthermore, it has been observed that ion thrusters express strong, high-frequency oscillations in the potential of the plasma at certain operating conditions, and the effects of these oscillations were explored in order to determine their implications on the plasma properties used for this characterization and future modeling efforts.

A Model of Titan's Atmosphere

The Cassini Huygens Probe, which descended into Titan's atmosphere, directly measured temperature and pressure from the surface of Titan to a height of 160 km in the atmosphere. From 160 km to 1500 km above the surface, density measurements were derived from an accelerometer. This project concentrated on generating temperature and pressure profiles of Titan's atmosphere from existing Cassini Huygens Atmospheric Science Instrument (HASI) and Composite Infrared Spectrometer (CIRS) data. This atmospheric model, based on the condition of hydrostatic equilibrium and the ideal gas law, utilizes the barometric formula in which temperature is considered a variable. Differences between observed atmospheric pressure and the atmospheric model can be used to determine if there is a variation from the ideal gas law dependent upon height. Further modeling can also be used to yield the mole fractions of the atmosphere constituents, including scattering particles thought to be very high molecular weight hydrocarbons or nitriles made from CH4 and N2. The density of these particles, which scatter radiation, is responsible for the reflective characteristics of Titan's atmosphere. Future results could be used to constrain models of heat transfer through Titan's atmosphere.

Automated Generation and Optimization of the OT-MACH Filter for Pattern Recognition in Image Analysis

An automatic OT-MACH (an optimal trade-off MACH) filter generator for use as an optical correlator has been developed for improved target detection at JPL. The OT-MACH filter has been shown to serve as a near-theoretical optimal filter for target detection, but actually finding that maximum is too laborious to attempt for every type of training target. Instead, various gradient descent methods were attempted as iterative approaches of setting the three parameters—a, ß, and .—to maximize the performance measures, correlation peak heights and peak-to-side lobe ratios of known target locations in test images. This automated method creates and tests multiple filters in order to approach the optimal filter more quickly and more reliably than the current manual generation method used. Initial usage and testing has shown preliminary success at finding the correct region of the optimal filter (in terms of a, ß, . values), but further direct testing is needed to quantify how well this automatic filter generator method works.

Long-Term Climate Change Trends in Coastal California Sea Surface Temperature and Mean Sea Level
Data

Global climate change has an immense effect on the world's oceans, as they absorb a large proportion of the solar energy captured by the atmosphere. Can these heating impacts be seen in local coastal waters? To answer this question, we analyzed the longest records of mean sea level (MSL) and surface temperature (SST) available, data from Pacific Grove and La Jolla, California. We found significant heating trends, some unexpected, that have had a large impact on California's coastal waters. The average heating trend for California's coast matches the global average, of approximately 1.0°C (1.8°F) over the last century. Instances of extremes also increased, with higher temperatures increasing in frequency and intensity, and lower temperatures becoming less common. The seasonal cycle has been altered, with fall and spring being much hotter now than in the early 20th century. These trends in SST are also related to the troubling effect of oceanic thermal expansion on MSL trends. Comparing annual sea level averages with average temperatures, a growing disparity between SST and MSL curves can be observed. MSL is increasing at a higher rate than SST, especially post-1950. Further research is needed to explain the causes of these interesting seasonal and decadal trends.

An Information-Based Adaptive Area Search Method

Isotropic sensors are often the exception rather than the rule for autonomous vehicles. Motivated by the challenges of path planning with range-limited non-isotropic sensors, this paper considers path planning for autonomous vehicles. These sensors collect information about objects of interest at rates that depend on the range to the objects. The mission of the vehicles is to travel through a given area and collect a specified amount of information about each object of interest while minimizing the total mission time. This information can then be used to classify the objects of interest. An optimal path planning problem is formulated where the states are the Cartesian coordinates of the vehicles and the amounts of information collected about each object of interest, the objective function is the total mission time, and the boundary conditions are subject to inequality constraints that reflect the requirements of information collection. Necessary conditions for optimality are given, whose solutions yield extremal paths, and whose utilization highlights analytical properties of these extremal paths. A generic nonisotropic sensor model with specific examples is provided. An optimization method is used to find families of optimal paths, and these paths are used to derive methods to quickly find optimal paths in unknown areas. These methods are tested on several simulation platforms and the results are illustrated.

The Use of GPU Shaders for Rendering Large-Scale Terrains

Terrain rendering is vital for the simulation of Mars, Moon and other planetary bodies. With current implementations, performance suffers because most of the work done for rendering is performed by the CPU. With the relatively new GPU architecture, we use GPU shaders to perform calculations determining height, position and texture of points to be rendered, significantly reducing the load from the CPU. This implementation is further improved by attempting only to render those points that are required by the simulation at any given time to reduce the rendering load. Furthermore, the on-demand loading of data allows the algorithm to work with the limited memory available on GPUs. Our work involves improvements to the current implementation to allow its use with terrains potentially as large as all of Mars. Future work includes addition of details such as shadows and use of a spherical planet instead of a flat world.

Simulation of Walking Stability in a Passive Dynamic Biped Traversing Rough Terrain

Legged locomotion has potential advantages over wheeled locomotion for dexterity and mobility in traversing rough terrain. However, most current humanoid robots are much less power efficient than animals or wheeled vehicles. Studies with passive dynamic walkers powered by gravity alone have proven that minimal actuation is required to sustain walking, implying that more efficient platforms are feasible. However, current passive dynamic bipeds are unstable in rough terrain and topple easily. To improve dynamic balancing in bipeds, we modeled a simple 2D biped and trained a neural network to predict the walking trajectory. We augmented current 2D passive dynamic anthropomorphic models to include noisy, rough terrain by adding robust ground contact detection. Once we were able to model random rough terrain, we implemented a cerebellum-inspired neural network to perform Dynamic State Estimation to predict falls in advance, using both Hebbian and reinforcement learning. Once the network was trained, we compared the variance of rough terrain from the ideal slope to the neural network's ability to predict a fall several steps in advance. This should lead to future control systems that improve dynamic balancing during biped locomotion.

Determining the Rotational Period of Asteroid 1564 Srbija Through Light Curve Analysis

We imaged asteroid 1564 Srbija for three nights in the month of July 2008 using a remote connection to a private observatory in Idyllwild, California. The equipment used was a Ritchey-Chrétien 12.5" scope on a Paramount with a SBIG STL11000M camera. CCD Autopilot was used to automate the whole system to run robotically throughout the night. Red filter 2x2 binned exposures of the asteroid began as it rose 35 degrees above the horizon and continued throughout the night until 4:00 a.m., except when the telescope

slewed to SA112 Landolt field standard stars for calibrating exposures. After flat fielding and dark subtraction, the MPO Canopus software will be used to analyze the magnitude change over the course of the evening, revealing information about the shape of the asteroid, its rotational period, and possibly its composition. Additional data will be secured in August using the JPL Table Mountain Observatory 0.6 m telescope with an LN2-cooled camera.

A User Interface System for the Technical Inventory Management Group

The objective of the Technical Inventory Management (TIM) Group is to assist projects, programs, and divisions at the Jet Propulsion Laboratory by reducing material cost, lead-time, and risk by providing material, information, and support during the entire project life cycle. This research develops user interfaces that support ensuring usability and accessibility of the inventory. Firstly, a system functionality list was assembled indicating the needs of the users. The current system and functions were analyzed through interviews with customers and personnel. Secondly, information architecture, prototyping and graphic interface designs were developed. Finally, usability testing was conducted to evaluate how well the design supports the effectiveness, efficiency, and user satisfaction. Qualitative and quantitative data indicated that the system provides successful human-computer interaction.

Weak Lensing and Measurements of Multiband Galaxy Morphologies

Weak gravitational lensing, a consequence of general relativity, is a result by which gravitational fields of large, intervening matter distributions distort the images of background objects such as galaxies. The effect known as cosmic shear appears as tidally distorted images at the periphery of such large mass distributions. Our novel method of extracting useful shear signals from multicolor data sets requires an accurate and unbiased means of galaxy shape measurement. We generated sheared, multi-color images of galaxy fields in the B, V, I, Z, J and H bands by using simulations of the Hubble Ultra Deep Field (constructed via the polar shapelets method) and systematically catalogued the unique objects appearing across the bands. Combining shape measurements in different color bands allowed us to reduce systematic measurement errors, increase the overall signal-to-noise ratio of our measurements, improve our understanding of intrinsic scatter of galaxy shapes and minimize complications introduced by the telescope's point spread function. By measuring second-order weighted moments and ellipticities of these galaxies, we quantified correlations between galaxy shapes across different colors and obtained number counts of usable objects in each band.

Reliability Testing of the Small-Signal SiC JFET for Venus Mission

NASA's future exploration plans include missions to Venus. Extremely high temperatures, approximately 460°C, and crushing atmospheric pressure make a 90-hour surface mission impossible with current electronics. The principal objective of this project is to evaluate the reliability of SiC technology, a technology that could allow future electronics to withstand Venus's environment and make such a mission possible. This will be done by characterizing and performing reliability testing on small-signal SiC junction gate field-effect transistors (JFETs) up to 500°C. A number of SiC small-signal JFETs with 5V operating voltages are to be investigated. Characterization of these devices will be performed at the following temperatures: 25°C, 100°C, 200°C, 300°C, 400°C, and 500°C. When the temperature reaches 500°C, or the maximum temperature for the test, the devices are stressed while either forward or reverse biased for up to 300 hours. Characterization also occurs during the stressing, but at predefined time intervals. This data allows us to monitor the degradation of the small-signal SiC JFET under these conditions with respect to time, ultimately allowing us to determine the capabilities of this technology for a Venus mission.

