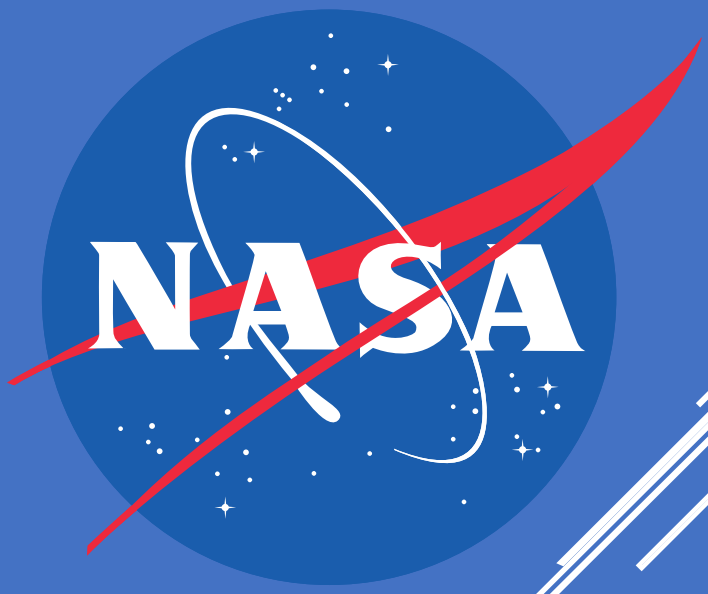

2014 Summer Intern Poster Session and Abstract Proceedings

NASA Goddard Space Flight Center

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Greenbelt, MD, USA

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Preface

NASA internships provide unique NASA-related research and operational experiences for high school, undergraduate, and graduate students. These internships integrate participants with career professionals emphasizing mentor-directed, degree-related, real-world task completion. During the internship participants engage in scientific or engineering research, development, and operations activities.

As part of their internship enrichment activities offered by Goddard's Office of Education, the Greenbelt Campus annually hosts its Summer Poster Session. Here, interns from Science, Computer Science, Information Technology, and Engineering and Functional Services domains showcase their completed work and research to the entire internal Goddard community and visiting guests. On July 31, 2014, more than 300 interns gathered in the atrium of building 28, breaking all records in participation from previous years. Interns were able to present their work while having the opportunity to receive feedback from scientists and engineers alike. It is this interaction with Center-wide technical experts that contributes significantly to the interns' professional development, and is therefore a culminating highlight of their quality experience at NASA.

NASA's internships reach out to students not just from the Maryland area but also worldwide. This year, 60 percent of the interns participating in the poster session were from out-of-state, while 32 percent live permanently in Maryland. While NASA internships are available to students with a wide variety of majors, predominately NASA-related STEM fields, individual internship opportunities target specific disciplines. Engineering and Science were the two domains with most participants in the poster session, with 43 percent for Engineering and 33 percent for Science.

Goddard Space Flight Center's Office of Education acknowledges the outstanding potential assembled at the poster session each year, where great ideas are presented to the NASA public. It is our goal to make all this information accessible. Hence, we are releasing a compilation of the contributions submitted and presented by the interns during the poster session and in individual presentations. A total of 233 abstracts from the summer 2014 Goddard Internship Program is now accessible, on a limited basis, for research and educational purposes.

Producing the 2014 Summer Intern Poster Session Proceedings required the dedicated effort of many individuals. In particular, the quality of this publication depends on the commitment of the many mentors who took time from their busy schedules to review and edit papers. We thank you all for your support! It is very much appreciated.

Last but not least, this compilation of abstracts directly reflects the work of our interns. Without your hard work and dedication, neither the Poster Session nor this publication would be possible. We thank you for preparing your presentations and papers, and for showing the professionalism and enthusiasm that makes the Summer Poster Session such a great event time after time!

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Computer Science / IT- NASA's IV&V

Klocwork Checker Studio for MPCV Static Code Analysis Abstract

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The MPCV project has moved to further expand their Static Code Analysis capabilities by incorporating special checks for violations against the C and C++ coding standards and best practices as defined by the MPCV Software Development Plan and NASA Software Safety Guidebook. The MPCV program has been very interested in receiving issues resulting from this process as rapidly as possible due to the nature of these standards not being covered by typical Static Code Analysis tools.

The MPCV team had created Unix-based shell scripts for searching through Flight Software code to find coding standard violations that were identifiable via simple text-based searches. However, this only covers approximately 20% of the coding standards. In the hope to expand coverage of the coding standards, the MPCV team is experimenting with Klocwork's Custom Checker Studio. The tool has the potential to identify coding standard violations that are more complex.

Currently, no IV&V people have experience or knowledge of neither Klocwork's Checker Studio nor its XPATH-based Abstract Syntax Tree. The focus of this activity is to learn how to use the tool, learn the syntax, develop code, create test cases and test code to verify the checkers, and finally how to deploy them. As a pre-requisite, one would need to know or learn how to program in C++ language, develop and test code in a UNIX environment, understand Unix-based shell scripts, and make use of Microsoft Office. This activity would allow for the development of engineering techniques and exposure to demands within the workplace.

West Virginia Space Public Outreach Team (SPOT)

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This summer, my project was to develop a presentation for the West Virginia Space Public Outreach Team (SPOT), which recruits and trains college presenters to bring presentations about current West Virginia space science, technology, and engineering to k-12 classrooms, museums, and youth programs. WV SPOT is supported through a joint partnership between the National Radio Astronomy Observatory and NASA.

The SPOT presentation "The International Space Station" focuses on the science onboard the International Space Station and how it is contributing to the future of human space exploration.

"The International Space Station" presentation will be used in schools all across the state of West Virginia and is designed to inform students about space science and to inspire students to pursue careers in STEM fields.

Space Telescopes: A Glimpse into the Unknown SPOT Presentation

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The West Virginia Space Public Outreach Team, WV SPOT, sole mission is to inspire an appreciation of STEM and STEM careers in K-12 students through the delivery of interactive presentations by undergraduate students that highlight cutting edge space science and engineering research in the Mountain State. Not only does SPOT influence the audiences of these presentations, it is also impactful on the students who present them. These presentations provide the audience the opportunity for increased awareness and appreciation for astronomy and other space related topics through Science, Engineering, Technology and Math (STEM). In addition the students providing these presentations are attaining a wide range of skill sets such as science communication, public speaking, autonomy, and space science content knowledge.

These SPOT presentations utilize a variety of slides, videos, animations and have an inquisitive approach to relay the excitement of new discoveries in space science. NRAO and NASA research and careers here in West Virginia are highlighted in each show. Presentations are either presented in a classroom or assembly setting. After this summer concludes there will be four SPOT presentations readily available. These presentations include: Invisible Universe, Mars: Past, Present and Future, Station: A look into the International Space Station, and Space Telescopes: A Glimpse into the Unknown. Each show lasts approximately 30-45 minutes.

The presentation I decided to prepare this summer for WV SPOT is on space telescopes. More specifically space telescopes that have a focus on exoplanet missions. An exoplanet is a planet outside our solar system. I chose this because I firmly believe that in the next twenty years we will know of life outside our solar system. And we're going to know this because of the space telescope technology that we currently are using and the technology that will be launched within the next decade. It was not too long ago that the human race knew of only nine planets, now eight, within our universe. In the past five years we've discovered thousands. Every star in the night sky is a sun, and each star has the possibility of hosting at least one planet, some even earthlike. I believe increasing awareness on this will greatly impact the future of STEM careers and hopefully will inspire future generations.

My method for approach was to first do extensive research. I spent approximately one month researching space telescopes that specially focus on exoplanet research. I studied their technology, functions, locations etc. With the immense of research I found I narrowed down my presentation to five space telescopes: Hubble, Kepler, Spitzer, The Transiting Exoplanet Survey Satellite (TESS), and James Webb Space Telescope (JWST).

The results of this presentation thus far have been positive. However, the expected outcomes and statistics for meeting the WV SPOT goals are yet to be determined. The presentation will need to be shown

throughout the state of West Virginia through the 2014-2015 school term to have the data to make the evaluation of how impactful this presentation was to the targeted audiences.

I plan to be heavily involved with WV SPOT throughout this school term and continue to help with this presentation's development. In addition to this, I am the SPOT officer for the Space Club of WVU and plan to incorporate and instill some interest to the members of the club and throughout the university. I think the WV SPOT presentation program is an excellent way to impact the younger generation of West Virginians and increase their awareness/interest in space science and I am optimistic that the program continues to have success and excel.

James Webb Space Telescope JWST Tool Development

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Interns with the James Webb Space Telescope (JWST) team spent the summer of 2014 working with software tools to increase efficiency at NASA IV&V. The goal of their summer project was to implement Ceptah Bridge, a Microsoft (MS) Project plug-in, and document how to use it. Interns interacted with IV&V staff, such as people working with project management or analysis, to better understand how implementation of the plug-in would benefit IV&V as a whole. They then downloaded the tool, learned its functionalities and settings, and created a report of the information collected. Ceptah Bridge was found to be incredibly dynamic and useful, as it utilizes capabilities for increasing time management and productivity. Its main function is to connect JIRA, a proprietary product for keeping track of work being done within a project, to MS Project. It creates a "bridge", so to speak, that synchronizes data between both products at the click of a button. This saves project managers from having to manually transport one piece of data at a time from JIRA to MS Project (or vice-versa). Because this tool has been documented, employees may easily learn how to implement it in their daily activities, thus increasing overall Earned Value Management (EVM) at NASA IV&V.

SGSS Fault Management Analysis Abstract

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The Space Network Ground Segment Sustainment (SGSS) Project is responsible for refurbishing the existing Space Network (SN) Ground Segment, which involves implementing a new extensible, flexible, and scalable ground terminal architecture. The SN is a 24/7 operation which has stringent reliability, maintainability, and availability requirements; therefore, the system must have robust fault management to ensure that problems are easily detected and corrected such that the system is continuously operational. The purpose of our intern project at IV&V is to assess SGSS requirements, design, and code related to fault management functions related to messaging to ensure the implementation is correct and consistent. The project allows us to increase our knowledge of the JAVA programming language and schemas, fault detection and isolation, Microsoft Excel usage, and the software development life cycle. Various tools such as Notepad++ and Agent Ransack are used to generate a Data Dictionary (DD) of software implementation parameters. By using the DD and reviewing the Java source files, we are able to develop a visual representation of the code hierarchy related to faults and determine what actions (i.e. error logging, operation alerting) result from handling fault conditions within the code. With this, we can compare the original requirements and design with the data collected in the DD to ensure the fault management requirements and design features are met.

Robotics Image Processing and Interpretation

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The Robotics Capabilities IV&V project for summer 2014 is called Robotics Image Processing and Interpretation. The goal of this project is to assist the Robotics Capabilities Development (CD) team here at IV&V with their analysis of computer vision software and its applications in NASA missions.

Our intern team will be working with the Robotics CD team to study and characterize different types of vision processing algorithms and determine their strengths and weaknesses under a variety of conditions, such as lighting, resolution, noise, and sharpness. Two of the main types of computer vision algorithms that we plan to test are ellipse detection and cross correlation.

Our team will also work to create an experimental test environment to demonstrate real-time control of a robotic arm using computer vision. Simplified versions of two NASA mission scenarios will be setup in this environment: autonomous satellite refueling, and asteroid redirection. This test environment can then be used by the Robotics CD team to perform tests of computer vision algorithms to help them understand how the algorithms perform under certain conditions.

Finally, our team will help generate content for the Robotics CD team's technical reference on computer vision. When working through tests of different algorithms, data and comments about the performance of the algorithms under different conditions is to be collected and documented. Determinations must be made about how well and how reliably the algorithms perform their intended tasks, what kinds of adverse conditions cause them to become unreliable.

James Webb Space Telescope Fault Management End-to-End Database Event Network Development

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The James Webb Space Telescope (JWST) is a collaborative and ambitious project combining the science and technology of many US based universities, aerospace companies, NASA, and the Canadian Space Agency. In addition to explaining the evolution of the galaxy, the JWST mission hopes to provide understanding of the formations and interactions between planetary systems, the birth and formation of stars, dark matter, and the evolution of the chemical and elemental composition of the universe.

To protect the Observatory (the space-based portion of JWST) in case of an on-board failure or command error, the JWST Fault Management system exists on board. The Optical Telescope Element (OTE), Integrated Science Instrument Module (ISIM), and elements of the Observatory also perform internal fault management and identify fault conditions when they pose a threat to the Observatory's safety.

To verify and validate this robust Fault Management system, the IV&V team is generating a database and quasi-dynamic model to analyze the various JWST system and subsystem components operating in unison. The intern will be involved in the development of system models. Using JWST system artifacts, Microsoft Excel, Microsoft Access, and custom database visualization tools, the intern will: 1. Identify and model the components and states of the JWST subsystems in a component database, and 2. Model the effects of commands, state changes, and fault triggers on the system in an event network. These relationships will be documented in databases to produce a comprehensive archive of event networks and to ensure that traces support Fault Management.

Defining, Categorizing, and Aggregating Adverse Conditions

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Adverse Conditions tend to be characterized in numerous, contrasting ways. They come from many diverse projects which lack a standard process for defining and characterizing them. This current process breeds inconsistences, thus necessitating a central repository of Adverse Conditions, which serves to centralize all of the Adverse Conditions, unify the data fields by which they are characterized, and provide ease of traceability for those utilized as part of the IV&V effort.

Our project hopes to create a widely accepted definition that distinguishes Adverse Conditions from other NASA conditions. In addition we will be creating data fields to characterize these Adverse Conditions, defining the relationship of Adverse Conditions to other IV&V terms, and creating a domain model which will serve as a schematic of how Adverse Conditions fit into IV&V's Analysis Management Framework (AMF).

As a result, our project, current and future, will have a centralized repository of Adverse Conditions. This will not only provide current projects with a plethora of Adverse Conditions that perhaps they had not thought of, but also act as a reference for up and coming projects, thus saving man-hours and increasing cost efficiency in line with IV&V's strategic goal 4.8 and agency-wide goal 2.3. In addition, our project creates new capabilities, such as tracing Adverse Conditions as evidence through the use of the AMF, per IV&V's strategic goal 2, and leads to outcomes 2.1-2.3 while simultaneously furthering risk mitigation and mission safety.

User Control Interface Improvement for RoverX

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Rover-X is a 4 wheeled all-terrain surface rover platform built and partially developed during the summer of 2012 by the Robotics Capabilities Development (CD) team at NASA IV&V. The goal of UCI^{2}R, User Control Interface Improvement for RoverX, is to redesign the software architecture for improved functionality which will assist IV&V analysts and their applications with future NASA missions.

The focus of this project is to improve RoverX's software architecture from a manual computer input system into an untethered field-testable robotic hands-on training tool for IV&V analysts. This system will be used to evaluate traversal, navigation, and manipulation software behaviors, and explore teleoperation and autonomy. This was done using an Xbox-360 gamming controller to control the rover's basic motor and robotic arm manipulation capabilities as well as camera Pan, Tilt and Zoom. A Ground Station will also be developed for live feedback to eliminate the need for a computer monitor directly connected to the rover during field testing.

The Ground Station was built as a Graphical User Interface (GUI), developed using Microsoft Visual Studios 2010, and was implemented with the Xbox controller and video feedback for remote operation. Code was developed for the Xbox controller to control the rover's motors, robotic arm, and camera. This was implemented into the Ground Station.

The new RoverX platform is an untethered field-testable system for IV&V analysts to implement software to test system behaviors, thus enhancing the IV&V program's domain knowledge in teleoperation and autonomous robotic systems and support in future missions such as Mars 2020.

Kennedy Space Center Automated Subsystem Software Evidence Tool (KSC-ASSET) Development Project

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GSDO uses Compact Unique Identifiers (CUIs) embedded in its ground software to send and receive data within the GSDO subsystems and components. CUIs serve as the primary interface to exchange data between systems that are within as well as outside of GSDO. Upwards of half a million CUIs have been identified so far, and within the GSDO IV&V analysis performed to date, CUI discrepancies have been identified as the most significant class of problems. So, the main focus of the internship was to analyze and revise scripts to make the analysis of these CUIs and their associated documentation more efficient. Although several different scripts had been created over the years, none of these performed all the work necessary for analysis. The end goal was to create an "ultimate" script that would help to extract the data necessary for and assist with analysis of these CUIS and their associated requirements. Along with this, documentation on the revised scripts and templates would be created for better understanding and more efficient use.

Updating the scripts increased the speed by almost 50%. Along with the increase in speed came an increase in capabilities. Scripts were modified to extract all the necessary analysis data and copy it to the Clipboard where the information could then be placed in an Excel document for further analysis.

Additionally, an Excel template was created that will allow users to input the extracted CUIs from all documents for a more detailed analysis.

The process of analyzing the scripts and creating the template included learning to better read and write scripts, doing extensive research, and having many trial-and-error stages. Some important lessons learned include: learning to save the Excel template before you close it, and learning that it is bad to compare CUIs that are not related in any form.

As a final project, the internship involved cooperation with interns from other programs to create a Systems Tool Kit (STK) Scenario, which contained both past and present satellites that IV&V has been involved with. A movie highlighting not only IV&V accomplishments but also the combined accomplishments of the NASA Interns from the summer of 2014 was created that can now be shown on the digital media all over the campus.

Analysis of MPCV EFT-1 Entry, Descent and Landing Software

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The success of the Entry, Descent, and Landing (EDL) portion of EFT-1 is crucial to the validation of the Multi-Purpose Crew Vehicle (MPCV) design. A failure may result in the loss of the capsule, as well as any cargo or crew that may be onboard. Success will allow further testing of the MPCV to determine whether or not it will be able to perform future manned missions. Therefore, it is necessary to confirm the robustness and accuracy of the control software dedicated to the EDL sequence. The purpose of this project is to guarantee these qualities.

The tasks assigned to the intern are to confirm a) that relevant EDL code meets the coding standards as detailed in the Coding Standards Document (FltDyn-CEV-08-148), b) that the EDL triggers are utilized accurately and efficiently, and c) that the code will produce the appropriate commands and responses during the EDL sequence. These tasks will involve tracing the EDL triggers through all of the GNC files and models, through multiple coding environments such as MATLAB/Simulink® and Rhapsody®, and verifying that the triggers are utilized properly. The intern will also perform basic engineering analyses to check whether or not the EDL trigger conditions will match or approximate the expected conditions for EFT-1.

This project is more of a verification process than a validation process, given that the most files are unable to run individually and require the entire MPCV control system to be running. The main tasks for the intern are to check that the code calling or reacting to the EDL triggers meet the project coding standards, that the triggers will activate in the proper order and at the proper conditions, and in general that the EDL sequence software will perform properly during EFT-1.

Technical Quality and Excellence

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Technical Quality and Excellence (TQ&E) has a major role in curating archived mission data and providing current data, associated to the database containing various mission elements, to different users. Beneficiaries include the Office of the Director, Project Managers/Project Leads, and the Metrics team. The efforts help IV&V conduct project functionality analysis, pursue new business, characterize past missions, query for heritage, and query for statistics.

TQ&E is not only gathering data for current IV&V projects, but additionally for completed, archived projects. As part of the effort the students researched project-wide data available to the public. Further research was necessary to populate several fields, with this information coming from mission concept documentation and IV&V final reports. The interns made sure to include relevant data while applying export-controlled and sensitive data concepts. The collected data was entered into a unified spreadsheet, and verified on the TQ&E level before confirmation from Project Leads. Once the information was confirmed, the database was shared with IV&V Data Management for distribution. Sorting mission data in a single file means it is easier to find; therefore, saves time when transferring this data into the larger data repository.

This opportunity helped the student interns gain experience working in the STEM field. Participating within the TQ&E team taught the interns a variety of information, including spacecraft subsystems, flight software, mission operations, computing systems, and orbit specifics. The interns met with project specialists for further enrichment. Through the course of TQ&E the students learned how to create and manage databases.

Integrated Java Static Code Analysis

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The goal of the project is to help establish and document a standard process for the independent static analysis of Java code. The scope of the project includes both open-source tools (FindBugs, PMD, and SonarQube) and commercial tools (Klocwork, CodeSonar and Understand). The final documentation will include information on ensuring the developer included all necessary source code files (this section will be reused from pre-existing documentation) and a description of each of the different tools with instructions on how to use them. As part of reaching this goal, it was necessary to become familiar with the use, capabilities, and flaws of several static code analysis tools, specifically where analyzing Java code is concerned. The document will also include a list of the rules checked for by each tool, as well as more details on the most significant rules that will help IV&V analysts when they are reviewing results from the various tools. A comparison of the rules used by each tool will also be included, so that an idea can be established of which tools specialize in which types of checks. This information will be used to establish a recommended process for using the tools, which will also be included in the documentation. The document will also include any recommendations for how the entire process could be improved with the availability or development of other tools or plugins.

SLS Engines Program Summary

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During my internship this summer, I programmed two scripts for the SLS engines program. Arguably the most essential part of any vehicle, the engine of the SLS is an extremely complex piece of machinery, constitute of a multitude of parts that must be verified to meet safety requirements. During my time at NASA IV&V, I created black box script files to model all of the potential temperature outputs for the High Temperature and Low Temperature scaling algorithms. These programs will allow the SLS Engines team to quickly and efficiently verify and validate these algorithms.

The IV&V SLS team has not received the source code for the engines in the past. These scripts will allow the algorithms to be used in comparison with the results of the data received by running the actual code, given the same inputs. These scripts will hopefully serve as a valuable tool to the SLS team in the future for validating Engines software.

These scripts were developed in JavaScript and can be opened and used with any web browser. Theoretically, my scripts could be implemented or embedded into any website that it could be useful for. In the future, I would like to see my scripts used with inputs from the simulation software used to model the SLS liftoff and flight.

My time at NASA has been an amazing opportunity, and it has been an exhilarating experience to be even a small part of the grand scheme that will one day further the endeavors of human exploration.

Comparison of IV&V and MPCV Program Software Testing Environments

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The Independent Verification & Validation (IV&V) program was provided a pair of development test environments by the Multi-Purpose Crew Vehicle (MPCV) Program for the uncrewed Exploration Flight Test-1 (EFT-1) mission: (a) Software Only CEV Risk Reduction Analysis Test Environment Simulation (SOCRRATES) and (b) Partition Level Application Test for Orion (PLATO). These environments were used in verification and validation activities following a basic comparison of results between a test performed by IV&V and the same test performed on the same environment by the MPCV Program. Comparisons of results from the "gold standard" test environments were not performed or essential at the time. This approach was adequate but did not meet the full intention of technical independence within IEEE 1012 Annex C. Tests were later completed by the Program in gold standard environments so a more thorough comparison to assess differences between these environments could be completed and a higher degree of technical independence could be achieved by IV&V. This comparison was done by performing tests that recreated IV&V SOCRRATES or PLATO tests from gold standard environments using the latest version of Flight SoftWare (FSW) in each of the environments. Produced log files were edited and compared to the Program's results and data; in some cases, original code was edited so the correct data sources could be analyzed. Results were compiled into a Test Plan and Results document for easier reference and further analysis by the project engineers at IV&V and the Program. The comparison revealed some slight differences in restart test scenarios due to outdated test scripts being run on more mature FSW. These test scripts need to be updated to reevaluate the tested functionality in the current flight software. Overall, IV&V's use of the PLATO and SOCRRATES testing environments is acceptable to provide a higher level of assurance that the tested flight software will perform as expected.

Computer Science / IT

Printed Circuit Board Quality Assurance

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We compiled a database that contains all of the on-center printed circuit board jobs from the last couple of years, and provided a data analysis of trends within the coupon database in an attempt to create a more efficient manufacturing process.

For many years, general reference to internal and industry specifications coupled with post-production sample testing was considered satisfactory for ensuring high quality printed circuit boards for NASA missions even though defect rates were high. The wide range of PCB manufacturers in the NASA supply chain may overexpose missions to companies who do not work to the requisite specifications.

A Microsoft Excel spreadsheet was used to create a database for future reference when locating specific information. Then, data analysis was used to determine which printed circuit board manufacturers, best follow our guidelines and consistently produce conforming products.

After analyzing the database, it was found that seven manufacturers consistently met the required specifications. Hopefully restricted use of just these manufacturers will produce better quality printed circuit boards in the future.

If the printed circuit board manufacturers follow our stringent conformance guidelines, it will lead to a lower defect rate among the boards, which will increase the likelihood of successful missions and ultimately save money.

Safety Training Database

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The Safety Training Database provides flight projects a method too accurately and efficiently track personnel training records and status (active/out of date). Microsoft Access, a software application that is deployed on all NASA GSFC Windows computers, is used as the database engine. A Graphical User Interfaced (GUI) has been created to the Microsoft Access allowing staff no familiar with Access to easily add, modify, filter, and generate reports on training status. Additionally reports can be generated on staff that have expiring training.

Information is entered into the database that creates neat and well formatted tables, files and generates reports based on the employee, types of training, dates beginning, due date and the expirations of all training. Each course and employee information may be edited once input into the database to correctly identify each employee and their past, current or future training. The database also has the ability for the user to search according to the employees or the courses. This search criteria then displays the information based on the user's search.

The ability to upload existing excel spreadsheets with training data has recently been added. Additionally, an automated email client has been added. A trial version containing real training records, has been deployed in the code 320 secretary. This is currently being used to inform the contractors of their contracting status.

The long term plan for this tool is for use by multiple projects to track personnel training records. To help in this effort the database has been broken into a two parts allowing multiple simultaneous instances of access to the database. Additionally, a user's manual has been created.

Tropical Rainfall Measuring Mission I&T Test String

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As a Systems Engineer, one of the main responsibilities is to ensure that Tropical Rainfall Measuring Mission's (TRMM) I&T Test String software is operational through a series of assessments and observations. It is of the utmost importance that all new software releases and patches are tested before being integrated into the Mission Operation Center for TRMM's satellite.

The purpose behind maintenance of the automated system components is ensuring that all is operating nominally when in the process of receiving telemetry. It is vital that communications between systems are intact as to have a fully functional system of automation between machines.

The method of ensuring that the system is indeed nominal is a series of checks through the usage of functional, quick look, and miscellaneous tests that assess each individual component and its ability to work with other components. If we observe discrepancies between what is seen and what is expected then we quickly pin-point the problem and formulate a solution.

A great understanding of how TRMM's satellite ground control is configured on a wide spectrum was gained while learning through testing how to run a nominal telemetry playback simulation and how the system takes in data and processes it. Part of the learning experience includes reading and creating rule sets in the Criteria Action Table software to send out directives to other components. Also, how Event Analyzer displays said messages from different components, whether it is a heartbeat or a text message, and what that means for the system's current status such as a failover state from one of the other components being non-operational.

In conclusion, TRMM's satellite system exhibits behavior of autonomy so that it does not need constant human oversight or management. This means that as time progresses, there grows room for an even more complex system that alleviates the burden of manual input and leaves us able to discover and create.

Analysis Tools for Joint Polar Satellite System Data Product Monitoring

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The environmental satellites of the Joint Polar Satellite System (JPSS) generate a massive number of data records, some of which can take up enormous amounts of space. The GRAVITE system, which supports JPSS calibration and validation, ingests each day more than 250,000 files from the S-NPP satellite, resulting in a daily data volume of approximately 4.5 TB. For many of those who work with this data, it can be cumbersome having to sift through this much information to find a particular piece of information. Thus, it would be helpful to have certain tools to assist with the processing of the data provided by these environmental satellites. Specifically, the tools that were developed as a result of this study were a remapper, which takes raw satellite image data and coverts it to a more readable image, a compression tool, which takes large data sets and shrinks them down by a certain factor (which can then be re-expanded as needed, with a quantifiable error that is a function of the shrinkage), and a search tool which uses certain filters to determine if specific pixels in data products meet certain criteria. All of these tools were developed using Java, and no such tools previously existed to assist with processing such large amounts of data. As a result of the development of these tools, there are now efficient methods of making satellite images readable by the average person, reducing file sizes of data taken from the satellites, and searching through enormous amounts of data for specific information. If these tools are fully fleshed out (ex. The search tool is parallelized to speed up searching even further), they would be of great help to anyone wishing to efficiently work with the environmental satellite data.

Earth and Planetary Image Processing for IMAGESEER Database

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Currently, image data from earth, the moon, and other planets is difficult for users unfamiliar with the topic. The goal of our project is to make satellite image data more accessible to computer scientists at universities and places outside of NASA. To do this, we downloaded image data from existing databases and processed the data, creating cloud masks and geolocating the images. We also wrote and edited articles that explain the processes we went through so that others who are also trying to write algorithms or download and process data can have a guide. The IMAGESEER database which is the product of our project will serve as a tool to benchmark new algorithms and as a resource to learn about Image Processing (IP).

Getting 30 Languages for the Price of One

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The Java Script Engine Application Programming Interface (API) enables about 30 different languages to interface to Java without the use of bindings. This opens up vast possibilities for any project at an extremely low cost. Applications are usually developed in Java, C, or C++; however, there are unique capabilities found from other languages and the overhead of creating a wrapper to these languages is not feasible both in cost and time spent. Fortunately Java's extensive libraries has helped to solve this problem by allowing languages such as Python, Ruby, Groovy, JavaScript, and many more languages to be used in conjunction with Java programs. Hammer creates a structure around the Script Engine API to facilitate the process and make it simple to incorporate into an application. The structure can be set up so that multiple scripts are running at the same time using different languages which means for example Python, or any of the 30 languages, can pass data to Hammer and Hammer can then forward that data out to Ruby, or another one of the languages. The process is completely unbounded and up to 30 languages can be used at the same time. Hammer has already demonstrated it can run GSFC Mission Services Evolution Center (GMSEC) API's publishing and subscribing features within Python and JavaScript. Hammer enables all Java libraries to be used from inside any of the 30 languages, speeds up testing, and allows an application to take advantage of whatever unique capability the 30 languages have to offer. Hammer is sure to give Software Engineers more possibilities by widening their tool kits in a time saving and cost effective way.

Goddard Mission Services Evolution Center Wiki

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GMSEC, which stands for Goddard Mission Services Evolution Center, was formed in 2001 with the purpose of coordinating ground and flight systems for all current and future missions. GMSEC's reference architecture model is comprised of a message bus, an API translator, and various components, including legacy components. GMSEC is cost effective, can quickly integrate components, and can support legacy components. The GMSEC Wiki is a young and developing tool used by GMSEC team members to store information about GMSEC components, keep track of personal work, schedule meetings and releases, and connect GMSEC customers and missions. Our main goal was to update, restructure, and populate the Wiki to make it more useful to the team. That included creating software pages, finding a way to output each page to a PDF file, creating many customers/users pages, and updating the middleware pages. To obtain the knowledge needed to accomplish this task, we interacted with the GMSEC team to gain knowledge and input on many different subjects. As each person had their own idea for how they wanted the wiki to look, we had to balance between everyone's different opinions. In the end, we took most of our direction from the Product Development Lead, learned how to research and collect our own material in order to complete a project, and used our creativity combined with advice from our supervisor to create a hierarchal list of customers/users and a diagram that depicts the list visually. We also learned how to navigate and utilize new software and communicate with higher-level supervisors to gain complete access to the GMSEC Wiki.

Joint Polar Satellite Systems Simulator Interface Design

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The Joint Polar Satellite Systems (JPSS) program is dedicated to creating and launching polar satellites. These satellites are expensive and simulators are needed to ensure successful launch. The task was to build display pages and GUIs for these simulators. These pages are used to display information about the simulation to the simulator user. This data allows the user to check on the functions of the simulation and ensure that everything is running smoothly. In order to create the pages, properly formatted excel files were created that logically split the data points. Then, a script was run that converted those files into .page files. These pages then required code manipulation and formatting. Some pages had more data than others and required special formatting. For some pages, creating a table was the most logical way to organize them. One of these tables was based on a hexadecimal system and included over 512 data points. Another method for displaying the data was buttons that lead to more pages. This method was useful for some of the large sets of data. Another possible approach to this project would be to create a script that formats the pages uniformly. However, with the amount of special cases creating such a script would be extremely difficult. Overall, the project was successful and the display pages were used to give information to the simulator user. Another possible approach to this problem would be to create a script that formats the pages.

Web Development

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If there is one thing that is most admirable about the Goddard Site, it is the workplace that the interns are placed in. Much of the time if not all of the time there was somebody willing to help me fully understand aspects of the projects being worked on. Much of the summer was spent learning programming languages which comprised a web page containing a web game which utilized what is known as a Golomb sequence. This sequence follows an abnormal integer system and will yield seemingly abstract results on an autocorrelation matrix grid. My job, at first was to create a user interface which would be used to label "Solutions" with the User ID and then save the solutions to a database. Having never worked with a database it seemed rather difficult creating a login form which would connect to a database. Most of the learning came from completing tutorials and documenting preexisting code which formed the webpage. There was a great deal of code which went uncommented and this made things very complicated, it was indeed a good learning experience though. One of the most important findings was that documentation of code can really save much time and help a team cooperate more efficiently and this lesson will definitely be remembered. This was the only instance which I was working with a database and multiple languages working cooperatively to create a complex site, but it will not be the last instance and I know that the things that I learned here this summer will definitely prove useful in the near future during school.

Dellingr 6U Cubesat

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Dellingr began as an idea and a hollow 10x20x30 cm block of aluminum. If it were ever to fly, serious work had to be done with the mechanics, electrical systems, and programs. The programming is where I offered my services. However, with little coding experience and programming languages unfamiliar to me, how was I to write the necessary programs to make this idea a reality? This was the question I struggled with, and eventually answered, throughout the course of my internship. Due to the urgency of the Dellingr project, I thought on my feet and learned as I worked. Asking questions of those who knew more than I did about coding in C, PDE X, and MatLab, I quickly gained a basic knowledge of the capabilities and syntax of the languages. In addition to this, I was informed of courses in C and MatLab programming located in the GSFC Learning Center. I quickly made use of that resource and became well acquainted with the languages. Combining the work I did on Dellingr with the individual studies I conducted, I became skilled in writing programs for a number of tasks. With that knowledge and experience I was more adequately equipped to aid in the task of making a chunk of metal worthy of being sent into the orbit of our home planet; but more importantly, I was able to work with, and learn with, an amazing team that was pivotal in my programming experience.

Web Forms for the Sciences and Exploration Directorate

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The Sciences and Exploration Directorate (600) is in need of a new set of web forms for their website. The goal of my assignment is to improve the current state of these forms by recreating them and adding new functionalities to them which will make them easier for the users to fill and use as desired. The first form is an Emergency badge request for Foreign Nationals. The Second form is an approval memo from the Information Technology and Communications Directorate (700) for foreign travel with NASA IT equipment. The third one, which is the longest of the three, is the Security/Technology Transfer Control Plan (STTCP).

These forms were developed using HTML, PHP, JavaScript and SQL. Before submitting each of these forms, each input field has to be filled; otherwise, an alert box shows up in the screen indicating that the form has to be completed before submission and the input fields that are empty are highlighted in red.

After completing the form and clicking “Preview”, which is the button we have for submission, another page is loaded which outputs the same form but with the information that was entered by the user. This information is not shown inside input fields, only the input is shown as to not make it editable.

At the bottom of each preview page we have three buttons: Print, Download as MS word and Go back to edit. The STTCP form has an extra button called “Save” in its preview page, which allows the user to save the information in our database for further editing.

Creating a Multi-Display Visualization Wall Using Open Source Software

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Currently, each of the 15 monitors in the Visualization Wall is driven by a Dell Precision WorkStation R5400. Each server contains a NVIDIA Quadro FX 1700, 2 dual-core Intel Xenon Harpertown processors, and is aware of its position relative to the other monitors. A head node appropriately manages all 15 display nodes, as well one file server used to store the simulation data. Custom software has been developed within GSFC to support this particular system. This is a complex system with some reliability and performance problems. A 2 by 2 prototype display was used to test the installation of various operating systems, video card drivers, and software packages, in hopes to improve the current system. Ultimately, the NVIDIA driver and associated Mosaic technology running on CentOS 6.5 has the least complications. The four monitors are configured using “Base Mosaic” mode such that they function as a single desktop. Multiple windows can be open at one time, or applications can be executed in fullscreen to utilize the full size of the configuration. The Visualization Wall could potentially be made simpler using the same operating system and software as the 2 by 2 prototype. A single server could house four 4-port video cards equipped with NVIDIA Mosaic technology, leaving a total of 16 ports for 15 displays. This would significantly reduce the cost, size, and complexity of the system. However, 4 video cards in a single server might produce too much heat, and require a great deal of processing power.

Evaluating the Use of Hive and Impala for Storage and Processing of Climate Data

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Climate data fits into the domain of "Big Data," which are large and complex data sets. A major Big Data challenge is the inability to move the data sets, requiring that analyses be brought to the data. It is also important that complex analyses complete in a reasonable amount of time. Hadoop is an open source software framework that has been developed to store Big Data sets. Hadoop also uses MapReduce, a programming model that allows for parallel processing of data stored on a distributed cluster. This project compares the performance of two data warehousing and query engines built on Hadoop, Apache Hive and Cloudera Impala, to a previously implemented Climate Data Service Application Programming Interface (CDS API). Hive and the CDS API both implement MapReduce to execute queries, whereas Impala uses Massively Parallel Processing. The study tested the same query running in all three environments for four different sized subsets of NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA) data set. This study also compared performance using text files and three different types of compressed file formats: Sequence, RC, and Parquet. The CDS API runs faster on average than Hive running on Sequence files, though Hive has faster runtimes than CDS API when using RC and Parquet files on larger data sets. Overall, Impala running on Parquet files consistently offered the fastest runtimes and was at least four times faster than the CDS API for all queries tested. These results provide good insight to how the performance of the CDS API can be improved.

Science Data Analysis in a Collaborative Workbench

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At the Goddard Earth Sciences Data and Information Services Center, scientists and analysts work on different data services that help users retrieve and analyze data to use for visualization, plotting, and other capabilities. We use Geospatial Interactive Online Visualization And ANalysis Infrastructure (Giovanni), which is a web-based application developed by GES DISC to provide a simple way to visualize, analyze, and access vast amounts of Earth science remote sensing data. A different approach to data analysis tools drives the Collaborative Workbench, a shared system consisting of analytics tools such as upload, validation, and open search added to an Eclipse Rich Client Platform for integration of data services and visualization. The main objective of this project was to add the ability of users to supply their own data via the Collaborative Workbench to Giovanni, thus serving as a bridge between the desktop analysis environment and the web environment. The capabilities that are added to the workbench are: data uploading, validation, and open search for user-supplied data. These features allow the user to supply their own data for the use of research purposes for one's self and other collaborating users.

MyGiovanni: Online analysis and Visualization with User Contributed Shapefiles

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Giovanni is an online Earth Science tool developed by the GES DISC that provides a simple, intuitive, and fast way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data. Currently, users are limited to data and parameters that Giovanni provides; however, the relevance of the outputted analyses and the strength of conclusions drawn from them would be greatly enhanced with the addition of user supplied information such as datasets and user-defined geographical regions. In the current version of Giovanni, analysis regions are selected in the web interface by either drawing a box on a map or by or typing in latitude and longitude boundaries. The aims of this project were to implement and integrate a system in Giovanni by which users could upload files known as shapefiles that would allow for analysis and visualization over polygonal geographic regions, including both pre-defined regions (such as states or watersheds) and user-supplied regions. This system will enable users to draw stronger conclusions from the output of several analyses offered by Giovanni since the analyses will only include the specific areas users wish to study. The targeted analyses for this project were Area Averaged Time Series, Time Averaged Map, and Area Averaged Scatter Plot, although others may be added in the future. A front-end system was developed to support the upload and selection of user shapes for analysis and backend routines were developed to handle the upload process and the algorithmic steps of the analyses involving shapes. Giovanni shapefile capability is currently in the prototype phase and should be expected to be publicly available within the coming months (http://lilt.ilstu.edu/ewpeter/geo361/scientific abstracts.pdf)

Analyzing Plant Fluorescence with Matlab

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When vegetation undergoes photosynthesis, it emits some of the absorbed light at a longer wavelength than that at which it was it absorbed. This emission is known as fluorescence. The spectral pattern of this fluorescence can be used as an indicator of the composition, function, and health of the observed plants. The spectral pattern can also vary based on a variety of factors including the intensity of the sunlight and the angle at which it hits the plants. The FUSION project involves mobile towers placed so that they are surrounded by canopy and vegetation. These towers have spectrometers on them that collect spectral data on the incoming light from the sun and on the light being reflected by flora. The sensors are oriented at different angles repeatedly throughout the day, allowing for extensive coverage at different times. The data allows for the analysis of fluorescence and its variance based on solar intensity and angle of incident. Understanding the variances from those factors will be helpful for future projects. In order to analyze the massive amounts of data put out by the remarkably precise spectrometers, calculations need to be done more effectively than they have been using Excel. Matlab is a perfect program for handling large scale delimited data like this. The code written to handle the analysis and calculations is notably more streamlined than containing the data within Excel, and will be capable of producing more informative graphical representations given just a few simple additions. Using Matlab has allowed for significantly more efficiency. Rather than combing through a giant spreadsheet for data, this script will allow for more digestible presentation, better plotting, and greatly more volume processing.

The Neutron Star Interior Composition ExploreR (NICER) – Telemetry Pages Development

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NICER is an x-ray timing instrument that will resolve the nature of ultra-dense matter by studying the dynamic processes and radiative mechanisms active within neutron stars. The NICER instrument requires telemetry pages to be designed and developed in order to view research data in real time. Telemetry is data that is automatically transmitted between a ground station and a satellite, in this case the International Space Station. The ASIST computer program is used to simulate the technology of the NICER instrument. The editing function in ASIST, Sammi, is used to design and develop the data mapping required in the telemetry pages to report operation status and desired research data from the NICER instruments. The main telemetry pages developed for NICER are for the Star Tracker (ST), Global Positioning System (GPS), and Gimbal Control Electronics (GCE). Each of these smaller instruments requires telemetry pages to report their operation status and specific research data taken by the instruments. The telemetry pages developed during this internship will allow the creators of NICER on the ground to comprehensibly view the data in real time taken by the NICER instrument.

SEA^5: Space Environment Automated Alerts & Anomaly Analysis Assistant

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Space weather affects virtually all of NASA's endeavors, from robotic missions to human exploration. Knowledge and prediction of space weather conditions is therefore essential to NASA operations. The diverse nature of currently available space environment measurements and modeling products pose a unique challenge for anyone seeking to quickly evaluate the space environment for any location and time throughout the heliosphere. There exists a compelling need for accurate real-time forecasting of both large-scale and local space environments – and their probable impacts for specific missions and orbits.

SEA^5 is designed to provide past, present, and predicted space environment information for specific missions, orbits, and user-specified locations throughout the heliosphere, geospace, and on the ground. The system is built on top of a comprehensive data model that we have implemented that stores spacecraft metadata, along with both observational and simulation space environment information. An innovative feature of the SEA^5 system is its ability to model the relationships between disparate data sets and the regions these data cover in space, along with mapping the dynamic locations of orbital bodies in relationship to the data sets registered within the SEA^5 system.

Recent work has culminated with the development of a prototype system with existing functionality that supports a variety of queries for three ongoing satellite missions. Included in the prototype are many new features for the system including a solar coordinate transformation package that was translated from C to Java, a number of spacecraft anomaly calculators for geosynchronous satellites, and a state-of-the-art, web component based user-interface using Google's Polymer library. SEA^5 will be publicly available online but is targeted for use by NASA robotic mission operators. The final product will allow mission operators to efficiently discover all space environment data relevant to their mission and receive automatic alerts and notifications when hazards go beyond their specified thresholds.

Software Optimization for Processing and Interpreting Cassini CIRS Titan Data

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This project's original objective was to translate already written IDL code that compresses large amounts of line-by-line calculated absorption coefficients of Titan related gases into C++, using the correlated-k approximation technique. The compression is computationally expensive, so the parallelization methods present in C++ would allow for an exponentially faster compression of the absorption coefficients. As the project continued, further research showed that IDL also contained methods for parallelization that can produce results similar to a parallelization using C++. To parallelize the ISL code, the object class IDL_IDLBridge was used to create multiple IDL sessions, each of which could access a different computer core. Due to the independent nature of the computationally expensive calculations, they can be run simultaneously to reduce the runtime of the program. By spreading out the computationally expensive generation of the correlated-k functions over the cores of the computer, the runtime of the program is roughly equivalent to the reciprocal of the number of cores contained in the computer. While the creation of the instances of IDL and parallelization of the code creates computational overhead that prevents the runtime from reaching the ideal proportion of the reciprocal of the number of cores, the comparatively large computational cost results in a significant reduction in the runtime of the program.

Computation Intensive and Parallel Data Applications Solved with OpenCL

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The goal of this research was to find a better approach to processing data for LVIS, which is a laser altimeter that collects thousands of data points per second about specific areas of land, vegetation, and ice being observed via aircraft. Currently this process can take up to several days to complete, which is not optimal. After initial research, it was determined GPU processing could possibly solve this problem. Therefore, for this project, the objective was to obtain a greater knowledge and understanding about the computation power of GPUs that can be harnessed through a relatively new programming standard called OpenCL and to learn how to apply it to current applications that have extremely large data sets that require significant operations to process data. In the past, applications with these attributes suffered from extremely long execution times due to the sequential nature of CPUs and the lack of large scale parallel processing achieved with this type of hardware. In order to significantly reduce execution time, GPUs were chosen because of their unique characteristics and available processing power. Since GPUs are natively asynchronous and parallel in terms of performing operations, code was written that not only could take advantage of these characteristics but also could use them to achieve better execution times for problems designed to fit the OpenCL programming model. Thus far, when given the right type of problem that can be broken into independent parallel pieces, execution times as 10 times faster than the original code executed on a CPU were achieved.

Historic Risk Data Collection and Analysis Effort

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The purpose of this project is to collect, consolidate, and analyze historical risk data from projects in the IT and Communications Directorate (ITCD), to find opportunities to improve the risk management process. A few subject matter experts were consulted for key questions, such as: Is there a significant difference in risk levels from one project to another? These questions led to the development of the hypotheses. One hypothesis was based on the observation that the risk likelihood and consequence levels had a tendency to decrease or stay the same over time. This process led to the data requirements. For example, the risk types, priority, and consequences to ascertain the most common risk type, the frequency of changes in priority, and the most impactful types of risk, respectively. Another factor that informed the analysis was the amount of risk data that the project managers omitted from their reports. A substantial amount of risk data needed to be retrieved from historical reports in PowerPoint. After transferring this data to the risk list template in Excel, it was analyzed. It was found that not all of the hypotheses were true. For example, a few projects had trends that increased in both consequence and likelihood levels. The most common risk types were Technical, Schedule, and Management-Programmatic. These also had the highest criticality level, meaning that they are the riskiest types. Based on the percentage of missing data, it was found that project managers should be more thorough and consistent in reporting risk data. In conclusion, there are concrete measures that can be taken to improve the amount and quality of risk data such as increasing the availability of risk training tailored to ITCD project managers and incentives for reporting quality risk data more frequently.

Data Center Efficiency Saves Money and Reduces Greenhouse Gases

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Improving data center efficiency can significantly reduce GSFC's budget and reduce its carbon footprint. Goddard spends many millions of dollars a year powering its data centers and other IT installations. Additionally, it reduces the HVAC strain on aging buildings and helps meet several federally-mandated Green policy and sustainability directives.

One major recent efficiency development is data center containerization, which involves placing IT equipment inside a container. These range from repurposed ISO shipping containers to purpose-built containers that can be assembled in a modular fashion to build out very robust and efficient data centers. Due to the smaller volume, utilizing a container as a data center can provide a 40-50 percent overhead power improvement, even without introducing any of the other current revolutionary efficiency-enhancing technologies.

There are many other technologies available to reduce data center power consumption. Since the most significant non-IT energy consumption results from cooling the IT equipment, much attention is focused in this area. These solutions range from simple techniques, such as blanking plates and curtains which reduce the mixture of server-generated heat with ambient air, to very sophisticated technologies which entirely re-imagine the traditional HVAC process, such as submersion in eco-friendly dielectric, rack-mounted devices.

Another area with efficiency improvements is power distribution. Since power is distributed to the data center from one central source, even slightly improving that source's efficiency can yield significant savings. These developments include on-site power generation (reducing the energy lost in transport), systems which reduce the number of energy-expensive conversions from AC to DC power, and even transitioning to a DC power distribution system.

With careful application of these and other technologies, it is possible for Goddard to save significant budget while also decreasing energy usage and reducing its greenhouse gas emissions.

Enterprise Virtualization with Failover Clustering

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Hosting applications on servers before most modern virtualization required the use of backups and preventable maintenance to ensure healthy systems. The reason for this was because when a server experienced some fault more than likely the server would shut down or cease to function. This causes downtime and lost avenues of revenue depending upon the effected services. With the availability of Virtual Machines (VM), physical servers can be converted to virtual servers and the efficiency of the hardware can be utilized to greater effect. However, much like the fault of standalone servers, if the physical machines faulted and failed the virtual machines will fail as well. What is the solution for this problem? This is where the solution of a failover cluster presents a remedy for this issue. A failover cluster is a grouping of servers with a shared storage space where VM's are stored. The way a failover cluster works is that in the case of one physical server's failure the VM's will migrate to another host in the cluster. Due to this, hosted applications and services upon the servers will continue to operate. A failover cluster was implemented with a five node cluster with storage space upon a Netapp Filer. The result of this was a stable production system used to host critical VM for the NASA network.

Designing a Prototype for the Fee-for-Service Program Tool

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Fee-for-Service is a payment model where services are unbundled and paid for, individually by each user or group of users, where the customer can make independent decisions regarding management of technological services rendered to them via Code 760. It is imperative to have a secure tool that produces detailed invoice reports, tracks and collects funds, processes usage data and provides an online Graphical User Interface (GUI) for both customers and system administrators to maintain services on a day-to-day basis. Given such requirements, I have been tasked with assisting with the development of a prototype for the fee-for-service tool. This process included the design of an entity relationship model to describe the system requirements in depth. In doing so, we chose to develop the database models in Python programming language using the Django Web Framework. Through the establishment of the system's entities, which are any type of objects we would like to store data for, we are able to define the attributes of each and establish the relationships between them. There are three types of relationships: one-to-one, one-to-many and many-to-many. A one-to-one relationship is when an attribute of one entity is associated with an attribute of another entity. In addition, a one-to-many relationship is when an attribute of one entity is associated with multiple attributes of another entity. Lastly, a many-to-many relationship is when multiple attributes of an entity are associated with multiple attributes of another entity. Our model addresses all of the relationships between each entity and reveals a user-friendly graphical representation of the system according to the requirements set by the organization's data needs and ultimately prepare us for the implementation of an effective prototype of the system.

Next Generation Voice (NVG) Enhancement Project Voice over Internet Protocol (VoIP) Vs. Private Branch Exchange (PBX)

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The Next Generation Voice (NGV) Enhancement Project is an initiative to identify, procure and implement an enhanced solution to meet GSFC's telecommunications needs. The NGV Enhancement Project is implementing an advanced telephony technology called VoIP. VoIP utilizes an Internet connection instead of an analog, digital or ISDN connection to transfer voice data between two parties. The new solution collaborates the existing voice and network systems; therefore, offering a cost savings of operating and sustaining two separate systems. VoIP systems typically cost less to install and sustain. Also, additional wiring is not required because the network infrastructure is already in place. The VoIP solution also offers system efficiencies and advanced feature sets to users. The system is composed of the Cisco Call Manager (CCM) and devices such as: desktop phones, mobile applications, and soft-client applications. With these combined technologies, the VoIP solution enables many teleworking features, for example, you could access your voice mail remotely and receive calls from your desk phone number to your NASA-issued laptop or mobile device. VoIP is a great option for companies with multiple locations. The solution makes it easy to connect to employees at other branches and telecommuters. The system also allows features to be shared across multiple locations. A PBX phone system relies on older technology that is not as friendly or productive to today's mobile workforce. It cannot be integrated with laptops and mobile devices. A PBX phone system tends to be more expensive than VoIP, although the price difference isn't as dramatic as expected. The wiring and installation costs are comparable, but purchase of obsolete equipment for repairs and continued maintenance support can be more expensive.

Technical Writing Internship

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The original goals of this technical writing internship were to complete an Agency Consolidated End-user Services (ACES) seat validation/invoice cross reference, update the Code 800 IT Management Plan, and gather information to aid in the creation of the Back-Up and Recovery Study Team (BURST) database. The ACES contract is NASA's service provider of computers, cellular devices, printers, office software, and email. This seat validation required creating a spreadsheet catalogue of the results by contacting users in each code 800 organization (800, 801, 802, 803, 810, 820, 830, and 840) to confirm their assets and cross-reference their information with the ACES invoices. This information will save NASA time and money when validating services. Updating the Code 800 IT Management Plan from the existing 2009 document involved reformatting and editing the sections for each organization to reflect changes in functionality and IT requirements. Gathering information for the BURST database required listing the Wallops Research Range facilities and their IT capabilities. This data will be used to identify mission critical buildings and create contingency plans in the event of damage to facilities. Additional projects included updating the Patch manager database with information from the Wallops Island and Mainland campuses, aiding in the architectural planning process of a Code 763 personnel move into a new building, and completing a Virtual Desktop Interface (VDI) proof of concept test for IT developers at the Greenbelt center. Patch manager is an application used to document the Wallops cable plant, including physical connectivity (fiber optic cables) and network equipment, and provide a detailed view and usage of these assets. VDI testing involved testing applications for a virtual Windows desktop on an iPad tablet. This internship consisted of multitude of projects and was an excellent opportunity for the development of writing, editing, computer, and professional skills.

Engineering

Robotic Arm Controller Evaluation Report

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This work focuses on the rapid integration and evaluation of various controller interfaces for operating robotic manipulators. Current controller methods require extensive training and focus for a successful operation. The goal of this research is to explore a combination of different control methods to determine which controller properties are best for operating robotic manipulators in scenarios that require a high degree of accuracy and precision. In this work, the input devices explored were: joysticks, momentary push buttons, pressure sensing triggers, and multi-touch surfaces. The devices were integrated to control robotic test platforms and coupled with visual and haptic feedback systems. An evaluation process was designed to assess the usability of each control method by measuring the precision and comfort of an operator's ability to track points on an object. It was found that the ranking of the control method was dependent on the prescribed task and robotic dynamics model. Overall, tracking and end-effector placement was best achieved using joystick control. If the controller was configured to move individual joints of the manipulator, a 3D joystick was ranked as an invalid control method. However, if the robot was configured to operate using end-effector placement, or Cartesian control, three-dimensional joysticks were ranked as a viable control method and offered similar accuracy to dual 2D joystick configurations. The experiment concludes that different control methods are appropriate for specific tasks and scenarios, thus multiple input methods should be available to the operator.

Classification and Organization of Robotic Arm Design

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The objective of this study is to collect performance data of robotic arms from both Mars and space missions. A future conference paper from the Satellite Servicing Capabilities Office (SSCO) is planned to be released summarizing the results. The data collected on the arms includes: payload lift capabilities, reach, degrees of freedom, accuracy, repeatability, and speed of the arm. Data was found in published specification sheets documents and from personnel who designed and built the arms. The data points were then placed on scatter plots to indicate groupings for both in-space arms as well as those designed to work on Mars. The distinction between robotic arms designed for Mars and in-space demonstrates significant differences. Arms designed to work on Mars have more accuracy, shorter reach, fewer degrees of freedom, and less payload. In-space arms have better repeatability, longer reach, more degrees of freedom, and heavier payload lift capacity. The main source of error is missing data since some of the data is proprietary.

Reach and Access Trajectory Planning for Restore Refueling Mission

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The study conducted was on mapping the trajectories for the Restore robotic arms. The data gathered from these trajectories will be used to define the requirements for the arms' operation. The production of the arms and supporting accessories will use the data, such as total joint rotation and overall joint velocity, as a guideline for operation requirements. Using the Geomod program, points of interest are found in a universal frame and then converted over to the robot control software. This software then allows the user to control the robotic arm and view its motion over time in the Freespace Visualizer. Data is then taken from the logging capabilities of the robot control software to be graphed and analyzed. Through mapping the trajectories for a Visual Panel Survey and a Payload Deck Survey, the total time, total joint motion (in degrees), collective joint velocities and individual joint velocities were recorded. The data gathered reflects the trajectory that the arms travel through, which takes joint limits, velocity limits, and safe distances from surrounding objects into account. The resulting data will serve as requirements for the motors of each joint in the arms, as well as give information on power consumption and total time for these segments of the mission. The information drawn from the data will help determine if additional power sources (solar panel arrays) are needed for a servicing mission, and also give those who control the arms guidelines to operate the arm safely on a specified trajectory.

Performance and Characterization of Helicoil Locking Inserts

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Helical wire inserts (commonly referred to as Helicoils) are used frequently to protect sensitive parts from being damaged during threading and fastening operations in the integration and test phase of critical flight hardware. They also provide a secondary locking method (running torque) that is not available with standard tapped threads. A study is being completed on tanged and tangless Helicoils of various sizes and material makeup to determine which types are easiest to install/remove and offer the longest functional lifespan under standard conditions. To complete this study, six sets of plates were designed with each set containing an insert plate to hold 90 flight certified Helicoils and a spacer plate which ensures full engagement of the flight certified fasteners. After installing and recording the installation time for each Helicoil, torque measurements will be taken as a fastener is repeatedly inserted and removed until the running torque falls below the minimum specification. Once each Helicoil has been tested, each will be removed while being timed. This study is still in the testing stages, but the goal is to use the data collected to determine which type of Helicoil can maintain an acceptable level of running torque for the most insertion and removal cycles. Ultimately, the SSCO project and perhaps other Goddard projects will use this data to standardize future designs in order to maximize efficiency as well as to minimize risk to flight hardware during ground processing operations.

ST-5: A Spacecraft Dynamics Simulation

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The Space Technology 5 (ST-5), consisting of 3 micro-satellites, was launched in March of 2006 to test and validate several innovative technologies for future science missions. However, shortly after detachment from the launch vehicle, ST-5 began to spin down. By remodeling the satellite's orbit, the predictive validity of the satellite's trajectory can be applied to future missions. The goal of the investigation was to create a dynamics model of one micro-satellite, featuring orbit, rate, and attitude. After first calculating the Sun's position relative to Earth, a fourth-order Runge-Kutta was used to propagate the spacecraft's orbit, rate, and attitude (represented as a quaternion). The Sun's position and attitude were used to reverse engineer a Sun slit sensor. A magnetometer was modeled assuming a simple dipole for the Earth's magnetic field. The attitude was then calculated from the body and GCI reference frame Sun and magnetic field vectors. From these analyses, the unexpected spin down can be attributed to eddy currents and a residual magnetic dipole within the spacecraft.

Data Analysis of S-NPP ATMS Anomalous Events

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In late 2012, the Advanced Technology Microwave Sounder (ATMS) instrument on the Suomi National Polar-orbiting Partnership (S-NPP) satellite experienced a large scanner anomaly event spanning several months. Since then, smaller events have occurred sporadically. The aim of this project was to create tools to quickly and easily access and analyze ATMS instrument data for anomaly resolution. A Python script was adapted to extract and aggregate application packets from Raw Data Record (RDR) products downloaded from the NOAA CLASS website and the NOAA GRAVITE system. A Fortran tool was used to parse and extract telemetry information from daily binary data packet files to human-readable Excel files. For instrument dwell data, a MATLAB script was written to ingest the Excel files and produce visualizations of dwell time series and Fast Fourier Transforms (FFT). A MATLAB script was written for housekeeping data to ingest the Excel files and output a time series plot of the selected telemetry points. For science data, 2-D and 3-D plots of the radiance difference were created in Excel. Experts are presently analyzing the 3-D FFT and science plots output by these tools for the recent on orbit anomaly that occurred on May 27-28, 2014. Through use of these tools and inspection of the output plots, experts may gain an understanding of the causes and effects of these anomalies in an effort to better predict and prepare for future events.

Testing a Calibrator for an Earth-Imaging Radiometer

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The JPSS-1 Visible Infrared Imaging Radiometer Suite (VIIRS) instrument requires pre-launch calibration. One calibration method uses a device called a Flat Plate Illuminator (FPI), which produces uniform radiance in the visible through mid-wave infrared range, and which itself requires calibration. The FPI needs to produce consistent radiance in the temperature range that VIIRS will experience on-orbit. This research measures the FPI's radiance over that temperature range. The research method involves taking and analyzing measurements of radiometric data while the FPI is in thermal vacuum. The radiometric output should be fairly consistent over the desired temperature range, and the measurements should be reproducible. However, the measured radiometric data thus far has been inconsistent. Separate measurements at the same conditions have produced varying results. Further investigation is needed to determine the cause of the inconsistencies and implement a solution. Research on this topic will continue until the FPI's performance meets specifications. It will then be usable as a calibrator for VIIRS in pre-launch testing.

Neutron Star Interior Composition ExploreR (NICER) Ten Percent Model

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A ten percent scale model of the Neutron star Interior Composition ExploreR (NICER) was created to simulate the structure that will be sent to the International Space Station (ISS) to calculate the density of neutron stars. A model provides a tangible object in order to perform demonstrations, explain thoughts and ideas, and market the design to customers and collaborators. Additive manufacturing was developed in the 1980s and originally used an inkjet printer head to create ink layers. The most current form of plastic rapid prototyping is fused deposition modeling, which works by extruding thin layers of plastic repeatedly to create a solid piece. This system allows for objects to be manufactured quickly, and is useful for pieces that are difficult to machine due to geometric complexities. The objective of this project was to design and create a fully-functional and robust model of NICER. Creating a ten percent scale model began by using a 3-D modeling Computer Aided Design (CAD) program to design parts. Each part must be made separately and then inserted into an assembly to ensure the pieces fit together correctly. These files were then converted into printable files and additively manufactured using either Acrylonitrile Butadiene Styrene (ABS) or Polylactic Acid (PLA) plastic. By employing additive manufacturing a ten percent model of NICER with full-range of motion was created from several pieces and assembled.

LDE Checklist and Handling Fixture Certification

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In order for NASA to create large machinery, it must use the correct Lifting Devices and Equipment (LDE) required to move heavy and/or large objects. Before each use of LDE, it must go through extensive testing to verify that it is safe to use. A checklist was created to ensure that all testing was thorough and streamline, but the initial checklist created proved to be too vague to perform its duty. The checklist would have to be seriously modified in order for it to achieve its intended purpose. The checklist was expanded, color-coded, and cleared of unneeded instructions. As the new, modified checklist was used in LDE testing, a number of new problems were discovered with the new checklist and promptly alleviated. The checklist's alteration was important because without it LDE assessments would take much longer and would be more difficult, making project deadlines harder to abide by. Also, if the vague, confusing checklist was still in use it could have also led to the misinterpretation of vital information. Misinterpretation could easily result in damage to extremely expensive material and/or serious injury/death to personnel working near or on LDE equipment.

Pressure Vessel Systems Certification

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The summer intern project will be to work with simple pressure vessel systems, developing an improved process to quickly certify that they meet all requirements. Upon completion of the project, the work will provide process improvement for the certification program and a rough estimate for how long it should take to certify all simple systems on center. In order to achieve these aforementioned goals, twenty simple systems were assigned for certification during the internship. By certifying 20 systems, the experience taken from the certification process will be used to provide a better understanding of areas needing improvement. In addition to process improvement, a rough time table can be utilized to determine how long it will take to certify the remaining systems at GSFC and WFF. The results show that with the rate the systems were certified, the remaining simple systems should be certified in approximately 4 years. Some flaws were found that would help improve efficiency in the certification process. The completion of this project allows NASA to have an idea for how long this certification project will take. NASA will also be able to work on reducing the amount of flaws in the systems and be able to perfect the certification process.

Piezoelectric Stack actuator for Micro-Mechanical Testing

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In the Materials Engineering Branch's small-scale mechanical test system, the micro-force load sensor is very sensitive to subtle noise and vibration. The vibration from the existing screw-driven actuator in the mechanical test system itself can significantly affect experimental data. For this reason, testing of MEMS structures such as microshutter devices must be done very slowly so as to avoid noise artifacts. Moreover, the existing screw-driven actuator tends to have repeatability issues due to inherent slack and grease between contact surfaces. The purpose of this project was to incorporate a piezoelectric stack actuator into the existing mechanical test system to reduce the noise level, increase repeatability, and enable faster testing. Piezoelectric material has the benefit of low noise and high speed due to the absence of mechanical parts. A linear piezoelectric stack actuator was fully characterized with respect to performance characteristics and repeatability. The actuator was controlled by varying the applied voltage to simulate different modes of mechanical testing. A LabVIEW force/feedback program was developed to manipulate the voltage applied by the power source. Since the actuator has inherent hysteresis behavior, tests were performed to measure the hysteresis curve. The hysteresis behavior was then accounted for by adjusting the applied voltage as a function of time to yield a linear displacement. This system upgrade will generate more reliable and faster experimental data for small-scale mechanical testing.

Improving Temperature-Dependent Honeycomb Panel Modeling Approaches

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The Wide-Field Infrared Survey Telescope (WFIRST) uses honeycomb panel laminates in places where temperature will vary significantly from launch to operating conditions. This project improves on modeling approaches for temperature-dependent laminates using finite element software Femap and NASTRAN. Fully temperature-dependent material properties were modeled in NASTRAN and verified. Three honeycomb panel laminate modeling approaches were considered: 3D core model linear analysis, 2D offset plate linear analysis, and 2D PCOMP non-linear analysis, where a PCOMP is a simple way to represent laminates in Femap and NASTRAN. The thermal strains for the 2D modeling methods both had a maximum of 8.3% difference from classical laminate theory predictions across the temperature range of interest. For the 3D model, the maximum difference from classical laminate theory was 8.5%. These maxima all occurred at a temperature of 60 Kelvin. Based on concerns with computation time and ease of implementation on existing models, this study recommends using offset plates to represent the layers of temperature-dependent laminates. To assist analysts with implementing this approach, a program was written using the Femap Application Programming Interface. This program converts elements using Femap's easy-to-create PCOMP representation of laminates to elements using offset plates for each layer so that temperature-dependent properties can be included in a linear analysis.

Developing an Analysis Approach for Evaluating the Effects of Defects in Composite Materials

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Despite well-defined processes when manufacturing composites, structural defects are unavoidable due to the unique nature of composite materials. These defects cause inconsistencies in the material properties of the composites and are accounted for with high safety factors in design and analysis. This project focuses on developing an analysis approach for evaluating the effects of defects in composite materials in order to determine the severity of such defects in regards to ultimate (catastrophic) failure of the material.

Four-point-bend tests will evaluate the effect of defects on jointed composite specimens that will have either particular defects within the structure or no defects. A cut plan was devised to make an optimal amount of test specimens from a manufactured composite panel while maintaining specimen dimensions that would ensure joint failure (rather than core of face-sheets away from the joint).

A theoretical baseline for un-jointed and jointed specimens without defects was to be verified between hand calculation and finite element analysis. The un-jointed specimen deflection calculations between the two showed a maximum of a 1.26% difference and were thus very similar, as predicted. The un-jointed specimen hand calculation also showed more deflection under a given load when it was compared to the deflection of a computer calculated jointed specimen, as expected, due to an increased stiffness of the jointed article from the joint doublers.

Moving forward, this project will conduct the actual tests and analysis which will not only give information about the effect of defects, but will also test the effectiveness of the configuration of the jointed specimens. This information will help to validate or improve current finite element analysis approaches.

As the effect of defects is more accurately predicted through progressive failure analysis, more complex composite structures can be maintained and manufactured with much higher reliability and better risk mitigation. This innovation paves the way for more cost-effective and efficiently designed structures for various applications and future aerospace missions at NASA.

OVIRS Shipping Container Design

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OVIRS is an optical instrument which is part of the OSIRIS-REx mission. Optical instruments are sensitive and must be shipped in specialized containers which must be approved by the lead mechanical engineer, lead analyst, lead designer, and the contamination group. A sealed Hardigg case will be used for OVIRS. The design of the container system will regulate vibration/shock and humidity. The wire rope isolation system is designed according to the weight of OVIRS and the type of travel and it will absorb shock and vibration. A nitrogen purge system and desiccant will control humidity. Humidity and shock will be monitored using sensors mounted on the inside of the shipping container. Temperature will be controlled by the transportation vehicle and also monitored inside the container. Upon arrival, the sensor data will be sent back to Goddard's analysts to determine if shock, humidity, or temperature were outside of acceptable range during transportation. The instrument will be bagged twice in the clean room using Dunshield electrostatic dissipative film as per the contamination requirement. The outer film will be removed upon delivery and the inner film will be removed inside the clean room. Also, all materials inside the case have been approved by a contamination engineer. These precautions will allow for a successful transportation of the OVIRS instrument.

Advanced Topographic Laser Altimeter System Structures Integration & Testing

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The Ice, Cloud, and Land Elevation Satellite 2 (ICESat-2) mission is one of the earth science decadal survey missions, a continuation of the science done by ICESat. Its objectives are to measure changes in the land ice and sea ice over the course of at least three years, and to measure vegetation canopy height. Advanced Topographic Laser Altimeter System (ATLAS) is the sole instrument on ICESat-2 that will fire a laser split into six beams at a rate of approximately 10 kHz to provide a better method to estimate elevations on sloped and rough land surfaces. The Integration & Testing (I&T) period is when all assembly and integration of any scientific components to the Box Structure and OB (Optical Bench) of ATLAS happens. This includes the design and analysis of any Mechanical Ground Support Equipment (MGSE) to support I&T activities. My tasks were generally associated with assisting the ATLAS I&T phase by aiding in the design and assembly of MGSE and the integration of flight and non-flight components to the Box Structure and OB. This included overseeing and directing integration operations in the SCA cleanroom, designing a protective cover for the OB, writing proof test plans for ATLAS MGSE, and writing an assembly procedure for the ATLAS Turnover (TO) Dolly.

3D Printing for WFIRST-AFTA Concept Development

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During the formulation stage of the WFIRST-AFTA project, engineers have begun trade studies on various concepts. One of the priorities this year is reaching consensus on the most effective arrangement of instruments within the instrument carrier which is integrated into the spacecraft. However, even with CAD models, it was difficult to visualize the scale and scope of this concept and whether it would work on the spacecraft.

With the capabilities of a 3D printer, multiple models were created of the WFIRST-AFTA telescope and interior structure at approximately 3% scale. Because of the quantity requested, it was optimal for an entire model to be printed at once, rather than printing small components that would require manual assembly. In order to print any model, the 3D printer must print additional support material beneath overhanging components. Therefore, it was proposed to print the support material using a dissolvable type of plastic, instead of traditional hard plastic. The combination of High Impact Polystyrene (HIPS) dissolvable filament as support material and Acrylonitrile Butadiene Styrene (ABS) hard plastic filament for the actual model was discovered by experiment to be most effective. Various other printing issues arose, which were resolved by instituting minor changes. With the appropriate settings, a complete model could be made in two prints. Because of the size and detail of the models, printing the two parts took up to two days.

Magnetic Bearings for Space Flight Applications

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The goal of this project is to reconstruct and operate an existing magnetic bearing system that was developed by the Electromechanical Systems Branch (Code 544). During the mid-90s, HIRDLS Earth Observing System-Chemistry (EOS-CHEM) required an optical chopper that needed to be operated at 5,000 rpm throughout the mission life. Due to concerns that mechanical bearings might not be able to meet the life requirement, a magnetic bearing based optical chopper was developed as a parallel effort, but was never flown. Magnetic bearing can reduce vibrations, allow higher precision, eliminate friction and lubrication, and have a longer life compared mechanical bearing.

Reconstruction of the magnetic bearing system required understanding all the details of the magnetic bearing mechanism, electronics, and controller hardware and software. This required discussions with the engineers who were originally on the project, digging into documentation that was available, and consulting with dSPACE technical support. Since there is a multiplicity of sensors, windings, driver circuits, sensor processing circuits, etc., these all needed to be identified with the magnetic bearing coordinate system. A harness was designed to connect between the electronics and a dSPACE controller. Matlab/Simulink is where the controller algorithm resides. Sensor signal voltage range and scale factor was determined, as well as magnetic bearing parameters, and all circuit gains, in order to develop the closed loop control system. This effort will lead future magnetic bearing space flight application.

Investigation on the Practicality of Developing Reduced Thermal Models

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Before a spacecraft is launched, or indeed even constructed, advanced thermal models are created to simulate its on-orbit environment to ensure that it does not exceed any thermal limits (e.g. temperatures and gradients). These detailed models, while highly accurate in their calculations, can sometimes lead to long run times. Therefore, reduced models are typically produced in tandem with the detailed models so that results may be more readily available, albeit less accurate. This study focuses on the impact that reduced models had on run-time and the consequent loss of accuracy when compared to its detailed pair. Preexisting thermal models of several projects (namely: GEMS, ICESat-2, and LADEE) were used to determine trends between detailed and reduced thermal models. Similarly, hot and cold cases were run for each model to capture the behavior of the models at both ends of its constraints. As expected, it was found that reducing the number of nodes in a model also brought about a reduction in the run-time, though a large time savings was not observed. However, a direct consequence of the simplified model is that it brought about significant losses in accuracy. Therefore, while reduced models are useful in decreasing run-time up to a certain degree, there exists a threshold of reduction where, once exceeded, results are no longer within an acceptable range of accuracy.

Testing a Cryogenic Heat Transport Device for Satellite Temperature Control

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Some spacecraft require cooling at extreme low temperatures. Current approaches use an open refrigerant system, which has lifetime issues. This may be resolved by a loop heat pipe operating at cryogenic temperatures as a closed loop system. Because no cryogenic loop heat pipe has been used in space flight in this manner, characterization of its behavior is essential. The existing demonstration unit is tested in a thermal vacuum chamber with two-phase helium, and its thermal performance is assessed.

The unit demonstrates excellent performance, but testing is still underway. Loop startup is achieved with the application of 10 mW, 20mW, or 30mW of pumping power. The maximum pumping capability of the loop is shown to be around 70 mW. As much as twice the pumping power is removed from the heat load, up to 120 mW, but the total heat removal capability has not been determined as of this writing. The device displays a high tolerance for sudden changes in heat load. Experiments show it is feasible to utilize a cryogenic loop heat pipe for large area cryocooling.