Use of Lanthanide-Macrocycle Platforms for the Detection of Dipicolinate and Other Analytes

We are investigating the enhancement of sensitized lanthanide luminescence using macrocyclic ligands for the detection of various analytes. These analytes include any aromatic anions that coordinate to lanthanide(III) cations and can participate in energy transfer to the lanthanide following UV excitation. A prime candidate for this detection scheme is dipicolinic acid, or DPA, a unique biomarker found at high concentrations in bacterial spores. As one of the most robust forms of life, bacterial spores are of great interest in fields ranging from detection of biological agents (i.e., anthrax) to Mars exploration, where the need for efficient and rapid detection is critical. Using a macrocyclic ligand DO2A (1,4,7,10-tetraazacyclododecane-1,7-diacetate), we have observed enhanced affinity for DPA by two orders of magnitude over Tb^{3+} alone. By constructing similar receptor sites that increase the sensitivity and selectivity of the method, we are developing lanthanide-chelator systems for the detection other analytes, such as dopamine, epinephrine, and salicylic acid (SA), which have applications in medicine and life detection.

Helioseismology: Studying Waves on the Sun

Helioseismology is the study of waves (similar to sound waves) that travel within the sun. These waves are detected as Doppler shifts in absorption lines in the spectrum of the sun. While much of the research in helioseismology has been concerned with understanding the internal structure of the sun, recently interest has focused on understanding the structure of the low solar atmosphere. We are developing instruments that will allow us to examine these waves at different altitudes in the sun's atmosphere. I will describe some of the work being done on one of these instruments, which is intended to measure both Doppler shifts and magnetic fields in the sun's chromosphere using light absorbed by helium around 1083nm.

Using Fractal Interpolation to Enhance Resolution of Terrain Data

At the Jet Propulsion Laboratory's Dynamics and Real Time Simulation (DARTS) lab, one of our jobs is to simulate the dynamics of moving a rover on its target planet. DARTS lab has developed a middleware toolkit called SimScape in order to represent terrain elevation data. Terrain elevation data from satellites and rovers may only be at a resolution of a few dozen meters or more. Unfortunately, we cannot do real dynamics simulations with terrain data at such a high resolution because accurate simulations require data with resolution on the order of the length of the rover's wheels. Hence, we must employ a fractal interpolation algorithm called Diamonds and Squares to generate more data and enhance the resolution of the terrain. My job is to make this algorithm work for large terrains well over the 4 gigabytes of memory available in the DARTS lab computers by breaking the data up into tiles and storing each tile onto the hard drive using HDF5 stores. HDF5 is a software library commonly used to store data. These stores on the hard drive will be loaded on demand using a lazy loading system so that only small parts of the data are loaded in memory at any given time. A recursive algorithm has been developed so that enhancing the largest data sets we need takes a few dozen hours.

Demonstrating Capabilities of ISAAC (Instrument ShAred Artifact for Computing)

ISAAC (Instrument ShAred Artifact for Computing) is a research and technology development project whose objective is to provide an FPGA (field-programmable gate array)-based computing and control platform that will control a variety of onboard instruments ranging from imagers and radar to radiometers. There are six sub-parts that make up ISAAC (iBench, iCore, iPackage, iBus, iBoard, iTool), each performing separate tasks. The objectives for this summer are to assist the engineers who are working with the iCore and iPackage sub-parts. iCore is a subpart that holds the library of RTL (Register-Transfer-Level) codes and is reconfigurable depending on the specific instrument. The task for iCore is to help with the verification, validation and resourceusage estimations. iPackage includes a branch called iPanel; its purpose is a

high-level interface in which the user will be able to gather telemetry from the instruments. The task for iPanel is to create the GUI (graphical user interfaces) in Python that will display telemetry from the instruments and to serve as a command console for the user to send instructions to the instruments. Another task for iPackage is to put together a demonstration for the FPGA computer platform, which includes the capability to gather telemetry from an I2C (inter-integrated circuit)thermal sensor and UART (universal asynchronous receiver/transmitter) motor.

Spitzer IRS Analysis of Neptune

Recent (2005) Spitzer Infrared Spectrometer (IRS) data of Neptune between 5 and 20 μm contain a wealth of information about the chemical composition and temperature structure of Neptune's cold atmospheres. Emission features in its spectrum arise from many hydrocarbons—including ethane, acetylene and methane—and they appear to be superimposed on top of a collision-induced H2 continuum. As the derivation of all other parameters depends on the assumed temperature profile, a great deal of time was spent on fine-tuning the stratospheric profile between 1 bar and 0.3 mbar to match the H2 continuum and the H2 S(1) quadrupole feature at 17 μm.
Additionally we matched the methane .4 feature at 7.6 μm in order to constrain the stratospheric temperature profile above the 0.3-mbar level as well as the methane stratospheric volume mixing ratios (VMRs). After the determination of the temperature profile and methane VMRs, the VMRs for several species were then determined through fitting their corresponding features in the spectrum, initially by scaling existing photochemical models. These species include methylacetylene, diacetylene, benzene, acetylene, ethane, methyl radical and ethylene— which are all driven by methane photochemistry.

Reflection Nebula Emission Features From the Spitzer Infrared Spectrograph

Reflection nebulae are clouds of interstellar dust and gas that are close to stars that are bright, but not bright enough to ionize the gas. The absorbed light is reradiated at infrared wavelengths, making reflection nebulae an ideal target for study using the Infrared Spectrograph (IRS) instrument onboard the Spitzer Space Telescope. We study a series of broad emission bands between 3 and 20 μm, which are attributed to aromatic hydrocarbon fluorescence. Although these emission features have been studied extensively since their discovery in reflection nebulae 20 years ago, the nature of the emitting species is still not understood very well. We find evidence of possible C60 emission in two of the four nebulae observed, as well as striking overall similarities in the emission structures, which suggests that chemical processes in reflection nebulae may be less random than currently believed.

Phase Stability in the Ground Equipment for the Uplink Array

The uplink array uses three 34 meter antennas at the Goldstone site on Fort Erwin to communicate with spacecraft. So far, efforts have focused on combining the signal from the three antennas to increase the power of the transmitted signal. Some of these methods include using a phase modulator to apply a phase shift to the signal of one or more antennas so that a coherent signal arrives at the spacecraft. My research focuses on the stability of the ground equipment. This involves quantifying how the phase of a signal transmitted from the exciters to the antennas varies with temperature. This requires collecting data over a few to many hours during important changes of the day; for example a change from day time, when it is hot, to night time, when it cools down. Once the affect of temperature is known, the variations can be compensated for to further increase the transmitting power of the uplink array.

A Deep Sea Hydrothermal Vent Bio-Sampler for the Discovery and Understanding of Thermophilic Organisms

The hydrothermal vent bio-sampler (HVB) system aims to filter large volumes of untainted, pristine samples of hydrothermal vent fluid. This fluid is heated by underlying magma and spews forth out of the porous seafloor crust. The HVB system is designed to sample fluid temperatures approaching 400°C and vent depths of up to 6,500 meters. The vent fluid is filtered through a series of filters down to a pore size of 0.2 µm. These filters can later be extracted for lab analysis, with the objective of finding microbial life thriving in such a hostile environment. The project contributes to science in two ways. First, any life forms found living within the vent plume will help us identify the upper temperature limit for life and will greatly increase our understanding of how organisms survive in extreme environments. Secondly, the technology and techniques developed during this project can be applied to future missions searching for primitive life on planetary bodies such as Jupiter's moon Europa. A newly designed fluid-intake and temperature-sensing mechanism was added to the system and tested. Further field tests on the latest update to the system will be required.

Phoenix Animation Pipeline (Operations)

The Solar System Visualization (SSV) project has been tasked with generating imaging products for the Phoenix 2007 Mars Scout mission, both for scientific planning and analysis purposes and for public release. In order to increase the speed and variety of the imaging product output, certain steps in the pipeline from raw data to product release have been automated. One central focus in the improved information flow has been location data for named mission targets and features. A web interface has been

constructed to provide users interactive access to image products and accompanying target and feature data.

Development of Integrated Low Temperature Mechanisms for Next Generation Robotics Missions

Motor and gearbox systems are central to practically every robotics mission developed by the Jet Propulsion Laboratory. Currently, however, there is a substantial limitation to the use of these systems. Specifically, as robots are sent to places much colder than Earth, such as the surface of Mars, heat sources are necessary for them to operate properly. In turn, these require the use of power, which is often limited, yet essential to the functionality of other systems. Thus, an integrated motor and gearbox mechanism that can run without external heat at extremely low temperatures would greatly simplify and make more robust many of JPL's future missions. In fact, such a mechanism has recently been developed but not yet tested to characterize its performance. The testing of this mechanism is a complicated task, as it must operate in a thermal vacuum chamber at temperatures approaching absolute zero while allowing a rotary interface through the wall of the chamber. Moreover, a shaft must then connect with test equipment outside the chamber without allowing substantial heat transfer to occur. Such a setup has been developed, and successful test results will have positive implications on robotics missions at JPL for years to come.