Investigating the Effect of 9924 Primer Thickness on Conductivity with a Z307 Topcoat; Development of a Pigment Database for Inorganic Silicate-Based Colored Coatings

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This poster encompasses two different projects related to thermal coatings. The first project is based off of past data showing varying resistivity values through a conductive topcoat (Z307) with an insulative primer (9924) applied to aluminum substrate. The lower resistivity values may indicate that thinner layers of 9924 primer still allow charge flow from the topcoat to the substrate, allowing the coating to be conductive overall. The purpose of this investigation was to determine the range of primer thickness needed to ensure conductivity, and to investigate other measures that can be taken to increase conductivity when the primer thickness is not in that range. This involved first applying the insulative 9924 primer in varying thicknesses to a conductive substrate. After the conductive Z307 topcoat was applied to the insulative primer, the resistivity from the topcoat through to the substrate was measured in order to determine how conductive the coating is. It was shown that most samples were sufficiently conductive when the primer thickness was under around 0.5 mils. In addition, it was shown that making a small mark through the primer to the substrate significantly increased conductivity for all primer thicknesses. These two findings are important in developing guidelines for spraying to ensure conductivity. However, the data did not show a significant relationship between decreasing humidity and conductivity, so more research should be done. The second project involved assisting the development of inorganic silicate-based colored coatings for Robotic Refueling Mission (RRM). There is a need to spray satellite hardware with colored coatings so that robots on satellite servicing missions can easily identify them. The purpose of this project was to develop a color pigment database which will aid in the formulation of these colored coatings. However, this goal was not met because of multiple problems in creating calibration samples. When applied to polyurethane substrates, the silicate-based coatings did not adhere well and did not spread evenly, especially when the percent colorant was low. In addition, the lower percent colorant samples degraded after a few weeks, some coatings cracked, and one pigment was found to be incompatible with the binder. These results have important implications for future work with colored coatings.

Mitigation of Thermal Coating Contamination from Particle Fallout

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Thermal coatings are used on all spacecraft to regulate temperatures while in the extreme environments of space. However, these coatings can shed particles when the spacecraft undergoes high levels of acoustic vibration, which can then contaminate optical equipment and other devices on the spacecraft. This study examined the effect of applying additional binder to the coating after it cured in an attempt to lower the particle fallout. Half of each sample was treated with additional binder, while the other half was left untreated as a control to compare against. The samples underwent acoustical vibrations comparable to those experienced at launch and the Percent Area Coverage (PAC) and distribution of particles were both measured with an Image Analysis (IA) system. The results showed that a solution of 30% KASIL 2130 reduced the fallout the most, compared to other concentrations, by reducing the PAC by a factor of 10. The doped hybrid binder, containing both sodium and potassium silicate, also showed substantial reduction, but was not tested as thoroughly. More tests will need to be run with different treatments and larger sample sizes in hopes of achieving greater precision and more definitive results.

A Look at Planetary Protection Implementation

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Planetary Protection Engineering is a subset of Contamination Control Engineering that focuses on preventing biological contamination. Key concerns are to preserve the Earth's eco-system during sample return missions, preserve possible traces of life on other planets, and preserve the science of life-seeking missions. One component of a life-seeking mission being built at Goddard Space Flight Center is a mass spectrometer that will be part of the 2018 ExoMars rover. One method to decrease the level of biological contamination on spacecraft components during the integration and testing period, prior to launching them into space, is to introduce ultra violet C radiation in the construction environment. To test the effectiveness of this strategy, a foil was inoculated with local environmental bacteria and later exposed to UV-C lights for various time increments. After exposure, the bioburden was examined by transferring bacteria from the foil onto trypticase soy agar plates. The plates were observed for one week for growth of bacterial colonies, and it could be seen that there were differences in the amount of colony growth based on the times of UV-C exposure. By day 6, the samples that had not been exposed to UV-C radiation had too many colonies to count (over 200 colonies per plate), while samples from 60 minutes of exposure had a total colony count of four. In conclusion, the hypothesis that UV-C exposure would lead to a dramatic decrease in bioburden was supported. Further analysis and replication of the experiment will be necessary once Goddard's planetary protection lab is in commission in order to obtain more precise and accurate results. This research provides preliminary data justifying the use of UV-C radiation in clean-rooms housing hardware essential in life-seeking missions.

Improving Adhesion of Thermal Coatings through Oxygen Plasma Exposure

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The purpose of this research was to gain insight on what surface preparation methods resulted in the best adhesion of a silicate thermal coating, Z93C55. In stressful situations such as bending, Z93C55 can flake off of its substrate if it hasn't adhered properly. The question this experiment attempted to answer is, does oxygen plasma exposure as a surface preparation method improve Z93C55 adhesion? To complete this experiment, 216 samples of 3cm x 9 cm black kapton were cleaned, sprayed with MLP 300 primer, and either sent into the vacuum chamber for plasma exposure or set aside. Then all samples were burnished and sprayed with the Z93C55, cured, and put through a Mandrel Bend Test and a Tape Lift Test. The samples that were exposed to plasma before spraying performed better in both tests than the samples that did not receive plasma exposure. These results suggest that plasma is a useful preparation method for applying thermal coatings.

Analysis of Thermal Optical Properties regarding the Degeneration of Z93C55 Substrate

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The sensitivity of instrumentation in varying climates and environments is essential to producing very accurate and precise measurements. The Z93C55 coating is composed of Zinc Oxide and a Sodium Potassium Silicate binder which favors galvanization and enhances durability. The purpose of this study was to analyze how Z93C55's thermal optical properties (Solar Absorptance and Emittance) were affected with respect to time in a neutral and basic environment. Coated substrates were initially analyzed by an IR Reflectometer and a Spectrophotometer. The substrates were divided into 4 even groups where the coated material was submerged in either a basic or neutral solution for 10 minutes and 30 minutes. The substrates were then re-analyzed by the IR Reflectometer and the Spectrophotometer to observe changes to the initial thermal optical properties. It was initially predicted that the neutral solution would increase the Solar Absorptance as the water seeped into the porous substrate and widened the pores, causing the Emittance to decrease. The basic solution was thought to increase the Emittance due to deteriorating the binder. This would produce an uneven top-layer on the substrate causing additional Specular Emittance which inversely corresponded to lower Absorptance. Results displayed that the basic solution caused Emittance to continuously decline while the Solar Absorptance increased as time progressed. The neutral solution conveyed a negative loss in regards to both thermal optical properties. These results illustrated how ineffective the coating was to resisting thermal changes in certain environments, and thus directed attention to discrepancies amongst the pigment to binder ratio.

The Impact of Different Parameters on the Effectiveness of the Nitrogen Purge

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The purpose of this experiment was to better comprehend how the nitrogen purge works and the factors that change its effectiveness. The nitrogen purge, which was developed to keep flight hardware clean, works by flowing gas through a vessel to maintain a positive pressure. Thus, the vessel would remain free of contaminants. In this experiment, the relationships between aperture size, flow rate, number of apertures, and geometric makeup were all tested to increase knowledge surrounding the purge. The majority of research went towards the relationship between the aperture size and the time it takes for the relative humidity inside the vessel to reach 1%. The experiment was based off of Dr. Lubos Brieda's, but utilized a rectangular vent to test instead of a cylindrical pipe. The aperture size, as well as the volume, was adjusted to test certain parameters. The results indicated that the calculations currently used in relation to the nitrogen purge are moderately accurate. The results also suggest that aperture size has no effect on the time needed for a purge. However, this only seems to be true after a certain flow rate is reached. Although much of the data confirmed the current method of calculating purge time, it does not account for the minimum flow rate that the results indicated. This study will help future technicians and engineers better understand the nitrogen purge and minimize the wasting of resources from incorrect or unnecessary use of the purge

Innovation Lab: R.O.G.E.R. Project

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The Remotely Operated Ground Exploratory Robot (R.O.G.E.R.) project was carried out by the 547 Innovation Lab intern team comprised of five high school and college interns. The primary goal of the project was to build a rover that could be remotely operated from a computer. The intern team ordered and designed new parts using SolidWorks in order to further stabilize and improve the rover's structure. Code 547 collaborations helped complete the project, resulting in a rover that could react to keystrokes, while sending video feed for proper driver decision making. Preliminary stages of integration with the arm and basic autonomous collision prevention were implemented. The project road-maps an industrial robot capable of human-like tasks. R.O.G.E.R. also shows the practicality of the progression and integration of several projects over many years toward an end goal.

Mechanical Design of Coronagraph CubeSat

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To know the effects that the Sun's corona has on the solar system, there must be means to study it. A coronagraph on a CubeSat platform gives NASA a relatively inexpensive way to view the sun's corona and thus be able to perform various studies on it and surrounding celestial objects. However, to accomplish all this, all the components needed to create this instrument must fit into a module (U) that is 10x10x10 cm in volume with a mass limit of 1.33 kg. The objective was to package this entire instrument into this tiny volume and within this mass. To achieve this, each component was carefully designed with a specific material mass and meticulously assembled within a standard CubeSat frame using the Solidworks CAD software. The main components of the coronagraph consist of a spring canister, an optics mount, a sun tracker, a sunshield with an occulting structure at the end, and a motorized filter wheel. A torque study to find the required turning force needed to rotate the filter wheel was performed with the results showing an achievable quantity can be provided by the selected motor. With some other design changes the components were able to fit within the volume. The current model has a mass budget of about 0.9 kg which left approximately 30% margin for any needed modifications. This complex unit, now called the instrument deck, will be attached to two more modules housing the power supply and guidance system for the spacecraft. There is optimism that the rest of the structure for the CubeSat will conform to the mass and volume requirements. Successful development of this coronagraph may inspire the implementation of the CubeSat platform for other studies.

Innovation Laboratory: Moving Forward

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The Innovation Laboratory is a unique environment within NASA's Goddard Space Flight Center where innovators can make their visions a reality. Additionally, high school and college interns collaborate to support and supplement Goddard's operations at a low cost. This experience serves to develop and encourage the next generation of NASA's workforce. The goals for the summer of 2014 were to prepare the lab for future innovators by repairing the lab machines to make them fully functional, as well as instructing the high school interns in the operation of appropriate equipment. Repairs included the adjustment and restringing of wire, replacement of outdated software, inversion of axis motors, and the fabrication of missing parts. The results of the internship were the complete repair and setup of six machines, as well as the instruction of all high school interns. Additionally, each piece of equipment had documentation and manuals for future usage and repair.

Space Simulation Testing for the James Webb Space Telescope

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Environmental testing is a vital phase in the engineering design process of spacecraft. The objective of thermal vacuum tests is to ensure that the spacecraft will be able to survive and operate in the extreme conditions of space. During my internship as a thermal vacuum test engineer, I supported thermal vacuum testing for the James Webb Space Telescope project. I was responsible for the test of the Beam Image Analyzer to verify readiness for testing at Johnson Space Center. To this end, I communicated with project engineers to gather test requirements and coordinated with the facility technicians to design the environment needed to achieve those requirements. Then I wrote procedures to specify the test objectives, equipment, and thermal profile. In addition to this, I helped disassemble a previous thermal vacuum test of the Integrated Science Instrument Module Electronics Compartment and analyzed data to evaluate the helium injection used for Free Molecular Heat Transfer during the test. Working on several different tests allowed me to experience every aspect of the testing process and learn more about the engineering process of spacecraft design.

Cellular Controlled Remote Magnetic Observatory

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One of my mentor's primary responsibilities is to manage the Goddard Space Flight Center Spacecraft Magnetic Test Facility (SMTF). The magnetic test site is used to simulate an environment with magnetic forces similar to those experienced while on orbit. To do this, the facility utilizes a Braunbeck coil system. This system consists of a total of twelve coils, four in each of the three axises, the largest of which is forty-two feet in diameter. By running a current through these coils, we can generate a magnetic field going through the center of the coil. The addition of each coil along the axis makes the magnetic field more ideal (consistent/predictable). Consequently, by running a precise current through the coils, we can manipulate the magnetic field in the center of the coils to almost zero, thereby negating Earth's magnetic field.

To improve the Goddard's ability to create the ideal magnetic field within the coils, my mentor would like to create a cellular controlled, remote magnetic observatory. There would be multiple units placed at various locations around the site. Each unit would be composed of a science grade magnetometer, a cellular modem, and a solar panel for power. As a whole, the unit will relay magnetic readings back to my mentor's work station. In doing so, we hope to better understand the local magnetic gradients of the area both during testing and on normal days. Ultimately, this information will be used to improve the facility both in its function and its aesthetics.

Digital Beamforming Synthetic Aperture Radar, 2nd Gen. (DBSAR-2)

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DBSAR-2 is a novel approach to Synthetic Aperture Radar (SAR), which enables multi-mode radar techniques not possible with conventional SAR, such as scatterometry, altimetry, narrow-beam SAR, and wide-beam SAR. DBSAR-2 consists of three main sub-systems: Radar Digital Unit (RDU), Radar Electronics Unit (REU), and the antenna. The RDU is responsible for generating the waveforms and control signals used by the radar. The RDU also processes the signals received by the antenna and performs beamforming during post-processing. This functionality was implemented using two custom-designed boards, each with Virtex-5 FPGAs. Firmware was written for these boards which enabled generation of the arbitrary waveforms used by the radar, converted the signals received by the antenna into a digital representation, and output control signals to the REU which set the operational mode of the radar. The REU was responsible for increasing the output power of the waveforms generated by the RDU in order to achieve effective transmit/receive operation. Additionally, the REU upconverts and downconverts the signals used for antenna-processor communication and filters out unwanted signals in the process. Sixteen transceiver boards were tested and characterized to verify they operated as the design intended. The testing procedures included: checking integrity of transmit and receive paths of as well as the signals that passed through them, testing a new filter placed in receive path, ensuring nominal output power to antenna, and general hardware debugging. Finally, the antenna radiates the electromagnetic wave pulses generated by the RDU and receives the pulses reflected off of the target. Future work for the project will include the full DBSAR-2 system calibration and flight tests on board a NASA aircraft.

Laser Stability Applications for Spectral Radiometric Calibration Demonstration Systems

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The purpose of this study is to demonstrate capabilities of a laser-based calibration system to support future climate missions. A main objective of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission is to achieve SI-traceable observations over decadal time scales to detect and project changes in the climate system. The Solar and Lunar for Absolute Reflectance Imaging Spectroradiometer (SOLARIS) is the calibration demonstration system for the reflected solar portion of CLARREO. Means for achieving high accuracy calibration (<0.3% uncertainty mission requirement) derives from the Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources (SIRCUS) at the National Institute of Standards and Technology (NIST). SIRCUS is a high-power tunable laser source providing SI-traceability capabilities for linking instrument measurements to internationally recognized standards. This source will enable observations of small errors using SOLARIS to understand climate variability. Project objectives include the following: (1) evaluation of laser power stability and variability, and (2) retrieval and confirmation of target stability <0.1%. The key to SIRCUS is the use of transfer radiometers with highly accurate monitoring capabilities used to calibrate output sources. Project methods included multiple data acquisition sets using SIRCUS to study variables including wavelength variability and power stability. Preliminary data analysis focused on effects of stabilizer applications by comparing plots, averages, and the standard deviation of transfer radiometer values between 700-1000 nm. Results indicate decreased power level fluctuations were observed during preliminary laser measurements using the stabilizer mechanism. SIRCUS SOLARIS tests were conducted at the 560-1000 nm range in 1 nm, 10 nm, and 20 nm steps. A standard deviation of less than 0.1% was achieved throughout laser measurements between 800-1000 nm. Laboratory results and field-based tests validate laser-based calibration methods to assess accuracy of radiometric spectral characteristics of SOLARIS.

Pre Assembly and Experimentation of Calibration Breadboard for Laser Communications Relay Demonstration (LCRD)

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The Laser Communications Relay Demonstration (LCRD) is the next step in optical communications and aims to eventually have satellites communicate via laser rather than the traditional Radio Frequency (RF) waves. This will both increase the bandwidth available for sending and receiving data as well as greatly reduce the amount of energy required to do so. LCRD uses an Optical Test Set (OTS) to test the Optical Assembly, and then the Optical Module. The goal was to assemble and test the calibration breadboard portion of the OTS and apply the lessons learned in a more general sense to the rest of the OTS and LCRD. The study looked for the best methods of alignment, sources of instability, and the pros and cons to using commercial mirror mounts. A secondary goal was to produce an optical ray tracing model in Zemax and compare it to the actual setup. The coarse alignment of the Off-Axis Parabolic mirror (OAP) was done using a shearing interferometer and a Laser Unequal Path Interferometer (LUPI). Live fringe analysis was used to obtain mid-level alignment and Durango Interferometry Software for fine alignment. The study found causes of drift in the number of fringes seen in the interferogram and reduced most of the instabilities found in the mounting of the mirrors. It was also found that temperature was a major contributor to drift and instability, creating as many as 4 fringes with a 0.5 °C change. An optical model was also developed in Zemax that can be used to predict further budgets in error and create a more elaborate and extensive model for the rest of the OTS. Moving forward, LCRD can apply the data and information collected while testing and assembling the calibration breadboard to the rest of the project and future endeavors.

OVIRS Primary Mirror Characterization

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Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS Rex), is an asteroid sample return instrument that includes an optical system, OVIRS (OSIRIS-Rex Visible and Infrared Spectrometer) which will be built at NASA GSFC. The primary flight mirrors were calibrated this summer in order to more accurately place the instrument in its optic box during integration and testing and to reduce set up time for future testing. This was done by measuring the metrology features with respect to the mirror focus, finding the true optical axis of the mirror, and obtaining a final interferogram. Engineers were able to accurately obtain results that were consistent with the manufacturer's data and the actual focus was found to be only a few hundred microns from the theoretical value. This process improved set up time from days to hours. Valuable lessons were learned in this year's testing that will streamline OVIRS as NASA GSFC begins to inch ever closer to the launch of OSIRIS-Rex in September of 2016.

Characterization of Graphene Chemical Sensors

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Chemical sensors are vital monitors for industrial, environmental, military, and space applications. Currently available sensors are non-ideal and are either power-hungry, large, or unreliable. Single-layer graphene shows promise to be a small, durable, minimal power, and high-sensitivity solid-state chemical sensor. By donating or accepting electrons, different gas species can adsorb to local areas of graphene and induce a measureable change in the bulk resistance. Functionalizing graphene will allow for tunable selectivity among different gas species. In the experiment, pure hydrogen was diluted in nitrogen at various concentrations and introduced to the sensor at a constant rate – the resistance of the graphene sensor showed significant variations between concentrations. This is important as it shows that graphene can respond sensitively to variable gas species concentrations. Ongoing tests will repeat this measurement at very low hydrogen concentrations to establish the lowest resolution of the sensor. Because the graphene sensors are very small, a large array of multiple different functionalized sensors can be placed on the same chip to simultaneously detect many different chemical species. This technique can augment existing spectrometers to provide a more sensitive and reliable gas measuring system. Direct applications of this sensor include many planetary science or heliophysics missions where accurate trace gas sensing and hazardous gas detection are necessary, including: the Titan/Saturn System Mission, Neptune Orbiter & Probe and Mars Sample Return.

Detector Process Development for X-ray WHIM Measurement

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High resolution x-ray spectroscopy is required for future space-based measurements to determine the chemical makeup of warm-hot intergalactic medium. Warm-Hot Intergalactic Medium or WHIM consists of gases between star systems in our galaxy that can reach high enough temperatures to emit x-rays. To detect these x-rays, an array of x-ray absorbers is needed in order to create an x-ray detector which can then be used to take the necessary readings needed for x-ray spectroscopy. The goal of this project was to develop a process that would produce large (millimeter scale) flat absorbers, that have limited contact with the substrate, to absorb incident x-rays without unwanted energy loss to the substrate. Previous processes have used titanium-gold for the absorber material, which has resulted in wavy absorbers. The result of these wavy absorbers is greater absorber breakage, unwanted substrate touches, degraded energy resolution and detector arrays with lower yield. In this project gold was used instead of titanium-gold to produce wrinkle free absorbers. In the process of producing these absorbers it was discovered that uniformity of the absorbers is not only affected by stress, but also size and spacing. Smaller absorbers appeared to be more uniform than larger ones and more spacing between absorbers resulted in more uniform absorbers. These aspects could be looked at in more detail in order to optimize the absorbers used in x-ray detectors for future use.

Characterization of Thin Dielectric Quality towards Megapixel Array Integration of Magnetic Calorimeter X-ray Detectors

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Magnetically Coupled Calorimeters (MCCs) developed at Goddard have achieved sufficient soft x-ray energy resolution and sensitivity to begin to consider the challenges associated with their integration into megapixel arrays for extended source spectroscopy. One set of challenges is associated with the size reduction required; pixels for megapixel-scale arrays will be less than 1/6th the current size. This work focuses on the development of appropriate dielectrics for a 50 nm insulating layer that insulates Nb leads from the ground plane and magnetic sensor in an MCC device. The desired insulating layer must have a sufficiently low pinhole defect density to prevent shorts between layers, as well as the ability to cover steps up to 10 times thicker than the dielectric itself. For these tests, the dielectric layer was sandwiched between sputtered Nb layers which were patterned to provide appropriate features. Electron-beam evaporated alumina did not insulate, and neither did combinations of alumina and anodized niobium oxide with each half the target thickness, regardless of whether the anodization was performed first or second. However, success was achieved with only anodizing.

Optimization Techniques for Deep Wet Etching of Borosilicate Glass

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Different techniques for optimizing the etching of borosilicate glass (Pyrex) were explored. A group of wafers were annealed overnight, while a control group remained unannealed. A protective metal mask was deposited onto all of the Pyrex wafers. Using photolithography, channels were then patterned on the wafers. The patterned channel was etched away until reaching the Pyrex. Each wafer was individually submerged in a solution of HF:HCl for 10 minutes. Etch depth, undercut, pitting, and etch rate were looked at. Since the same solution was used for multiple wafers, the etch rates between each wafer were examined to determine any noticeable difference. The goal of performing this process was to maximize channel depth while minimizing the undesirable side effects known to occur during Pyrex etching. Between the annealed and unannealed wafers, there was a significant difference in channel depth, as well as channel width. The resulting channel width among the annealed wafers was 81 µm less than the unannealed. Etch rate between the annealed and control group was also noticeably different; annealed wafers had an increase of 30% due solely to annealing. For the annealed wafers, there was wafer to wafer reproducibility within the experiment itself; therefore, results are in good agreement with the hypothesis.

Characterizing the Thermal Conductivity of Porous Silicon

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Porous silicon is a candidate for many detector applications due to its tunable optical and thermal properties, which are dependent on porosity. Porous silicon's remarkable tunable properties in a bolometer would allow control over its time constant and specific detectivity, a measure of signal-to-noise in optical detectors. It may provide a path towards eliminating the need for mechanically fragile membrane structures. It could also be employed for an optical bandpass filter, an anti-reflective coating, or an etalon, a resonant mirror which is only reflective at certain frequencies. This project focuses on characterizing the thermal conductivity κ [W/K] of porous silicon. Measuring thermal conductivity requires precise measurements of temperature change versus distance from heat source. Samples of different porosities and geometries were compared using the 3-ω method, which allows accurate tracking of sample heating by signal analysis. This method involves heating a substrate using an alternating current. As the sample heats up, its resistance changes. The phase of this response can be used to back out the thermal conductivity of the substrate. In practice this is accomplished by measuring the third harmonic voltage signal across the sample. Thus, by Fourier analysis and further characterization of the sample's other thermal properties like thermal diffusivity, the device's thermal conductivity can be calculated from this third harmonic voltage signal. The results of this project compare with the expectations based on different sample porosities and geometries. The study found that a lower porosity corresponds with a higher thermal conductance. This relationship can be further characterized for use in controlling the thermal conductance of porous silicon samples through the porosity.

Fourth Order Interference

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The fourth order interference is phase insensitive. In order to prove this property, the location of the zero point must be determined. At the zero point, the variance will be much higher than the mean. However, at all other points, the mean is equal to the variance according to the Poission distribution which is the probability of finding photons at a coherent state. The goal of the experiment was to check if the experimental results agreed with the theoretical conclusions. In the experiment, there were two light paths that went through the polarizer to the photon counter. One light (M1) was located at a fixed vertical location of the polarizer. The other one (M2) was set 90 degrees from M1, and the distance between M2 and the polarizer was adjustable. As shown by the data from the experiment, at the zero point, the mean was much smaller than the variance; at any other point, the data resulted in agreement with the Poission distribution. Based on the zero point, if future experiments can confirm phase insensitivity by applying different experiential conditions, fourth order interference can play a significant role on ranging measurement.

Laser Communications Relay Demonstration Laser Vibration Qualification

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The Laser Communications Relay Demonstration Project aims to revolutionize space communication systems by incorporating laser waves in place of the traditional radio waves to transmit and relay data at faster speeds and larger quantities. The key instrument in this project is the laser; thus, it is crucial that the lasers are able to endure the intense vibrations that occur during launches and function properly in space. In order to ensure the integrity and durability of the laser, the lasers must undergo a vibration test, which will mimic the vibrations subjected during a launch. Thus, the objective of this study was to compare the performance of three EM4 lasers before and after conducting the vibration test. The approach taken began with a "Mechanical and Electrical Performance Test" to establish a baseline and gauge the normal functionality of the laser. After implementing the baseline test, the laser underwent the vibration test which involved random vibration, sine vibration, and a sine burst vibration. Following the vibration test, the "Mechanical and Electrical Performance Test" was conducted again in order to determine how well the lasers fared. After comparing the data from the pre-vibration test and post-vibration test, it was determined that the lasers had passed the Vibration Test as the PER parameter did not change by more than 10% and all test parameters met specifications. Therefore, the lasers were qualified for space flight, and the LCRD Project may continue progressing smoothly.

Ultra-Wideband mm-Wave Planar Via-less Crossover for Cosmic Microwave Background Polarization Detector

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A microwave planar crossover has been designed for the use in cosmic microwave background polarization detectors. The crossover is designed on a five micrometer thick single crystal silicon substrate. The via-less design allows two microwave signals to cross using only two metal layers, the microstrip layer and its ground plane. This approach reduces cost and the complexity of the fabrication. Finite element electromagnetic simulations were carried out to verify this approach. The simulated crossover meets the necessary bandwidth of 115 to 235 GHz, and has a return loss of 22 dB, and an isolation of 34 dB.

Software Development for D3R Operational Data Analysis and Manufacture of IF Oscillator Subsystem

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An integral part of Global Precipitation Measurement (GPM) mission, Ground Validation (GV) program is to establish an independent global cross-validation process to characterize errors and quantify uncertainties in the precipitation measurements of the GPM program [1]. To this end, software needed to be developed to analyze the performance of the Dual-Frequency Dual-Polarized Doppler Radar (D3R) which is one of the radars to enable GPM ground validation. Also, to minimize radar downtime due to maintenance and to test future modifications, spare parts must be manufactured – in particular, construction of the IF Oscillator Subsystem. The IF Oscillator Subsystem creates a clock signal that is referenced by every component in the D3R, and it creates signals that will be used to process radar returns. Assembly of this spare will ensure maximum operating times, and increased data. Testing and validation that subsystem operates within specified parameters is another crucial part to manufacture. This paper will chronicle these two tasks.

RFI Blocker Testing at GGAO to Enable Space Geodetic Technique Colocation

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Goddard Geophysical and Astronomical Observatory, or GGAO, is setting the new standard in research facilities when it comes to connecting space geodetic techniques. The GGAO is one of the few sites in the world where over four space geodesy techniques such as: Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), Global Navigation Satellite System (GNSS), and Doppler Orbitography Radiopositioning on Satellite (DORIS) reside. In order for these techniques to function most efficiently, the site needs to be frequently surveyed to determine the exact position and elevation of calibration piers, antennas, and beacons of each technique. The VLBI antenna is one of the most sensitive equipment at GGAO because it operates by timing the difference of the arrival of very faint and distant waves emitted by a quasar at the other end of a long baseline. An issue for developing research facilities is the colocation of the techniques and the interference between equipment especially equipment as sensitive as the VLBI antenna. To prevent interference between techniques within GGAO, we are creating a Radio Frequency Interference (RFI) Blocker to allow the operation and coexistence of these modern techniques in a single research facility. This research is to be applied to developing and existing research facilities with similar geodetic techniques and that have an issue with internal interference. We have currently attenuated up to 14 dBm of interference from the test DORIS to the VLBI antenna. We achieved this by placing an 18 mesh 7.5 meters away from the test DORIS and 4 meters high. Moving forward, we are still trying different heights and angles to attain even more attenuation from the test DORIS beacon.

Modeling, Fabrication, and Testing of D3R Arbitrary Waveform Generator and Low-Cost Doppler Radar Design Definition

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Some of the tasks and research done during the summer internship involved the modeling of an Arbitrary Waveform Generator (AWG) and an IF Distribution box for the D3R radar used for Global Precipitation Measurement (GPM) ground validation.

Solidworks was learned during some period of the summer internship to model and draw the schematics. After modeling, the components were ordered and panels were sent for fabrication to be later assembled and tested with laboratory equipment. Drilling, soldering and other skills were used for the assembly. A working AWG model was constructed and is being successfully tested and will be available to be used with the D3R ground validation tool for GPM. These models have been created in 3D CAD software Solidworks with real components and accurate dimensions.

As part of a master's thesis topic definition, research was also done for the modification of a low-cost X-band, single-polarized marine radar used in the Puerto Rico Weather Radar Network (PRWRN), to provide the ability of Doppler velocity measurements. The research involved studying different architectures with the goal of implementing a magnetron based coherent-on-receive system. With advancements in software defined radio, and Universal Software Radio Peripherals (USRP) it is possible to obtain samples from transmitted signals to be compared with received echo signals to calculate and analyze Doppler spectrum. Several design options have been determined for the radar modification and are being studied seriously.

Development of an Infrared Microscopy Screening Technique for Foil Resistors

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A foil resistor consists of a thin, typically 2 to 5 micron, nichrome sheet (an alloy of nickel chromium) etched into a serpentine pattern and adhesively bonded to a ceramic substrate. The advantage of foil resistors is their precision and stability over a wide range of temperatures not offered by other resistors. However, during their manufacturing, a process which includes rolling and etching of the foil, defects can be introduced causing localized current constrictions and latent failures manifesting as shifts in resistance values and electrical opens. The focus of this project is the development of a non-destructive screening technique to identify defective regions of the resistor through infrared microscopy. A resistor under testing is electrically pulsed and will illuminate defective regions as visible 'hot spots' as they warm up more than the surrounding defect-free areas of nichrome. To confirm the validity of the infrared microscopy screening, a supplementary screening test using pulse power cycling is in development to thermo-mechanically stress and fracture defects in nicrhome foil. The pulse power cycling test induces thermo-mechanical stress which accumulate into a fatigue failure. The use of this two-step screening technique has proven to be a capable method to screen out resistors prone to future failures due to localized constrictions like rat bites, unwanted bridging, or undesirable embedded nonconductive particles in the nicrhome foil.

Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller

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The microcontroller is widely used in our daily life nowadays. It provides 'intelligence' embedded systems, such as mobile phone, car and so on. Programming microcontroller is very important in using embedded systems. This study conducted fast and effective microcontroller interfacing design and software programming using the ARM MBED microcontroller and performed experiments to test the interfacing design and software programming. This study also used C++ as programming language. As the results of this study, fast and effective microcontroller interfacing has been successfully designed and tested. The Arduino microcontroller in aquaponics system, which is a food production system that combines aquaculture and hydroponics in a symbiotic environment, has been programmed and tested to control different devices, such as temperature probes, relative humidity and temperature sensor.

Prescreening and Testing for RFI Risk Reduction on Goddard Radio Frequency Explorer

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The Goddard Radio-Frequency Explorer (GREX) is the latest fast-sampling radiometer digital back-end processor that will be used for radiometry and Radio-Frequency Interference (RFI) surveying. The GREX system would be able to be used in airborne L-band RFI surveys. It could also be interfaced to microwave radiometers and detect RFI within the data collected. The GREX system contains an AC waveform capture board that will take in 2 channels of data that are vertically and horizontally polarized. The waveform capture board consists of Field Programmable Gate Arrays (FPGAs), which will be used for post processing and RFI detection algorithms. However, before the full algorithms can be implemented, it is essential to conduct initial tests of the reliability of the system and the custom software to avoid potentially costly errors in real application of the system. The GREX system was prescreened by testing some Digital Signal Processing (DSP) algorithms such as FFT, DDC, and FIR filters on the Virtex-5 FPGA, which would mimic similar functionalities of the RFI detection. First, the internal noise of the system was characterized and verified. Then, post-processing algorithms were implemented with waves stimulated into the GREX system. The results show that the system is capable of implementing RFI detection algorithms and that the internal noise is negligible.

Designing Modular Electronics for Multiple CubeSAT Missions

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CubeSAT projects are becoming an increasingly common choice for space based experiments due to tight budgets and fast project turnaround. With a growing base of CubeSAT missions, designs are being put together with similar functional operation, re-inventing the wheel on a per mission basis. This project intends to develop a standardized analog front end circuit and layout that can be used across multiple CubeSAT projects. Part selection incorporated performance requirements from multiple pre-existing CubeSAT missions, radiation up-screening data from COTS that have been incorporated into previous projects, and radiation profiles from similar orbit. The parts selected met mission requirements, yet maintained adequate affordability. A set of schematics were developed and went through an informal schematic design review. Based on the amount of effort that goes into designing flight hardware, it is clear that a series of modular, re-usable, and affordable designs would be beneficial to the entire CubeSAT community.

Calculating Ground Station Access Times for Spacecraft

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Access reports document what times a spacecraft can communicate with a target ground station and are an important tool for mission planning. The purpose of this project was to design an executable program to create these reports and replace the commercial software, Systems Tool Kit (STK) that had been used previously. The code was created from proven orbital mechanic algorithms and checked against STK for accuracy. Although the code was not as accurate as STK in some cases, it still satisfied our requirements. The final program could create usable access reports given satellite trajectories and ground station locations. The conclusion was that it was possible to replace commercially licensed software with code created in-house. This allows NASA to save on the licensing fees and time used to run STK.

Error Correction Coding for TDRSS Demand Access System

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Tracking and Data Relay Satellite System (TDRSS) is a fleet of nine satellites that provide telecommunication services to NASA and several costumers. In order to provide high reliability and high data rates TDRSS is capable of using powerful techniques such as Error Correction Coding (ECC). The project consisted of implementing ECC techniques for a Demand Access Systems (DAS) such as: Convolution codes, Reed-Solomon (R-S) codes and Concatenated codes.

First part of the project consisted of MATLAB implementation as proof of concept while the second consisted of practically relevant C++ implementation. In order to guarantee fast implementation of the second stage, parallel computing tools such multithreading where used in the C++ implementation.

Project also provided various performance evaluations such as the Bit Error Rate (BER) that tells how reliable ECC is at a specified Signal to Noise Ratio (SNR). Another, important matric is the Computational Complexity that describes speed and efficiency of the implementation. Project provides well documented user guided. Also, as result of our implementation we were able to compare performance of ECC used in DVB-S2 standard.

Simulating a Receiver for Tracking and Data Relay Satellite System (TDRSS) Demand Access Service (DAS)

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The Demand Access System (DAS) allows the first-generation Tracking and Data Relay Satellites (TDRSs) F1-F7 Multiple Access Return (MAR) capability to be scheduled for extended durations or in a near real time manner. The MAR service of DAS uses Code Division Multiple Access (CDMA). In this project, a DAS receiver is simulated in MATLAB. The source code is capable of operating in near real-time.

Web-based Communications Design Agent Development

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The Web-based Communications Design agent supports Goddard Space Flight Center's on-going SCaN Network Integration Project by providing NASA centers, commercial partners, and academic institutions access to link budget analysis tools. The current prototype of the Web-Agent fulfills the critical design requirement of producing a maintainable, easily distributed and robust communications design tool at minimal financial cost. The prototype demonstrates the tool's functionality can be expanded to support additional communications and mission planning functions.

The Web-Agent prototype asks users input satellite orbital parameters, mission data requirements and network specifications into a JAVA applet which uses Apache POI to send these values to Excel for calculation. The link budget analysis is performed in the Excel workbook and the results are returned to the applet. The user will be able to sort the returned link budget results by enabling or disabling factor loading parameters to find optimal link budget values. The applet is embedded into an HTML webpage linked to a server where the Excel workbook is stored.

Future iterations of the Web-Agent prototype will test the implementation of JavaScript and SQL to reduce the agent's dependency on Apache POI and Excel. User testing will be performed to optimize how users interact with the agent and to improve both client and server side error detection and correction.

Test Conductor Report System

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The James Webb Space Telescope (JWST has many components; one of the most important pieces of hardware within it is the MicroShutter Array (MSA) which is used for image processing. Since the microshutters are so important to the JWST, much testing has to be done to ensure that the hardware will not fail once it is launched. All of the different tests generate many electronic logs and other forms of data that are not centralized, making any potential data checking tedious and difficult. A sensible solution for this was to design a server that stored data entered and retrieved data requested quickly and efficiently. The Test Conductor Report System (TCRS) was designed to complete this task in three parts. It would grab the files from the user, insert them into the database, and then retrieve them based on what the user asked for. The relational database used is called MySQL (SQL stands for Structured Query Language), and, with a Java library, MySQL and Java code could be interfaced to create a program that handled data entry and data retrieval, respectively. The database model that was created for the TCRS was entered into a server and prepared for program use. The input/output programs both have a GUI created through Netbeans (a Java Integrated Development Environment), and an option was added for images and documents to be uploaded into and retrieved from the database. The TCRS provides a safe, structured method of collecting data and a user-friendly method of handling it. Lost data can easily be restored, and the process of error-checking and data inspection is made significantly easier with the functionality of the system.

Designing a Portable CubeSat Ground Station Trainer

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Over the course of six weeks, rising University of Southern California (USC) freshman Matthew Davis (KB3TVB) researched and compiled many of the materials necessary to develop a “Portable CubeSat Ground Station Trainer”. The final products are to be used by his mentor to train fellow university level students in the "NASA hidden art" of tracking satellites and retrieving their prized CubeSat downlink data and telemetry. The project entailed developing, testing and documenting a 16-element circular-polarized yagi UHF antenna out of cost-effective materials and configuring the computer software, SatPC32, to automate the antenna tracking process with a Yaesu G-5500 rotator pair through an LVB Tracker interface. Numerous public domain resources were pooled to write an article on the construction details of the antenna and on properly configuring SatPC32. As an educational & outreach spin-off, the deliverables also will be presented to local AMSAT amateur radio operators and the general public during a planned antenna workshop this coming March 2015 at the NASA Goddard Visitor Center in Greenbelt, Maryland

Improving Feature Extraction for Image Registration with Shearlets

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Image registration is the process of aligning two or more images of the same scene, taken by different sensors or at different times. While registration can be performed manually by humans, it is time-consuming and extremely inefficient. Therefore, the need for automatic image registration algorithms is dire. Existing algorithms attempt to extract features from images with a variety of mathematical techniques. Prominent among these techniques are those based on wavelets. These techniques attempt to separate edge-like features, such as roads, rivers and mountains, from textural features, with the hope of finding useful features for an optimization procedure to use to register images. While wavelet-based registration methods are established, they often fail to be robust to choice of initial conditions. That is, if the images to be lined up are too far apart, the methods fail. In order to address this, we propose to introduce the recent harmonic-analytic technique of shearlets to existing automatic registration algorithm.

The shearlet algorithm produces stronger and more concentrated features than wavelet techniques. Initial experiments show a much-improved robustness to initial conditions when compared to wavelets. A combined approach to image registration, using first shearlets and then wavelet, has yielded improved results over existing algorithms.

Accelerated Space Computing

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In the pursuit for high-performance computing on satellites, the combination of a conventional processor with a programmable logic device is explored. This combination of two distinct approaches to data processing is the result of optimizing computational performance against power consumption, while contending with the logical complexity of exploiting such a system's potential in mission applications. The work presented approaches the philosophy of high-performance through accelerated computing by pursuing different avenues, but each is motivated by the common goal – using the intricacies of a computational architecture to advance the capability of space processing systems. Achieving higher computational potential aboard a satellite enables greater opportunities for scientific data collection and autonomous controls to resolve the challenges of real-time processing constraints and limited downlink bandwidth. The choice of processing architecture on which to run an algorithm is as critical as the algorithm definition itself for maximizing performance. Combining a conventional processor provides a programming paradigm for which most applications are developed with mature tools in languages such as C++, while designs for Programmable Logic Devices (PLD) are defined in terms of processing circuitry in a hardware description language such as VHDL. In such a hybrid device of processor and FPGA (a type of PLD), the ability to specify the architecture by specifying logic resource allocation can result in higher performance, while development for general processors offer greatly reduced application complexity with adept performance. These efforts collectively accelerate the capability of what can be achieved on satellite processing systems from application development, deployment and project execution.

Understanding Spectroscopy on JWST

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This project was to research and understand spectroscopy and its use on the James Webb Space Telescope (JWST). Spectroscopy is the study and use of the interaction of light with matter in order to gain information about that matter. Every wavelength of light interacts with a molecule in a very unique way. This allows for the identification of a substance based solely on analysis of light that has interacted with that substance. Spectroscopy is the means by which astronomers can determine the composition of celestial objects. The JWST will use infrared spectroscopy to complete its objectives. Two of the JWST objectives rely on spectroscopy. “First Light” requires spectroscopy to confirm the composition of Population III stars, which consist of only Helium and Hydrogen. “Planetary Systems and the Origins of Life” requires spectroscopy the chemicals in the atmospheres of exoplanets, in addition to the materials in asteroid belts and gas-giant exoplanets. Scientists will use the data collected by JWST to model the make-up of the stars and the atmospheres of the exoplanets.

Restructuring Conventional Web Platforms to Reduce Dependence on Hierarchical File Systems

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"Cloud" computing is the delivery of computing as a service, rather than a product. In terms of web applications, such as servers, cloud providers manage the infrastructure (e.g. hardware) that they run on, as opposed to operating your own dedicated computer hardware. However, code that is written for a dedicated system will not work correctly when deployed on a cloud system, and vice versa. For this reason, web applications previously deployed on dedicated systems must be restructured for the cloud in order for normal data manipulation to function at all. The content of my research discusses the advantages of cloud computing and the process of restructuring a web application that was written to run on a normal web server. I describe the replacement of typical I/O functionality that work with file systems with a database model that is able to scale properly with the cloud. I also discuss the restructuring necessary to work with these changes. This new approach to web application development will allow less maintenance, continuous availability, and of course, scalability.

Point Spread Functions in Astronomy

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When telescopes capture images of stars or galaxies, they appear blurry. The pattern of this blur is known as a Point Spread Function. The James Webb Space Telescope will encounter Point Spread Functions when capturing images, which makes it important to understand methods to reduce the blur they cause. This project was to research and understand Point Spread Functions. This required researching several documents to determine what Point Spread Functions are, how they can be reduced to produce better telescope images, and how Point Spread Function reduction can be modeled to expedite the reduction process. The Point Spread Function represents the magnitude of light intensity in an image. The blur results from light diffracting as it enters an optical system, which in part arises from an optical system's trouble mapping light onto a 2-dimensional image, because light is 3-dimensional. Taking a Fourier Transform of an image is the first step in reducing a Point Spread Function. The Fourier Transform is a mathematical operation that is important for manipulating incoming light waves and eliminating distorted light. Next, phase retrieval methods are applied. Then the Inverse Fourier Transform of the image is taken. The process for reducing a Point Spread Function can be time-consuming; therefore, astronomers use software programs to produce Point Spread Function models which will reduce the blur in an image. The James Webb Space Telescope will use software called WebbPSF to model its Point Spread Functions. Although Point Spread Functions cannot be completely removed from an image, the blur they cause can be reduced; this will allow astronomers to gather more information from images the James Webb Space Telescope will capture of distant stars and galaxies, newly forming planetary systems, and objects at the edge of the solar system.

PiSat

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PiSat is an Internal Research And Development (IRAD) project to create a low-cost mission testbed for flight software systems and a potential CubeSat prototype. The Raspberry Pi, an embedded Linux system the size of a credit card, was the platform used due to its versatile General Purpose Input/Output (GPIO) pins and USB ports, not to mention its extremely low cost. The Raspberry Pi and its peripherals including modules such as a GPS receiver, compass, accelerometer, RF transceiver, and camera allow us to test the flight software being developed while collecting actual data from the testbed instead of using simulations. PiSat used the Core Flight Software System (CFS), a system developed for multiple satellites including LADEE, LRO, GPM, and MMS, as the software framework for developing on the Raspberry Pi. Using the CFS required little time to be spent working on the core flight systems and allowed for more attention to be paid to the actual mission testbed and mission applications which can easily be added to the CFS. The key flight software applications created include interfaces with the GPS/Compass/Accelerometer modules to collect navigational data, interfaces with the camera to take images and video, and a file transfer application using a protocol similar to Trivial File Transfer Protocol (TFTP). Development of all flight software applications included creating ground system components to communicate with. The IRAD created a small, low cost system with basic navigation.

Requirements Management for DAT

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Data Access Toolkit (DAT) is a multi-satellite information archive, access, trending, and analysis software system that takes in data from a variety of NASA missions. It is separated into three different sections: a data ingest layer, a data archive layer, and a data access layer.

In the data ingest layer, DAT can ingest telemetry data (data coming from the spacecraft) to create an archive comprised of original, processed, and statistically compressed telemetry data (also known as lifetime trending). Since telemetry data comes in many different formats, once the data is processed it is then converted into a standard data definition that DAT can understand in order to trend that data (i.e. a mission telemetry database).

The data archive layer manages the archival of ingested data into the DAT repository. All ingested data, regardless of its type, are stored in files in a database called MAD files that DAT accesses. This is so that in the future if certain scientists wanted to look at old data, they would not have to re-ingest that data, but simply access it via DAT's database.

Once data is saved into the DAT archive layer, the data access layer allows the user to access data in different trending formats for analyzing (i.e. plots, graphs, etc.) Two methods of accessing the data are: using a web portal interface (GUI) or using a web-service application programming interface called an API (or a command line). Both methods provide easy discovery of and access to archived data in DAT without previous knowledge of how the data is ingested and archived

Robot Pianist

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The purpose of the project is to conceptually develop high level requirements and their associated rationales for an anthropomorphic robot that will give piano concerts to entertain the human inhabitants stationed on the Mars base (this hypothetical mission would not begin design phase until 2035). The robot will be designed and built on Earth, then shipped to Mars via spacecraft, where it will give piano concerts–walk onstage, sit down, play for 30-60 minutes, stand up, bow, and walk offstage–all without direct human control. As a secondary capability, the robot will perform general maintenance and administrative tasks autonomously, as well as being reprogrammable to provide the capability to adjust to changing needs in the future and for other possible functions. The method through which these requirements and rationales were created was by research of technology applicable to robotic systems by using system engineering methodology and National Aeronautics and Space Administration (NASA) and Institute of Electrical and Electronics Engineers (IEEE) standards. This resulted in 45 high level requirements (both functional and performance) and their associated rationales, as well as an Operation Concept Document describing the robot. The robot will be anthropomorphic in appearance and design, gather and store energy from its environment and be autonomous to a high degree. The robot will also serve as proof of technology. Much of the technology used or developed for the robot will have a wide range of applicable uses in the field of robotics and other fields of science.

Doppler Shift Compensation in Satellite-to-Ground Station Communication

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Ground communication is a very important aspect of a successful satellite mission so that data and commands can be transmitted to and from the satellite. The quality of the communication with the satellite can be affected by the Doppler shift effect in a negative way. However, Doppler shift can be calculated and compensated for by changing the ground station's receive and transmit frequencies. This is calculated with a simple equation and several different satellite parameters, such as the actual receive/transmit frequencies and the range rate (rate of change of the elevation of the satellite with respect to the ground station), in addition to other parameters. Using the open-source SGP4 library created by the Department of Defense and CelesTrak along with a Two-Line Element (TLE) from any satellite, passes over the specified ground station are predicted for a specified number of days from the current time. A table is then created with a list of the predicted passes and the adjustments that need to be made to the receive/transmit frequencies of the ground station in order to compensate for Doppler shift. Knowing these frequency adjustments (calculated in intervals chosen by the user i.e. every 30 seconds) allows for a stronger communication with the satellite and less information lost.

Developing a Test Platform for IMU Parameter Identification

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The Spacecraft Servicing Capabilities Office (SSCO) is developing Raven, and ISS-hosted pan/tilt gimbal platform with visible, infrared, and lidar imagers to observe spacecraft docking with ISS. As part of this platform, we will incorporate an Inertial Measurement Unit (IMU) to assist with platform attitude determination. Our IMU is a low-cost Micro-Electrical-Mechanical System (MEMS) that is not designed for spaceflight and comes with no calibration data, so we must test and calibrate it ourselves.

We have designed a test and calibration campaign that verifies the IMU will operate in Low Earth Orbit, will determine the misalignment and non-orthogonality of the IMU axes, fit a model for the deterministic error and random noise in IMU measurements, and determine the effect temperature has on these measurements. We will use a three-axis rate table to determine misalignment and non-orthogonality and will use a thermally controlled single-axis rate table to determine the effect of temperature on IMU measurements. In preparation for these tests, we have developed hardware and software to communicate with and control the rate tables and thermal chamber, as well as hardware and software to wirelessly log data from our test IMU. Our current data characterizes part of our noise/error models and, with our new test systems, we will continue to gather data to calibrate our IMU.

Finite Horizon Model Predictive Control for the Alignment of Two Cubesats Acting as a Virtual Telescope

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The Cubesat Alignment by NASA and Yonsei using Virtual Telescope Alignment – eXperiment (CANYVAL-X), an offspring of NASA's Virtual Telescope Demonstration Mission effort, utilizes a 1U and a 2U cubesat to demonstrate a separated spacecraft science instrument using precision alignment control, known as a "virtual telescope." The Optics cubesat contains the occulter of the virtual telescope, and the Detector cubesat contains a sensor for imaging the solar corona. The use of small platforms is an innovative means to produce a cost-effective pathfinder for precision formation flying advancement. However, packaging of the required Guidance, Navigation, and Control components (e.g. microthrusters set) into such a small platform results in unique challenges to the control design. There is simply not enough space for the typical set of control effectors needed for full 6-degree of freedom control in the CANYVAL-X 2U platform.

The focus of the present work is to develop control algorithms utilizing a minimal set of co-aligned thrusters for the transverse position and attitude alignment of the Optics and Detector satellites. This thruster arrangement does not permit simultaneous range control, which is out of the scope of CANYVAL-X objectives. The dynamics of this problem are given by Hill's equations, with the control objective being to maintain the Optics satellite along the line of sight between the Detector and the Sun. Model Predictive Control (MPC) provides a tuning mechanism for control design with constrained control authority, and continuous non-impulsive low-thrust maneuvers resulting from the use of microthrusters. Solar alignment of the Optics satellite is achieved by adjusting the tunable parameters of the MPC cost function, with weights on state error and control usage. This provides an intuitive method for trading fuel expenditure and targeting performance to achieve the time-accurate formation alignment required for science imaging.

Slosh Modeling for Spacecraft Applications

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Fuel slosh can be a significant disturbance for spacecraft, and WFIRST has very tight pointing and stability requirements. From modeling slosh, these stability requirements can be met by accounting for slosh forces and frequencies.

At the simplest level, slosh can be modeled as a system of two masses: one that is stationary and one that behaves as a pendulum. This approach is an approximate model, but shows important trends that help validate more substantial models. Slosh forces increase for higher fill fractions, but the percent of fuel that acts as slosh decreases with increasing fuel fraction.

A more complex slosh model for surface waves is done using geometric, variational integrators that preserve energy and momentum, and is based on a system of springs and masses. If the potential and kinetic energy of the system can be defined, and the initial positions, velocities, and momenta are known, the system can be solved.

A third model was studied and uses shallow water wave differential equations based on Airy Wave Theory. The method relies on a fully implicit spatially centered finite difference scheme and is qualitatively accurate, but has numerical dissipation.

The future final slosh model should incorporate the laws of Airy Wave Theory and use a Lagrangian Approach. Once this model is complete, it can be compared to the mechanical pendulum model, and the results should be qualitatively similar. Next, the model can be used for various tank configurations, including size, shape, gravity conditions, and even the addition of a fuel bladder. By using a combination of wave theory and geometric variational integrators, the goal is to produce a model that exhibits accurate slosh and energy behavior, and also preserves momentum.

Development of Model-Based System Engineering (MBSE) at Goddard Space Flight Center

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Studying the Systems Engineering process is an essential piece of understanding its application to Model-Based Systems Engineering (MBSE) being investigated in Code 592, Instrument and Payload System Engineering Branch. After reviewing current NASA and Goddard system engineering standards, processes, and documents such as looking over risk and requirements, I provided support to improve Goddard MBSE software capabilities. Recently acquired software, Maple and MapleSIM, is one example of the types of analysis tools available that would allow System Engineers to perform parametric studies for their mission trades. For example, engineers are able to construct and experiment with models that will simulate the potential engineering solutions for missions quickly before doing more detailed discipline trades with their engineering teams or helping to set the requirements for a specific component of the baseline design. Being the first to learn and practice with this software within GSFC, I was able to take a real mission example from the Comet Surface Sample Return (CSSR) mission concept and began constructing a model for its Mass Verification System. My goal was to model a way to measure and verify mass on a spring loaded instrument used to verify mass during retrieval of regolith at a comet. To date, I have constructed a simple spring mass model without any detail-given modifications. Most of my time was spent learning and experimenting with MapleSIM to acquire expertise knowledge of the software that will be shared with Goddard engineers. After mastering the overall uses of MapleSIM, I will teach the Systems Engineers in Code 592 on how to use and master this valuable tool. Eventually, this will lead to performing parametric studies with MBSE software, such as with Magic Draw and its Paramagic add-on. The maturation of integrating physics based modeling tools with Model Based Systems Engineering tools using the Systems Modeling Language (SysML) are rapidly increasing systems engineers' awareness of subsystem and component product development while maintaining near real-time linkage to the verification of requirements. This has a significant impact on the discipline of systems engineering to continue to provide appropriate and timely technical leadership as NASA missions continue to increase in technical complexity within budget constrained environments.

GPM Mission Evolution

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Analyzing previous MDL studies shows the evolution of a mission's life and how major changes and constraints affect the final outcome and how it changed from the original concept. The GPM mission changed the most because of the tightening and loosening of constraints. The biggest factors working against GPM were money and electrical power. The biggest factor helping GPM was launch vehicle capacity. The parts that changed the most from start to finish were:

- Mass
- Solar arrays
- Electrical Power
- Constellation type
- Launch date

Mass and electrical power are important components in the success of a mission which makes the need for the MDL's estimates to be as accurate as possible. With GPM, the TRMM data numbers for mass and power were more accurate to GPM's outcome than the MDL's prediction. But, you have to take into consideration that GPM was less conservative with their mass allowances because of the high mass capacity on the launch vehicle. Also, the MDL only has a week to create all of a mission's logistics when it could take months to do an analysis. The MDL was very close with the orbit type and altitude/inclination, instruments (payload numbers and types), and was on the right track with their solution to the solar array problem. GPM's biggest problem was money, which caused most of the delays in the launch date and constellation changes. The MDL is an important factor in the early stages of a mission and can play a major role in its success.

Atmospheric Aerocapture through Saturn/Titan

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The goal of this project is to analyze an aeroshell as it travels through Titan's atmosphere for aerocapturing. The aeroshell is initially mounted inside a carrier that takes it from Earth to Titan at a top speed of 6.23 km/s. The carrier eventually is set to release the aeroshell traveling directly into Titan at 4.7 km/s. Since it is entering Titan's atmosphere at Mach 19, the aeroshell employs a Super Lightweight Ablator (SLA) as a Thermal Protection System (TPS) to protect it from searing temperatures. Within the aeroshell there is a Titan Orbiter and Polar Surveyor (TOPS) that soon will be put into orbit to analyze Titan's atmosphere and surface. The method employed to analyze aerocapturing is through the Computational Fluid Dynamics (CFD) software STAR-CCM+. This software enabled the analysis of the aerothermodynamics and the aerodynamics of the aeroshell as it traveled through the atmosphere in roughly 17 minutes. It yielded post-processing data that determined the aeroshell's stability, flight characteristics, and heat flux. The data found that the aeroshell is in fact stable and can handle the heat flux necessary to travel through Titan and put TOPS into orbit.

A High-Fidelity Mission Analysis and Design Toolchain: EMTG-GMAT

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The Evolutionary Mission Trajectory Generator (EMTG) is a mission analysis and design tool for interplanetary spacecraft trajectory problems. EMTG is a global optimizer capable of solving the complex spacecraft control problem. Highlights of EMTG capabilities include its automated ability to select a sequence of flybys for both impulsive and low-thrust spacecraft. EMTG includes third body effects, solar radiation pressure and detailed power and thrust models. But dynamical simplifications for flybys, which are extremely sensitive for global optimization, are made to allow for quick solution of the global optimal trajectory problem. For this reason, EMTG is a medium to medium-high fidelity solver. The General Mission Analysis Tool (GMAT) is another recent Goddard mission design tool with high-fidelity capabilities, but lacks the global optimization capabilities of EMTG. Work was conducted during this project to connect EMTG with GMAT, such that a continuous mission design process from medium fidelity to high fidelity will exists at NASA Goddard. The resulting tool-chain capability allows for extremely quick mission design of complex impulsive and low-thrust missions at a high-fidelity.

JWST Trajectory Modeling

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The James Webb Space Telescope (JWST) is the next-generation astronomical observatory which will gaze deep into space, observing red-shifted light from the early universe to study the evolution of galaxies, stars, and planetary systems. The Ariane-5 launch vehicle will launch JWST to its elliptical orbit around the Sun-Earth L2 gravitational saddle point at around 1.5 million kilometers away from Earth where JWST will execute its science commissioning.

The overall complexity of the mission demands an analytical and graphical model of JWST's launch trajectory, attitude, and mechanical deployments, and the need for such a model for simultaneous visualization and data analysis of mission requirements serves as the foundation of this project. The JWST mission was modeled in STK (Analytical Graphics, Inc. Systems Tool Kit) and accurately depicts JWST's nominal trajectory and simulated attitude as well as solar array deployment. A powered flight trajectory was modeled using launch vehicle latitude, longitude, and altitude data provided by Arianespace, and a complete attitude history for powered flight was generated using data provided by Arianespace for rotation about two of the launch vehicle axes coupled with its roll profile generated by JWST's thermal engineering team. The STK model has served as an important graphical resource to illustrate JWST's planned flight path and orientation with reference to the mission timeline during launch, including rocket staging and fairing jettison. Additionally, the current model has verified the baseline reference trajectory and simulated attitude and has provided for further analysis of JWST's compliance with navigational, mechanical, and thermal requirements. Potential future applications of the JWST model include ground systems analysis of communications with the spacecraft, analysis of power generation by solar array after deployment, and attitude targeting of observatory pointing for science observations.

OSIRIS-REx Asteroid Sample Return Mission: High-Fidelity Modeling of Solar Radiation Pressure during Orbit B

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This work investigates high-fidelity modeling techniques of Solar Radiation Pressure (SRP) for application to Orbit B of the OSIRIS-REx (the Origins Spectral Interpretation Resource Identification Security – Regolith EXplorer) trajectory about the asteroid Bennu. Sunlight absorption and reflection (both specular and diffuse) are considered, and the vector directions (and subsequent reflected directions) are determined using ray tracing. All SRP forces are computed using such techniques via the GSFC Solar Pressure and Aerodynamic Drag (SPAD) analysis tool. A simplified OSIRIS-REx spacecraft model was constructed in SPAD for the analysis. The Orbit B portion of the OSIRIS-REx trajectory was propagated in GSFC's General Mission Analysis Tool (GMAT) using the SRP accelerations computed in SPAD. Significant trajectory differences were found between the high-fidelity SRP model (from SPAD) and the traditional "cannonball" SRP model. One key difference found is an increase in eccentricity of up to 0.25 (from the nominal circular orbit) when the high-fidelity SPAD SRP model is used, whereas the trajectory produced using the cannonball SRP model only exhibits an eccentricity increase of up to 0.15.

Visually Navigating an Asteroid: A Summer of Working with Stereophotoclinometry

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Stereophotoclinometry (SPC) is a procedure developed by Dr. Robert Gaskell of the Planetary Science Institute that uses multiple images to construct a 3 dimensional topographical map of a surface being observed. The SPC procedures were originally written and implemented in the Fortran programming language. The Fortran executables utilize a command line/scripting interface with limited visualization capabilities. One component of the overall SPC process is the ability to recognize and register topographic features in navigation images. The goal of this work was to gain a deeper understanding of this specific SPC process and to improve user experience and visualization. Image processing and maplet registration capabilities were replicated in MATLAB using the original Fortran routines and SPC technical papers. A Graphical User Interface (GUI) was developed for loading maplet data, processing images, and visualizing correlation and registration results. MATLAB is the preferred programming language of the branch and supports matrix operations natively. The GUI has simplified the user experience and provided a tool for instantaneous visualization of SPC image processing. These utilities could potentially be used as a valuable asset for ground-based SPC processing during the Origins Spectral Interpretation Resource Identification Security-Regolith Explorer (OSIRIS-REx) mission.

Star Tracker and Gimbal Driver Board

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This summer at Goddard I worked on three main projects. The first was Software development for a star tracker, second was the hardware test configuration for an Astrometric Alignment Sensor and last was the design and construction of a Gimbal Driver Board. Initially at the beginning of the summer I was doing software programming for a star tracker in MATLAB. While doing software development the goal was to finish a stellar identification program, by identifying every star in the field of view. Toward the middle of the summer I began a new project for LCRD, which was to build a Gimbal Driver Board for LCRD Control Electronics test equipment. My assignment for the Gimbal driver board was to draft the schematic of my board, build the board, and then test it. This included running test for continuity in the cables for correct connections, wiring the board correctly to appropriate locations, and soldering in every connection. I then had to make a very specific test procedure, and then follow that procedure to complete the testing of the board. During the latter part of the summer I worked on a test setup for an Astrometric Alignment Sensor. My object for the Astrometric Alignment Sensor was to simulate the Field of View (FOV) of the optics spacecraft that is flying in formation with a detector spacecraft. The FOV of the optics spacecraft contains background stars and laser beacons coming from the detector spacecraft. Overall, the results for the Gimbal Driver board was a success and both the Star ID Algorithm and Astrometric Alignment Sensor are progressing in their research developments.

R/F Board Design for Space Cube in Navigator

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The goal of this project is to aid in the development of a miniature a GPS Receiver system (Navigator) which has demonstrated the capability to provide GPS position of satellites far outside the GPS constellation. The new version of Navigator, Space-Nav, has a smaller volume and lower power. Thus, it can be utilized on smaller satellite platforms to extend mission life by conserving fuel usage. Space-Nav also has increased processing capability. This device will serve as a significant advance of GSFC technology.

However, one difficulty in achieving this goal is that in order to achieve the same capability as a larger GPS system, but remain under sized, Space Nav must fit large electronics on a small board. To develop the mechanical design for the Radio Frequency (R/F) Electronics Card Assembly (ECA), the requirements of the sounding rocket project and the design goals of the project must be gathered from the product development lead. The goal is to redesign the RF card front panel and stiffener to ensure it can properly interface and plug-in to the Space-Nav chassis. In addition, it must be verified that the RF card can survive sounding rocket demonstration mechanical and thermal environment. In order to accomplish this goal, structural analysis of the ECA must be done to ensure the electrical parts will not fatigue due to printed circuit card flexing. Also, mechanical components must be below their materials' strength limits. Each of these tasks can be simulated in Autodesk Simulation Multi-physics software. Vibe test will simulate the actual sounding rocket vibration that a chassis would encounter when flying in space. If successful, this system will greatly improve NASA/GSFC capability.

Low-gravity Investigation of Propellant Slosh (LIPS)

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Validation of current computational fluid dynamics models and the ability to understand the motion of the fluid and its interaction with the propellant management device will provide for reduction of mission risk. This risk reduction comes from the ability to reliably calculate forces and torques exerted on the spacecraft due to slosh and better understanding of low gravity liquid orientation. This will potentially increase boundaries on everything from structural limits to propellant usage and these margins can be kept for better propellant management and an increased payload weight due to decreased propellant load. There is limited data on fluid dynamics in low-gravity flight-like tanks and the current models cannot be fully validated by available experimental data. A question emerges as to how this information should be gathered. A thorough review of spacecraft propellant slosh research illustrates numerous experimental variations and platforms that are available to gather significant data. The underlying theme is a clear tank of some geometry that has accelerometers and cameras to gather both numerical and visual results. Three experiments are proposed to fill in the gaps, all three capture the fundamental data but the various platforms (parabolic flight, International Space Station mission, and CubeSat mission) each have attractive and exclusive additions. Pertinent factors such as time in microgravity, available space for maneuvers, and cost were weighed and although each experiment is capable of producing significant data, the small differences indicate that a fleet of CubeSats would capture the most comprehensive results.

Systems Engineering Support for NEXT PPU

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NASA's Evolutionary Xenon Thruster (NEXT) has demonstrated its capability of replacing current Electric Propulsions (EP) and is moving closer towards flight readiness. It requires a Power Processing Unit (PPU) that can produce 12.6 kW of power to maximize the potential performance envelope of the thruster. NASA Goddard Space Flight Center is developing improvements to an existing PPU in the areas of power handling, thermal management, and modularity. Therefore, in order to ensure these requirements are met, an effective yet concise requirements document was created. This document addressed PPU subsystems and how they were interconnected, the functionality of each subsystem, as well as faults/failures for the PPU. Previous requirements were reviewed and modified to better fit the new design. Thruster operation flowcharts were created to better understand the functionality required from the PPU. The document also contains information on each individual sub-system. Currently, only one subsystem of the PPU is being developed. The rest of the PPU subsystems require further research to assess modification in the power capability and require similar documents.

ISS Earth Science External Payloads Proposer's Guide

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The International Space Station (ISS) contains several labs and facilities which allow experiments to be conducted in the unique environment and conditions of space. This project examined the process behind sending an external payload to the ISS, and focused on developing a mid-level guide for potential proposers. The guide is divided into several sections, including sections on visiting vehicles and ISS program provided hardware. The former focused on launch processes, payload launch interfaces, and travelling accommodations, and the latter focused on resources and assistance available for the integration of payloads onto the ISS. Procedures to gather information included examinations of official ISS documents, meetings with current and former proposers, and observation of ISS payload development. A first draft of the guide was developed by the end of this period. The guide is meant to be a living document, as project requirements and ISS circumstances are always in fluctuation. No permanent version of this guide will be established, but rather new versions will be released as necessary. As a result, this guide will be an aid for all future Earth Science payload proposals. The significance of this guide is that it provides a new mid-level document with more details than ISS introduction documents, but still less complex than official ISS accommodations documents. It will simplify and facilitate the process of writing Earth Science ISS payload proposals, and greatly increase the efficiency of potential payload proposals.

Narrow Gap Detector Testing

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The Gravity and Extreme Magnetism Small explorer (GEMS) team have modified the design of the detector assembly inside the polarimeter to improve the sensitivity to X-ray polarization. After the modification was made, the design had to be re-validated against Technology Readiness Level (TRL)-6 qualification requirements. Along with TRL-6 testing, additional testing was done to demonstrate that the new design will remain satisfactory throughout the life of the mission. Types of testing performed on the detector were: Vibration testing, Thermal Shock testing, Creep testing and Thermal Cycle testing. Vibration testing was successful with no major issues found during post testing inspection. Thermal Shock testing showed no indication that the extreme temperature had a significant effect on the detector. Creep testing shows no positive or negative trends in flatness. Thermal Cycle Testing is still on going. As of now, all the requirements have been met and the team expect the Narrow-Gap detector to reach TRL-6 by summer's end.

NICER Pointing System

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The Neutron Star Interior Composition Explorer (NICER) is an X-ray timing and spectroscopy instrument that will be installed as an external payload to the International Space Station (ISS) in 2016. NICER will resolve the nature of ultra-dense matter as well as demonstrate pulsar navigation by studying the dynamic processes and radiative mechanisms active within neutron stars. Pointing the instrument presents a unique challenge due to the accuracy required and the dynamics of both the ISS and the stepper motor actuators. Hardware, software, and data transfer units were tested for functionality and validation of the pointing performance simulations. For hardware, several tests were implemented on a NICER engineering testing unit actuator to investigate how various factors affect pointing performance. Additionally, data was collected for future use by the NICER design team to evaluate and improve the proposed pointing system. Tests included a high-resolution camera to determine kinematic error (differential position between the actuator output and expected output), a Kistler Table to measure outputted force and torque from the actuator, and a weight system to test backdrive torque.

The results verified current tracking models, which predicted greater errors. For software, over twenty different components of the high fidelity pointing simulation including library, subsystem, and controller logic blocks were unit tested. Through these tests, functionality and overall performance of the simulation, which will be used to create the future pointing control flight-software of NICER, was confirmed and improved. Furthermore, flight-software interface to the hardware and star-tracker to the gimbal control electronic unit was successfully tested by using a ground xPC target system. For data transfer, the Main Electronic Box and the Main Processing Unit, simulated by two Raspberry Pi computers, were tested for accurate, synchronized, and precise timing communication. All the work completed this summer puts the NICER Pointing System in a great position for flight software and hardware built as well as validating the flight pointing performance.

NanoSat Star Scanner for Next Generation Precision Attitude Determination

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A nanosat Star Scanner (SS Nano) is being development at GSFC to meet Size, Weight, and Power (SWaP) restrictions on Cubesats. Before the sounding rocket launch, the star's scanner on board hardware must be validated on ground. This includes: (1) proving that objective and detector will see enough stars to converge on an attitude solution 95% of the operational life and (2) creating a robust attitude determination algorithm to solve with as little stars, high precision, and least amount of faulty solutions. If the star scanner performs well in the sounding rocket mission, we will have found made one of the smallest precision attitude determination devices in the current aerospace market. The hardware is different in two drastic ways: (1) only uses one set of optics, not two, which drastically decreases the size of the instrument and (2) type of detector used: Photomultiplier (PMT) vs Multi-pixel Photon Counter (MPPC). Multi-pixel Photon Counter detectors have never been used for the purpose of star sensors on spacecraft. To characterize performance in space, a testing platform was built in a controlled environment to simulate star transits across the detector. A star transit can be imitated using a light source in an extremely dark setting and a rotating platform/function generator. One method of simulating a transit is by physically rotating the platform at varying speeds, using the rotational motors. Another method is pulsing the light source with varying pulse lengths to simulate longer or shorter transits. The shortest detectable pulse represents the fast rotation rate during operation in space. The detector seems capable of detecting pulses that correlate to 1 ms (~120 RPM) for brightest stars, and 20 ms (~6 RPM) for the dimmest stars, just out of reach of the operational goals. With post processing filtering and custom electronics, the detector should be able to detect faster, dimmer pulses.

Silicon Drift Detector Alignment for NICER

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The NICER project's mission is to study the nature of ultra-dense matter near collapse to a black hole. NICER is an X-ray observatory composed of an array of 56 X-ray concentrator optics focusing onto 56 Silicon Drift Detectors (SDDs) that detect X-rays from rapidly spinning neutron stars. The concentrators and the detectors must be perfectly aligned so that they can receive maximum throughput. This alignment is accomplished by shining an optical light beam on the alignment test bed and moving the SDDs from edge to edge through the light beam while monitoring the detected optical light from the SDDs. We have developed Python code to operate the picomotors used in the detector scans and to monitor a reference light detector, position encoders, and the SDDs during the alignment scans. Operation of the alignment test bed demonstrated that maximum throughput was obtained at a position of X= 5.93 +/- 0.02 mm, Y=3.84 +/-0.01mm. We have shown that this alignment technique can meet the requirement for knowledge of the detector position to 50 microns. Now that this alignment is done and the Python code that made it possible has been created, it can be assured that the SDDs are getting the maximum amount of throughput possible. This also means that the observatory can properly study pulsars and their X-ray output.

Software Development for X-ray Image Analysis and Metrology

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The overall goal of the Next Generation X-ray Optics (NGXO) group is to develop the technology needed to produce X-ray optics capable of a large collecting area and spectacular angular resolution while being lightweight and low-cost. The current design dictates the need for a Flight Mirror Assembly (FMA) which contains many shells consisting of thousands of mirrors. These mirrors must be permanently bonded and aligned very carefully in order to ensure the quality of the mirrors and their overall assembly is maintained. However, since they are so thin, is not easy to accomplish without distorting the mirrors. Because of this, it can take a full day or more to bond a single pair of mirrors. Any help in automating this process will therefore be very beneficial. One step requiring automation occurs after a mirror pair, or multiple pairs, have been permanently mounted to the module and are ready for X-ray testing. When the module is placed inside the test chamber, it must be aligned with the incoming X-rays and the CCD imaging device. Python was used to create software capable of finding the optimal position of the module when considering focal length, pitch, and yaw and then performing the final image analysis. In addition to this, Python was also used to develop the software needed to control a laser scanner capable of measuring the low-order shape of silicon blocks. Slices will then be removed from the block to form highly reflective surfaces that may replace the current glass mirrors.

Simulating ISS Ammonia Leaks

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This summer's work with the ISS-Lobster project has been to simulate conditions for International Space Station anhydrous ammonia leaks in the lab. The ISS is currently leaking ammonia from its cooling pipes into space, and Lobster is studying the possibility of using X-ray emissions from ammonia to locate these leaks for repair. Tests investigated the behavior of liquid anhydrous ammonia as it flows into a vacuum chamber via small 1.6-0.4 mm diameter orifices. These tests show what the Space Station leaks might actually look like based on their given flow rate. In particular, chunks of frozen ammonia which are large enough to be detected by Lobster are of interest. There have been many successful flow tests this summer where detectable ice chunks formed on and around the orifice when using 0.6 mm and larger orifices. When testing with the small 0.4 mm orifice the ammonia flows out as a fine mist or vapor with occasional small ice shards. The flow rates measured during these tests are within range of the actual ISS leaks. Ice forms easily when the flowing ammonia hits a cold surface, so a device using thermoelectric coolers was built and installed to cool the orifice which simulates ISS conditions and encourages ice formation. Anhydrous ammonia is hazardous to spacewalking astronauts, so if successful the ISS-Lobster project could potentially give them the information they need to repair these leaks and make the ISS a safer place to work.

Mechanical Design and Construction of the Primordial Inflation Polarization Explorer (PIPER)

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The Primordial Inflation Polarization Explorer (PIPER) is a balloon-borne telescope looking for evidence of gravitational waves caused by inflation in the early universe. The main objective for the summer was to construct and measure the frame of the PIPER telescope. Doing so will ensure the frame components are in the correct location. Engineering drawings were created for each frame component and the frame was constructed as the parts were manufactured. A coordinate measurement arm was used to compare the actual locations of frame components to the ideal CAD model. Alongside this task a sun sensor was designed and manufactured by the interns. This sensor will prevent the telescope from pointing directly at the sun which would otherwise boil off the liquid helium in the dewar. A SolidWorks model was created and exported to a Computer Aided Machining (CAM) program that produces code for a CNC mill to read. The manufacturing process was improved after initial test runs caused unforeseen problems to arise such as undesirable surface finish in the o-ring groove. A mathematical model was created to predict the voltage output of the sun sensor which was then compared to data from testing. It was found that a shorter tube allowed detection of the sun at a greater angle while a longer tube increases sensitivity. Voltage caused by reflected light within our test setup skewed the measurements at high angles. The measurement of the telescope frame is in progress and the manufacturing process of the sun sensor is near completion. Both tasks illustrated the dynamic nature of designing, manufacturing and constructing an instrument. The hands-on nature of the tasks resulted in lessons that aren't included in a typical college curriculum but are essential to become an engineer.