A Model of Titan's Atmosphere

The Cassini Huygens Probe, which descended into Titan's atmosphere, directly measured temperature and pressure from the surface of Titan to a height of 160 km in the atmosphere. From 160 km to 1500 km above the surface, density measurements were derived from an accelerometer. This project concentrated on generating temperature and pressure profiles of Titan's atmosphere from existing Cassini Huygens Atmospheric Science Instrument (HASI) and Composite Infrared Spectrometer (CIRS) data. This atmospheric model, based on the condition of hydrostatic equilibrium and the ideal gas law, utilizes the barometric formula in which temperature is considered a variable. Differences between observed atmospheric pressure and the atmospheric model can be used to determine if there is a variation from the ideal gas law dependent upon height. Further modeling can also be used to yield the mole fractions of the atmosphere constituents, including scattering particles thought to be very high molecular weight hydrocarbons or nitriles made from CH4 and N2. The density of these particles, which scatter radiation, is responsible for the reflective characteristics of Titan's atmosphere. Future results could be used to constrain models of heat transfer through Titan's atmosphere.

Geothermal Testbed

The Geothermal Testbed is a chamber designed for simulation of the lunar regolith environment, intended as a facility to test extraterrestrial penetration methods and mechanisms for ultimately measuring planetary heat flow and thermo-physical properties of in-situ regolith. This testbed will replicate the estimated geothermal gradient in a regolith column designed to simulate the bulk mechanical and thermal properties of lunar and Mars regolith. The chamber is pumped down to <10 torr in order to match the thermal properties of regolith in low-pressure atmospheres; it is extremely well insulated, and it is held at constant temperature. This summer's work has encompassed the design, fabrication, and preliminary testing of the Geothermal Testbed. As the cooling system must be very precise, it utilizes a phase-change material (water) in place of a refrigerant to circulate the fluid at constant temperature. A refrigerator freezes water and drops the ice into a bath to be circulated around the chamber. This cools the chamber to the temperature of the water. To minimize parasitic losses that could disturb the subtle geothermal heat flow environment, a thermal control system surrounds the chamber. This passive structure is composed of a spray polyurethane foam (SPF) encased in a two-part wooden shell. Amalgamated, these parts will form the test chamber necessary to investigate the possible conduction of insitu measurements of heat-flow in lunar and Mars environments.

Magnetic Field Configurations for Miniature Ion Thrusters

As part of a collective effort to develop the technologies of the 3-cm Miniature Xenon Ion thruster, also known as MiXI, the present work has focused on issues surrounding ion production within the plasma discharge chamber. In ion thrusters, ions are created by the bombardment of neutrals with electrons from an electron source; thus in order to increase plasma production, the electron path length is extended with the interaction of magnetic field lines. Due to the change in surface-to-volume ratio associated with miniaturization, traditional magnetic field designs must be reevaluated for smaller thrusters. Different configurations of line and ring cusps were explored using the 3-D magnetic field solver packaged in COMSOL Multiphysics®. The design space explored various spacing and quantity of magnets. The magnetic field from one of the line cusp configurations was found to have the largest field-free region, and was therefore selected to test experimentally against existing ring cusp performance.

Characterization of IPC Effects on HgCaTe NIR Detectors

Our ability to detect and characterize dark matter structure is of the utmost importance for our understanding of the evolution of the universe. One particularly sensitive detection method is the use of weak gravitational lensing as a probe of gravitational effects caused by dark matter. Because weak lensing requires a high level of precision, the reduction of systematic errors caused by instruments is crucial. One such effect is inter-pixel capacitance (IPC), which is present in the HgCaTe near-infrared detectors that could be used in weak lensing surveys. IPC is the coupled capacitance between neighboring detector pixels that induces a "false" voltage reading that can mimic weak lensing signals. The IPC can be characterized by resetting voltages on individual pixels and analyzing the effect on neighboring pixels. Using obtained characterization parameters, a procedure was created for the addition of IPC effects to simulated images. Another procedure was created for the removal of these effects. More research will be required to further examine more detailed IPC effects and to modify the removal procedure so that it outputs an accurate reading of lensing signals in the hopes that it can be used in future weak lensing surveys.

Moulin Explorer: Investigating the Flow of Melt Water Through Glacier Mills in Greenland

In the past decade, there has been a noticeable increase of movements in the surface of ice sheets due to seasonal and short-term surface melting in Greenland. This surface melt water penetrates to the glacier beds through a narrow, tubular chute or crevasse, known as moulin, or glacier mill, which lubricates the glaciers and causes the movements in ice sheets. Two Moulin Explorers, one tethered and the other self-contained, are designed to better understand the characteristic effects of moulins. The tethered explorer, with its camcorders and light, provides stereo vision of the pathway. The self-contained explorer—with its accelerometer, pressure and temperature sensor, and GPS—provides insight into free falls, average pressure and temperature, as well as its location once it emerges in the ocean for pick up. While the former explorer is limited to a few kilometers, the latter explorer will travel the length of the moulin, providing a glimpse into the unexplored world beneath the glaciers. With the exploration of moulin environments, the Explorers prepare the way for studying icy bodies beyond Earth.

Galaxy Intrinsic Alignments in the COSMOS Survey: An Upper Limit on the Contamination of Weak Lensing Measurements

One of the assumptions used in weak lensing measurements is that galaxies do not have a preferential alignment. That is, the average eccentricity for a large field of galaxies is zero (circular). But we have reason to believe that galaxies are not randomly aligned due to an intrinsic alignment amongst neighboring galaxies. However, the degree to which this effect is present has never been well constrained. For this project, we take a catalog of more than one million galaxies from the Cosmological Evolution Survey (COSMOS) and extract all of their shape information. This is accomplished using sophisticated computer software to correct for contaminants, such as the point-spread function in the images, and to reconstruct the galaxies mathematically. Once we obtain the shape information, we show the magnitude of any correlation effect at different redshifts (distances). Even though we are currently unable to separate the alignment signal from the lensing signal in this study, we are able to place an upper limit on the magnitude and range of the intrinsic alignment effect. Further studies will be devoted to separating the two effects.

Lunar Composite Tweel™ Cold Temperature Performance

Planetary exploration on the moon and beyond will require surface mobility systems to allow exploration beyond the immediate area of landing sites. These surface mobility systems, both crewed and robotic, will be of a mass that will require the use of compliant wheels that mimic the properties of pneumatic elastomeric tires using spacegrade materials and without being inflated. The objective of this project was to subject a glass composite Tweel™ developed by Michelin to a battery of performance tests at cryogenic temperatures and under dynamic loading. For testing, a dynamic wheel loading apparatus built by Clemson University was adapted for use with a Sigma Systems thermal chamber and a drive motor from the All-Terrain Hex-Legged Extra-Terrestrial Explorer (ATHLETE) rover. The resulting testing rig measured temperature on the internal frame and Tweel™ as well as vertical load, contact patch displacement, Tweel™ velocity, and motor current. Performance tests subjected the Tweel™ to the chamber's full temperature range for several constant loads at maximum velocity; varying loads at minimum temperature and maximum velocity; varying velocities at minimum temperature and maximum load; and endurance at minimum temperature, maximum velocity, and maximum load. Results are pending, as completion of endurance testing may require several months of continuous testing.

Full-Dome Planetarium Presentation on the STEREO Mission

The implementation of the technologies and processes that make space missions possible is a crucial step in ensuring the success of a space mission. Equally important are the educational and community outreach programs that run before, during and after a NASA space mission, as such programs work to ensure the public's awareness and knowledge about NASA mission goals. The aim of this research is to use images and graphics from the solar mission Solar TErrestrial RElations Observatory (STEREO) in order to create a comprehensive, flexible full-dome planetarium presentation for use at the Glendale Community College Planetarium. Using DigitalSky planetarium software in conjunction with the Festival STEREO image-handling software, this research details the process of creating modular, flexible segments called "buttons" for use in planetarium presentations that detail images and sequences presenting goals, spacecrafts, and data related to the STEREO mission.

PyCraft: A Multibody System Dynamics Algorithm Workbench

Multibody systems dynamics modeling is used to analyze and predict the dynamical behavior of robotic, space, biomechanics and molecular systems. A major issue in modeling multibody systems is algorithm complexity, computational time and efficiency. The PyCraft algorithm workbench utilizes a new spatial operator algebra to allow for efficient and concise computation of the dynamical equations of motion and kinematic behavior of multibody systems. The numerical implementation of this spatial operator algebra simplifies the implementation and evaluation of multibody modeling and control algorithms that have been hitherto impractical for large systems.

Feed Forward Control Feasibility Study for SIM PlanetQuest Light Using Error Analysis Methods

The Space Interferometry Mission–PlanetQuest Light (SIM-PQL, or SIM-Lite) is a global astrometry mission to search for planets at nearby stars. To accomplish this requires high levels of accuracy, on the order of microseconds, in pointing position. The current system architecture includes guide and science interferometers and a telescopic guide two sensor to accurately conduct astrometry. A method of feed forward control from the guide interferometer to the science interferometer has been proposed to reduce cost of an additional feed-back pointing control system for the science interferometer. This study uses optical pointing models to gather error estimates using this feed forward control and draw conclusions into the feasibility of this proposed design. Various perturbation sources are explored to gain a full worst-case error budget for this application.

Facilitating the Export of Phoenix Images

This summer I focused primarily on the formatting and modification of images taken by the Phoenix lander to facilitate their release. The primary targets were images taken of the trenches and high-resolution images of the surrounding landscape. Besides making panoramic and zoom animations using the Shake program, I also created a website that will allow the user to easily manipulate a labeled panoramic image of the Phoenix landscape. Additionally, I worked on creating another web page that will allow users to create their own pans and zooms using Mars Reconnaissance Orbiter images without opening the Shake program. Both of these projects will be highly usable as they can be modified as the mission proceeds and still provide excellent methods for exporting mission data.