Calibration of the Mini Ion Neutral Mass Spectrometer

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The Mini Ion Neutral Mass Spectrometer (INMS) is responsible for measuring ionospheric composition by conducting high-resolution, in-situ measurements of [O], [H], [He], [O+], [H+], [He+], and total ion density in order to serve as benchmarks for upper atmospheric composition and abundances thus enabling a multitude of valuable investigations. The primary task was to calibrate INMS by designing and fabricating a high precision, motion system in order to mount and test the instrument through various angles and positions in order to simulate the collection of particle through its two apertures, one for ions and one for neutrals, while in space. In order to develop this simulation, INMS had to be given four ranges of motion: left/right, up/down, pitch, yaw. These desired ranges of motion were achieved through the use of two rotary tables, a translational stage, and a lab jack. These components were successively positioned and locked down flush on top of one other using specifically designed mounting plates machined to fine tolerances for precision positioning. The final steps in completing the motion system are connecting in-vacuum motors via flexible couplings to the translational stage and lab jack then creating a virtual instrument in LabVIEW that will control the precise position of each motor and thus each range of motion for exact positioning. Calibration of INMS will further support investigations regarding global structure and climatology, model validation, constraints to forward-modeling of airglow emissions, exospheric behavior, quantification of charge exchange processes, and characterization of storm-time behavior and response.

Distortion of a Scanning Mirror

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This study focuses on the distortion of a scanning mirror which is used in Land Vegetation and Ice Sensor (LVIS). The mirror rapidly rotates as it scans the surrounding area. The mirror moves 20 degrees in 1/20 of a second, this results in movement rate of 400 degrees per second. The angular resolution that is observed is .05 degrees. This swift rotation potentially could result in distortion of the scanning mirror. To determine if the mirror was distorting, various camera techniques were used. The mirror reflected a standardized grid composed of dots spaced half an inch apart and lines spaced five inches apart. If distortion was present then these elements would appear to be curved or shifted parallel to the expected motion. Capturing the pictures of the grid required the aperture, shutter speed and ISO of the camera to be manipulated. Originally high speed cameras were considered an applicable tool to test the distortion of the mirror; however, these cameras have poor resolution when used at the speeds needed, and the extreme cost was prohibitive. An external flash with a speed of 1/13,500 was used to freeze the motion of the rotating mirror. Evaluating the captured images in GIMP revealed that there was no visible distortion of the mirror. None of the dots shifted nor did any of the lines display curvature. Given that there was no visible distortion, the mirror that was tested could be redesigned to a thinner thickness or rotated at greater speeds.

Radio Observatory on the Lunar Surface for Solar Studies (ROLSS) Prototype

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The Radio Observatory on the Lunar Surface for Solar Studies (ROLSS) will be an observatory made to measure signals from the sun under 20 MHz on the lunar surface. Sun activity, such as solar flares and Coronal Mass Ejections (CME), often produce radio waves under 20 MHz. The project involved constructing a making a proof-of-concept prototype of ROLSS, which included a solar panel that would act as the power source of ROLSS and a radio system that would perform the primary functions of ROLSS. The radio system was expected to receive a radio signal below 20 MHz, convert the signal into a digital format, and store the data for later analysis. The radio system was constructed using a signal generator and AM band transmitter to simulate a signal from the sun and an AM radio receiver to pick up the signal. A data logger was connected to the radio receiver to record the signal for later computer analysis. The solar panel was made by soldering together 40 gallium arsenide solar cells and attaching them to a Lexan sheet. The signal recorded by the data logger resembled the sine wave created by the signal generator, though some interference was present. Under direct sunlight, the solar panel produced 16 V and 100 mA. The prototype gives a basic outline of the ROLSS radio system and gives a possible method of constructing solar panels for ROLSS and other spacecraft.

Development of a Gentle Non-Tactile One Terrestrial Atmosphere Contamination Mitigation Tool

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A major consideration with current spaceflight is preventing terrestrial dust particles from contaminating spacecraft and interfering with their intended function. This occurs before the spacecraft is launched while components are in storage or during system integration. Although the amount of dust particles in contact with the spacecraft may be controlled through the use of clean rooms, microscopic particles still gather on surfaces over time and are a major concern during spacecraft preparation. This study focused on the upcoming launch (2017-2018) of the James Webb Space Telescope (JWST) and preparing the primary and secondary mirrors for launch. Tactile methods are unable to remove the smallest, submicron particles and if used, could damage the surface of the mirrors. If chemicals are used in the cleaning process a residue could be left behind. These chemical washes can also be expensive and are not ideal for long-term use. Using compressed gas or brushes to get rid of dust is also ineffective because the dust would simply be transferred to a different location on the surface. The problem of dust particles and other contamination is one that exists in clean rooms across the globe. The purpose of this research was to create a handheld dust mitigation device that is capable of non-tactile interaction with surfaces in one terrestrial atmosphere. This tool was created using a 3D modeling soft called PTC Creo and includes the use of an electron gun (operational in one atmosphere), two gold-plated fractals, and two copper coils. This tool will be extensively tested and improved continuously until the functionality is maximized.

GSFC Functional Services

Color Me Happy: The Effects of Color Psychology as an Applied Function of the NASA Workplace

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Color is one of the most important aspects of a workplace environment. It has been proven to promote positive psychological well-being, brain stimulation, relaxation, physiological responses, and change perceived size and temperature of a room. Numerous studies in the psychology field have demonstrated a relationship between color and human behavior in the workplace. For example, studies have shown that monochromatic white and off-white business environments result in a 25% or more decrease in human efficiency and productivity. However, little evidence suggests that color has been considered as an important factor in fostering increased innovation and productivity in the NASA environment. Moreover, the results of an extensive literature review suggest that color can have an impact on psychological, physiological, and emotional well-being in the workplace environment. This paper suggests a workplace design based on color to improve workplace productivity and innovation at NASA. A color chart was created describing the psychological, physiological, and emotional implications of different colors and the effect on human behavior in the NASA workplace environment. These color based implications will increase productivity, innovation and well-being of employee performance. In conclusion, the appropriate use of colors in the workplace can increase positive psychological and physiological performance of NASA employees, promote the emotional well-being of NASA employees, improve learning in training sessions, and can improve employee satisfaction of their work environment.

The Patent Protection and Technology Transfer Process

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The USA Patent process has been a slow and cumbersome one since its genesis in the 1600s. For the first time in 50 years, laws governing the patent process have been revised. The America Invents Act (AIA) is the new governing authority, which simplifies the process. Instead of the previously murky process of verifying proof of first use for patent prosecution, the AIA dictates the first to file authority.

Here at Goddard, inventions can quickly be documented by contacting the office of Patent Counsel (140.1) or the Innovative Technology Partnerships Office hereinafter referred to as ITPO (Code 504). Inventors are guided through the process of filing the invention or software. Depending a few factors, such as invention readiness and implication of impact on Space, Humanitarian, Aeronautical, or Technical significance-and its potential to impact societal advancement-the work may be recommended for publishing, monetary award(s), and royalties.

Building Energy – Efficiency Profiling and Assessment

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The purpose of our internship was to document the methodology and progress that Goddard Space Flight Center has made their facilities more energy efficient. Energy Management encompasses facility Energy Management Control (EMC), building profiling, and sustainable buildings. First, the Federal government is under several mandates to reduce its energy consumption by 3% per year (30% by FY15). This energy consumption reduction is validated by first establishing a baseline energy usage for each building by entering a year of energy consumption data into Web-based software, EPA Portfolio Manager, which enable benchmarking, tracking, and manage energy and water consumption of individual buildings. Second, the goal of the "Five Guiding Principles" is to apply best sustainable management practices in pursuit of excellence in environmental and energy-efficient performance for federal agencies. To facilitate this goal, an effort was initiated to define divisions within the Management Operation Directorate responsibilities to the development of sustainable buildings, and how to document data in Portfolio Manager to measure the Center's progress. The final energy management activity was to increase the number of HVAC units that are controlled the Center's EMCS, the procedure used were to provide a list of currently control HVAC units and drawing showing the HVAC control area of each unit to Building Managers (BMs) and Facility Operation Managers (FOMs); The BMs and FOMs identified which building HVAC units can be put on the EMCS.

Using the baseline year of 2003, the 2013 results show that the energy intensity reduction (BTU/GSF) has reduced by 33.9% for GSFC-GB and by 25% for GSFC-WFF. Overall, GSFC-GB has met its FY15 30% energy intensity reduction goal, but the agency and WFF have not. This work is ensuring 15% of the Center's buildings are sustainable by complying with the Five Guiding Principles and complying with federal mandate to track energy use (EISA 2007, section 432). Portfolio Manager, will enable GSFC to continue to monthly monitor the energy use of the Center's buildings in order to make them more energy efficient by pinpoint buildings needing energy assessment with follow on implementation of identified energy conservation measures.

Energy Management at Goddard Space Flight Center

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Energy Management encompasses facility energy management control, building profiling, and sustainable buildings to make Goddard Space Flight Center (GSFC) more energy efficient. Since the Federal government is under several mandates to reduce its energy consumption by 3% per year (30% by FY15), our study benchmarked, tracked and managed energy and water consumption for Greenbelt (GB) and Wallops Flight Facilities (WFF) buildings through a Web-based software, EPA Portfolio Manager, in order to establish a baseline energy use profile for each property. The purpose of profiling was to monitor the building energy use and identify and prioritize buildings for energy audit and develop a process to certify that buildings are sustainable in accordance with the Five Guiding Principles. Based on the results, GB has met its FY15 30% energy intensity reduction goal, but the agency and WFF have not; therefore, after completely benchmarking all GB & WFF buildings using 2012 and 2013 data this work will continue to monthly monitor the energy use on the Center's buildings in order to make all properties more energy-efficient. Also this process will be ensuring 15% of the Center's buildings are sustainable by complying with the Five Guiding Principles.

Hazardous Waste Minimization Project

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As a research and development center, NASA Goddard Space Flight Center in Greenbelt (GSFC – Greenbelt) produces many types of waste through laboratory and fabrication processes. Toxic waste not only poses a threat to human and environmental health, but there are also economic consequences to hazardous waste disposal. The goal of this project was to use the Hazardous Materials Management System (HMMS) database to identify the areas at GSFC – Greenbelt that are potentially generating hazardous waste through the use of EPA regulated U-listed and PBT chemicals. After visiting selected labs and researching the lifecycle of the hazardous chemicals from storage, to use and disposal, recommendations were made for chemical regulation and minimization of hazardous waste streams. In total, thirteen lab visitations were conducted in buildings 33 and 34. Glues and epoxies were determined to be the most viable for widespread substitution because of their frequent and extensive use across the center and replaceable generic properties. Though, these substitutions would be most effective when implemented in the planning stages of a project. It was also discovered that understanding the research being conducted at Greenbelt is essential because not all processes or experiments lead to waste generation. Overall it was determined that continued improvements to the HMMS are the most important next steps to provide more efficient and effective management of hazardous waste at GSFC – Greenbelt. Even if it is not possible to completely eliminate the use of U-listed chemicals, as long as there is proper management of the materials to ensure safe practices in storage, use and disposal of hazardous chemicals, the safety of people and the environment will be preserved.

Photography and Archiving at NASA GSFC

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Along with the engineering and science tasks of a project or mission at NASA, it is just as important to document every step of the process and all events during mission lifetime. A personal interest in the scientific field together with creativity and a high degree of professionalism are key elements to a successful career as a photographer in this environment. My contribution to the Technical Information and Management Services Branch will ensure that images from important missions in science and engineering will be available to scientists and the public for future retrieval.

Just like NASA engineers and scientists use sophisticated equipment such as satellites and measurement instruments to discover the secrets of space, a NASA photographer uses cameras and image processing software to record and demonstrate scientific discoveries for the public. Learning to use professional camera equipment such as an SLR camera, different lenses, and lighting equipment was one of the opportunities of this project. Being able to use programs such as Adobe Photoshop and the Portfolio database system was another one. To stay current with the latest software technologies available on the market, attendance to a local professional Adobe Creative Cloud event in Washington, DC was necessary and very helpful. All the skills learned were applied documenting worksites for summer interns under the NASA Scholar program. This included laboratories, computer facilities, and testing and integration facilities that support space flight hardware.

Along with photography skills, the ability to speak publicly as well as distinguished social skills were essential to cover certificate awards and high profile events involving, for example, the Center Director and prominent representatives of local businesses. The documented and preserved archival images will eventually be sent to the National Archives as a permanent record of the NASA mission.

Investigating Indoor Air Quality in GSFC

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The Industrial Hygiene unit at NASA Goddard Space Flight Center works to recognize, evaluate, communicate, and control risks in Goddard's working environment that may affect the well-being of its employees. Goddard Space Flight Center employees have the ability to call the Industrial Hygiene with concerns of several environmental hazards including noise, asbestos, lead, and indoor air quality issues. On July 10th, the Industrial Hygiene office received a request from employees in Building 8, Suite 041 to conduct an indoor air quality assessment. There were complaints of stuffiness in the rooms, allergy symptoms, and unpleasant odors. The employees also noted that there was an insect infestation, previous flooding in one of the rooms, and poor housekeeping. On July 14th, an indoor air quality assessment was conducted in Building 8, Suite 041.The humidity, temperature, concentration of carbon dioxide, and airflow in all the rooms in Suite 041 were measured using an indoor air quality meter, balometer, and ventilation meter. The humidity, temperature, and carbon dioxide measurements were within the range recommended by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). However, the airflow in all the rooms except one was below the acceptable rate recommended by the ASHRAE standard. As a result, the Industrial Hygiene office made recommendations for Suite 041 to call the Facilities Management Division to increase airflow. They also made recommendations to have the carpets cleaned and to place lids on trash cans to address the insect infestation issue.

Mastering Workplace Effectiveness

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The Flight Projects Directorate (FPD) enables exploration, Earth, and space sciences by transforming concepts into reality. For performance-driven organizations like FPD it is important to continuously evaluate processes, environment, and strategies in order to build communication and boost efficiency. One key piece to enhancing workplace effectiveness is gathering evidence on how well the workplace supports its employees. The study tested seven objectives ranging from informing FPD-funded interns about FPD and its missions while inspiring FPD interns and leaders to connect, to identifying FPD workforce, staffing, and retirement trends. Projects, assigned separately by two mentors, required unique focus dominate skill sets and applied concepts combined with similar main objective to support FPD and its mission. Project tasks were further divided by process, focus, and implementation needs. Using programmatic and administrative approaches, identified challenges were sent through a seven step "Development Wheel" to evaluate the challenge, research and develop a strategy, deploy a plan, gather data, analyze results, collect feedback, and re-evaluate the challenge for further development needs. Solutions were designed to produce results and products that would complement FPD and FPD's missions. Products and results were unique to each of the seven objectives and challenges with some challenges producing more than one product. Results were further defined by impact on FPD culture and workplace function. Overall, we found consistently evolving processes and improving communication helps amplify workplace effectiveness and elevates performance outcomes. By utilizing data collection, historical evaluation, and strategic planning, this study helped streamline business procedures, addressed mission needs, highlighted important aspects of daily duties and existing data, increased open discussion about underlying cultural behavior, and enhanced directorate wide collaboration.

Measuring Contract Performance with Earned Value Management

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This summer, I worked with the James Webb Space Telescope (JWST) project management team to evaluate contract performance with Earned Value Management (EVM). EVM is a project management tool that measures project performance by integrating schedule, cost, and technical aspects of the project. EVM measures cost and schedule performance against a baseline plan and derives a set of metrics that not only act as an early warning system for problems, but can also be used to forecast the final project costs and completion time.

JWST uses EVM to measure the performance of its contracts, which allows project managers to have a similar base for fair evaluation and a way to create universal understanding of the progress of all aspects of the project. JWST also uses EVM in award fee assessments, to give project management additional data to make technical/cost/schedule trades at the project level, to gain insight into how well a contractor or specific effort is structured, and to provide insight to the program headquarters and external organizations like Congress.

A few of the most important Earned Value (EV) metrics used for analysis are the Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI), Schedule Performance Index (SPI), and To-Complete Performance Index (TCPI). The CV is the difference between the cost of the actual work and the cost of the planned work. The SV is the difference between the performed work and the scheduled work, shown in dollar value form. The CPI shows how successfully the project is keeping to budget. The SPI shows how successfully the project is keeping to schedule. The TCPI shows how well the contractor will need to perform in order to complete the project on budget.

The Earned Value Management System calculates EV metrics using monthly data that contractors send in about the planned work, performed work, and the actual cost of the work. Resource analysts then look at these metrics for significant changes and data trends and to evaluate whether a contract is behind or ahead of schedule and over or under budget. They then develop an Independent Estimate at Completion (IEAC) for all contract Work Breakdown Structure (WBS) elements. After developing an estimate of the final cost for each element, the analyst writes an EVM Assessment for project management that details the contract's schedule and cost performance and notable changes and trends related to individual WBS elements.

EVM is a very valuable project management tool, especially for large flight projects like the JWST that need to carefully monitor many contracts. Using EVM, project management can gain a more accurate picture of cost and schedule status, better communicate project performance, and also make better informed decisions about the project.

Infuse Tech Transfer with NASA Goddard and Abroad

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The Innovative Technology Partnerships Office (ITPO) is responsible for licensing patented NASA technologies to companies. Focusing on tech transfer, the high school interns were assigned three main tasks: (1) create four videos promoting the NASA Goddard OPTIMUS PRIME Spinoff Challenge (Challenge), (2) enhance a new portion of the upcoming Challenge, and (3) design innovator cards for ITPO use. When creating the videos, the goal was to spark interest in the Challenge while teaching students about tech transfer and spinoffs. The interns brainstormed, scripted, storyboarded, filmed, and edited the videos while effectively managing time to balance other tasks. This video creation process taught studio lighting techniques, Adobe After Effects™, and Adobe Premier™. Another task was to enhance the InWorld portion of the Challenge. New this year is the addition of the InWorld Challenge, where students will work collaboratively with peers to create their own James Webb Space Telescope spinoff using CAD software in a virtual world. The goal was to make the virtual world more visually appealing and user friendly so that first-time users could easily learn to navigate InWorld. Building in InWorld taught CAD design skills and how to film in a virtual world. Another task was to create Goddard-inspired innovator cards teaching others about tech transfer, New Technology Reports (NTRs), and the functions of ITPO for inreach and outreach purposes. This process taught the interns intellectual property, team workflow dynamic, time-management, and NTR basics. All of this content will be a part of a larger marketing plan that will educate the public about spinoffs and tech transfer, as well as how significantly these affect their lives.

Creation of Explanatory Posters for NASA GSFC Science Directorate Laboratories

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The Goddard Space Flight Center's Science Directorate has over 25 labs and offices to identify, research, and help solve today's pressing Earth and Space science problems. The Science Directorate (Code 600) management requested a series of posters describing each of the labs purpose, goals, and fields of study. The research required contacting Lab Chiefs, collecting images and culling information from papers, posters and web sites. Several iterations of each poster were discussed with and approved by Lab Chiefs and graphics managers. After completion of preliminary set of posters, half sized versions were generated and test prints were made to determine sizes and spacing for both Lobby and Lab display. The divisions in this Directorate include: Earth Sciences, Astrophysics, Heliophysics and Solar System Exploration. Through this project, the broad range of scientific investigations that are actively taking place at the Goddard Space Flight Center are explained and elucidated. Computer applications such as Adobe Illustrator CS6, Adobe Photoshop CS6, and Acrobat Pro were used to complete each poster. Graphic Design, photography and communications skills were needed to complete the project.

Science

EM Field Propagation through Lithography Masks for Assessment of Intensity Suppression

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To suppress the back-reflected light from the secondary mirror of eLISA telescope, several different shape coronagraphic masks have been designed and fabricated. An optical testbed in transmission mode has been setup in the Optics Branch Wavefront Sensing and Control Group Lab to verify and validate the suppression capability of these masks. A series of experiments have been conducted where a solid-state laser source of 532 nm illuminated the masks that are on substrates. An EMCCD detector has been placed at the shadow region to record the intensity behind the mask. The optical experiment adheres to the eLISA optical testbed setup of near-field diffraction where the Fresnel number is around 4.7. A set of circular masks was used in the experiment to verify the presence and intensity of the Poisson spot at the detector and these values were then compared to their dimensionally equivalent petal masks in order to determine the suppression. The current binary petal shaped masks show expected suppression of intensity up to two to three orders of magnitude.

Kinetic Inductance Detectors for Far-Infrared Spectroscopy

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A rich variety of spectral lines exist at far-infrared wavelengths that can serve as tracers of star formation in the early universe. However, these lines are very faint, so a balloon-or space-based telescope with high-sensitivity detectors is the ideal platform from which to observe them. This project focuses on developing a system of Kinetic Inductance Detectors (KIDs) suitable for such an instrument. KIDs are superconducting resonant circuits which, as a result of the kinetic inductance effect, have resonances that shift in frequency and amplitude when incident radiation is absorbed. In particular, lumped-element KIDs use separate lumped-element inductors and capacitors in combination with relatively low frequencies for detector readout. The lumped-element approach also uses the inductor as a direct absorber for incoming radiation. This summer, we designed and fabricated a prototype array of lumped-element KIDs with the properties necessary to perform far-infrared spectroscopy. The prototype aims to achieve high sensitivity by leveraging a high-kinetic inductance TiN/Ti/TiN trilayer material, and using low-volume inductors. More specifically, the array uses a modified microstrip design and consists of 1600 capacitatively coupled lumped-element KIDs with resonant frequencies between 100 and 250 MHz. Parallel work on the supporting cryogenic and electronics systems is ongoing at the University of Pennsylvania so that the detectors can be tested and characterized in the fall.

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Preliminary Analysis on Two Space Instrument Databases

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Although several online databases exist for Earth observing instruments, there is no standard data record available that includes all past, present, and proposed Earth observing instruments. Combining two of these databases: the Observing Systems Capability Analysis and Review Tool (OSCAR) and the Committee on Earth Observation Satellites (CEOS) Database Online, will provide for a more comprehensive and organized data record of Earth observing instruments and will promote improved data analysis for future developments. The project approach included extending OSCAR identification numbers to all identical CEOS instruments. Once the common index was created and the datasets were compiled, comparisons were made that differentiated the types of information each database offered. OSCAR included more instruments from the past (1960-2015), while CEOS included mostly instruments from recent years and into the future (2000-2050). Additionally, the compiled dataset was used to make graphs for analyzing instruments developed and used by USA space agencies versus Non-USA space agencies. The main findings confirmed that the USA was the first major developer of Earth observing instruments. The compiled dataset also provided a closer look at the types of instruments used and developed by USA versus Non-USA. USA develops a major portion of the heliophysics instruments, but is no longer a top developer of Active Microwave instruments. The project depicts the improvements in data analysis that may be possible with a common index for Earth observing instruments.

Slow Down, I'm Not a Scientist: A Field Guide to Science Writing

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How do you tell your story? You're at the cutting edge of research, but communicating what you do to people outside of your discipline can be daunting. Good writers can be your conduit to the public – to support, funding, and to scientific understanding in the communities you serve. Effectively translating complex scientific information and presenting it to the public requires patience, curiosity, and a willingness to dive into foreign territory, often without a net. WWW.EARTHZINE.ORG is an online publication created to help build bridges between what is happening in the Earth observing community and the public-at-large. An Earthzine internship offered me the opportunity to hone my writing skills in a truly extraordinary environment; this will serve me well as I begin the transition from academia to a career as a science writer. At the end of a summer at Goddard spent interviewing scientists and NASA administrators about groundbreaking technology and research, I'll be armed with a portfolio of published articles that demonstrate my potential to future editors and employers. Since my internship did not necessitate doing scientific research, I used the poster presentation as an opportunity to outline the writing process; I believe that this helps demonstrate the work that I am currently doing here as a writing intern in a cohesive manner. Additionally, the presentation helps illustrate the similarities between science writing and scientific research, which may be of benefit to fellow interns as they move towards a career in the sciences where they will need to be able to effectively communicate with the public in a written format.

Creating Hyperspectral Test Scenes for the Wide-Field Imaging Interferometry Testbed

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I present here results of an effort to develop astronomically realistic hyperspectral test scenes for the Wide-Field Imaging Interferometry Testbed (WIIT). As part of a research program designed to mature spatio-spectral interferometry for future application on a spaced based far-IR interferometer, our aim is to understand how such an interferometer will respond to the sky. The derived test scenes have both spatial and spectral information. The Calibrated Hyperspectral Image Projector (CHIP) in WIIT is capable of projecting spatially and spectrally complex scenes.

The developed test scenes depict scientifically interesting targets as they would be seen in the far-infrared. The first scene is a 'deep-field' image of an extragalactic background. It includes simulated galaxies, foreground zodiacal emission, and Galactic cirrus emission. The galaxies have realistic spectra, including spectral line emission, and have realistic redshift and luminosity distributions. The second type of scene represents a simulated planetary disk. The planetary disk is viewed at two different angles: face-on in one case and inclined by 60 degrees to the plane of the sky in a second case. In both cases the disk is placed into the extragalactic background and foreground emission scene used as a 'deep field' as these foreground and background emission components will be present in all far-infrared target fields, and we need to understand how well we are able to differentiate sources. Until now, we have observed relatively simple test scenes in order to develop an understanding of the interferometer's performance. The new test scenes will give us valuable experience with astronomically realistic observations, allowing us to refine our data processing techniques and learn how well a real space-based far-IR interferometer will work. This work is part of an effort to mature technology for the Space Infrared Interferometric Telescope (SPIRIT)

Relationship between Earth's Auroral Kilometric Radiation (AKR) and the Auroral Electroject Index (AE)

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The purpose of this research is to determine whether Auroral Kilometric Radiation (AKR) has a direct, indirect or no relationship to the Auroral Electrojet Index (AE). Recent studies have shown that the Auroral Kilometric Radiation (AKR) and Auroral Electrojet Index (AE) have a positive correlation. This theory is based on the collection of data from one satellite. By collecting data from multiple spacecraft's using the Virtual Wave Observatory (VWO) it will eliminate the factors of doubt toward this theory. Furthermore, using this method has proven that AKR and AE do not always have a direct relationship. The Earth being a very intense radio emitter similar to Saturn and Jupiter discovering how it really works can help discover exoplanets.

Optical Modeling of the Wide-Field Imaging Interferometry Testbed (WIIT)

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A far-IR interferometry mission has been a high priority for the astrophysics community over the past decade. Observation of far-IR wavelengths will help physicists gain new insights concerning the formation of planetary systems from protostellar disks and the formation and evolution of galaxies. Several space-based interferometer designs have been proposed for such a mission, including the Space Infrared Interferometric Telescope (SPIRIT). SPIRIT is a far-IR, high-resolution observatory that will be capable of observing far-IR emissions from Galactic and extragalactic sources. Before SPIRIT can be developed, a small-scale model must be constructed to test and validate the wide field-of-view spatio-spectral interferometry technique. To this end, the Wide-Field Imaging Interferometry Testbed (WIIT) was previously built, and a computerized optical model of WIIT was created using the FRED optical engineering software package.

In this project, the WIIT software model was configured to operate and successfully image a test scene intermediate in spatial and spectral complexity between the simple scenes previously explored and the astronomically realistic scenes yet to be explored. This test scene, consisting of six binary pinholes, with a variety of controlled pinhole spacings and spectra that vary from pinhole to pinhole, was “observed” at different interferometric baseline lengths and rotation angles. The simulated data gathered from the computer model will be compared to actual WIIT data to further verify the functionality of the test bed and gain insight into the practical limitations of wide-field spatio-spectral interferometry. The successful imaging of the test scene will help pave the way for imaging more astronomically complex scenes with WIIT and demonstrate the validity of the techniques that will be used in the SPIRIT mission.

Large Scale Data Analysis Using the CDS API – Indicators of Climate Change in MERRA

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The purpose of this study was to find indicators of climate change within Modern-Era Retrospective Analysis for Research and Applications (MERRA) data. Specifically, an analysis was conducted to find climate change indicators within the global and northern polar region surface temperature data between 1980 and 2010. Indicators were determined by comparing actual observations to the results of the MERRA analysis. The expectation was that MERRA would show an overall trend in temperatures that agrees with observations during the thirty-year time period. The MERRA surface temperature data was gathered using the Climate Data Services (CDS) Application Programming Interface (API). Since not all MERRA grid cells are equal in size, a spatial average had to be calculated for each cell. The results indicated a global temperature increase of 0.51K (0.017K/year) over the thirty years. The study also found that the northern polar region was warming at double the global rate. This resulted in an increase of 1.20K (0.040K/year) over the thirty years. Reports from the Intergovernmental Panel on Climate Change (IPCC) have shown that their observations support these results. This support was used to verify that that the MERRA data does show a temperature trend that agrees with observational data. As a result, it was concluded that implications of climate change do arise within MERRA data.

Climate Change: How do we know?

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Climate change is the difference in usual or "normal" temperature and conditions in an area over a long period of time. Climate refers specifically to the atmosphere. In order to confirm that climate change is occurring, we need to figure out what is changing. A basis for change needs to be established before determining whether or not change is occurring. We created this basis by examining key indicators that we as humans directly notice and are affected by in everyday life. By analyzing these key indicators (atmospheric carbon dioxide concentrations, mean global temperature, precipitation patterns, sea level, and sea ice), we determined that there is significant change in each of them over a significant period of time. The atmospheric changes are impacting the environment, confirming that climate is in fact changing and could become a problem for us human beings (rather than just the earth itself) in the near future.

Investigating the Link between Biomass Burning and the Water Cycle in Northern sub-Saharan Africa

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This study uses satellite observations and modeled data to investigate potential effects of biomass burning on the water cycle in the Northern Sub-Saharan Africa (NSSA). Thirteen years' worth of observations of fire radiative energy (FRE) from 2001-2013 from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard Terra and Aqua are compared to observations of precipitation, precipitable water vapor, and model estimates of evapotranspiration and soil moisture from the Global Land Data Assimilation System (GLDAS). Several statistical techniques are used to investigate the potential effects of biomass burning on the water cycle, including cross-spectral analysis as well as correlations between time series. Cross-spectral analyses suggest biomass burning may affect soil moisture and evapotranspiration on seasonal time scales, but this effect varies by land cover type and region. Spatial maps of correlations between FRE and other variables also suggest large differences between regions in the NSSA. This study hints at a relationship between biomass burning and the water cycle, but further investigation is needed to understand this complex interaction and its impact on the region.

First-Look Statistics of Precipitation Estimates from the Global Precipitation Measurement (GPM) Constellation Satellites

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Global Precipitation Measurement (GPM) is an international earth science observation mission led by NASA and JAXA. The core observatory is equipped with a microwave imager GMI and Dual-frequency Precipitation Radar DPR. The core observatory provides a calibration standard for a constellation of multi-platform observations on global precipitation. Since its launch on February 27, 2014, the first GPM scientific datasets are released in June 2014, including global precipitation estimates retrieved from microwave measurements. Because physical or empirical based retrieval procedures are affected by measurement resolution, accuracy, assumptions and approximations on precipitation property and environment, it is important to verify and validate the precipitation estimates by inter comparison and statistical characterization.

In this work we conduct a first-look statistical analysis on the Level-3 products from the first GPM scientific datasets. Level-3 precipitation estimates contain geophysical parameters that have been spatially and/or temporally re-sampled from Level-2 pixel-resolution retrieved surface precipitation. We examined the statistics of global precipitation collected during April, May, and June 2014, measured by 5 instruments in the GPM constellation: GMI, Advanced Microwave Scanning Radiometer 2 (AMSR2), and Special Sensor Microwave Imager /Sounder (SSMIS) on DMSP f16, 17, and18. Inter-comparison was made of global precipitation in terms of spatial and temporal variability and intensity distribution among constellation satellite measurements. The retrieved precipitation over different surface types was also evaluated to identify any systematic differences. Our results quantitatively evaluated the uncertainties associated with limited sampling frequency, sampling time, and sampling spatial resolution of different satellite measurements. We found that the sampling errors are largest over land regions with large diurnal cycles in precipitation. The instruments with coarser spatial resolution resulted in lower variability and less frequent detection of intensive precipitation events particularly over ocean surface.

Snowfall Observations at NASA Wallops Flight Facility

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The National Aeronautics and Space Administration (NASA) Global Precipitation Measurement (GPM) Mission ground validation program has been conducting a field study of precipitation observations at the NASA Wallops Flight Facility (WFF) during the past year. The purpose of the study is to provide a better parameterization of the microphysics of precipitation including falling snow for the GPM algorithm developers. Under the umbrella of physical validation, GPM algorithm developers use the disdrometer based hydrometeor size distributions to test parametric form of the size distribution from dual frequency radar measurements on board GPM core satellite. In the presence of snow, GPM algorithm developers seek additional information on fall velocity and snow density. Additionally, there is need to quantify the partial beam filling within the satellite footprint.

The main objective of this study is to investigate the microphysical characteristics of falling snow and its spatial variability within the GPM core satellite footprint. To accomplish this goal, eight snow events that occurred at WFF were analyzed. The network comprises of six sites encompassing a variety of instruments: Automated Parsivel Units (APU's), two-dimensional Video Disdrometers (2DVD's), a Precipitation Imaging Probe (PIP) and pluvio200 weighing bucket rain gauges. These respective instruments have the ability to detect particle size and velocity of both solid and liquid precipitation with the pluvio200 measuring the melted equivalent of snow accumulation. The distances between sites ranged from 0.5-2.3 kilometers. The following steps are taken to accomplish this objective: (1) comparison of the event snowfall and snow rates between different instruments, (2) parameterization of the snow size distribution and snowfall velocity, (3) determination of snow density and spatial variability of falling snow and its microphysical characteristics, (4) comparison of disdrometer derived and radar observed reflectivity and derivation of reflectivity and snow rate relationships.

Dust Activity and Transport in the High Latitudes

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While normally associated with warm arid regions, dust production also occurs in cold arid environments commonly found at many high latitude locations. However, there are few studies that go in-depth on the characterization of these active dust locations. This study focused on two of these locations – the Patagonian Desert in southern South America and the Copper River Delta in Alaska. The goal of this research was to study two dust locations that are still poorly understood and attempt to answer many questions for each location. For Patagonia: Is there a strong seasonality shown for dust events? Does precipitation and wind speed play a large role in determining dust event frequency, and is there any sort of lag time between drought and dust events? Is there a correlation between annual mean element concentration and total dust events for that year? For Alaska: What are the typical synoptic conditions for known dust events, and what are the expected dust concentrations at different resolutions? In order to answer these questions, standard meteorological data was collected by the Argentina National Weather Service for seven stations throughout Patagonia and analyzed to determine the seasonal and yearly changes for dust events, while synoptic weather maps and HYSPLIT4 atmospheric model data was analyzed in Alaska to determine the typical synoptic setup and dust concentrations during a dust event.

There were many interesting results made during this study. In Patagonia, the average monthly precipitation correlated well with monthly dust events, albeit with a slight one or two month lag for precipitation. Wind did not play a significant role in producing dust events, as the majority of events occurred during light to moderate winds (wind speed < 8m/s). Also, the typical synoptic setup for dust events in Alaska showed a low in the Gulf of Alaska and high over interior Alaska, which produced a strong northerly katabatic wind over the Copper River sediment fields. This study showed that dust does play a major role in the high latitudes and that it could be possible to predict these events in advance. It is important that more studies are conducted on high latitude dust activity in the future to further advance knowledge, as it is clear this region is important for dust transport but is still relatively unknown.

Retrieval of Plume Heights from Volcanic Eruptions Observed by MISR

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The purpose of this project is to provide volcanic injection height as a constraint for climate models that predict environmental impacts of volcanic eruptions. By collecting and analyzing injection heights and their relationships with other factors, we aim to understand how much of an effect the eruptions have on climate, wind systems, energy budget and water cycle. Using stereo imaging, we digitized both major and minor volcanic plumes observed by MISR from 2000-2014 to extract height data and compare it to Volcanic Explosivity Index (VEI) and SO_2 emissions. From the data, we have learned that the heights of volcanic plumes are influenced by factors in addition to those that comprise VEI.

Effect of Stratospheric Intrusions on Tropospheric Ozone and Air Quality

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Ozone can have negative impacts on air quality and cause respiratory problems for humans. Stratospheric intrusions transport ozone rapidly from the stratosphere across the tropopause and into the free troposphere. The impact of stratospheric intrusions on tropospheric ozone and their possible influence on surface air quality are investigated. Aircraft and ozonesonde data from the NASA Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) Maryland field campaign were used to locate stratospheric intrusions. Relative humidity profiles, from the Atmospheric InfraRed Sounder (AIRS) satellite instrument, confirmed the presence of stratospheric intrusions when dry stratospheric air was co-located with ozone-rich and nitrogen dioxide deficient air as measured by the ozonesondes and aircraft instruments. The Goddard Earth Observing System Model Version 5 (GEOS-5) was run with stratospheric tracers to test the accuracy of its prediction of stratosphere-to-troposphere transport. At the DISCOVER-AQ Edgewood Maryland site, there were four definitive stratospheric intrusions and one possible intrusion identified; observations showed little impact on the eight other days investigated. Based on our results, identified intrusions enhanced tropospheric ozone, but did not impact surface ozone levels on days with poor air quality. Further research will examine the presence of stratospheric intrusions during other campaign deployments (Houston, California, Denver) and the seasonality of these dynamic features.

Using Geostationary, MODIS and OMPS Data to Determine Smoke Injection Heights during the SEAC4RS Field Campaign

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Accurate forecasting in global aerosol assimilation models, such as GEOS-5, requires an accurate background model. One of the largest inaccuracies in modeling Biomass Burning (BB) aerosols stems from aerosol injection height assumptions. Currently, GEOS-5 injects aerosols into the atmosphere at ground level though much BB aerosol is indeed emitted below the Planetary Boundary Layer (PBL), special circumstances permit aerosols to be injected above the PBL. When a fire is large enough (i.e. has a high enough heat flux), a Pyrocumulus cloud forms. In addition, an Overshooting Top (OT) may form, puncturing the PBL and allowing aerosol injection into the Free Troposphere (FT). Once in the FT, an aerosol layer can travel great distances. The purpose of this research project is to develop a working algorithm that will identify likely Pyrocumuli so that the model injection height can be adjusted accordingly. Our algorithm involves collocation of OT, MODIS fire locations, and a high enough Aerosol Index (AI) in the surrounding area indicative of a strong fire. To verify this model works, we will examine MISR aerosol plume height, model-predicted PBL height, and observations taken during NASA SEAC4RS aircraft mission in August-September 2013.

Satellite Remote Sensing of Sea-Surface Salinity in the Polar Regions – Observations and Validations

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Sea-Surface Salinity (SSS) can be an indicator of currents, thermohaline circulation, sea-ice melting and/or formation, precipitation, evaporation, and river run-off. Therefore, it is a variable of the Earth's climate system and its evolution can shed light on global climate changes. SSS measurements are taken in-situ and by satellites. This study aims at validating satellite SSS retrievals by the Aquarius instruments at high latitudes using ship in-situ measurements as a reference. Aquarius uses L-band (1.4 GHz) radiometry, and such sensors' accuracy is expected to be lower for cold waters. Therefore, we assess whether Aquarius is retrieving SSS within the error limit expected for lower latitudes (0.2psu), and if not, what could be done to improve the retrievals. Error sources that need to be compensated for when retrieving SSS from Aquarius are: Sun, Moon, celestial sky, atmosphere, Faraday rotation in the ionosphere, Radio-Frequency Interference (RFI), temperature, rain, sea-surface roughness, land, and ice. We use the version 3 of Aquarius level 2 (i.e. along track) data from 2011-2012 (NASA PO.DAAC). Ship data products are from the Nuka Arctica vessel and project SURVOSTRAL (www.legos.obs-mip.fr/observations/sss/monitoring). Aquarius data was collocated over 50km and ±3, ±5, and ±7 days around the ship measurements. Data analysis was performed through plots, maps, and statistics (filtering out the ice and land fraction >0.2%) generated with Matlab. Through these, it was observed that ice and land contamination lead to significant errors in SSS retrieved by Aquarius. Once the filter was applied, SSS retrievals agreed well with ship data (with a standard deviation ~ 0.2 psu). However, significant regional biases are observed (median difference ~ 0.2psu) increasing the RMSe. Additional errors may be caused by the difference in the depth of ship measurements (≤10m) and Aquarius retrievals (1cm), RFI, and the colder sea-surface temperatures. Near Tasmania, an increase in SSS, both from ship data and Aquarius, is evidence of a poleward shift of the East Australian Current attributed to climate change.

Assessing the Properties of Snow in West Antarctica

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In the past two decades, satellites have observed accelerating rates of ice mass loss across the West Antarctic Ice Sheet (WAIS). Both laser and radar altimeters are used to monitor surface elevation changes. However, radar altimeters like CryoSat-2 (CS2) can penetrate the snow surfaces that cause an elevation bias. The Satellite Era Accumulation Traverse (SEAT) project in 2011 collected in-situ measurements of elevation and snow and ice properties along a 600-km traverse of the WAIS in order to investigate the accuracy of CS2 radar penetration. SEAT collected radar measurements and Near-Infrared (NIR) reflectance of snow stratigraphy at sites that received either high or low levels of snow accumulation. A comparison of SEAT and CS2 elevation datasets showed a bias in CS2-derived elevations against those recorded by SEAT GPS. The cause of the bias was investigated by examining the influence of elevation on various snow properties and the corresponding SEAT radar data. The NIR reflectance corresponds to snowpack grain size while the radar backscatter is more sensitive to snow density. Graphs were generated in Matlab to see how NIR and backscatter values (and therefore snow grain size and density) compared between sites with low accumulation and high accumulation. CS2 overestimates the elevation in regions of low snow accumulation in which snow density increases with depth at a relatively high rate. CS2 underestimates the elevation in areas of high snow accumulation in which density increases with depth at a much lower rate. This study shows that the bias in CryoSat-2 derived-elevations needs to be calibrated in order to more accurately predict the total rise in global sea levels.

Investigation of the Potential Use of Aquarius Data for Sea Ice Thickness Retrieval

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Brightness temperature from Aquarius data, along with other parameters, are used in attempting to calculate sea ice thickness in the Polar Regions. Development and testing of various methodologies were carried out for the analysis of the simulations. By comparison of the data from Cryosat-2 and Aqua, a correlation to the Aquarius data from the month of March 2014 has been made. A model was used with the Aquarius data to see how well it predicts the outcome. The results of this model are not accurate enough. The accuracy of the Aquarius sea ice thickness is likely due to uncertainties in the parameter measurements. In this research project, sea ice thickness is estimated in Polar Regions by using an empirical model with data given on brightness temperature.

Measurements of Particulate Organic Carbon in Estuarine, Coastal, and Offshore Waters of the Gulf of Mexico

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In September of 2013, multiple water samples were taken from estuarine, coastal, and offshore waters of the Gulf of Mexico. These samples were then analyzed in the lab for Particulate Organic Carbon (POC). POC is an important component in biogeochemical studies; it conveys crucial information about carbon sequestration and climate change. Additional samples were collected for analyzing chlorophyll concentrations. When these two data sets were regressed, a clear and positively linear relationship was revealed. This relationship can be used to predict the concentration of POC from chlorophyll measurements and vice versa. At the Gulf of Mexico, higher POC concentrations (up to only 1400 µg/L) were found along the coastline because of nutrient availability. At Galveston bay however, POC concentrations didn't get below 500 µg/L and went up to 2500 µg/L. On a more global scale, POC concentrations are higher right along coastlines as well as nutrient-rich north and south regions due to wind and circulation patterns. Lowest levels of POC are found in the gyres of the ocean. In situ measurements will be matched up with satellite overpasses to validate remote-sensing algorithms that detect POC at the surface as well as to develop new and improved algorithms.

Validating Flood Mapping Products Using a Digital Elevation Model Comparison Technique

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This preliminary study assessed the validity of a pixel analysis elevation comparison technique and determined necessary steps for improvement. The pixel analysis sought to assess the probability of a flood occurring in a particular area by comparing the spatial extent of flood mapping products to the local elevation. The method was developed to determine if the physical relationship between elevation and floods as shown in satellite images is accurately represented in a flood mapping product. The data incorporated in this study were raster Digital Elevation Model (DEM) tiles, a scene from Landsat 5 during a flood period, and a scene from the NASA DEVELOP Flood Disasters Team Flood Product. Pixels representing flooded areas were compared to the elevation height pixels using horizontal transect lines to create pixel value profiles across a 727 km area of Vietnam and Cambodia. The elevation model comparison validates the Flood Product by depicting water presence in alignment with areas of low elevation. Future research will focus on streamlining the pixel analysis process to yield comprehensive results.

Addressing Media Bias in Rainfall-Triggered Landslide Reporting

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While landslides are not generally as well-known as other natural disasters such as floods, fires and earthquakes, they present comparable societal and economic hazards to populations at a global scale. The necessity of understanding past and present landslides has been realized in recent years and much work has been conducted in the development of a Global Landslide Catalog (GLC). Analysis and collection of events at a global scale has led to progress in the development of an algorithm for predicting landslide susceptible regions in real-time. With this progression in landslide event cataloging and susceptibility prediction efforts, it has become apparent that there is a deficit of event reporting in specific areas where landslides should be occurring. Regions where an intersection between steep slope level and high rainfall rate is present are especially prone to landslides. A clear rise in rainfall-triggered landslides can be observed in these areas; however, in certain regions where greater incidence of landslide events should be evident, there is a lack of reported events. This media bias presents a challenge to the landslide research community by impeding efforts to construct a complete global event catalog, inhibiting understanding of where and why landslides occur, and creating an obstacle in the development of a landslide prediction algorithm. Many of these underreported, landslide-susceptible regions coincide with low population levels. This study seeks to determine the reasons behind a lack of event reports from seemingly susceptible areas as well as to geographically define these regions. ArcMap software was utilized in the spatial analysis of landslide event locations, slope rates, rainfall amounts and population levels. Because Tropical Rainfall Measuring Mission (TRMM) Composite Climatology (TCC) data was used, this restricted the study area to the confines of TRMM's satellite coverage. The primary causes for media bias in landslide event reporting in regions of high susceptibility include low population levels in general which present a variety of issues for media reporting, event reports in languages that are not tracked by landslide catalogers, media databases not online and/or searchable, as well as the fact that many events are not reported by the media unless human injury, loss of life, or significant economic and structural damage has occurred. By defining underreported, landslide-susceptible regions and presenting causation behind media bias in these areas, this study has furthered understanding of rainfall-triggered landslides at the global scale and formed the basis for future research and efforts in addressing areas exhibiting media bias.

Sea Level Rise along the East Coast of the USA from Tide Gauges and Satellite Altimeters

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Satellite altimeters have detected sea surface height trends which are positive over the majority of the north Atlantic and negative near the Gulf Stream, the western boundary current of the subtropical gyre. However, discrepancies between rates of sea level rise from tide gauges and altimeters exist. Tide gauge records of relative sea level must be adjusted for vertical land motion – often as approximated by Glacial Isostatic Adjustment (GIA) models – in order to be comparable with altimetric observations. Recently, the use of GPS devices has furnished independent estimates of vertical land motion which reflect GIA, groundwater extraction, sediment loading, and tectonic activity, yet spatial coverage is sparse. In this study, the contribution of vertical land motion from GIA models and GPS observations to the sea level rise discrepancy was assessed. Specifically, linear rates of sea level rise from tide gauges adjusted for vertical land motion were compared with altimetric rates from the SSALTO/DUACS ¼° x ¼° gridded sea level anomaly product based upon the TOPEX/Poseidon (1993-2005), Jason-1/Jason-2 (2002-), ERS-1/ERS-2 (1992-2003), Envisat (2002-2012), Cryosat-2 (2012-), GFO (2000-2008), and SARAL/AltiKa (2013-) satellites. Tide gauges and altimeters were collocated by selecting the grid box of maximum Pearson R correlation, ensuring that the sea level time series represent similar ocean variability. The dependence of the correlation upon the temporal resolution and choice of statistic was also investigated. Generally, vertical land motion may not fully account for the discrepancies between the tide gauge and altimetric rates. Spatially, correlations are weakest for tide gauges near the Chesapeake Bay and vary based upon the temporal resolution and presence or absence of the annual cycle. This study has implications for altimeter/tide gauge validation and for understanding the relative contributions of ocean dynamics and land motion to regional sea level rise in a warming climate.

A Dynamic Model for Rainfall-Triggered Landslides in Central America

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Rainfall-triggered landslides are a consistent threat to life and property around the world and are extremely challenging to physically model over large areas. The Dynamic Landslide Assessment model combines a static landslide susceptibility map with a decision tree approach that considers satellite-derived rainfall and soil moisture thresholds to designate landslide "warning" or null value for the evaluated pixel. This model is used in order to facilitate the development and implementation of an online landslide 'nowcast' system for the region of Central America. For initial diagnostics, Receiver Operating Characteristic (ROC) curves were generated from a 3-year model run of 125 landslide points in Central America.

To optimize the threshold necessary to trigger a landslide, normalized rainfall was evaluated against landslide occurrence in each model run and the True Positive Rates (TPR) and False Positive Rates (FPR) recorded. Each curve is evaluated against other instances by locating the minimum distance from a perfect fit (TPR = 1and FPR = 0) on a calculated ROC curve. The preliminary runs of the model are promising; the smallest R value is associated with a TPR of 0.79 and a FPR of 0.21. In addition, the inclusion of soil moisture data improves the skill of the model when rainfall is considered within a temporal window of a single day. However, consideration of larger precipitation windows (e.g. 3-day) somewhat diminishes the effectiveness of the inclusion of soil moisture data. Nevertheless, the simplicity of the model will continue to facilitate evaluation and inclusion of new data sources and metrics, as well as rapid integration of the model components within the developing online system.

Modeling Stormwater Runoff Reduction from Low Impact Developments for GSFC using the EPA's Stormwater Management Model

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Recent dramatic increases in urbanization have severely increased stormwater runoff in many areas, at the cost of ecosystems, property, and even human life. In response to this threat, the Goddard Space Flight Center (GSFC) is attempting to reduce its stormwater runoff through the implementation of Low Impact Developments (LIDs), which are small, decentralized changes focused on reducing the flow of water off a basin. Effective placement of these structures is greatly enhanced with the predictive capabilities of a hydrological model such as the EPA's Stormwater Management Model (SWMM). This study uses a SWMM model of a small drainage basin on the GSFC campus to assess the effectiveness of various LID options and provide decision-making support. The model domain consists of two parking lots separated by a small forest, and the model tested two swale LID possibilities, one densely vegetated and one grass, that carrying the runoff from each parking lot. Three historical storms, one low intensity one-year storm, one high intensity one-year storm, and one five-year storm, were selected for runoff testing. The effectiveness of these LIDs is measured by reductions in both peak stream discharge and total runoff volume. The densely-vegetated swale effectively controlled peak discharge of the two one-year storms, but not the five-year storm, while the grass swale only reduced the peak discharge of the low intensity one-year storm. Both swales were ineffective in controlling total runoff volume. Swales are only effective controls of peak discharge, not total runoff volume, and densely-vegetated swales perform better in high intensity storms.

Project: Effects of Urbanization on Surface Climate

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This project aims to assess changes in surface climate directly caused by urbanization. Landsat and MODIS data are combined to create a Land Cover (LC) explicitly discriminating the impervious surfaces from the vegetated lands over the contiguous U.S. The LC and associated biophysical parameters are used as boundary conditions in the Simple Biosphere model (SiB2) forced by 2001 climate data. We found on the local analysis that urban areas are hotter than vegetated areas in the summer, and cooler during the winter. Additionally, the recent-past (2001) has consistently higher temperatures than the pre-urban scenario, and the change is amplified during the summer than during the winter.

Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems

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This work describes and evaluates the use of low-cost, rapid-scanning, ultraportable terrestrial lidar to obtain detailed three dimensional representations of the lower canopy, trunk buttresses and understory of tropical rain forests to augment traditional field measurements and aid in the assessment and refinement of remotely sensed estimates of above ground biomass.

Field, airborne and spaceborne methods have been shown to generally capture the bulk of above ground forest biomass at varying spatial resolutions. However, a tropical rain forest is composed of multiple canopies and dense understory and these components, along with characteristic tree buttresses and enveloping lianas, contribute to the overall biomass. These lower components are difficult to definitively characterize from airborne (or spaceborne) measurements. Fortunately, terrestrial lidar scanning 3D reconstructions can be used to non-destructively obtain detailed estimates of the biomass contribution of these lower foliage and woody contributions in order to verify and refine remotely sensed estimates. This demonstrates how low-cost, rapid-scanning, and easily deployed terrestrial lidars such as the University of Massachusetts Boston Canopy Biomass Lidar (CBL) can be used to obtain these 3D reconstructions at the long term tropical rain forest plots of the CARBONO project at La Selva Biological Station, and plots near the Sirena Research Station, Costa Rica.

Holidays from Space: the urban social data embedded in VIIRS NTL signatures

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While much attention has been devoted to the drivers of the magnitude of urban energy consumption, the timing of urban energy demand is rarely discussed. Where and when urban centers use energy is largely a function of human activity patterns and social practices deeply embedded in culture. One apparent manifestation of energy use patterns in human settlements is in the celebration of holidays – when human activity patterns change-affecting short-term patterns in energy consumption. Using daily images of nighttime lighting during three major holiday periods (Christmas and New Year's, the Holy Month of Ramadan, and the Chinese Spring Festival) we demonstrate that cultural variations within and between human settlements contextualize and shape the timing of energy use. Using novel environmental remote sensing techniques, urban night luminosity captured from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Visible Sensor are tracked for two years over 1200 cities. The luminosity signatures are decomposed into seasonal, trend, and remainder signals—revealing strong, consistent patterns of activity changes during holiday periods. Though holiday lighting electricity use has little importance for the magnitude of total energy consumption, the patterns of holiday luminosity reveal changes in human activities important for understanding urban demographics and urban dynamics, and are strong examples of the socio-cultural data embedded in remote sensing imagery.

Characterizing the Long-Term Variability of X-ray Binary 4U1705-44: Evidence for an Underlying Double-Welled Nonlinear Oscillator

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4U 1705-44 is a bright Low Mass X-ray Binary (LMXB) containing a neutron star and a close, low mass companion. The Rossi X-ray Timing Explorer (RXTE) All-Sky Monitor obtained approximately 14 years of daily monitoring on 4U 1705-44 in the 2-20 keV energy range. Understanding the x-ray variability of 4U1705-44 is critical to the study of all low mas x-ray binaries because they share many of the same global characteristics in their high-amplitude transitions and non-periodic variability. After comparing the long-term light curve and phase space trajectories of 4U1705-44 to various nonlinear oscillators, the Duffing Oscillator was revealed to be a strong candidate to describe these systems. The parameters of the Duffing equation were optimized and six solutions sharing the same characteristics as 4U1705-44 were found. Striking commonalities were revealed via a phase-space analysis of both 4U1705-44 and the six Duffing solutions: the low-order driving period is no less than 87 days and spans up to 180 days, which is seen and highlighted in the power spectra, zero-crossings and close returns analysis of 4U1705-44. Furthermore, the driving frequency of all six Duffing solutions tend to converge to a range of 3.6-4.5, corresponding to driving periods in the range from 130 to 175 days, in agreement with that found in 4U1705-44. Nonlinear analysis methods such as close returns and zero-crossings of the Duffing solutions also show the same trends. This strongly suggests that 4U1705-44 shares the same topological characteristics as the Duffing equation. With further analysis, we hope to develop a model to explain why 4U1705-44 shares the unique topology of the Duffing Oscillator specifically, rather than those of other families of nonlinear differential equations.

Search for Optical and UV Variability in Be/X-ray Binary Transient Swift J1626.6-5156

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Swift J1626 is a Be/X-ray binary system discovered in outburst in December 2005 by the Swift Burst Alert Telescope. It was extensively monitored in the X-ray by the Rossi X-Ray Timing Explorer from discovery through quiescence, ending in October, 2009. The system was also frequently monitored in the UV, optical and X-ray by Swift. Be stars are hot young stars, believed to be rotating so rapidly that a disk of circumstellar matter is forced out along the equator, giving rise to unusual and strong emission lines in the stellar spectrum. When a Neutron Star (NS) is in orbit with a Be star, material from the stellar disk can accumulate on the NS giving rise to episodic hard X-ray flares. Swift J1626.6-5156 has very strong Ha emission, a very small eccentricity of just 0.08, and an orbital period of 132.9 days. We have analyzed 52 Swift observations to search for variability in the optical and UV and compare this to the X-ray variability when the source is in outburst and quiescence.

X-ray Bursts in the Bright Low Mass X-ray Binary, Cygnus X-2

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Cygnus X-2 is a Z-type Low Mass X-Ray Binary composed of a neutron star and an evolved stellar companion. Cygnus X-2 is a bright system that accretes near the Eddington Luminosity, and therefore the matter falling onto the surface of the star should burn stably. However, at intervals of approximately 10.4 hours, intense thermonuclear reactions explode across the neutron star. These X-ray bursts happen during accretion rates that should suppress all such behavior. We studied these bursts in an attempt to understand the behavior of the source. We studied 2.32 millisecond of data over 12 years from 574 observations from the Rossi X-ray Timing Explorer to study the X-ray properties of Cygnus X-2. We study the spectral properties of 40 of the 62 X-ray bursts, analyzing the source behavior before and during each burst in an attempt to find the cause of this unusual behavior. Despite the varied behavior of the source, the properties of the individual bursts are all very similar, and the majority of bursts can be confirmed as Type I X-ray bursts. The properties of bursts are consistent with the properties of Type I X-ray bursts from other sources. However, unlike in other sources, the burst rate increases as the intensity increases. The bursts we analyze show that current burst theory does not account for all situations that lead to Type I X-ray bursts occurring in neutron star X-ray binaries.

Swift Burst Alert Telescope Trigger Simulation for High Redshift Gamma-ray Bursts

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Gamma-Ray Bursts (GRBs) are extremely bright flashes that originate from the most energetic events in the universe, such as supernovae and colliding black holes. Because they are so luminous, we are able to detect them to when the universe was only 520 million years old. This makes GRBs a vital tool for studying the development of the early universe. Using the Swift satellite Burst Alert Telescope (BAT) trigger simulator, we investigated the detection rate of distant GRBs by simulating bursts and characterizing the effectiveness of various trigger criteria. Due to the redshifting effect of the expansion of the universe, it was expected that the lightcurve profiles of GRBs would become softer in energy and broader in duration. By redshifting various lightcurve profiles and passing them through the trigger algorithm, we verified that long-exposure image triggers are more effective at detecting higher redshift bursts. We also investigated the loss of broad features and peaks at high redshifts which made burst durations seem shorter than expected. The importance of detecting high redshift bursts is evident from a brief investigation into the connection between GRB and stellar formation rates. A larger sample of distant GRBs and unbiased redshift measurements will better constrain this relationship, especially at high redshifts.

Studying the accreting X-ray pulsar Centaurus X-3 with Suzaku

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Centaurus X-3 is a binary system of a neutron star and an O-type supergiant with an orbit of ~2.1 days. The neutron star produces X-rays when material from the companion star accretes onto the neutron star's magnetic poles along its magnetic field lines. Because the neutron star is rotating, we see the X-rays in pulses (~4.8s for Cen X-3), so these types of neutron stars with very high magnetic fields (10^{12}Gauss) are called pulsars. One of the main goals is to study the cyclotron line, a broad absorption-like dip that, for CenX-3 is around $29.0^{+0.8}_{-0.6}$keV, where the line energy is directly proportional to the magnetic field strength of the pulsar. Another goal is to determine the pulse period during this observation and study profiles. The data were obtained over one full binary orbit using the satellite Suzaku, which covers an energy range of 0.2-700keV. Using the hardness ratio (flux in a higher energy X-ray band divided by flux in a lower energy X-ray band), a bright, relatively unabsorbed part was selected for time resolved spectral analysis in the range of 1-50keV and pulse period determination. We used several spectral models and confirmed the cyclotron and iron lines. We obtained the best constraints on the cyclotron line parameters to date, which correspond to a B-field of ~3.4×10^{12}Gauss. We determined a pulse period of 4.8046±0.0007s. The energy resolved pulse profiles show a single peak and do not change much with energy. Future work includes modeling pulse phase resolved spectra. By studying the phase resolved cyclotron line, the magnetic field configuration can be further constrained. Constraints can also be obtained on the accretion geometry and accreted material close to the neutron star. Finally, studying other time selected spectra, such as a partially absorbed flare, can help to further explain the structure of the stellar wind that is accreted (clumpiness, ionization structure).

Determining a Better Estimate of the Short Gamma Ray Burst Rate: A Comparison Analysis of Swift and Fermi Data

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It is believed that Short Gamma Ray Bursts (SGRBs) are produced by the coalescence of two compact objects of stellar mass, either a neutron star-neutron star or a neutron star-black hole system. Both the Swift and Fermi missions explore these events, but their true rate is not well understood because of instrument-specific criteria which affect the detection sensitivity of each satellite. Therefore, it is important to compare observations between the two satellites in order to better understand the rate of SGRBs in the universe. To do this, we use SGRB data from Fermi GBM to retroactively generate source light curves for each burst by performing spectral fits with XSPEC. We analyze the results with the Swift BAT Trigger Simulator to determine whether each burst is detected. We consider such factors as the fluence and incident angle of the bursts in order to ascertain the characteristics of the population of Fermi-detected SGRBs that would go undetected by Swift. By better understanding the complexities of the Swift BAT trigger criteria using real burst data, we hope to improve the trigger algorithm to correctly identify a greater number of SGRBs. We find that the strict “image threshold” of BAT prevents many possible SGRB detections, but that the Swift and Fermi detected SGRB populations are likely similar. Finally, we suggest a skeleton procedure to determine a better estimate of the SGRB rate in the nearby universe, contingent upon future work to understand the jet opening angle and fluence variability of SGRBs.

The Collimation and Energetics of Short Gamma-Ray Bursts

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Short gamma-ray bursts (SGRBs) are a subclass of the most energetic explosions in the universe, characterized by prompt-emission durations of < 2s. These events are thought to be caused either by the violent merger of a Neutron Star and a Black Hole (NS-BH) or of two Neutron Stars (NS-NS). The collimation of SGRB afterglows is directly related to the true energy scales and rates of these events, which in turn give insight into the driving force behind SGRB relativistic jets. In order to better understand SGRB collimation, we study the signature of collimation: the jet-break. Simultaneous modeling of the multi-wavelength afterglow emission with a synchrotron radiation code that includes spectral scaling after the jet break allows us to place constraints on SGRB collimation and energetics and in order to better understand the emission mechanism and environments of these events. Our dataset includes SGRBs with well-sampled afterglow data and measured redshifts. We present our preliminary results for two such events: GRB051221A and GRB120804A.

Very High-Energy Gamma Rays from Gamma Ray Bursts: Predictions for New and Current Telescopes

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To date no Gamma Ray Bursts (GRBs) have been detected in Very High Energy (VHE) gamma-rays (100 GeV-100 TeV). However, upgrades to the current generation of ground-based air Cherenkov telescopes: HESS, VERITAS and MAGIC make them more sensitive than ever. Moreover, the next generation water Cherenkov telescope, HAWC, which recently completed construction, is observing the multi-TeV sky with unprecedented sensitivity and the future CTA will be an order of magnitude more sensitive than the current generation. We take photon data from a subset of GRBs detected by the Fermi-LAT and extrapolate their light curves from the high energy gamma-ray (100 MeV-100 GeV) to the VHE energy range. We simulate these bursts occurring across the sky with changes in redshift, time binning, zenith angle, and Extragalactic Background Light. This work systematically characterizes if and how LAT GRBs will be detected by VHE telescopes. HAWC, with its large field of view and duty cycle, presents the best candidate, in the near future, for detecting a burst in the VHE range.

Constraining Cosmic Ray Origins through Spectral Radio Breaks in Supernova Remnants

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The emission of non-thermal gamma radiation in SuperNova Remnants (SNR) is thought to indicate the production of cosmic rays. As the remnant expands into the interstellar medium, particles trapped in the shock fronts accelerate to high enough energies necessary for cosmic ray production. The accelerated particle spectrum of both electrons and protons can be constrained through modeling the non-thermal emission from radio to gamma rays. Here we analyze the synchrotron radiation spectrum of four remnants using Planck data to extend the radio spectra to higher frequencies. The presence of a break in the radio synchrotron spectrum puts an upper bound to the magnetic field of the remnant. This helps to understand the emission mechanism responsible for gamma rays by constraining the underlying electron distribution, and therefore the contribution from bremsstrahlung radiation. We detect a spectral break in three out of the four remnants, which complement the possible spectral break previously reported for WMAP data. Interestingly, the lack of a spectral break in Cygnus Loop fits the hadronic model better than the two leptonic dominated models. Our results, therefore support the origin of gamma rays from accelerated protons, which in turn supports the idea that cosmic rays originate from SNRs.

Exploring Evidence of Cosmic Ray Acceleration in Westerlund 1

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Westerlund 1 (Wd 1) is a massive stellar cluster located within the Galaxy at a distance of ~5 kiloparsec (kpc) from the Earth. The cluster is thought to be a site of significant galactic cosmic ray acceleration. Further insight into this possibility can be gained through the study of gamma-ray emission from the cluster. The High Energy Stereoscopic System (HESS) has detected Wd 1 as an extended TeV source and now the Fermi Large Area Telescope (LAT) has detected extended GeV gamma-ray emission from the region. Examining this data allows for a more precise understanding of the emission originating from Wd 1 itself. An initial GeV spectrum for the cluster has been determined using the standard galactic diffuse model, by determining the maximum likelihood distribution of sources and by performing analyses to determine the best-fit parameters. Then, the source was tested for spatial extension by introducing various extended source models. It is clear that a significant extended GeV source is present and likely associated with the stellar cluster. Continued examination of the emission originating from Wd 1 will reveal details about the composition and energy of cosmic rays, providing essential information on the possibility of cosmic ray acceleration in the region.

Simulation Studies of a Small, Cost-Effective TeV Cherenkov Observatory

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Ground based gamma-ray astronomy is a growing branch of astronomy dedicated to the study of Very-High-Energy (VHE) gamma-ray emission from various types of astronomical sources. The dominant method of conducting this sort of astronomy is through the use of optical Cherenkov telescopes, which detect radiation in the sky caused by an incident gamma-ray. Current experiments have been successful, but make use of large (> 10 m), expensive Cherenkov telescopes, and their performance decreases dramatically at multi-TeV energies. A smaller, more cost-effective telescope would be useful for detailed studies above 1 TeV, and would be an excellent complement to the large, expensive observatories already being planned for the future. In this study, the performance of a single, small (1.5 m) Cherenkov telescope was investigated. Monte Carlo simulations were used to generate Cherenkov showers, and the response of a simulated 1.5 m telescope was modeled and measured. Preliminary results show a peak effective area above 10^5 m^2, and a differential sensitivity within ~ 2 orders of magnitude of the much larger (four 12 m telescopes) VERITAS instrument. With a small collaboration leading to higher observation times, even a single 1.5 m telescope will be able to see bright gamma-ray sources; an array of telescopes was not thoroughly investigated but would likely enable detailed study of a large number of sources at multi-TeV energies.

Exploring Biases in the Measurement of Isotropic Equivalent Energies of Gamma-Ray Bursts with the Fermi Telescope

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This study was performed to determine if isotropic equivalent energies, E_{iso}, measured for gamma-ray bursts are significantly biased by lack of high-energy gamma-ray photon data, leading to inconsistent best-fit spectral models which diverge at high energies. Isotropic equivalent energies are often measured between energies of 10 keV to 10 MeV and prior to the 2008 launch of Fermi, gamma-ray satellites were limited to observable energies below 700 keV, missing ~90% of the integrated energy band. The brightest bursts often peak at energies exceeding previous detector thresholds, therefore missing large portions of a burst's fluence and leading to incorrect modeling of the spectral shape. Despite these limitations on accurately measuring the full energy output, correlations have emerged, treating E_{iso} as an intrinsic property with physical application to gamma-ray burst physics rather than an observational quantity. We explore the impact of detector truncation on E_{iso} by performing time-integrated analysis both with and without spectra from Fermi's high-energy Large Area Telescope (LAT). We show that multiple models, providing good statistics, measure inconsistent isotropic equivalent energies for the same burst, and consistently underestimate the energy output when LAT data is excluded from the analysis.

Exclusion of the LAT data leads to unconstrained high-energy spectral slopes of the Band function allowing for observer influence on the choice of how to constrain the slope or to accept a cutoff power-law as the better fit. This proves that correlations involving E_{iso} are currently biased by detector limitations and the true meaning of E_{iso} has yet to be determined.

Next Generation X-Ray Optics: Mirror Assembly Development Process

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The Next Generation X-Ray Optics (NGXO) team at the Goddard Space Flight Center is working to achieve the development of lighter, less expensive, and more accurate mirrors for a future orbiting X-ray observatory. X-rays are emitted by a vast number of astronomical objects, such as supernova remnants and black holes. By accomplishing this goal, the team would be able to revolutionize X-ray astronomy. The full process of developing these mirrors is quite complex and difficult to understand, especially for any interested members of the general public with non-science backgrounds. To address this issue, a short video was designed and produced that animated and narrated each step of the process. The Blender animation program was used to create the individual animations; the animation for each section consisted of 500-2,000 frames and required over 100 hours total to render. The iMovie program was then used to combine the animated clips into one smoothly transitioning video. This animation project provided the opportunity to study and learn the Blender program, as well as understand every important aspect of the NGXO mirror development process. As a result, the entire process can be explained in an audiovisual manner that the general public would understand. The video will be uploaded online to maximize the number of viewers, which could easily increase the interest in the NGXO project.

Lifetime and Performance of the GEMS Narrow-Gap Detector

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The Gravity and Extreme Magnetism SMEX (GEMS) is a proposed small explorer mission to measure the polarization of X-rays from persistent astronomical sources. Accurate recovery of polarization data depends on symmetric transport of a charge cloud through a gas volume. To achieve this, the detector ReadOut Board (ROB) was redesigned to reduce the transfer gap between the gas electron multiplier and the ROB by employing an epoxy binding instead of a mechanical clamp to mount the strips. This alteration facilitated sufficient charge collection while minimizing systematic error. The new, "Narrow-Gap" ROB is compared to the earlier Performance Design Review (PDR) version on the basis of performance and lifetime. Measurements of the electron capture coefficient suggest that both ROBs will meet GEMS lifetime standards for polarization measurement. Furthermore, performance comparison shows temperature dependence in a set of DC bias voltages related to data acquisition. This dependence is potentially heightened in the Narrow-Gap design. While this behavior has yet to be fully characterized, it will likely lead to an alteration of in-orbit protocols for the GEMS mission.

Expansion Velocities of Ejected Material from Tycho's Supernova

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Tycho's supernova remnant shows clumped material and variable expansion of material in the ejecta. Three-dimensional construction of the velocities of these clumps in various locations of the ejecta can give a greater understanding of the explosion progenitor and the dynamics of the remnant expansion. Using data from the Chandra X-ray Observatory, twenty-two regions are examined for proper motion and line of sight motion to form a net velocity vector. The proper motion of the region is calculated by fitting 2000 data to the 2009 data through spatial shift, using chi-squared statistic. Line of sight motion is found through the Doppler shift of silicon emission lines from a baseline expectation value, accounting for the ionization state of the material. The relative line strengths of four silicon emission lines give the ionization state of local material. Proper motion is found to range between 1950 and 4990 km s^{-1} among the regions examined, and spectra show varying Si Heα centroid locations ranging from 1.846 to 1.875 keV, corresponding to Doppler velocities in the range -1625 to 3040 km s^{-1}. Results indicate that expansion velocity varies among the regions examined.

GRB Suite a Visualization, Animation, and Data Sonification Composition of Gamma-Ray Bursts Presented in 4 Movements

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Visualization, Animation, and Sonification provide different ways to examine and interpret raw data through the senses of sight and sound. Our project combines these techniques with data from the brightest gamma-ray bursts detected by the Fermi Large Area Telescope to produce a dynamic audiovisual experience that tells the story of these events from a different perspective. In doing so, we hope to reveal the underlying essence and structure of these events in a way that cannot be shown through charts and language. It is our goal to bridge the worlds of art and science together, making both more accessible through the story of gamma-ray bursts.

NICER X-Ray Concentrator Simulations of Diffuse Emissions and Extended Sources

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The Neutron star Interior Composition Explorer (NICER) mission, planned for launch in 2016, will attempt to discriminate amongst many proposed theories of neutron star interiors, expanding our understanding of stellar endpoints and nuclear physics. The ray-tracing software CONSIM simulates how NICER's mirrors concentrate X-rays from point sources onto detectors at a given energy. Previously, the concentrators' focusing ability for diffuse/extended sources had been predicted but not modeled. We have developed a Python program, Raygen, to simulate observations of real instances of such sources. Raygen accepts as input image data from the Chandra X-ray Observatory and generates a list of photons conforming to the source morphology (in off-axis θ, ϕ angles) as a function of a user-specified pointing direction, in a CONSIM-readable FITS format file. We have also added to CONSIM the functionality to accept an input list of photons at varying energies. We use CONSIM and Raygen together to simulate observations of intended NICER calibration targets and other sources of interest, such as Cassiopeia A and the Crab Nebula. We also investigate cases in which the target lies near potentially-interfering sources, such as PSR J0437−4715 and the supernova remnant 1E 0102−7219. The results of our work will inform NICER's calibration observation planning and data analysis.

Characterization of Nitromethane for Use in a Time-Projection Chamber Polarimeter

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The Gravity and Extreme Magnetism Small Explorer (GEMS) team have successfully demonstrated polarization sensitivity using the photoelectric effect from x-ray interactions in a gas. The GEMS gas is Dimethyl Ether (DME) and the electrons generated from an x-ray event are drifted under uniform field to the detection plane. The GEMS polarimeter is designed to observe faint, persistent sources and the polarimeter is mounted behind a mirror, enabling use of a small (<2cm) drift distance. To study transient events such as Gamma-ray Bursts, the polarimeter must observe a wide field, and will not make use of a mirror. To obtain the required collection area, the detector must be large, and to minimize the supporting electronics the drift distances must also be large. Electron diffusion would cause reduced sensitivity in such a detector. By using Nitromethane (NM) and CO2, x-rays interact with the CO2 to create an electron cloud, which is picked up by the NM molecules. The NM ions then drift to the amplification stage, where the electrons are stripped and amplified.