Analysis and Quantification of Ocean Radar Cross Section, SigmaNot, Versus Sea Surface Temperature and Ocean Wind Speed

The Cloud Profiling Radar (CPR), the principal instrument of the Cloudsat Mission, is a 94-GHz nadir-looking radar that measures the power backscattered by clouds as a function of distance from the radar. The quantity of interest, the ocean radar cross section, is a measure of the ocean reflectivity in clear air conditions. At constant sea surface temperature (sst), a relationship can be established between the ocean wind speed and the reflectivity. In a similar fashion, a relationship involving the sst and the reflectivity can be formed at a constant ocean wind speed. In this presentation, those relationships involving the three variables are shown, and a linear function between the wind speed and reflectivity is defined. The coefficients of the function are also calculated.

In-Situ Techniques for Polar Surface Wind Mapping and Glacial Meltwater Exploration

With the vast amount of data gathered recently, it is now undeniable that human interaction with our environment is causing a steady increase in global temperatures. As the climate warms, the behavior of our polar regions, where the vast majority of frozen water is located, is of particular interest and importance. The current Tumbleweed rover is a wind-blown, inflatable shell that will be used to map changing wind and weather patterns in Earth's ice caps. It contains a suspended payload in its center that will relay GPS and elevation data as the rover is blown about the ice sheets at the discretion of the wind. This data will be used to map current wind patterns and terrain to help get a better understanding of the effects of a warming climate on our frozen poles. The glacial Moulin explorers are units that will traverse the meltwater channels of glaciers and

follow the waters' trip to the ocean. The explorers will collect data on their journey through the inter-glacial channels and will provide a glimpse into a rarely seen, but greatly important, world. These harsh-environment instruments may eventually be used on other harsh planetary bodies, such as Mars, Titian, and Io.

ATHLETE Lunar Habitat Design

The study of a prototype lunar habitat aims to yield future design decisions with regard to modularity and human habitability. The concept driving design is the need to demonstrate a logistics vehicle that dismantles into a living space on the lunar surface. The habitat rests atop the hexagonal lunar rover, the All-Terrain Hex-Legged Extra- Terrestrial Explorer (ATHLETE). The ability to dismantle the logistics setup matched with the weight limits imposed by ATHLETE's payload requires a lightweight, modular, reconfigurable assembly. The solution involves thin aluminum sheet metal frames used as hard points for the suspension of webbings that form the interior "walls." In the logistics mock up, cargo transfer bags of the sort currently employed on the International Space Station, are secured within the webbing walls. Post-human arrival these walls may be detached and the bags unfolded to form a flat unit capable of filling roles from partitions to beds. The habitat also features a command center for the control of ATHLETE, and common amenities required in a living space to maintain hygiene, ventilation, nominal comfort, and a kitchenette. Continued development in LED lighting methods makes an attempt to eliminate the boundary of the habitat with indirect RGB lighting. The effect of color lighting also enables the transmission of a sense of time passage or information. Stylistic and structural elements combine to lend a touch of habitability to a living space forged out of a modularly optimized logistics unit.

Three Disparate Approaches: Project Constellation Lunar Operations, Orion's Fault Detection Visualization, and a Hands-On Introduction to Controls

Our work this summer supported Orion's Fault Detection Isolation & Recovery Implementation Tool (FIT); Project Constellation's Level 2 operations concepts (OpsCon) and abort scenario conditions; and, with the Measurement Technology Center, the design and implementation of a proportional–integral–derivative (PID) controller in LabVIEW. This tripartite approach to disparate tasks was the student's effort to reconcile the multi-leveled approach of JPL missions. FIT, a program in development by Johnson Space Center, aims to interact with subsystem failure detection already observed and reconcile these errors on a system level, in an effort to prepare for system-wide responses scripts. Our tool, utilizing its outputted system-level error, introduces a concomitant visualization. This is an effort to illustrate, by way of highlighted CAD, where these errors occur in Orion, enabling later planning for architectural redundancies. The result was a working demonstration copy. The OpsCon analysis concerned a six-month Lunar mission in which even incredibly elementary logistical questions, such as the presence of

a separate communication asset, were unresolved, inspiring further planning and mission design. Finally, the manually tuned PID controller was constructed and successfully tested on a thermocouple/resistor rig in a laboratory setting.

Tunable Laser Spectrometer

The tunable laser spectrometer is an instrument on Sample Analysis on Mars (SAM) for Mars Science Laboratory (MSL). The tunable laser spectrometer (TLS) will be used to measure gases on the surface of Mars. TLS is strong enough to detect parts per trillion of gases such as methane, carbon dioxides, and their isotopes, which will help detect sources of carbon. MSL is set to launch in the fall of 2009; while the TLS is in flight, its safety and systems must be ensured. To ensure the system is working during the entire flight, a copy of TLS is needed in Lab to do testing.

User Interface Enhancements to ROAMS

My project focused on extending the graphical user interface to the Rover Analysis, Modeling and Simulation Software (ROAMS) in order to improve its usability. Specifically, I improved a graphing software package, Graphviz, so that the user can interact with the graph and, eventually, be able to alter it. Ienhanced a table class that lists components from the simulations and their properties, aiming to simplify the table's creation while increasing its potential customization. Finally, I wrote a small program that graphs data from the simulation in real time. These new capabilities will lead to improved debugging, simpler future enhancements, and insight into the operation of the ROAMS.

Using Image Processing and Machine Learning to Detect and Classify Mars Surface Features

Current pixel-based methods of image analysis are too computationally expensive to feasibly discover meaningful changes in Mars surface features in NASA's large, continuously expanding database of satellite imagery. We worked on the beginning stages of a more efficient method of change detection that will compare information about landforms appearing in subsequent images of the same region. By avoiding the direct comparison of pixels, this method reduces computational complexity and is more robust against variations in lighting. We experimented with the automation of selecting regions that differ greatly from their surroundings. Next, we evaluated the regions chosen by this general detection software against the regions manually highlighted by planetary geologists. We then built a support vector machine classifier using the manual

annotations as training data to assign the features such labels as "dark slope streak" and "crater." Finally, we applied our trained classifier to the regions found by our detection algorithm and evaluated its accuracy.

Lunar Navigation Trade Study and Analysis for the Constellation Program

NASA's Constellation program will develop crewed and robotic systems to explore the surface of the Moon in the coming years. The program requirements call for the ability to precisely land and safely return from virtually anywhere on the lunar surface. The guidance and navigation system must support the precision landing of these systems at diverse landing sites, as well as support the systems' associated trajectories and orbits. In addition to the three NASA Deep Space Network complexes, a number of other Earth-based ground tracking stations have been proposed to meet the needs of the Constellation program. A network of up to two lunar communications and tracking satellites has also been suggested to meet these needs. Using JPL/Caltech proprietary software, a comprehensive number of low lunar orbits were simulated and analyzed in a radiometric navigation trade study to determine the performance and optimal combination of proposed tracking assets. Comparisons of these results were made to an Apollo navigation network for reference.

Development of Verification and Validation Documentation for Models and Simulations

Verification and validation is the systematic process of ensuring that software not only produces the correct results within design requirements and constraints, but also performs the right functions. This process is multistep and requires familiarity with the device under test. Because model designs tend to have varying levels of manipulability, the amount of verification and validation involved requires more effective techniques. This paper seeks to describe such techniques. Throughout the design and development of a Verilog HDL code, errors and failures are expected and encountered. Using techniques that include the use of test bench waveforms and code, root cause analysis, and other failure analysis techniques, the errors are identified and removed. The techniques used to resolve these errors as well as the resulting effects are surveyed and documented, and through the compilation of these scenarios in the form of an operations manual, the outcome will be a description of the verification and validation process.

Photometric Mapping of Centaurs and Comets

We make use of the extensive Near-Earth Asteroid Tracking (NEAT) program database of images as a photometric base for characterization of select centaurs and comets. By using relative photometry and a linear model for atmospheric magnitude extinction, it is possible to use a current, well-analyzed CCD image of a skyfield to find the offset and subsequently the true photometric magnitude for a centaur or comet present in an image taken under varying atmospheric conditions. This data analysis employs the use of stored image archives to provide new photometric information for outer solar objects and can be continued further to make use of archives containing otherwise unused image collections. Included in the process is the generation of a program to utilize multiple object ephemerides to find their CCD location and offset on every Palomar-Quest/Maui image taken. We show its application to Survey of Ensemble Physical Properties of Cometary Nuclei (SEPPCoN) objects and various comets.

Estimating the Meridional Overturning Circulation (MOC) in the Atlantic

Estimates of Meridional Overturning Circulation (MOC) produced by the Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project are compared with observations from the Rapid Climate Change (RAPID) array in the North Atlantic at 26.5°N. Warm water emerges from the Gulf Stream close to the ocean surface and moves northeast, losing heat to the atmosphere and surrounding waters. As this occurs, the cooler water is now denser and sinks at higher latitudes. At depths of 2 to 5 km, the cool water moves back south. Surface winds and water density gradients drive the northeast flow of water, resulting in the MOC. An array of moorings, the RAPID Array, currently in the Atlantic at 26.5°N contains sensors that measure pressure, temperature, and conductivity. These data are used to determine the ocean density, which in turn can be used to determine water transport. The RAPID Array is currently in use and has been collecting data since 2004. An in-depth comparison of first-generation ECCO estimates and RAPID data has been done in the past. The higher-resolution ECCO2 estimates will now be compared with the RAPID data using Matlab. Because of the difference in the time scale of the two data sets, interpolation (currently under way) of the ECCO2 data set must be finished before final conclusions can be made.