Swift Observations of the Recent X-ray Activity of Eta Carinae

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The extremely massive Luminous Blue Variable binary star, Eta Carinae, lies 7,500 light years away deep within the Homunculus nebula. Vigorous Wind-Wind collisions between the primary star and the companion star generate high-energy gases that produce X-rays. Complex X-ray variations occur near periastron, point of least stellar separation between two stars. Understanding the changes of the high-energy photons give scientists a better understanding of η Carinae's physical and stellar properties. Processing and analyzing weekly observations done with the X-ray Telescope on Swift allow the spectrum changes, flux levels, and column density trends to be examined meticulously. In over 18 years of observing with RXTE/Swift, the maximum X-ray flux of η Carinae in the 2-10keV band occurred on June 21, 2014, at a level of $3.53\pm0.13\times10^{-10}$ ergs $s^{-1}cm^{-2}$. On July 20, 2014 a flux of $8.3\pm0.5\times10^{-11}$ ergs $s^{-1}cm^{-2}$ as seen in the quicklook data strongly suggests that the 2 –10keV flux is declining as η Carinae approaches periastron. Every 5.54 years, the X-ray activity enters a minimum stage that we predict will last a shorter time than observed in previous cycles. Understanding the mechanisms of the deep minimum stage time and closely examining the differences in column density in each cycle would give scientists reason to believe that the mass-loss rate of the system has changed.

Particle Acceleration at the Shock of Tycho's 1572 Supernova

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Young supernova remnants may exhibit thin (~1-10% of shock radius) X-ray rims of synchrotron radiation from forward shock-accelerated electrons that travel downstream of the shock and quickly cease to radiate. Rim widths limited by radiative energy losses should decrease with energy and require magnetic field amplification 10-100× that expected from adiabatic shock compression. Damped magnetic fields behind rims may produce thin rims without strong field amplification but require energy-independent rim widths. We measured rim widths around Tycho's supernova remnant in 5 energy bands using a 750 ks Chandra observation. Rims narrow with increasing energy, favoring loss-limited radiation over magnetic damping. Observed widths are best fit by electron transport models requiring amplified magnetic fields ~0.1-1 mG and particle diffusion ~1-10× Bohm values, consistent with prior work. Inferred magnetic fields, diffusion coefficients, and diffusion-energy scaling may constrain models for cosmic ray acceleration in supernova remnants and plasma turbulence in astrophysical shocks.

Photoreceiver Measurements for a Future Space-Based Gravitational Wave Observatory

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Precision long-baseline interferometry in space requires low-noise photoreceivers to achieve the high sensitivity required to observe small phase-domain signals. These signals can be signatures of the gravitational waves from distant massive astrophysical mergers. Characterizing the intrinsic noise properties of the receiver is necessary to create an accurate model of the interferometric system. In this work, we have studied the noise contributions of a candidate photoreceiver, developed in collaboration with Discovery Semiconductors, including Johnson noise, shot noise and electronic noise from operational amplifiers. Furthermore, we compared these noises to a Matlab-based model of the system behavior.

By measuring both the dark noise and the output noise at various incident power levels we determined the equivalent input current noise using a self-calibrating method. Additionally, we compared these results to those determined via a direct transfer function method. We constructed and utilized several types of infrared light sources to investigate the origin of non-intrinsic input noise to the photoreceiver. This work was done within Goddard's Gravitational Astrophysics Branch.

CubeSat Swarm for Science (CSS)

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CubeSats are small satellites that adhere to a set of standards defined in 1999 by California Polytechnic State University at San Luis Obispo and Stanford University. The small satellites are widely used by universities as a means of providing students with an opportunity to carry out an entire space mission because the costs are low and the mission can be developed in about two years. The CubeSat small size makes for low-cost space access, but the size also limits the science it can explore. In this study we demonstrate that using a swarm of CubeSats can slash traditional space mission costs dramatically while exploring interesting science like space weather and radiophysics that cannot be explored with single unit CubeSats.

Analyzing and Visualizing Black Hole Binary Simulations

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Supermassive black hole binaries are extreme and exotic gravitational systems that, according to General Relativity, radiate energy by distorting spacetime in the form of gravitational waves. In numerical relativity these systems are modeled to better understand their behavior; however, visualizing the results of these models is rarely a trivial task. This project investigated the potential of the visualization program VisIt to aid in analyses of black hole binary simulations. Grid data from General Relativistic Magnetohydrodynamic (GRMHD) simulations were processed in VisIt to test its post-processing and visualization capabilities. Data visualizations included two-dimensional time-varying color magnitude plots of matter density and the magnetic field, three-dimensional field lines of evolving magnetic vector fields, and isosurfaces of the Coulomb scalar field. Time-varying plots of two-dimensional data were not only successful, but also helped identify and revise errors in the GRHMD code, leading to more accurate simulations. Field line visualizations were possible, but computationally demanding: visualizations of longer time evolutions ($t \sim 200$ M) could only be rendered on the Pleiades supercomputer. Isosurfaces exported from VisIt required additional post-processing, but were successfully decomposed into spherical harmonic series to investigate coordinate mapping through the Coulomb scalar. Therefore, VisIt is a powerful visualization program that will allow for more “in-house” data analysis. While computational limits exist, VisIt may assist in developing numerical and visual descriptions of spacetime curvatures, allowing for easier coordinate mapping between different numerical models.

Visualization of Particle Trajectories in Magnetospheric Pair Cascades around Rotation-Powered Pulsars

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Formed from collapsed stellar cores during supernovae events, Rotation-Powered Pulsars (RPPs) are a subclass of rotating neutron stars whose spin-down rates are governed by torques from radiation and particle emissions. Currently modeled as rotating magnetic dipoles, pulsars are accompanied by intense magnetic fields (~1012 G) and induced electric fields that dominate plasma behavior in the pulsar magnetosphere. Using output from a 1D simulation of rotation-powered pulsars run by Andrey Timokhin, a Python-based graphical user interface employing matplotlib and PyGTK was developed to visualize particles' trajectories within the magnetospheric pair cascades. Upon application, it was found that significant oscillations and cycling of particles occurs in the magnetosphere, particularly in regions where the pulsar's electric field is shielded by pair cascades. In addition to exploring the plasma physics in neutron-star magnetospheres, this tool may also provide insight into the phenomena behind subpulse and micropulse structures witnessed in pulsar pulse profiles based on event timescales.

Micronewton Thruster Modulation and Analysis for the LISA Pathfinder

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The micro-propulsion system control loop on the LISA Pathfinder relies on knowledge about thruster positioning and specifications. Consequently, a system identification protocol was developed and implemented to determine thruster calibrations, orientations, and time delays. Thrusters were commanded to generate a sinusoidal thrust at distinct frequencies, which allowed for their concurrent characterization via a frequency-domain analysis of space craft response signals. Differential position data between the space craft and inertial test masses together with propulsion control loop signals were combined to measure the force exerted on the space craft at each thruster frequency. A principal component analysis of these forces yield their magnitude and direction, which translate to corresponding thruster calibrations and orientations. The phase of the transfer function from commanded to measured thrusts at the respective thruster frequencies yields the time delay of each thruster. In simulations, calibrations are thus measured at $\sim$1.02 of their injected value and orientations to $\sim$10 microradian accuracy; measured time delays are $\sim$130 ms. Discrepancies between injected and measured calibrations and orientations are currently being resolved, and models of the space craft are still being interpreted and resolved to determine an expected time delays, though they are anticipated to be on the same order as those measured. Efforts to identify confidence intervals on these measurements are also currently underway.

Theoretical Modeling of Exoplanet Atmospheres

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One of the major goals in the study of exoplanet atmospheres is to detect biosignature gases that may indicate the existence of life outside of our solar system. In order to find these biosignatures, astrophysicists need to characterize and model Earth-twins, which are exoplanets with liquid water, oceans, continents, and atmospheres. The methods for this research project included the development and integration of a set of Fortran codes originally developed by Dr. James Kasting into a single code that theoretically models planetary atmospheres. CLIMA is a one-dimensional, cloud-free, radiative-convective climate model that calculates the temperature, pressure, heating rates, etc. in each layer of the atmosphere from a given set of mixing ratios of gases and incoming radiation. PHOTOCHEM is a one-dimensional photochemistry model that solves the continuity equation at each height for each of the long-lived species, including transport by eddy and molecular diffusion. Together, these codes produced the simulated data needed to plot and understand the composition, temperature, and characteristics of various atmospheres. Ultimately the results of this model will be analyzed with radiation-transport codes to determine how future missions such as the James Webb Space Telescope and the Advanced Technology Large-Aperture Space Telescope might be able to observe Earth-like exoplanets and identify biosignatures in their atmospheres.

Quenching of Galaxies as a Function of Mass

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Over cosmic time, galaxies shut down their star formation – quenching – and join the red sequence. We find that the rate at which galaxies quench star formation is mass dependent. Higher mass galaxies quench at earlier times, and most of them have long resided on the red sequence with relatively old stellar populations. Conversely, low mass galaxies are still actively quenching and joining the red sequence into the current cosmic era. Quiescent and star-forming galaxies at 0.2<z<2.5 with stellar masses >109 solar masses are selected from the FourStar Galaxy Evolution Survey (ZFOURGE) (Tomczak et al. 2014) in Chandra Deep Field South (CDFS), Cosmic Evolution Survey (COSMOS) and the Ultra Deep Survey (UDS) fields. Whereas the moderately deep precursor NEWFIRM Medium-Band Survey (Whitaker et al. 2011) only included large, representative samples of the most massive galaxies of log(M/M⊙)>11 out to z~2, ZFOURGE enables an unbiased census down to significantly lower masses of logM/M⊙=9. With the deeper NIR medium-band photometry from the ZFOURGE survey, we are able to measure the intrinsic color scatter of the quiescent population. The epoch where the intrinsic color scatter is highest marks the point in time when galaxies were most rapidly shutting off their star formation and joining the red sequence. In addition, we determine the redshift evolution of the fraction of galaxies in the quiescent and star-forming phases. We further divide the quiescent population into recently quenched and older galaxies, measuring the evolution in the number densities of these sub-populations across cosmic time to understand how the red sequence is building up in different mass regimes.

Sub-Arcminute Rotation Verification for RIMAS Filter Wheel

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The Rapid Infrared IMAger Spectrometer (RIMAS) is being developed to study GRB afterglows on the Discovery Channel Telescope in Flagstaff, AZ. This instrument requires several motors on a linear stage for focusing and a wheel to rotate filters into place within 10 μm in cryogenic conditions. The objectives of this project were to aid in the progress of these motor systems, generate testing methods for the filter wheel and carry out some initial tests. To measure the movement of the wheel, images taken of a high contrast pattern on the filter wheel are analyzed in pairs using phase correlation. The peak of the correlation is fit with a Gaussian to provide sub-pixel precision on the displacement of the pattern between consecutive images. On our setup, this method provided 1/4 μm precision measurement with two 1.3 MP images in under a second. This method continues to function, at a slightly reduced accuracy, even if light levels change mid-acquisition. We found that the test stepper motor, which has identical specs and is rewired to replicate the windings in the cryo motor, can only rotate the filter wheel with 29.25 μm precision. This lack of precision necessitates an additional method for indexing the filter wheel. We have assembled a test setup with a limit switch, a spring loaded ball bearing, and notches on the filter wheel to provide registration and are in the process of testing it.

Diverse Galaxies: Clumpy Regions in The UV HUDF at 0.5<z<1.5

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Presented is an investigation utilizing the deepest ultraviolet data in the Hubble Ultra Deep Field (HUDF) taken with Wide Field Camera 3 UVIS detector. Ninety orbits were taken with F225W, F275W and F336W filters during 3 epochs. These were of particular importance when observing clumpy regions within galaxies and allowed for an in-depth UV analysis of the data. Preliminary studies using selected galaxies in epochs 1 + 2 (F275W) showed disks with clumps indicative of star forming regions. This study presents the analysis of the epoch 3 data with the F275W band comprised of galaxies with a variety of clumps – from single clumps to galaxies littered with clumps. A morphological study of the ultraviolet-detected sources at redshifts $0.5 < z < 1.5$ in the optical rest-frame using a classification scheme similar to that employed by the Hubble CANDELS survey team was performed. Most of the clumpy objects found were disks, followed by irregulars. Galaxy luminosities at rest-frame UV, clump sizes, and luminosities for each clump in 7 passbands from the UV to optical were also calculated. We find that the majority of these UV bright clumpy galaxies are classified as Scd and starburst spectral types and have clump sizes between 0.7 to 1.9 kpc, as well as clump luminosities ranging from $\sim 10^{36}$-10^{41} erg/s/Å. We suggest that most of these clumps are giant star-forming regions or the building blocks of today's disks.

The Balloon Experimental Twin Telescope Infrared Interferometry (BETTII): Near-Space, Far-Infrared Astronomy

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BETTII observes the far-infrared wavelength ranges of 30-55μm – just outside that of James Webb Space Telescope (JWST) and Herschel – and of 60-90μm. These far-infrared bands are of importance because Young Stellar Objects (YSOs) typically emit at these wavelengths and are unobservable from ground interferometry. BETTII is a pioneer for future space observations that through interferometry will be much less costly and more portable than single-mirror telescopes such as JWST. BETTII will have a 16 hour high-altitude balloon flight at 34km. A main focus of the summer internship was to build the flight harnesses for the systems involving the Compensated Controlled Momentum Gyros and the Siderostats. Designing and constructing PCBs was required to establish a permanent one-to-one routing for the Azimuth System and External Sensor System. These systems will be ready for a permanent flight arrangement on the exoskeleton and will allow for flight testing.

P.H.A.S.T. Precision High Altitude Star Tracker

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The goal of the Precision High Altitude Star Tracker (PHAST) is to conduct a baseline investigation of low-cost, open source fine pointing instruments for use on balloon craft. Scientific ballooning provides a unique platform for subjecting experimental hardware to space-like conditions without expending a significant amount of budget. Advancing technologies are enabling powerful new payloads and these experiments will open new discovery spaces for science at a fraction of the cost of a space mission. PHAST's scalable and open-source design will be made available to all researchers to unlock this new discovery space for scientific ballooning. The current focus is on fabrication and optimization of a star tracker composed of commercial computers, cameras, and lenses, as well as open source astrometric software. Ruggedized computers and compact cameras have been shown to perform exceptionally well in float conditions without the need for a pressurized vessel. Small CCD and CMOS sensors are an excellent candidate for the camera system on PHAST. Now, that off-the-shelf components are a viable option for suborbital missions, PHAST software prototypes are on the verge of mission launch. Eventual total system integration testing procedures are in the works. Preliminary results suggest that fine pointing instrumentation can be built on a budget about 10% that of commercial star trackers and requires little to no specialized skill. PHAST, though still early in its development, has indicated great potential for similar low-tech, high-performance instruments. There are many areas that would benefit from such technology and with them, discovery spaces we have yet to imagine.

Ultraviolet Analysis of Eta Carinae Using Observations from the International Ultraviolet Explorer

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Eta Carinae is an extraordinary, massive binary star system. Recent research has indicated a 5.54-year cycle based upon X-ray flux modulation and low/high ionization spectral states (Damineli 1996; Damineli et al 2009). To further understand the system's current nature, data obtained by the International Ultraviolet Explorer (IUE) were searched for evidence of (1) ultraviolet flux increase over the time period from 1978-1996 and (2) the 5.54-year cycle. This investigation focused on the emission lines of [N III] at 1750Å, Fe II at 1786Å, Si III at 1893Å, Fe III at 1914Å, and Fe II at 2507/2509Å. By fitting Gaussian curves to emission line profiles from IUE ultraviolet spectra, values for integrated flux and continuum flux were measured in approximately eighty observations. The very limited observations recorded during the brief low-state, periastron event, were consistent with the 5.54 period. Furthermore, the fluxes of [N III], Si III, and Fe III increased across the 18-year interval. However, the Fe II emission lines did not show significant long-term flux increases. Likely the different behaviors are due to very different physical phenomena. Examination of the Grotian diagram for Fe^{+} demonstrated that hydrogen Lyman alpha can excite the outer electron from the ground state to upper levels, leading to population inversion and over-intensity of the Fe II emissions (Johansson and Letokhov, 2003). No changes in the Fe II emission fluxes indicated that Eta Carinae's secondary stellar Lyman continuum flux was constant, meaning that there was little change in the secondary star's temperature. The increase in the [N III], Si III, and Fe III emissions supports growing evidence that the primary wind mass-loss rate decreased across the time interval observed by IUE.

Crowdsourced Discovery of Protoplanetary and Debris Disks with Disk Detective

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The Disk Detective project (http://www.diskdetective.org) is scouring the data archive from NASA's WISE mission to fill in our knowledge of the distribution of protoplanetary and debris disks among stars of various populations. Using the power of citizen science to perform a robust, well-calibrated search, we stand to increase the pool of known debris disks by ~375, mostly by finding new disk candidates around B6-A6 dwarfs, A-F subgiants, and G-K giants. This new sample will trace the evolution of planetary systems around intermediate-mass stars from their youth through retirement and provide a crucial list of future targets for disk and exoplanet imaging with JWST. Since late January 2014, 5,000 users have performed over 700,000 classifications of 40,000 unique objects resulting in 1,800 positive classifications and 244 Disk Detective Objects of Interest (DDOIs) being followed up.

Detection of Exoplanets Using Microlensing for the Wide-Field Infrared Survey Telescope (WFIRST)

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We conducted preliminary research in the detection of exoplanets through microlensing for WFIRST by investigating several data reduction techniques for known exoplanet host stars and producing an updated luminosity function for the galactic bulge. We present photometric measurements of two host stars; 2005 OGLE-BLG-169 and 2007 OGLE-BLG-349 using HST data from WFC3 and WFPC2. A new parallel processing routine was performed to accurately correct for CTE loss in the WFC3 field, as well as an up-to-date procedure for CTE corrections in WFPC2 images. The photometric catalogs generated from the software package DOLPHOT were analyzed and compared with results from a team at Notre Dame using different photometry software in order to determine the capabilities and sensitivity of the DOLPHOT routine. We also performed photometric analysis in near-IR bands (J, Ks) of a 1.5x1.0 degree field within the galactic bulge using data from the VISTA VIRCAM-VVV survey. This field is a portion of the survey area WFIRST will utilize for microlensing detections. Reddened Color-Magnitude Diagrams (CMD) and Luminosity Functions (LF) were constructed, with contamination from foreground disk stars evident. This contamination may be corrected by statistically removing matches in the CMD data between the bulge field and a control disk field at least 30 degrees away. An updated luminosity function will enable an accurate projected determination of the microlensing event rate for the WFIRST survey. This will help justify the advantages of conducting microlensing science from a space-based observatory like WFIRST.

Instruments and Detectors for Exoplanet Characterization

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Several different projects were explored related to new technologies for the characterization of exoplanets with direct imaging. The first project used an Electron-Multiplying Charge Coupled Device (EMCCD), a new type of photon-counting detector that will overcome the detector read noise barrier that plagues conventional CCD technology. EMCCDs promise to enable single photon detection which dramatically improves the sensitivity of space-flight missions with faint sources. The technology demonstrations in the lab at Goddard set out to substantiate the operation concept and experimentally verify the capabilities of these EMCCDs. Additionally, EMCCD demonstrations were performed with out-of-band illumination that could free trapped charge within the detector, which has the potential to further reduce the limiting detector noise, called clock induced charge. This work was presented at the 2014 SPIE meeting in Montreal and published in Wilkins et al., 2014. The applicability and value of EMCCDs for future exoplanet characterization space missions was shown timely, as this detector is baselined for the upcoming AFTA Coronagraph mission. The second project was focused on current state of the art exoplanet characterization, namely the analysis of Integral Field Spectrograph (IFS) observations performed in 2013 at the Keck observatory in Hawaii. The data shows a possible exoplanet whose nature can now be characterized in a subsequent study. These projects have led to a better understanding of new photon-counting detectors and directly detected exoplanet atmospheres.

Seven Missing Years: Filling the Final Gap with MLSO MK3 Observations

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Since the discovery of CMEs in the 1970s, there has been continuous accounting of CME rates with one notable exception. We are attempting to close this 1989-1996 gap by detecting and analyzing CMEs using white light data from the Mark-III K-Coronameter (MK3) atop Mauna Loa Solar Observatory (MLSO). We used both direct and difference imaging techniques to detect CMEs, and recorded the start time, position angle, and morphology of the events. Considering the CME count for each year and the MKIII duty cycle for that year, we are able to calculate the average number of CMEs per day. We found the average speed during this seven-year period to be 450 km/s and the average width to be 32 degrees. Filling in the final gap of data establishes a continuous database of CME counts and measurements from 1973 to present. The statistics gathered are used to observe patterns, form models, and create algorithms, many of which are run by the Community Coordinated Modeling Center here at Goddard Space Flight Center. These models in conjunction with data from satellites such as SOHO, STEREO, and SDO, are used by the scientists in the Space Weather Research Center at GSFC to detect and predict the impact of earthbound CMEs so that any potential damage can be minimized.

Audification as a Tool for the Spectral Analysis of Heliospheric Time Series Data

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The effective navigation, mining, and analysis of large time series data sets presents a recurring challenge throughout heliophysics. Audification, a specific form of auditory analysis commonly used in other fields of research (such as geoseismology), provides a promising technique for the evaluation of spectral features in long heliospheric time series data sets. Following a standard research methodology for the development of new analysis techniques, this research presents a detailed case study in which audification was introduced into the working process of an experienced heliophysics research scientist and used for the identification and classification of features in high-resolution magnetometer data during a structured analysis task. Auditory evaluation successfully led to the detection of artificial, instrument-induced noise that was not previously observed by the scientist and also the identification of wave activity embedded within turbulent solar wind data. A follow-up interview indicated that the scientist continued using these auditory analysis methods in the assessment of every large data set during the 2 months after the study was completed. These findings indicate that audification can be valuable and enabling for researchers in forming a deeper understanding of both microstructures and macrostructures within large time series. Additionally, as both a standalone methodology and a supplement to visual analysis methods, audification can expedite certain stages of the data survey, analysis, and mining process and provide new qualitative insight into the spectral content of time-varying signals.

Ionospheric Neutron Content Analyzer (INCA)

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The main purpose of the Ionospheric Neutron Content Analyzer (INCA) is to build a neutron-gamma ray detector to measure neutrons and gamma rays in the inner radiation belts resulting from interactions of primary galactic cosmic rays and sporadic solar energetic particle events within the Earth's atmosphere. This instrument will fly on a New Mexico State University (NMSU) spacecraft sponsored by the Air Force Research Laboratory's (AFRL) University Nanosat Program (UNP). INCA will measure high-energy protons that pose a threat to satellites. Albedo neutrons are a major source of the inner radiation belt protons (CRAND source). High-energy protons pose a threat to satellites and astronauts, and so improved modeling of their intensity will be of great value. INCA uses modern scintillators with silicon photomultiplier readout to detector double neutron scatters, thereby measuring the incident neutron energy. The organic scintillator allows for neutron/gamma-ray discrimination. INCA will provide essential space-qualification for powerful new detector technologies (e.g. modern scintillators, SiPMs). My contribution to this project was to assemble all the parts of the instrument, help in characterizing the instrument, simulating it using GEANT 4, and create the Interface Control Document (ICD), which contains all the requirements, descriptions and designs needed for the entire mission between the INCA instrument and the spacecraft.

Foreshock Significance in Generation of ULF Waves

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Ultra-Low-Frequency (ULF) waves in the magnetosphere have been a topic of interest for many years. A variety of different events (including Kevin-Helmholtz Instabilities, reconnection, and flux transfers) are thought to input the energy for ULF waves. We use THEMIS observations at multiple points in both upstream solar wind and the magnetosphere to identify the role of foreshock presence in the generation of ULF waves. The ion foreshock is located upstream of the bow shock and contains ions reflected back by the shock front. Using THEMIS data, intervals with at least one satellite in the ion foreshock and at least one in the magnetosphere were identified. We used the x-component of the velocity (moments from THEMIS ESA instrument, 3 s resolution) and the magnetic field magnitude fluctuations (THEMIS FGM instrument, 3 s resolution). A Fast Fourier Transformation (FFT) was then performed on the data to determine the dominant frequency and hence period of the waves on 10 minutes and 1 hour intervals. The typical period for solar wind fluctuations is 209 s and typical period in magnetosphere is 267 s. Much more is still to be done with this study. Beyond a comparison of the quantity of different period ranges in both the magnetosphere and the solar wind, an important next step will be to compare the periods in the magnetosphere and the solar wind at corresponding times to look for a relationship and estimate the influence of upstream solar wind parameters on magnetosphere processes.

Characterizing Magnetospheric States

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The Earth's magnetosphere changes in response to solar wind, the Interplanetary Magnetic Field (IMF), prevailing magnetospheric conditions, and the response times of various processes. The purpose of this research is to understand and model how the magnetosphere responds to solar wind input and pre-existing conditions. By utilizing parameters that describe the driver conditions as well as the magnetosphere's responses, the magnetosphere can be categorized into different states. Multi-parameter linear regressions were used to determine statistically the magnetospheric responses as functions of the driver parameters and to model each magnetospheric state in a lookup table. The lookup table was then used to prescribe, or predict, magnetospheric responses during different time intervals, based on observed input variables. The predicted response parameters (Kp, AE, and Dst) were compared to the observed responses to test the validity of the magnetospheric state prescriptions. The prescribed responses were discovered to be highly correlated to the actual, archived time-series observations. Ultimately, we hope that our modelling technique can be used to accurately predict future magnetospheric responses and to help guide physical model formulations.

Plasma Sheath Analysis for Langmuir Probe Development

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Langmuir probes are currently limited by their inability to differentiate ion species in a collected current. In this study, SPIS simulations are employed under nominal IRI conditions of the C/NOFS spacecraft to determine the degree of current modulation induced by perturbed plasmas surrounding a biased planar Langmuir probe. Classical probe theory is inadequate to describe finite probes – an inadequacy reflected in the divergence of plasma density, electron temperature and spacecraft ground potential by Levenberg-Marquardt curve-fitting subject to C/NOFS Surface Probe (SP) measurements and SPIS results. Moreover, sheath effects are deemed central in defining the electron retardation/saturation interface. Electron (ion) currents collected by the SP are modulated by surrounding plasma perturbations via ambipolar (collisional) interactions. Net collected currents in the electron retardation regime are functions of ion mass in a result independent of electron temperature. The understanding of sheath effects and implications for Langmuir probe development allow for the discrimination of ion species in compact payloads.

Morphology and Dynamics of Auroral Arcs

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A magnetic substorm is the result of an explosive release of energy on the night-side magnetosphere due to the coupling of the solar wind and Interplanetary Magnetic Field (IMF) with the Earth's magnetic field resulting in a storage of energy in the night side magnetosphere. The consequential auroral substorm is characterized by a rapid brightening and poleward expansion of the aurora following the release of energy in the night-side magnetosphere. Two predominant hypotheses exist which predict the sequence of events leading to substorm onset and the physical mechanism responsible for triggering this onset, the Near-Earth Neutral Line (NENL) and Current Disruption (CD) models. The NENL model suggest that onset is the result of magnetic reconnection between 10-20 Earth radii in the magnetotail. The CD model suggests onset is the result plasma instabilities forming inside of 10 Earth radii. This study examines a newer model presented by Nishimura et al. (2010, JGR), which suggests that enhanced earthward plasma flows from the distant magnetotail to the near-Earth region lead to sub-storm onset, which is manifested in the aurora by a Poleward Boundary Intensification (PBI) and equatorward motion of a North-South auroral feature. The purpose of this study is to determine and identify the poleward-most and equatorward-most arcs, as well as the morphology of the aurora in order to develop a more complete picture of the auroral substorm and ultimately test the three substorm models described above. Preliminary results demonstrate that equatorward motion of the onset arc during the growth phase is typical and that no distinct North-South arcs exist during the growth phase. Future research will include characterizing the intensity and tracking the brightness of the arcs comparatively as well as the motion within the arc.

THEMIS Observations of Dayside Magnetospheric Interactions

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Hot Flow Anomalies (HFAs) at Earth's bow shock were identified in THEMIS C satellite data for August 2007 to December 2009. The 142 events were classified as "young" or "mature" and then "spontaneous" (SHFAs) or "regular". In this study, SHFAs and HFAs do not show major differences in their plasma parameters. Normalized HFA occurrence rate is largest for approximately radial interplanetary magnetic field, cone angles less than ~55° (less than ~35° for young regular HFAs), magnetic local times away from noon, relatively larger Mach numbers in the range observed, and high solar wind speeds. Analysis of our database shows THEMIS observed HFAs 13.7-19.6 RE from Earth center in 2007-2009. 81 HFAs were observed for quasi-parallel interplanetary magnetic field orientations while 61 HFAs were observed to have a quasi-perpendicular orientation. Seven events in the HFA database were identified as clear HFAs where multiple THEMIS spacecraft passed through the same event. We characterized HFA evolution after it had already reached the mature state. The most significant observation was a case study where the HFA core became cooler and less dense as the HFA evolved over time, suggesting a cooling mechanism such as adiabatic expansion. With multiple satellites observing the same event, HFA expansion speed against the solar wind was determined to be up to about 400 km/s. An energy analysis was performed for the ions and electrons of each HFA event. It was found that there was only a weak trend between the amount kinetic energy in the solar wind that was converted to the thermal energy of each event. This indicates that there are other heating mechanisms occurring in the observed HFAs. Frequency spectra case studies to study wave heating showed there were high amounts of wave power over large frequency ranges.

Space Weather Forecasting: Analyzing the July 8, 2014 Event

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Space weather is the environmental conditions created by the Sun's activity and solar wind. Solar activities can influence performance and reliability of spacecraft throughout the solar system (including those located in the near-Earth region). The goals of the study are to successfully monitor space weather conditions and produce an accurate and timely response. Every day, we utilize the Integrated Space Weather Analysis System (ISWA) to constantly watch solar activity. If a Coronal Mass Ejection occurs, we employ the StereoCat tool in order to obtain the preliminary parameters. After measuring a CME, we will enter those parameters and any additional information into the Database of Notifications, Knowledge, and Information (DONKI). If a particular CME is requested by the Air Force Weather Agency, we would be required to launch a WSA-ENLIL+Cone Model of the CME to predict its potential impact. Currently, we are supposed to be in a time of solar maximum. Over the months preceding solar maximum, increased solar activity has occurred. However, more recently, there has been little to no activity occurring daily. We have learned the essentials of space weather and are actively working towards becoming independent forecasters.

STEREO EUVI as X-Ray Proxy

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A solar flare is a sudden and intense brightening on the photosphere as a result of a conversion of magnetic energy into heat and radiation. Currently, GOES X-Ray Flux is used to classify the intensity of these powerful space weather events; however, GOES data is limited to the Earth facing half of the Sun. We will investigate and develop the use of NASA's Solar TErrestrial Relations Observatory's (STEREO) Extreme UltraViolet Imager (EUVI) as a proxy for GOES X-Ray Flux to fully understand solar flares across the entire Sun. The low cadence and image resolution of the beacon data, along with the lack of large flares during the early operational stages of STEREO limit our ability in finding a strong correlation between the two instruments. We also use the higher resolution and shorter cadence Science Data from STEREO to understand the necessary requirements for an operational, realtime proxy to be possible.

The Substorm Gordian Knot: Onset Patterns and Frequencies

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For decades, scientists have struggled to understand what causes the aurora, and have developed two different theories to explain the phenomena. The magnetospheric and ground-based data necessary to test the two competing theories have only recently become available with the launch of NASA's THEMIS mission in 2007 and the Canadian Space Agency's (CSA) deployment of an all-sky imaging network. We present research testing the "Auroral Streamer" hypothesis given by Nishimura, Lyons, et al. in their various papers from 2010 to present. We compiled a list of all their published events (numbering 455, and covering a span from 2007 to 2011) and reviewed ground-based white and red-light image files, THEMIS satellite bulk plasma velocity and magnetic field strength measurements, ground-based magnetometer observations, and 1-minute Auroral Electrojet (AL) index data. We visually categorized the events by auroral phenomenology, separating events with auroral streamers from those without, and analyzed the characteristics of the events with superposed epoch analyses. Although Nishimura, Lyons et al. argued that every event in their onset list constituted an "Auroral Streamer" onset, our results show that most events in the list are not Poleward Boundary Intensifications (PBIs). In contrast to these previous studies, the results suggest that the "auroral streamer" model is not widely applicable. This is the first time these events have been analyzed with such detail, and call into question fundamental aspects of this model.

Thermal Ions and Ion Cyclotron Wave Activity

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For my research, I worked with Michael Collier to analyze data from the Suprathermal Ion Detector Experiment (SIDE), part of the Apollo Lunar Surface Experiments Package (ALSEP). I examined whether or not there is a causal relationship between thermal ions on the moon and ion cyclotron wave activity. SIDE measures positive ions in the energy range between about 7eV and 3keV, and in one mode of operation, SIDE attracts thermal ions using a negative voltage on a grid on the top of the instrument to compensate for the positive potential of the lunar surface. I examined the particle data from SIDE and comparing it to ion cyclotron wave activity, using wave intensities that Peter Chi calculated from the Lunar Surface Magnetometer. I examined whether a correlation exists between high wave intensities and elevated count rates observed by SIDE in resonant energy channels and in the overall spectrum.

Parameters influencing the Fischer-Tropsch Type reactions

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The Fischer-Tropsch Types reaction are a set of catalytic reactions that may explain how complex molecules (such as amino acids) were synthesized in the Early Solar System based on simple gases like hydrogen, nitrogen, and carbon monoxide. The purpose of this project was to see how different parameters could influence the rate and efficiency of the reactions. This experiment was reproduced in the Astrochemistry laboratory at the NASA Goddard Space Flight Center, using a closed system where gases react between each other with the help of a catalyst (iron, magnetite, or smokes (i.e. lab-synthesized amorphous metal-silicate particulates). Both the temperature and the duration of the experiments were essential in the Fischer-Tropsch reaction process. They influence the rate of the reaction, as well as the fraction of initial carbon deposited. Also, this deposit was proven to increase the rate of the reaction, acting as a better catalyst than the original one. Finally, some catalysts, like the magnetite and the iron, were more efficient (increase of the carbon deposited and the rate of the reaction) than the smokes. This gives us a better understanding of the conditions in which such reactions could have occurred in the Early Solar System, and how simple molecules led to more complex ones like hydrocarbons and amino acids.

Radar-Reflective Minerals Tested under Venus Surface and Atmospheric Conditions

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Radar mapping of the surface of Venus shows areas of high reflectivity in the Venusian highlands at altitudes between 2.5-4.75 kilometers. While theoretical studies have been beneficial, the origins remain unclear and few experimental investigations have been completed. This research experimentally investigates the stability of minerals under Venusian conditions with implications as a possible source of the radar anomalies.

Several compounds thought to exist on Venus, bismuthinite (Bi_2S_3), tellurobismuthite (Bi_2Te_3), coloradoite (HgTe), and pyrite (FeS_2) were tested for stability. These experiments were conducted in the Venus In-Situ Chamber Investigations (VICI) chamber under Venusian surface conditions, and highland conditions (460°C and 90bar, 380°C and 55bar respectively) in a chemically replicated Venusian atmosphere. The samples were weighed and then analyzed using X-Ray Diffraction (XRD) to specifically look for mineral stability at highland conditions accompanied with instability at lowland conditions.

The least likely candidates are bismuthinite and tellurobismuthite. XRD analysis for both compounds indicated no change in mineral composition. Analysis on coloradoite showed evidence of a dissociation of elemental tellurium at higher temperatures. At 380°C, the majority of the sample (73%) remained as coloradoite while at 460°C, only 38% of the sample remained in its original form. Therefore, coloradoite is more stable under Venusian high altitude conditions. Analysis on pyrite showed that some of the sample transformed into $Fe_{0.875}S$ or Fe_3O_4. While pyrite may be thermodynamically unstable under Venusian conditions, iron sulfides may still be a potential candidate for the anomalies.

Several compounds theoretically existent on Venus were tested under both surface and highland conditions in a Venus simulation chamber. Two of these compounds were found to be of potential interest due to their stability at highland conditions where the anomalies are observed. Both compounds would exhibit a higher dielectric value than the surrounding basalts, creating a higher radar reflectivity in those regions.

Instantaneous Mapping of Titan's Daylight-Hemisphere HC3N Using ALMA

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This project presents the first spectrally and spatially resolved observations of sub-millimeter emission from cyanoacetylene (HC3N) molecules in Titan's atmosphere obtained with the Atacama Large Millimeter/sub-millimeter Array (ALMA) on 2013 November 17. Modeling of the disk-averaged J = 40-39 emission line of HC3N results in a vertical profile with a constant abundance of 19.0 ppb above 515 km. After a slight vertical gradient, a rapid decrease to a condensation level of approximately 71 km is indicated. Comparison to other models shows agreement at the observed altitudes. An anisotropic spatial distribution of HC3N is also observed with resolved emission peaks in the northern and southern hemispheres, possibly due to recent seasonal transitions on Titan. From spatial variations in the HC3N line profile, the horizontal location of the peaks in the HC3N emission are found to vary as a function of altitude. Contrary to lower altitude HC3N found near the poles, the locations of peak integrated emission intensity for high-altitude ($z > 300$ km) HC3N are found to be asymmetric with respect to Titan's polar axis, suggesting possible high atmospheric winds.

Residence Time of H2O in Analog Regolith Samples of a Carbonaceous Asteroid

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In 2016 OSIRIS-Rex will launch to the asteroid RQ36, use Touch And Go Sample Acquisition Mechanism (TAGSAM) to reverse vacuum up regolith through a screen, and return that sample to earth in 2023. If water is captured along with the surface material and persists long enough inside the sample container, it could significantly alter the sample decreasing its scientific value. This experiment was conducted to establish initial estimates of the behavior and residence time of water inside of a TAGSAM sample. A small-scale system meant to represent a piece of the donut shaped TAGSAM sample container was created. Sand and pebbles were used to simulate the regolith OSIRIS-Rex will obtain. Different masses of ice were mixed with different combinations of sand and pebbles, placed in the small-scale system, and pumped down to a low pressure (~20 millitorr) while a pressure gauge recorded the changes in pressure. Readings on the pressure gauge were used to detect the continued presence of water vapor in the system. The pressure readings were analyzed and it was determined that for a given sample composition the residence time of water was linear with respect to the initial mass of water and of significant duration. It was also found that the difference in residence time and behavior of water for different sample compositions was due to differences in resistance to the sublimation/release of vapor process that different compositions provided and not the resistance that different compositions provided to the flow of water vapor through the system.