High Redshift Galaxy Clusters

Galaxy clusters are the largest known gravitationally bound structures in the universe. Analysis of high-redshift clusters serves as a probe that can be used to study cosmological models and galaxy evolution. Single-band (F814W or .814 micron) images from the Wide Field and Planetary Cameras on the Hubble Space Telescope were obtained for six distant clusters (redshift > 1) originally identified by the Spitzer IRAC (Infrared Array Camera) Shallow Survey. A quantitative measurement of galaxy

morphology is made by fitting Sérsic profiles with GALAPAGOS code (Galaxy Analysis over Large Areas: Parameter Assessment by GALFITting Objects from SourceExtractor). We study the accuracy of Sérsic profiling by comparing results for galaxies in Hubble Deep Field F814 images with equivalent images from the Advanced Camera GOODS (Great Observatories Origins Deep Survey). The size and color properties of cluster and field galaxies are measured for five of these clusters, using additional ground-based J Band (1.2 micron) image data, and photometric redshift information used in an earlier study of these clusters.

On-Orbit Hyperspectral Data Compression

Satellite downlink capabilities often restrict the amount of data that a remote sensing mission can collect. To mitigate this problem, data compression algorithms can be implemented on the spacecraft to reduce the amount of data. This abstract focuses on data compression methods as one section of a complete paper called “End to End Data System Design of the HyspIRI Mission” discussing an Earth science remote sensing mission. The mission utilizes hardware compression to reduce the stream of data coming from the satellite instruments. The purposed compression algorithm is a low-complexity, fast, lossless compression algorithm designed at JPL specifically for hyperspectral and multispectral data. The design will allow three-to-one lossless compression in real time as the data is collected by the instruments. Hardware implementation of this design takes advantage of the low complexity of the algorithm making a field programmable gate array (FPGA) well suited.

Gamma Ray Sky Map Production Using an Inverse Radon Transform

The high energies of gamma rays make celestial gamma ray sources difficult to image in a conventional manner with telescopes and optics. Instead, a scintillator may be used to measure the flux of photons. This was done on the Compton Gamma Ray Observatory (CGRO), a satellite in near-Earth orbit. However, scintillators do not directly give either the origin of the gamma ray sources or images of the sources. One method of extracting this information is the inverse Radon transform. This uses the timing of the rising and setting of sources behind the Earth to produce an image. To use this technique, source simulation software was developed in conjunction with software to perform the inverse linear Radon transform. Images to demonstrate the technique and analyze its performance were produced from the simulated sources. This method will permit the application of spectral analysis tools that have already been developed to these sources.

Determining the Rotational Period of Asteroid 1564 Srbija Through Light Curve Analysis

We imaged asteroid 1564 Srbija for three nights in the month of July 2008 using a remote connection to a private observatory in Idyllwild, California. The equipment used was a Ritchey-Chrétien 12.5" scope on a Paramount with a SBIG STL11000M camera. CCD Autopilot was used to automate the whole system to run robotically throughout the night. Red filter 2x2 binned exposures of the asteroid began as it rose 35 degrees above the horizon and continued throughout the night until 4:00 a.m., except when the telescope slewed to SA112 Landolt field standard stars for calibrating exposures. After flat fielding and dark subtraction, the MPO Canopus software will be used to analyze the magnitude change over the course of the evening, revealing information about the shape of the asteroid, its rotational period, and possibly its composition. Additional data will be secured in August using the JPL Table Mountain Observatory 0.6 m telescope with an LN2-cooled camera.

Vegetation 3-D Structure With inSAR

Vegetation has a significant role in the carbon cycle. With recent attention drawn to global warming, a closer investigation of the vegetation, in particular its height and biomass, is desired to quantify its role. A new radar remote sensing mission is planned called Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI). This would be a U.S.-spaceborne L-band interferometric synthetic aperture radar (inSAR) and lidar mission. In order to plan for this mission, Dr. Simard is investigating the effect of several parameters on interferometric correlation using Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) data, similar to the data that will be obtained with DESDynI's radar. These parameters are parameters such as physical baseline, temporal baseline, vegetation type and seasonality. This study of inSAR correlation will be used to determine which parameters will impact DESDynI's ability to estimate vegetation height and therefore optimize results. To process the inSAR pairs from ALOS/PALSAR, I used the Repeat Orbit Interferometry PACkage (ROI PAC) software to obtain interferograms and correlation images. Then I identified the impact of the various parameters on the inSAR data. Generally, the better the inSAR correlation is, the better the accuracy of the height measurement. The areas of study included California, New Hampshire, Maine, and Quebec. Analysis of correlation results showed trends that may be notable in helping to model and plan DESDynI.

A Parametric Trade Study of Radiometric Tracking Architecture Baselines for Cislunar Flight and Lunar Orbit

This objective of this study is to perform a parametric trade study that evaluates the performance of several proposed radiometric-tracking baselines for the lunar objectives of the Constellation program. Performance metrics considered are convergence latency for a position and velocity fix, and the uncertainty in the final values of the position and velocity. Conceptual Flight Profile #1 (CFP1) is used as a basis trajectory for evaluating the radiometric tracking performance for each configuration. The Earth-based tracking asset configurations considered include the Apollo Manned Spaceflight Network, the Deep Space Network as currently configured, and various Earth-based augmentations to the Deep Space Network. The analysis also evaluates the performance of proposed lunar-based radiometric tracking assets consisting of lunar orbiters and lunar surface beacons. The study considers sensitivity of filter convergence latency, and final steady state values due to time of the synodic month, and time of day, and the orbital plane used during the lunar orbit portion of the mission.

Combining Electrodynamic Screen With CO2 Cleaning for Lunar Dust Mitigation

Dust mitigation is of critical importance for both robotic and crewed interplanetary missions. The feasibility of using ElectroDynamic Screens (EDS) for dust mitigation on the moon and Mars has been established. The EDS consists of a series of parallel electrodes embedded in a transparent substrate. These electrodes are excited by an AC voltage (1000V±, 4-30Hz) to produce a traveling electromagnetic wave. The particles on the surface of the EDS are levitated and propelled by the electromotive force produced by this traveling wave. One of the drawbacks of all the proposed dust mitigation technology is difficulty in the removal of submicron dust particles. Carbon dioxide cleaning has been proposed as an effective method for removing these particles, but there are also some drawbacks to implementing this technology. Drawbacks include the necessity for storing large amounts of CO2 and the inability of a single astronaut to clean the full surface of an extra-vehicular activity (EVA) suit. The purpose of this project is to combine both EDS and CO2 cleaning to provide a comprehensive cleaning system for EVA suits before the astronaut enters a lunar habitat. The EDS will be used outside the habitat to remove the larger dust particles. The astronaut will then enter a chamber designed to contain 0.1 atm, and the EVA suit will be allowed to cool to around -110C. Gaseous CO2 will be introduced and CO2 ice will form on the submicron dust particles collected on the EVA suit. The EDS will then be activated to remove the larger CO2 ice as well as the embedded dust particles. The scope of this project is to produce a proof of concept demonstration for the EDS/CO2 cleaning system.

Visualization and Research Tools for the JPL Tropical Cyclone Portal

The goal of this project was to develop an online tool for analyzing hurricane data. Although there are at present several instruments and agencies monitoring hurricanes and recording their relevant features, there is no single resource for obtaining and analyzing all of this data. The aim of this project was to provide such a tool. To that end, we have constructed an online application that queries the database of the JPL Hurricane Working Group for relevant storm data and generates plots and statistical analyses of them. The tool is written in Java for ease of network use, whereas the database uses mySQL. The tool is capable of generating histogram, profile, and map plots of various forms of storm data (wind speed, sea surface temperature, humidity, etc.), and additionally performs statistical analyses (mean, standard deviation, median, maximum, and minimum) of the data. The tool also allows users to compare one data type against another. The tool was constructed to be as modular as possible to allow for easy extension; all relevant parameters (which files to use, what types of data to analyze, what plots to generate for each file, where the files are located) are retrieved from the database, and, hence. these can be modified by updating the database instead of the tool. This article describes in detail the structure, development, and use of this tool.

Derivation of Spectral Parameters for Hydrated Minerals on the Martian Surface

The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter (MRO) allows for the identification of minerals on Mars. New parameters are derived to distinguish kaolinite from montmorillonite in the Mawrth Vallis region to aid Mars Science Laboratory (MSL) landing site selection, but CRISM data is determined to have too low of a signal-to-noise ratio to make a clear distinction. Additionally, new CRISM identification parameters are derived for two similar sulfates in Juventae Chasma. Elevations of the sulfate layers in three units of Juventae Chasma (two mounds and a chasma wall) are analyzed for a correlation in order to constrain the geologic history of the units. Preliminary analysis shows that the first type of sulfate is higher than the second type in all three units. High Resolution Imaging Science Experiment (HiRISE) and Context Camera (CTX) images are then used to compare the mineral maps to visual features. Correlations between the elevations of layers are evidence of a past inland sea in the chasma, which could help significantly extend the known time frame for the existence of water on Mars. However, evidence of tilted layers may suggest deformation after deposition.

Simultaneous Spectral Temporal Adaptive Raman Spectrometer

The goal of the project is to design and implement an instrument with the ability to detect Raman and fluorescence signals with time resolution information. This is to be achieved by using a pulse laser and sampling the resultant spectrum with a picosecond resolution streak camera. Currently the project has entered its initial implementation stage and the initial setup is in process. It is anticipated that data from the initial setup will soon be available.

Advancements in Imaging and Animation

The JPL Digital Image Animation Laboratory (DIAL) is responsible for creating presentable forms of data obtained from Mars missions and rovers such as the Mars Exploration Rover (MER), Mars Reconnaissance Orbiter (MRO), and the Phoenix lander. The output of the DIAL ranges from edited or enhanced photos, videos, DVD-quality animations, software and web content. Animations are created through the use of two-dimensional images coupled with elevation maps. This gives the animators a three-dimensional model to work with. This paper will describe the Java graphical user interface (GUI) program used to specify corresponding pixel locations on a stereo pair of images. This program will output a text file containing the file names and locations, as well as the locations chosen. A different program will take this text file and will use it to stitch the stereo pair together to form a 3D terrain object.

Development of in situ Water Isotope Spectrometer

Water isotopic ratio measurements are useful in a variety of applications from determining the metabolism of animals and humans and tracing plant water sources to studying and modeling atmospheric dynamics. Laser absorption spectroscopy is an ideal method for in situ measurement of atmospheric water and water isotope concentrations due to the low weight of the spectrometers and their ability to measure more than one isotope simultaneously and continuously. A new spectrometer has been developed to measure water isotopes as part of JPL's Aircraft Laser Infrared Absorption Spectrometer (ALIAS) instrument. By measuring the isotopic ratios of water samples with known isotopic ratios from Vostok Lake, Antarctica and Boulder, Colorado, as well as samples of Standard Mean Ocean Water (SMOW), the accuracy of the new spectrometer is tested. Field-testing will be carried out to assess its capabilities in out-of-lab situations.

Station Keeping Control Algorithms for Satellites in Formation

Two control algorithms for station keeping are developed with parameters optimized for the specific example of a low-Earth orbiting formation. A method based on the Clohessy-Wiltshire equations using a two-burn plan is presented first. This method is then compared to another algorithm that discretizes the dynamics and casts the problem in terms of a linear programming problem. A simple two-body model is utilized that includes the effects of J2, eccentricity, sensor noise, and drag. The algorithms are compared in terms of feasibility and fuel efficiency.

Improvement of the Martian Arctic Plain Visualization

A successor of the Mars Exploration Rover (MER) Project, the Phoenix Mars Mission, began as an effort to question whether the Martian arctic region once harbored life. In support of the Phoenix Mission, the engineers in the Digital Image Animation Laboratory (DIAL) at JPL create visualization products of Phoenix images. Of particular interest to the science community are mosaics created from images of the trenches and the area surrounding the Phoenix lander. Animations will zoom into a particular area and pan across the large mosaic. These animations reveal the detail of various parts of the mosaic, and enhance our understanding of the Martian arctic plain. In addition, a new graphical user interface (GUI) will allow scientists to interactively and easily modify the mosaic. This will facilitate the release of the mosaic to the science community and the presentation of NASA's space explorations to the general public.

Extensions and Optimizations of Tree-Based Wavelet Transforms With Applications to Distributed Data Compression for Wireless Sensor Networks

In this paper we present extensions and optimizations of a tree-based wavelet transform, i.e., a tree-let. We focus on distributed data compression for the standard data gathering problem in wireless sensor networks, where the goal is to minimize the amount of information that sensor nodes must forward to a sink node by exploiting internode data correlation. These developments rely on the facts that (i) a wavelet transform effectively de-correlates data and (ii) uncorrelated data can be encoded easily and efficiently. First, a technique is proposed that extends tree-lets to exploit the broadcast nature of wireless transmissions, and we show through simulations that incorporating broadcasts into a tree-let transform does not increase the amount of de-correlation significantly. As an alternative, we propose a multi-tree extension that performs additional levels of decomposition in the transform without additional communication overhead. This increases the amount of de-correlation in the network and so reduces the total amount of information that nodes must forward to the sink. A filter optimization technique is also proposed for the transform along with a distributed algorithm that converges to the optimal solution. Finally, we investigate spatio-temporal tree-lets and present preliminary results that show the benefits of using tree-lets over space and time.

Methane Band and Continuum Band Imaging of Titan's Atmosphere Using Cassini ISS Narrow-Angle Camera Pictures From the CURE/Cassini Imaging Project

The study of Titan's atmosphere, which bears resemblance to early Earth's, may help us understand more of our own. Constructing a Monte Carlo model of Titan's atmosphere is helpful to achieve this goal. Methane (MT) and continuum-band (CB) images of Titan taken by the Consortium for Undergraduate Research Experience (CURE)/Cassini Imaging Project using the Cassini Narrow-Angle Camera (NAC) were analyzed. The images were scheduled by Cassini Optical Navigation and were obtained at phase 53°, 112°, 161°, and 165°. They include 22 total MT1(center wavelength at 619nm), MT2(727nm), MT3(889nm), CB1(635nm), CB2(751nm), and CB3(938nm) images. They were reduced with previously written scripts using the National Optical Astronomy Observatory Image Reduction and Analysis Facility scientific analysis suite. Correction for horizontal and vertical banding and cosmic ray hits were made. The MT images were registered with corresponding CB images to ensure that subsequently measured flux ratios came from the same parts of the atmosphere. Preliminary DN limb-to-limb scans and loci of the haze layers will be presented. Accurate estimates of the sub-spacecraft points on each picture will be presented. Flux ratios (FMT/FCB=Q0) along the scans and total absorption coefficients along the lines of sight from the spacecraft through the pixels (and into Titan) will also be presented.

Prototype Tri-ATHLETE Docking Mechanism

The next generation of All-Terrain Hex-Limbed Extra-Terrestrial Explorer (ATHLETE), known as Tri-ATHLETE, will be composed of two three-legged rovers that can join to each other or to each side of an intermediate platform to form a six-legged vehicle similar to the current ATHLETE. A latching mechanism will hold the two halves of the vehicle to gather. The mechanism needs to pull the vehicles tightly together and withstand the forces generated as the vehicle lifts it legs. To this end, a device based on a hook and a screw was designed. The hook is attached to a nut, which rides on the screw, via pins that let the hook freely rotate in one plane. From the stowed position, actuation of the screw causes the hook to rotate 90 degrees until it engages a pin on the opposite vehicle—engagement stops the hook from rotating and any farther turning of the screw causes tension in the hook and pulls the vehicles more tightly together. Reversing the process causes the hook to loosen until it disengages and pivots back to its stowed position. A prototype device will determine if a similar device will be an effective method for connecting a full-scale Tri-ATHLETE.

A Visual Interface to Martian Climate Data

Analyzing the climate activity on Mars is a crucial aspect in understanding the movement of water and carbon dioxide around the planet. However, comprehending the data often requires transposing it into a visual form for easier analysis. Providing a flexible interactive tool for visually investigating different properties of the information collected is important to allow scientists a variety of perspectives to better fit their goal for analysis. This project in particular focuses on creating a means to compare data collected from the Mars Climate Sounder, the Thermal Emission Spectrometer, and the Weather Research and Forecasting General Circulation Model being developed at Caltech. Comparing data collected from orbiting satellite instruments to simulations being created locally allows scientists to make informed decisions on how to improve the model to more closely fit the actual atmospheric conditions on Mars.

Automatic Offset Correction and Annotation of International Space Station EarthKAM Images

With the NASA-sponsored International Space Station (ISS) EarthKAM program, students from around the world can request their own personal photographs of the Earth, which are taken by a camera mounted on the ISS. However, the exact timing and therefore the geographic metadata (location, rotation) associated with these images is incorrect. One aspect of my work was to find a way to automate the process of correcting the metadata associated with these images. Manually corrected images were analyzed and what was determined to be the best correction was applied to each image. The second aspect of my work is to find a way to automatically annotate these images with geographic features such as mountains and lakes. Using the GeoNames database, which contains geographical data for the entire Earth, and ImageMagick, a free image editing program, the images were labeled with major geographic features.

Engineering a New Capability for Operator Response to Errors

The focus of this project was to increase operator efficiency in responding to errors generated by ATHLETE (All- Terrain Hex-Limbed Extra-Terrestrial Explorer) lunar cargo-handling robot. To this end a software system was designed and developed that would present the errors and the proper recovery techniques in a reader-friendly outline to operators. This system was simultaneously integrated into the ground control software that comprised the ATHLETE workbench. Initial research involved analyzing the event reports generated during the last field test, as well as first-hand discussions with JPL scientists and engineers. The system being developed is nearing completion, and a final product is expected by summer's end. Currently all of the base functionality is in working order and will detect, diagnose, and offer recovery solutions for various errors. Further work may include handling the situation when multiple errors occur from one cause and,

possibly, adding the ability for users to save their preferences. ATHLETE workbench, which includes the error recovery system, will be used at the next field test, which is tentatively set for mid October.

Power Management and Distribution Electronics for a Personal On-Demand Integrated Power System

The Power Management and Distribution (PMAD) electronics control power flow from a dual-junction solar cell array to a Li-ion battery and/or load. The PMAD electronics design includes a bq24103A Synchronous Switch-mode Charge Management IC, a bq2050 Li-ion Power Gauge IC and a FPF2193 Full-Function Load Switch with Adjustable Current Limit. The bq24103A controls power flow from the solar cell array to the battery/load and monitors battery current, voltage and temperature. The bq2050 monitors remaining battery charge and outputs battery charge and battery temperature information. The FPF2193 limits the output current to the load. The three components and required passives and test components will be integrated onto a 15x70mm printed circuit board (PCB) using OrCAD 16.0 design and layout tools. The PMAD electronics will be tested for proper functionality and integrated into the power system.

Mid-Infrared Spectroscopic Observations of Neptune From the Gemini Telescopes

This work presents the reduction and analysis of some of the first-ever middle-infrared spatially resolved spectra of Neptune. Using data from the Thermal-Region Camera Spectrograph (T-ReCS) instrument located at the Gemini South telescope (Chile) and the Michelle instrument located at Gemini North (Hawaii), the objective of the work was to reduce the raw spectra into calibrated form, in both radiance and wavelength, so that they could be used to constrain physical and chemical models for the climate of Neptune as a function of latitude. Most of the effort was required to develop a data reduction code to accomplish this using the Interactive Data Language (IDL). The final version of the code can take any spectral image and plot the calibrated flux and brightness temperature vs. wavelength at any point on Neptune's disk, providing also the latitude and longitude of the point and its emission angle. Further work was done with colleagues to incorporate this program into a software suite called the Data Reduction Manager (DRM) so that it can be used for the analysis of additional spectroscopic data, allowing the JPL Outer Planet Group to progress towards a greater understanding of the spatially physical and chemical conditions leading to an empirical climatology of the icy giant planets.

Design of a Data Flow Model, Communication, and Broadcast Subsystems for the HyspIRI Mission

The Decadal Study Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (National Research Council, The National Academies Press, 2007) calls for the Hyperspectral Infrared Imager (HyspIRI) as an important mission to be launched in the 2013–2016 timeframe to study the earth's changing ecology. The HyspIRI low-earth-orbit satellite will carry two sensors—a hyperspectral Visible-Short Wave InfraRed [VSWIR] spectrometer and a multispectral Thermal InfraRed [TIR] spectrometer. The sensors, to fulfill the science requirements of the Decadal Survey, must operate with high resolutions and data rates, producing massive volumes of data that traditional communication systems are unable to handle. To make the mission feasible and to optimize data transmission and dissemination, a data flow model that takes into account instrument parameters, orbit, geography, communications schemes, power throughput, and mass was developed to conduct trade studies between different combinations. X-band high-rate radio, NASA Tracking and Data Relay Satellite System (TDRSS), and optical communications were investigated as communication options. A broadcast system was also proven to be feasible to transfer data directly to users, reducing data transfer latency. This work is part of a larger effort of the End-to-End Data System Design of the HyspIRI Mission.

System Engineering Behind a High Data–Requirement Satellite Mission

A team of six students came together to work on the "End-to-End Data System Design of the HyspIRI Mission." HyspIRI, the Hyperspectral Infrared Imager scheduled to launch between 2013 and 2016, is a mission using a hyperspectral infrared imager to map the global land and coastal surface. The satellite brings together hyperspectral and multispectral instruments to monitor environmental health, volcanoes, wildfires and urbanization. This mission is on the cutting edge of design with requirements to download a peta-byte of data per day. This large data capacity created an exceptional challenge to the team to address communications, downlink and data handling and dissemination. This challenge demanded a look at the system engineering behind the onboard data storage and mission operation capabilities. Utilizing JPL/Caltech proprietary software and scripting, the team began an investigation that modeled the satellite data paths and on-board storage capacity. This model was utilized to determine the best ground station configuration, the affects of pointing and alternate mission operations and, ultimately, the sensitivity of the mission requirements revisit times on the on-board data storage. These trade studies determined an objective function criterion to determine the best on-board data storage margins and handling that HyspIRI as defined could satisfy. Investigating these sensitivities will prove helpful to future JPL Team X studies and data dissemination operations for various customers.

Astrometry at Table Mountain Observatory

With the use of the 4k CCD camera on the 24-inch telescope at Table Mountain Observatory we are able to obtain highly accurate astrometric observations. By using transparent overlays labeled with small crosses at every 10s in right ascension and every 2' in declination we can compile offsets of reference stars to the target. The strategy to obtain accurate astrometric observations consists of capturing two to three exposures of picture plots for each observable target. During our run we use the camera to take pictures of asteroids and a few other stellar objects. After our run the data collected is then reduced. If we are satisfied with our data we produce a file containing all the astrometry and deliver it to the Minor Planet Center. The data will help track the orbits of asteroids and give us better calculations of their orbits.

Search and Browsing Interface for Spacecraft Data

Active missions produce large quantities of data, both from the spacecraft itself (i.e., collected science data) and ground operations (planning and instructions, annotations, etc.). Organizing and interacting with this data is a constant challenge faced by science teams. This research involves implementing a new interface for searching and browsing mission data. The primary objective of my research is providing a search interface that balances power and flexibility with ease of use. In designing a new search area, I consulted with Human Computer Interaction designers at NASA Ames, and examined various websites and software to determine which interface features users were most likely to find intuitive and useful. Throughout the development process we utilized agile and pair programming techniques to quickly implement new ideas without compromising quality and stability. The final product implements several features that greatly improve the usability of the search interface, such as breadcrumb trails (to allow for backtracking) and tagging (to group related pieces of data). The final results of this work will be included in Mars Science Laboratory Planning Software.

Characterization of Next-Generation Detector Arrays: A Study in Temperature Dependence and Noise

The detailed characterization of noise properties in next-generation detector arrays is essential to the calibration of a scientifically qualified camera system for use in future space missions. An important measure of particular interest to this project is the characterization of the dark current, which is related to the random thermal motion of electrons within the detector array. By measuring the dark current, we can determine the optimum detector array operating temperature at which the contribution from the dark current into the scientific measurement is minimized. Dark current minimization is essential to extracting the target source signal from the background, and it greatly affects

the system cryogenic design and its complexity. Furthermore, we are using specialized image acquisition hardware and software to characterize the dark current of a single detector array and using those results to calibrate our testing methodology. Also, we present a specially designed, extremely low-noise power supply, made with rechargeable 24-V NiMH 5000 mAh batteries, to measure the extremely low dark current and read noise of the next-generation detector arrays. Finally, future work will include testing under uniform illumination at various wavelengths to fully characterize and quantify all of the parameters necessary to evaluate the performance of a detector array, such as the quantum efficiency, linearity, full well capacity, gain, and charge transfer efficiency.

Response Stability and Flat Fielding of the WISE Telescope

The Wide-field Infrared Survey Explorer (WISE) satellite, scheduled to launch in November 2009, will be conducting an all-sky survey in the mid-infrared portion of the electromagnetic spectrum. The goal of this survey is to find and catalog nearby brown dwarfs, distant Ultra-Luminous Infrared Galaxies, and other objects ranging from nearby asteroids to distant quasars. Before launch, the instrument must be tested and calibrated to ensure reliable results, and to minimize the fraction of the cryogenically limited lifetime spent responding to unexpected instrument performance issues. Each picture transmitted from orbit will be comprised of nine samples that are weighted -4, -3, -2, …, 3, 4 respectively and then added together, thereby creating a "sample up the ramp" (sutr) image. Groundbased samples were added together according to the sutr algorithm, and these were examined over time to ensure stability. Each quadrant is read separately, and this results in some differences between each. Each quadrant was therefore looked at separately to determine individual stability. The four outermost pixels on every image (called reference pixels) are kept permanently dark, and these were subtracted from their respective lines to eliminate row-to-row differences. Once all of the images were processed individually, the overall median was used to create a "flat field" image for the telescope. The flat field is crucial in reducing pixel-pixel variations and is thus essential to improving sensitivity and photometric accuracy.

Gaussian Process-Based Active Learning for Directed Exploration of Complex Systems

Exhaustive studies of input parameter landscapes for asteroid collisions are computationally expensive. Hence, methods using support vector machine (SVM) classification and active learning have been developed to extract information using fewer simulation trials. In our physical simulation, we expect a spatial coherence in the input parameter space, and the Gaussian Process (GP) mathematically formalizes this hypothesis. The labeled data can then be combined with our prior expectations in a Bayesian way to compute probabilistic estimates about the structure of input parameter space. Combining these estimates with active learning methods, we can maximize

information gain. The main goal of the research is to acquire labeled data by presenting the physics-based simulation with a sequence of unlabeled points that return the highest expected information gain when labeled (Holub et al., 2008). Using a GP-based active learning algorithm, we were able to choose unlabeled points that maximally reduces the expected entropy, or expected uncertainty of the remaining points.

New Instruments to Study Greenland Ice Sheet Flows

The structure and formation of Greenland moulin have puzzled scientists for centuries. Two separate instrument units have been successfully designed, fabricated, and tested that offer an unprecedented view of the interior architecture of the glacial river inside a moulin. The first unit consists of two cameras and a video light housed in a rectangular box, and the second unit consists of an accelerometer, pressure transducer, iridium modem, and antenna housed inside a cylindrical shell. Both units have been developed fully from scratch and will be deployed in August 2008 in Greenland.

Hydrogen-Deuterium Atom Exchange in Photolyzed Methane-Water Ice Mixtures

Deuterium abundances found in organic molecules contained in the interstellar medium are of great interest to understanding the evolution of the solar system. Planetary ices have been found to contain not only large amounts of water, but also organic molecules such as methane. When these ices are irradiated with ultraviolet (UV) light, bonds are broken within the molecules and as a result new radicals and products are formed. Some new species that are formed are created by means of hydrogen and deuterium (H-D) atom exchange. Knowing the rates at which H-D exchange occurs is helpful in understanding photochemical processes that occur in the interstellar medium. Previous work has concluded that H-D exchange occurs readily in polycyclic aromatic hydrocarbons (PAHs) frozen in deuterated water (D2O) irradiated with UV rays. Additional work has studied H-D exchange of methanol in D2O and observed the formation of various methanol isotopologues. Now we examine the H-D exchange that occurs in methane frozen in D2O following exposure to UV radiation and analyze the products created as well as the rates at which they form.

Global Multi-Target Tracking and Prediction From a Single, Moving Camera

Much attention has been given to the multi-target tracking (MTT) problem due to its obvious uses in military surveillance. However, the tracking problem is complicated by the presence of motion of the observer in addition to the target motion. A method for estimating the motion parameters of the observer camera based on automatic image

registration and mosaicking techniques has been employed, allowing the motion of the target to be decoupled from the motion of the camera. With the target motions isolated, an unscented Kalman filter (UKF) tracker has been implemented to track the global position of a planar vehicle being observed from a single, out-ofplane camera. The UKF has been shown to be effective at predicting the target location many time steps into the future. Finally, the tracking system has been extended to a multi-target scenario, including measurement data association, track initialization, and track destruction modeling.

CxP Mission Operations Project Database Assessment

As NASA's Shuttle program nears its mandatory retirement date of 2010, work is being performed to ensure the success of the next generation of crewed spacecraft that is being built under the Constellation Program (CxP). The Constellation Program is divided into projects. The operations for Constellation are being planned and developed by the Mission Operations Project (MOP). The MOP Flight Preparation Process (FPP) is supporting the project by analyzing the current Plan, Train and Fly capabilities that support the Shuttle and Space Station. The JPL System Engineering Process for Operations Definition (SEPOD) team is analyzing the Manage and Control and the Maintain Infrastructure capabilities. These efforts intend to meet a requirement of the CxP to reduce Mission Operations costs to no more than 50% of the Shuttle/ISS costs by improving efficiency in the operational functions. Currently two tools, Core and System Architect, are being used to assist the analysis of the MOP functions. Use of two tools by separate vendors has created the issue of isolated, non-standard data storage between them. This situation makes data retrieval difficult, and creates single points of failure because often only a single individual has knowledge of each tool. An assessment by prototyping a centralized database along with the necessary web tools to collect the analysis data required for both Core and System Architect is being developed and will be described in the final report.

Aerobot User Interface and Monitoring

Autonomous flight in any case requires sophisticated software for monitoring and verifying movement characteristics. A graphical interface for visualization of telemetry data from an Aerobot prototype is important for studying the flight dynamics and effectiveness of onboard autonomy. In addition to monitoring capabilities, it is also important to simulate Aerobot flight patterns and receive interactive feedback. Thus, a realistic simulation is required to study these characteristics. The simulator can be run on a remote computer while multiple clients running the user interface can connect and monitor its flight patterns such as roll, pitch, yaw, altitude, and UTM coordinates as well as environmental statistics such as wind speed. The users are able to graph these values

and compare them to each other in real time. Verifying the effectiveness of the onboard autonomous system is made simple and easy with this improved user interface.

The Interannual Variability of Global Precipitation (According to 10 Years of the TRMM Data)

The effect of El Niño/Southern Oscillation (ENSO) on global meteorology have has been a topic of great interest. Before 1979, the evidence linking ENSO with the changes in rainfall around the world came from rain gauges measuring precipitations over land and a few islands. From 1980 until 1997, the launch of the Tropical Rainfall Measuring Mission (TRMM) instruments over land had very poor sensitivity. Because of the lack of the kind of data that would be required to make more definitive assessments, the question persists whether ENSO is the single most defining factor in interannual rainfall variability. In this project we conduct the principal component analysis of the global rainfall anomaly from TRMM's 120-month (1/98–12/07) data. Furthermore, using archived surface station data, the first TRMM rain anomaly index is extended back several decades. Juxtaposing the extended index with the Southern Oscillation Index confirms that the first principal component of the rainfall anomaly is significantly correlated with the ENSO indices.

Feature Extraction and Neural Networks in Computer Vision

Humans can effortlessly identify familiar objects under various orientations and scales in image or video. However, current computer algorithms are unable to replicate this task with adequate proficiency. A three-stage system has been designed at JPL to tackle this problem. Potential regions of interest are identified by the detection stage, false positives are eliminated by the verification stage, and future positions of moving targets are predicted by the tracking stage. This project specifically focuses on eliminating false positives using feature extraction methods in conjunction with neural networks. Features are extracted from the image within regions of interest to reduce dimensionality and input into a feed-forward back-propagation neural network. With a suitable choice of features and adequate training, good accuracy in eliminating false positives was obtained in the test sets used.

Utilization of Argon in Hall Thruster Cathode: Implications on Plume Properties

Hall effect thrusters currently operate using xenon for both the main discharge and cathode. This study investigates and compares results in regards to ion production and scattered energy when the cathode effluent is changed from xenon to argon. Based on

calculations of charge exchange and direct collisions using classical dynamics, we predict that the collisions between ionized and neutral propellant from the anode will remain the same, while the collisions between the propellant and cathode effluent will be reduced based on the smaller density and cross section of Ar. In comparing slow ion production rates, we predict that the Xe/Ar combination will have an approximate 40.6% reduction compared to the Xe/Xe pairing. Further analysis indicates that at any given angle, the scattered energy of the ions will be reduced with the Xe/Ar combination. In the laboratory, an ExB probe is used to distinguish types of ions produced at varying angles, and a Faraday probe is used to measure current at varying angles. Testing is performed on an SPT-70 Hall thruster and the data is compared to see if it supports the predicted reduction in slow ions produced to the sides of the centerline.

Frost-Induced Seasonal Variability on SHARAD at Vastitas Borealis, Mars

Seasonal variations in the Martian polar regions occur as volatiles composed of primarily CO2 and H2O condense from the Martian atmosphere onto the polar caps and surrounding areas. During the northern winter, the CO2 frost layer covers as far south as 60º N in latitude [e.g., James and Cantor, 2001]. The amount of volatiles that condense from the atmosphere during a seasonal cycle is intimately related to the overall volatile budget of Mars and its atmospheric dynamics [Smith et al., 2001]. Here we begin to assess the seasonal effects on the radar sounder data acquired by SHARAD (SHAllow RADar) on board the Mars Reconnaissance Orbiter (MRO). As the season progresses from fall to winter and the CO2 layer expands geographically and thickens, the effective dielectric constant of the surface decreases, since it is lower for CO2 than silicates. Consequently, the power of the surface reflection should vary over time. We focus on examining data from the areas surrounding the polar caps, particularly the Vastitas Borealis, which is almost completely covered in CO2 ice in the winter. Our approach consists of using a variety of data sets taken from instruments on satellites such as the Mars Orbiter Laser Altimeter (MOLA) to select areas of SHARAD coverage that have roughly uniform physical surficial properties (roughness, elevation, ice content, etc). After having defined the selected area in terms of the latitude and longitude of the Martian surface based on the properties mentioned above, we created a Matlab program to extract the radar and ancillary data from the SHARAD Planetary Data System reduced data record (RDR) data files within the selected area. We also create a program to pick the first arrival time and power within the extracted data set, and finally compare the reflected power at the surface to parameters such as solar longitude and geographic latitude. By comparing the reflected surface power with the time of season with which the data is taken, we find that there is an apparent increase in surface power as the season appears to increase from Fall to mid-Winter, over the range of solar longitude values, Ls = 180°–330°. However, this change is not statistically significant after taking into account the uncertainty in reflected power. Nunes and Phillips (2006), however, showed that the effect of frost layer on reflected power can be complex if the thickness of the layer is less than the radar wavelength (15m in free space for SHARAD). We are currently investing spacecraft geometry and orientation influence, expected to affect

SHARAD gain, to determine their influence on the selected data so that we may be able to extract a stronger correlation in the seasonal variation of reflected power.

Improving Atmospheric Cloud Detection Acquired by CALIPSO

It is believed that Earth's climate system has been changed gradually during the recent warming century. Clouds are a major uncertainty in understanding and quantifying how these changes occurred and what impacts cirrus clouds may have on future climate change. NASA's Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite uses lidar to detect cloud and aerosol particles in the Earth's atmosphere and provides vital information for studying cloud features. In cloud observations we first need to distinguish clouds from noise and other atmospheric matters such as aerosols. This is not easy because the backscatter data from CALIPSO is quite noisy and varies substantially with space and time. CALIPSO measures backscattered light signals at the 532 nm wavelength in two orthogonal polarizations and at the 1064 nm wavelength. By analyzing this data in the Python programming environment, a threshold is to be established that can identify clouds with precision and minimal false positives. Data from the perpendicular polarization of 532 nm backscatter is less sensitive to aerosol interference and facilitates identification of distinct cloud features. This information applied to the parallel 532 nm backscatter data then helps separate the data into separate cloud and aerosol components. This removes much of the present uncertainty in cloud identification and allows a more reliable threshold for cloud detection, varying based on altitude and geographic location.

Biological Archiving for Mars Missions

Spacecraft traveling to Mars are cleaned to precise standards, but are not actually sterile. Bacteria are commonly recovered from pre-flight planetary protection biological assays, and thousands of these isolates are currently being stored at JPL's Space Microbiology Laboratory (SML). This summer I extended my work from a Fall 2007 Student Independent Research Internship (SIRI) with the SML and the Archiving Task. The previously created and populated database was found to be lacking in critical areas, so we created a new database and transferred the existing data. We also expanded capabilities to include image libraries. Images and handwritten notes from 2003 to the present were electronically attached to microbial isolate entries and made searchable. In addition, I was trained to perform some of the basic characterization methods of bacteria used by the archiving lab, including the use of gram staining, compound microscope use, macro imaging of colony morphology, and biochemical characterization using the BIOLOG identification system.