Imaging Europa with Clipper

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Our project was about trying to identify ground track areas that the Europa Clipper Mission, set to take off in 2021, will fly over. By using computer programs such as Mathematica and PhotoShop, we were able to identify all ground tracks where the spacecraft's altitude would be less than 600 kilometers. Within that objective, we tried to identify interesting topography that we could learn more about from the mission, as well as calculate the lowest altitude for each flyby.

Exploring the Atmospheres of Exoplanets in the Infrared

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The main purpose of this project is to create model exoplanet spectra of the same resolution and noise that the James Webb Space Telescope (JWST) would observe. The telescope will observe mainly in the infrared region, allowing it to observe adolescent stars, planets, and galaxies. By using a wide range of parameters, one can determine which spectral peaks cause a spectrum to stand out against the rest. These spectral peaks, corresponding to the presence of different molecules in the atmosphere, are a deciding factor for the planet's habitability. When JWST sends data back for analyzing, a brief analysis of these peaks will allow scientists to quickly understand if the exoplanet is of potential scientific importance. Main peaks to search for include those that would imply exo-earths or other likely habitable planets. These produced spectra are significant because two dissimilar planets can produce almost indistinguishable spectra, an issue exacerbated by photon noise. Due to the advantages of JWST compared to Hubble, including field of view and mirror size, Webb should be a huge success is exoplanet research, bringing back data for more exoplanets than Hubble; a count that currently breaks five thousand. Scientists will use the model spectra to determine the habitability of these planets as well as various other characteristics, including atmospheric composition and temperature profiles.

Fabry-Perot Observations of Lunar Exospheric Potassium Emission

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The moon is surrounded by a sparse, tenuous atmosphere (exosphere) made of helium, argon, sodium and potassium, which are released from the surface by various mechanisms including photo-stimulated desorption and meteoric impact vaporization. Potter and Morgan first observed lunar exospheric sodium and potassium emission in 1988; however, this project represents the first high-spectral resolution time-series data of lunar potassium. While sodium emission correlates with lunar phase angle and is fainter and hotter as the moon transits the terrestrial magnetotail, the behavior of potassium as a function of lunar phase is unknown. Potassium observations were taken during the two weeks surrounding the May 2013 full moon at the National Solar Observatory McMath-Pierce Telescope using the joint University of Wisconsin/Goddard Space Flight Center dual-etalon Fabry-Perot spectrometer. The images were subsequently converted to spectral line profiles by binning data in concentric rings of equal area and plotting the average pixel value of each bin. Fitting these line profiles with Gaussian distributions provides direct velocity, column density and temperature measurements; such data constrain the various atmospheric and surface processes and allow one to quantify the source and escape mechanisms of lunar potassium. The fitting process revealed a steep gradient underlying the Fabry-Perot interference and circular fringes stemming from large amounts of scattered light entering the instrument from sources including dust/chips on the mirrors and the telescope superstructure. An iterative fit of a two-dimensional fifth-degree polynomial and a radial Gaussian distribution was used to remove this scattered light background. The subtraction eased the fitting process by significantly flattening the images' spectral line profiles, increased the observations' accuracy and, and, most importantly, allowed for the detection of potassium emission from within the magnetotail where noise had previously obscured the faint signal.

Using Magnetometers to Investigate Mars: An Analysis of MGS and MAVEN Data

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Understanding the magnetic activity at Mars is vital for recognizing possible chemical alterations of the surface and atmosphere, potential hazards to robots, astronauts, or science instruments, and may lead to the ability to probe the subsurface of the planet. An organization and consolidation of Mars Global Surveyor data was performed in order to better search for evidence of Schumann resonances associated with electric discharges oscillating between the surface of the planet and the ionosphere. These resonances are expected to manifest as signals from 8 to 14 Hz and be present at altitudes below 400 kilometers. Additionally, to ensure future data from Mars is as free of noise as possible, Mars Atmosphere and Volatile Evolution mission (MAVEN) data was carefully examined for artificial signals and possible sources of those identified were hypothesized. The Interactive Data Language was utilized for data organization and manipulation as well as plotting and mathematical processes, such as fast Fourier transforms and wavelet analysis. The fast Fourier transforms and wavelet analyses provided valuable information about which frequencies were most prominent in the data sets. Several days of data were determined to be of high interest due to signals appearing under the aforementioned conditions and as a result possibly contain evidence of lightning. Current data already shows some promising signs of the existence of lightning on Mars and further investigation of MGS data and MAVEN data may lead to a more definitive conclusion. A new Incident Surprise or Anomaly (ISA) in the MAVEN data was discovered and logged for future reference. With the knowledge and possible elimination of multiple ISAs, MAVEN data can be analyzed with a significantly lower chance of mistaking artificial signals as science data.

SPACE Interactive Tool

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As interest in the development of micro—and nano-satellites—for scientific mission applications grows, more commercial off-the-shelf components for CubeSats, nanosatellites of a standard volume, are becoming available. Our project at NASA Goddard was to create a program and user interface that facilitates the design of theoretical payloads for CubeSat missions in the early stages of mission design. The SPACE tool separates the design process of a CubeSat mission into selection of an instrument or payload and selection of various subsystems. In addition to the SPACE program, we created a database of commercially available satellite components designed for CubeSats, which the SPACE tool is able to search and select from. After subsystems are selected, the tool allows the user to tweak their mission concept or subsystem selections and then access 3D models of the CubeSat parts and bus. These parts can be printed individually or as a complete CubeSat layout assembled in a CAD program. This program allows scientists and engineers in early phases of mission design to determine the state-of-the-art technological capability of CubeSats and find initial estimates mass, power, volume, and bandwidth of a specific nanosatellites mission. Our hope for the future of this tool is that it will be made available online for public use, and as more scientists, engineers, and manufacturers use the tool, they will contribute to the CubeSat database, increasing the functionality of our tool.

Geologic Mapping of Arsia and Pavonis Mons, Mars

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The Tharsis Montes (Arsia, Pavonis, and Ascraeus Mons) are three broad shield volcanoes on Mars aligned in a NE-SW trend and spaced approximately 700 km apart. The relationship and geologic history between these shield volcanoes and the Tharsis region as a whole is still not well understood. The southernmost volcano, Arsia Mons, is believed to be the oldest of the three volcanic structures and also has the largest Fan Shaped Deposit (FSD) of the three. Geologic units in Arsia's FSD display evidence of interactions between glacial and volcanic activity. Geologic mapping of the Arsia FSD and surrounding lava plains can be used as a tool to decipher the geologic history, and lead to an understanding of the processes that result in different lava flow and glacial morphologies. Thermal Emission Imaging System (THEMIS) and Context Camera (CTX) basemaps were used to map geologic contacts, units, and structural features in ArcMap 10.2. High Resolution Imaging Science Experiment (HiRISE) and additional CTX images were used to create detailed maps of potentially young lava flows. Mapping of Arsia FSD volcanic and glacial features demonstrated the stratigraphic relationships among units. The surrounding lava plains were characterized by geologically older tabular lava flows that have been partially buried by younger glacial deposits within the last 100 million years. HiRISE image mapping provided evidence for post-glacial volcanism along a linear fissure. This eruption formed a line of cones, and the lava flows breeched the prominent end moraine (ridge) of the FSD. Geologic mapping of Arsia has resulted in an improved understanding of the formation of the Tharsis Montes.

Analysis of Physical Properties and Morphology of Impact Melt Flows on Venus Using Radar

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When a bolide collides with a planetary body and forms an impact crater, the cratering process sometimes produces melt that flows out of and away from the crater, producing an impact melt flow. These flows have been studied in the past using remote sensing on both Venus and the Moon. The purpose of this study is use radar to study the reflectivity, morphology, and roughness of impact melt flows on Venus. This study used reflectivity data from the Magellan mission to examine flow reflectivity and morphology, and Circular Polarization Ratio (CPR) data from the Arecibo Observatory to examine flow roughness. Reflectivity values were averaged and morphology was recorded for a sample of 25 Venus craters, and CPR values were averaged for five of these craters that had corresponding ground based polarimetry data. The CPR values of the 5 crater sample ranged from ~-0.032 to ~0.287 over a range of incidence angles from 17.5° to 61.8°. The study found that Venus impact melt flows are brighter and generally have higher CPR values than their surroundings, have both crisp and diffuse edges, and both reflectivity and CPR often vary along the length of the flow. The impact melt flows have similar CPR values to those from volcanic flows on Venus, indicating similar surface roughness. Channels within the flows more commonly occur in radar-bright portions of the flows and in long flows are often proximal to the crater. The Venus impact melt flows appear to be smoother than those on the Moon based on a comparison of CPR values at similar incidence angles. This study will be continued by comparing these results to those of impact melt flows on the Moon to investigate how the impact melt emplacement process is influenced by variables such as atmospheric temperature and pressure.

Bouguer Anomalies Associated with Lunar Floor-Fractured Craters

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Lunar Floor-Fractured Craters (FFCs) are a class of lunar craters marked by their anomalously shallow floors and prominent fractures. Additional morphologies include patches of mare material, vents, and pyroclastic deposits. These surface morphologies combined with morphometric data suggest that the deformation resulted from a sub-crater magmatic intrusion and sill formation. Gravity data provide information about the interior structure of a body. The recent Gravity Recovery And Interior Laboratory (GRAIL) mission provides, for the first time, lunar gravity data with high enough resolution to investigate the postulated formation mechanism for lunar FFCs. We selected three of the largest FFCs (craters Humboldt, Oppenheimer, and Petavius) to investigate because of their expansive crater floors. We band filter the Bouguer gravity product to degree and orders 6-600 and 100-600, and compare the strength and location of positive Bouguer anomalies located beneath the crater floor region. The order 6-600 products reveal broad positive anomalies beneath all of the crater floors; however, due to the crater diameters (near 200 km) there still exists a gravity contribution from mantle uplift processes that took place during initial crater formation. The degree and order 100-600 product removes this uplifted mantle contribution and reveals correlations between observed surface geology and subsurface gravitational anomalies. For example, in the crater Humboldt, two lobes of particularly high positive Bouguer anomalies correspond to regions of the crater covered in lava flows, supporting the postulate of a subsurface magmatic intrusion as the source for these mare deposits. Thus our analysis supports the proposed FFC formation mechanism of magmatic intrusion and sill formation.

Mapping Buried Impact Craters in the Chryse Basin to Understand the Distribution of Outflow Channel Sediment

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The Chryse Basin's location in the northern hemisphere of Mars allowed it to collect water from a number of major outflow channels. These outflows must have deposited significant amounts of sediment within the basin. This project's goal was to see if mapping buried impact craters, revealed as Quasi-Circular Depressions (QCDs) in Mars Orbiter Laser Altimeter (MOLA) data, could be used to determine the distribution and variation of sediment thickness within the Basin. QCDs, including likely buried impact craters, were mapped to test the hypothesis that further into the basin there would be fewer smaller craters because thicker sediments would have preferentially covered them. Mapping was done using Gridview, an interactive graphics program that manipulates data, in this case topographic data from the Mars Orbiter Laser Altimeter (MOLA). It should be possible to estimate the thickness of the sediment from the smallest buried craters found in a given area, and therefore map out the change in sediment thickness across the basin. The smallest QCDs beginning to be completely covered by sediment were just below 30 km in diameter. The minimum sediment needed to cover a QCD of this size was calculated to be between one to two kilometers. Therefore, the absence of QCDs below thirty kilometers in the NE corner of Chryse could be explained by sediment at least that thick. Lower thickness is expected elsewhere in the basin, especially in the SW, where more QCDs with smaller diameters were found. The method of mapping buried impact craters provides a way to determine variations in sediment thickness within the Chryse Basin. This method could be used on other sediment-covered areas to learn about past water flow.

Early Impact History of Mars

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Understanding the early geologic impact history of Mars can reveal clues about the early environment on Mars and the impact history of the entire solar system. To investigate this, we used topographic data to look for visible impact craters and buried craters that are only visible in topographic data from the Mars Laser Altimeter, or MOLA. We performed crater counts around the rims of the Argyre and Hellas impact basins and in the background terrain within Hellas's ejecta blanket to understand the chronology of the impacts that formed these basins and to try to find pre-Hellas terrain under Hellas's ejecta blanket. We found that the background terrain that Hellas formed on was older than Hellas itself, as expected, and that the Argyre impact basin is older than Hellas. In the data from the Argyre Rim count and the Hellas background terrain count, we found evidence for resurfacing events. In the Argyre Rim, saw at least one easily visible resurfacing event. The two resurfacing events for Hellas's background terrain were in found using data from larger craters that we had little data of. We presume one of the resurfacing events of the Hellas impact basin's background terrain was from the ejecta of the formation of the Hellas impact basin. Future studies could add to our dataset and give us clearer data on the distribution of craters at different sizes at these sites to verify the resurfacing events we found, and look into what caused the resurfacing events that we observed.

Preliminary results of Ar diffusion through silicate glasses

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The dating of lunar impact glasses through radiometric argon dating has greatly shaped the understanding of the impact history of the earth-moon system. These dates depend upon the assumption that argon is diffusively immobile in silicate glasses and melts after they have formed, meaning that argon will not degas out of the glass over time and the argon released in the dating experiment reflects the original inventory at the time of impact. To test this assumption, argon has been implanted into various synthetic glasses over a range of compositions, particularly with silicate abundance in mind. The glasses were pyrolyzed and the thermally evolved gas was measured as a function of temperature using mass spectrometry to determine the amount and rate of argon diffusion out of the glass. The results show that there is some argon degassing at lower temperatures. Future experiments will further explore the low temperature diffusion of argon through silicate glasses at variable silicon abundance.

Exploring Minimum Spectral Resolutions Required for Recognition of Potential Exo-Earths

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Since the first official discovery of an exoplanet in 1995, the field has burgeoned and today includes over 5,000 potential bodies. However, very little is known about the surfaces of these potential habitable "Exo-Earths." This is due to not only the vast number of planetary candidates, but also the limited nature of the time given for each observation over the course of an orbiting telescope's mission. In order to resolve this issue, it is necessary to calculate the minimum spectral resolution necessary to tell whether or not an exoplanet being investigated has the biochemical signatures indicative of life. This project completed that calculation by creating an algorithm that, given two planetary' bodies albedos across a range of wavelengths, generates a set of graphs containing raw data and the signal-to-noise ratio necessary to be confident of the spectrum being generated. In the vital comparison of the spectrum of Modern Earth and of a Sub-Neptune, the results indicated that such a differentiation is possible at as low of a level as R=20.

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Appendix A: Interns

Intern		*Mentor*	Code	Title
Adkins-Rieck	Ruben	*Mahmooda Sultana*	553	Characterization of Graphene Chemical Sensors
Aguirre	James	*Thomas Stevenson*	553	Kinetic Inductance Detectors for Far-Infrared Spectroscopy
Akhtar	Uzair	*Stephen Leete*	599	ISS Earth Science External Payloads Proposer's Guide
Akinwale	Akinola	*Paul Mirel*	665	Mechanical Design and Construction of the Primordial Inflation Polarization Explorer (PIPER)
Alappat	Thomas	*Randall Hintz*	180	Klocwork Checker Studio for MPCV Static Code Analysis Abstract
Albarran	Robert	*Jeffrey Klenzing*	674	Plasma Sheath Analysis for Langmuir Probe Development
Alburger	Michael	*Kate Whitaker-Tease*	665	Quenching of Galaxies as a Function of Mass
Aleksandrovych	Oleksandr	*Javier Ocasio-Perez*	568	Test Conductor Report System
Alexander	Robert Lewis	*D. Aaron Roberts*	672	Audification as a Tool for the Spectral Analysis of Heliospheric Time Series Data
Almonte	Rafael	*Joanne Hill*	662	Narrow Gap Detector Testing
Anderson	Nyki	*Richard Barry*	667	P.H.A.S.T Precision High Altitude Star Tracker
Angelo	Alexandra	*Olga Gutynska*	670	Foreshock Significance in Generation of ULF Waves
Armstrong	Ashton	*Justin Smith*	180	West Virginia Space Public Outreach Team (SPOT)
Atanassov	Alexander	*William Thomas*	474	Analysis Tools for Joint Polar Satellite System Data Product Monitoring
Bagley	Thomas	*Fred Duca*	740	Data Center Efficiency Saves Money and Reduces Greenhouse Gases
Baker	William	*Brain Roberts*	408	Robotic Arm Controller Evaluation Report

Intern		*Mentor*	Code	Title
Ball	Georgette	*Justin Smith*	180	Space Telescopes: A Glimpse into the Unknown SPOT Presentation
Barlis	Alyssa	*Thomas Stevenson*	553	Kinetic Inductance Detectors for Far-Infrared Spectroscopy
Barnes	David	*Charles Clagett*	596	Dellingr 6U Cubesat
Baukman	Shaheed	*Sean Semper*	596	Star Tracker and Gimbal Driver Board
Bean	Breahna	*Robyn King*	564	Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller
Beckert	Clara	*Terry Hurford*	693	Imaging Europa with Clipper
Beeson	Ryne	*Jacob Englander*	595	A High-Fidelity Mission Analysis and Design Toolchain: EMTG-GMAT
Bender	Sarah	*Kyle Murphy*	670	Morphology and Dynamics of Auroral Arcs
Benhidjeb-Carayon	Alicia	*Natasha M. Johnson*	691	Parameters influencing the Fischer-Tropsch Type reactions
Bermudez	Katrina	*Pamela Conrad*	699	Preliminary results of Ar diffusion through silicate glasses
Berry	Kyle	*George Bussey*	566	Calculating Ground Station Access Times for Spacecraft
Bierhals	Melinda	*Tim Dunfee*	700	Historic Risk Data Collection and Analysis Effort
Birchler De Allende	Alan	*LaMont Ruley*	583	Requirements Management for DAT
Bishop	Andrew	*Matthew Showalter*	547	Innovation Lab: R.O.G.E.R. Project
Blankenship	David	*Dave Leisawitz*	605	Creating Hyperspectral Test Scenes for the Wide-Field Imaging Interferometry Testbed
Board	Elizabeth	*Matthew Showalter*	547	Innovation Lab: R.O.G.E.R. Project
Bok	Brandyn	*Karen Richon*	595	JWST Trajectory Modeling
Bosworth	Rebecca	*Brendan McAndrew*	551	Laser Stability Applications for Spectral Radiometric Calibration Demonstration Systems
Bradford	Taylor	*Richard Harman*	444	ST-5: A Spacecraft Dynamics Simulation

Intern		*Mentor*	Code	Title
Brand	Jefferson	*Brian Roberts*	408	Classification and Organization of Robotic Arm Design
Bravo	Eric	*Matthew Showalter*	547	Mechanical Design of Coronagraph CubeSat
Brazil	Liza	*Paul Racette*	555	Preliminary Analysis on Two Space Instrument Databases
Bridenstine	Kyle	*Sharon Orsborne*	583	Getting 30 Languages for the Price of One
Brown	Alvis	*Robyn King*	564	Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller
Buss	Marjorie	*Mark Hasegawa*	546	Investigating the Effect of 9924 Primer Thickness on Conductivity with a Z307 Topcoat; Development of a Pigment Database for Inorganic Silicate-Based Colored Coatings
Cable	Steven	*William Thomas*	474	Analysis Tools for Joint Polar Satellite System Data Product Monitoring
Campion	Robert	*Keith Gendreau*	662	NICER Pointing System
Cannon	Luke	*Maureen Madden*	584	Joint Polar Satellite Systems Simulator Interface Design
Caraballo Alvarez	Irma	*Emmanuel Dinnat*	615	Satellite Remote Sensing of Sea-Surface Salinity in the Polar Regions – Observations and Validations
Castro	Marc	*Kongpop U-Yen*	555	Ultra-Wideband mm-Wave Planar Via-less Crossover for Cosmic Microwave Background Polarization Detector
Cecil	Clair	*Donna Swann*	400	Mastering Workplace Effectiveness
Chambers	Jessica	*Fred Minetto*	695	Radio Observatory on the Lunar Surface for Solar Studies (ROLSS) Prototype
Chen	Heather	*Mian Chin*	614	Retrieval of Plume Heights from Volcanic Eruptions Observed by MISR
Chen	Kevin	*Amy Lien*	661	Swift Burst Alert Telescope Trigger Simulation for High Redshift Gamma-ray Bursts
Chenot	Natasha	*Lora Koenig*	615	Assessing the Properties of Snow in West Antarctica

Intern		*Mentor*	Code	Title
Cheung	Stephanie	*Jordan Camp*	663	Simulating ISS Ammonia Leaks
Chu	Christina Seiman	*David G. Sibeck*	674	THEMIS Observations of Dayside Magnetospheric Interactions
Clamp	Joseph	*Daniel Duffy*	606	Large Scale Data Analysis Using the CDS API – Indicators of Climate Change in MERRA
Claus	April	*Ryan McClelland*	662	Next Generation X-Ray Optics: Mirror Assembly Development Process
Cockcroft	Bryant	*Elizabeth Timmons*	587	Accelerated Space Computing
Cole	Ryan	*Joe Hill*	662	Lifetime and Performance of the GEMS Narrow-Gap Detector
Comberiate	Daniel	*Jeannette Plante*	300	Printed Circuit Board Quality Assurance
Connaughton	Michael	*Debora McCallum*	271	Photography and Archiving at NASA GSFC
Coole	James	*Elizabeth Timmons*	587	Accelerated Space Computing
Corbett	Caroline	*Elizabeth Park*	472	Data Analysis of S-NPP ATMS Anomalous Events
Cornish	Sheyla	*Jay Friedlander*	605	Creation of Explanatory Posters for NASA GSFC Science Directorate Laboratories
Cox	Andrew	*Joseph Galante*	591	Developing a Test Platform for IMU Parameter Identification
Coyle	Nina	*Robert Petre*	662	Expansion Velocities of Ejected Material from Tycho's Supernova
Crogan	Keith	*Evelyn Baskin*	220	Building Energy – Efficiency Profiling and Assessment
Cultee	Christian	*Ben Lui*	585	Web Development
Dapremont	Angela	*Brent Garry*	698	Geologic Mapping of Arsia and Pavonis Mons, Mars
Davis	Matthew	*Patrick Kilroy*	568	Designing a Portable CubeSat Ground Station Trainer
Derr	Nicholas	*Ronald Oliversen*	695	Fabry-Perot Observations of Lunar Exospheric Potassium Emission

Intern		*Mentor*	Code	Title
Diaz	Walter	*Carmel Conaty*	592	Development of Model-Based System Engineering (MBSE) at Goddard Space Flight Center
Dichoso	Diogenes	*Kenneth Segal*	543	Developing an Analysis Approach for Evaluating the Effects of Defects in Composite Materials
Dong	Christine	*Lynn Carter*	698	Analysis of Physical Properties and Morphology of Impact Melt Flows on Venus Using Radar
Drohat	Grant	*Patrick Coronado*	606	Climate Change: How do we know?
Duckworth	Trey	*Rick Hess*	180	James Webb Space Telescope JWST Tool Development
Durofchalk	Nicholas	*Theodore Gull*	667	Ultraviolet Analysis of Eta Carinae Using Observations from the International Ultraviolet Explorer
Dytso	Alex	*Haleh Safavi*	566	Error Correction Coding for TDRSS Demand Access System
Erb	Angela	*Miguel O. Román*	619	Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems
Esman	Teresa	*Jared Espley*	695	Using Magnetometers to Investigate Mars: An Analysis of MGS and MAVEN Data
Etim	David	*Christopher Lynnes*	610	Science Data Analysis in a Collaborative Workbench
Ettz	Kevin	*Brian Roberts*	408	Reach and Access Trajectory Planning for Restore Refueling Mission
Farrall	Nicole	*James Chervenak*	553	Detector Process Development for X-ray WHIM Measurement
Farrell	Erin	*Gordon Casto*	543	OVIRS Shipping Container Design
Fasnacht	Zachary	*Anne Thompson*	614	Effect of Stratospheric Intrusions on Tropospheric Ozone and Air Quality
Fayne	Jessica	*John Bolten*	617	Validating Flood Mapping Products Using a Digital Elevation Model Comparison Technique
Finzi	Marc	*Alexander Kutyrev*	665	Sub-Arcminute Rotation Verification for RIMAS Filter Wheel

Intern		*Mentor*	Code	Title
Flint	Quincy	*Chris St Cyr*	670	Seven Missing Years: Filling the Final Gap with MLSO MK3 Observations
Forquer	John	*Joelle Loretta*	180	SGSS Fault Management Analysis Abstract
Franchek	Melanie	*Dalia Kirschbaum*	617	Addressing Media Bias in Rainfall-Triggered Landslide Reporting
Frey	Timothy	*Mark Hasegawa*	546	Mitigation of Thermal Coating Contamination from Particle Fallout
Fries	Timothy	*Lisa Wilson*	581	Tropical Rainfall Measuring Mission I&T Test String
Gandhi	Anshula	*Richard Barry*	667	P.H.A.S.T Precision High Altitude Star Tracker
García Burgos	Axel	*Georgia De Nolfo*	672	Ionospheric Neutron Content Analyzer (INCA)
Geisler	Katherine	*Bryan Blair*	694	Distortion of a Scanning Mirror
Gholian	Armen	*Obadiah Kegege*	566	Simulating a Receiver for Tracking and Data Relay Satellite System (TDRSS) Demand Access Service (DAS)
Gibbs	Jeremy	*Bonita Seaton*	581	Understanding Spectroscopy on JWST
Gibson	William	*Manuel Vega*	555	Software Development for D3R Operational Data Analysis and Manufacture of IF Oscillator Subsystem
Gilbert	Emily	*Richard Barry*	667	Detection of Exoplanets Using Microlensing for the Wide-Field Infrared Survey Telescope (WFIRST)
Gillespie	Turner	*Robin Corbet*	660	GRB Suite a Visualization, Animation, and Data Sonification Composition of Gamma-Ray Bursts Presented in 4 Movements
Gimar	Caleb	*Theodore Gull*	667	Ultraviolet Analysis of Eta Carinae Using Observations from the International Ultraviolet Explorer
Godin	Kyle	*Thomas Stevenson*	553	Characterization of Thin Dielectric Quality towards Megapixel Array Integration of Magnetic Calorimeter X-ray Detectors
Goldberg	Joshua	*Daniel Mandl*	581	Restructuring Conventional Web Platforms to Reduce Dependence on Hierarchical File Systems

Intern		*Mentor*	Code	Title
Goldstein	Alicia	*Matthew Showalter*	547	Innovation Laboratory: Moving Forward
Goldstein	Marc	*Matthew Showalter*	547	Innovation Lab: R.O.G.E.R. Project
Goodson	SeQuoria	*Robyn King*	564	Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller
Gottlieb	Amy	*Katja Pottschmidt*	661	Studying the accreting X-ray pulsar Centaurus X-3 with Suzaku
Gramlich	Matthew	*Ricky Forquer*	180	Robotics Image Processing and Interpretation
Grant	Lynnora	*Nancy Carosso*	546	A Look at Planetary Protection Implementation
Gravette	Shannon	*Marcello Rodriguez*	546	Calibration of the Mini Ion Neutral Mass Spectrometer
Grunsfeld	Mace	*Brain Roberts*	408	Robotic Arm Controller Evaluation Report
Guo	Jing	*Michael Krainak*	554	Fourth Order Interference
Gutstein	Kimberly	*Paolo de Matthaeis*	615	Investigation of the Potential Use of Aquarius Data for Sea Ice Thickness Retrieval
Hakun	Jennafer	*Phillip Coulter*	551	OVIRS Primary Mirror Characterization
Halabe	Esha	*Ryan Starn*	180	James Webb Space Telescope Fault Management End-to-End Database Event Network Development
Handleton	Taylor	*Richard Barry*	667	P.H.A.S.T Precision High Altitude Star Tracker
Hanely	Derek	*Ricky Forquer*	180	Robotics Image Processing and Interpretation
Harrison	Kierra	*Gary Crum*	587	Doppler Shift Compensation in Satellite-to-Ground Station Communication
Hemphill	Carlton	*George Manos*	553	Optimization Techniques for Deep Wet Etching of Borosilicate Glass
Hewitt	Robert	*Donald Kranz*	180	Defining, Categorizing, and Aggregating Adverse Conditions

Intern		*Mentor*	Code	Title
Hiett	Joshua	*Steven Hard*	180	User Control Interface Improvement for RoverX
Himwich	Zoe	*Pamela Clark*	695	SPACE Interactive Tool
Holford	Mira	*John Thompson*	606	Creating a Multi-Display Visualization Wall Using Open Source Software
Horan	Ashley	*Conor Nixon*	693	Exploring the Atmospheres of Exoplanets in the Infrared
Howl	Bryan	*Mian Chin*	614	Retrieval of Plume Heights from Volcanic Eruptions Observed by MISR
Hubbard	Alfred	*Molly Brown*	618	Modeling Stormwater Runoff Reduction from Low Impact Developments for GSFC using the EPA's Stormwater Management Model
Hughes	Kyle	*Alinda Mashiku*	595	OSIRIS-REx Asteroid Sample Return Mission: High-Fidelity Modeling of Solar Radiation Pressure during Orbit B
Hume	Shayna	*Shawn Domagal-Goldman*	699	Exploring Minimum Spectral Resolutions Required for Recognition of Potential Exo-Earths
Hurley	Samantha	*Steven Kenyon*	543	Neutron Star Interior Composition ExploreR (NICER) Ten Percent Model
Isaacson	Zachary	*Mark Secunda*	546	The Impact of Different Parameters on the Effectiveness of the Nitrogen Purge
Janus	Victoria	*Yihua Zheng*	674	Space Weather Forecasting: Analyzing the July 8, 2014 Event
Jin	Rubing	*Damon C. Bradley*	564	Prescreening and Testing for RFI Risk Reduction on Goddard Radio Frequency Explorer
Jin	Rubing	*Damon C. Bradley*	564	Designing Modular Electronics for Multiple CubeSAT Missions
Johnson	Ayanna	*Nadeeka Jayalitake*	114	Color Me Happy: The Effects of Color Psychology as an Applied Function of the NASA Workplace
Johnson	Holly	*Fred Minetto*	695	Development of a Gentle Non-Tactile One Terrestrial Atmosphere Contamination Mitigation Tool
Johnson	Jerrin	*Keith Gendreau*	662	Silicon Drift Detector Alignment for NICER

Intern		*Mentor*	Code	Title
Johnston	Benjamin	*Santiago Gasso*	613	Dust Activity and Transport in the High Latitudes
Jozwiak	Lauren	*Gregory Neumann*	698	Bouguer Anomalies Associated with Lunar Floor-Fractured Craters
Julius	Ethan	*Peter Blake*	551	Pre Assembly and Experimentation of Calibration Breadboard for Laser Communications Relay Demonstration (LCRD)
Jung	Dawoon	*Marc J. Kuchner*	667	Crowdsourced Discovery of Protoplanetar y and Debris Disks with Disk Detective
Kenigson	Jessica	*Mike Jasinski*	617	Sea Level Rise along the East Coast of the USA from Tide Gauges and Satellite Altimeters
Kenward	David	*Joe Hill-Kittle*	662	Characterization of Nitromethane for Use in a Time-Projection Chamber Polarimeter
Kerin	John	*Eleonora Troja*	661	Determining a Better Estimate of the Short Gamma Ray Burst Rate: A Comparison Analysis of Swift and Fermi Data
Khan	Zubair	*Darryl Mitchell*	504	Infuse Tech Transfer with NASA Goddard and Abroad
Khatib	Aisha	*Lahouri Bounoua*	618	Project: Effects of Urbanization on Surface Climate
Khayat	Shireen	*Lahouri Bounoua*	618	Project: Effects of Urbanization on Surface Climate
Kidd	Lauren	*Eleonora Troja*	661	The Collimation and Energetics of Short Gamma-Ray Bursts
King-Smith	Matthew	*Lyudmyla Panashchenko*	562	Development of an Infrared Microscopy Screening Technique for Foil Resistors
Kitzmiller	Wyatt	*Edward Meek*	180	Kennedy Space Center Automated Subsystem Software Evidence Tool (KSC-ASSET) Development Project
Klene	Paul	*Leonard Garcia*	605	Relationship between Earth's Auroral Kilometric Radiation (AKR) and the Auroral Electroject Index (AE)
Klingler	Noel	*Zaven Arzoumanian*	662	NICER X-Ray Concentrator Simulations of Diffuse Emissions and Extended Sources

Intern		*Mentor*	Code	Title
Knox	Qi'Anne	*Tammy Tuttle*	760	Designing a Prototype for the Fee-for-Service Program Tool
Koepping	Gregory	*Lawrence Hilliard*	555	RFI Blocker Testing at GGAO to Enable Space Geodetic Technique Colocation
Kohler	Erika	*Natasha Johnson*	691	Radar-Reflective Minerals Tested under Venus Surface and Atmospheric Conditions
Kowalczyk	Nick	*Michael Biskach*	662	Software Development for X-ray Image Analysis and Metrology
Krishnarao	Dhanesh	*Antti Pulkkinen*	674	STEREO EUVI as X-Ray Proxy
Kynoch	Mackenzie	*Richard Barry*	667	P.H.A.S.T Precision High Altitude Star Tracker
Latimer	Colin	*Julio Marius*	584	Robot Pianist
Law	Chad	*Lisa Wilson*	581	Tropical Rainfall Measuring Mission I&T Test String
Lee	Vincent	*Justin Jones*	541	Piezoelectric Stack actuator for Micro-Mechanical Testing
Leggett	Jared	*Gregory Black*	180	Analysis of MPCV EFT-1 Entry, Descent and Landing Software
Leiter	Robin	*Pamela Clark*	695	SPACE Interactive Tool
Liburd	Jamar	*Michael Corcoran*	662	Swift Observations of the Recent X-ray Activity of Eta Carinae
Lietuvninkas	Andrius	*Rafael Rincon*	555	Digital Beamforming Synthetic Aperture Radar, 2nd Gen. (DBSAR-2)
Lin	Rachel	*Darryl Mitchell*	504	Infuse Tech Transfer with NASA Goddard and Abroad
Liounis	Andrew	*Kenneth Getzandanner*	595	Visually Navigating an Asteroid: A Summer of Working with Stereophotoclinometry
Lister	Jonathan	*Ricky Forquer*	180	Robotics Image Processing and Interpretation
Little	Walter	*Brian Montgomery*	540	LDE Checklist and Handling Fixture Certification
Lituchy	David	*Darilyn Dunkerley*	180	Technical Quality and Excellence

Intern		*Mentor*	Code	Title
Lombardi	Giancarlo	*Kan Yang*	545	Investigation on the Practicality of Developing Reduced Thermal Models
Longlet	Anne	*Fred Minetto*	695	Development of a Gentle Non-Tactile One Terrestrial Atmosphere Contamination Mitigation Tool
Lord	Benjamin	*Oren Sheinman*	543	Advanced Topographic Laser Altimeter System Structures Integration & Testing
Loughlin	Hudson	*Jeffrey Livas*	663	Photoreceiver Measurements for a Future Space-Based Gravitational Wave Observatory
MacKinnon	James	*Elizabeth Timmons*	587	Accelerated Space Computing
Majarowsky	Bryan	*Umesh Patel*	544	Magnetic Bearings for Space Flight Applications
Marks	Hope	*Stephen Leete*	599	ISS Earth Science External Payloads Proposer's Guide
Marshall	Sierra	*Alice Liu*	591	The Neutron Star Interior Composition ExploreR (NICER) – Telemetry Pages Development
Martinez	Jose	*Matthew Showalter*	547	Innovation Lab: R.O.G.E.R. Project
Martínez	José	*David Mc Comas*	582	PiSat
Mata	Alberto	*Jeffrey Livas*	600	CubeSat Swarm for Science (CSS)
McGuffey	Megan	*Fred Minetto*	695	Radio Observatory on the Lunar Surface for Solar Studies (ROLSS) Prototype
McNair	Terrell	*Jeannette Plante*	300	Printed Circuit Board Quality Assurance
McPherson	Joshua	*Joseph Painter*	180	Integrated Java Static Code Analysis
McWithey	Christen	*Catherine Peddie*	448	3D Printing for WFIRST-AFTA Concept Development
Mellish	Rochelle	*Philip Calhoun*	591	Finite Horizon Model Predictive Control for the Alignment of Two Cubesats Acting as a Virtual Telescope
Mercer	Cortney	*Ricky Forquer*	180	Robotics Image Processing and Interpretation

Intern		*Mentor*	Code	Title
Merritt	Veronique	*Bryan Geurts*	140	The Patent Protection and Technology Transfer Process
Miller	Moira	*Herbert Frey*	698	Mapping Buried Impact Craters in the Chryse Basin to Understand the Distribution of Outflow Channel Sediment
Mittu	Anjali	*Umesh Patel*	544	Magnetic Bearings for Space Flight Applications
Montoya	Emily	*Richard Ryan*	443	Measuring Contract Performance with Earned Value Management
Moore	Keegan	*David Mc Comas*	582	PiSat
Morales Otero	Michael	*Umesh Patel*	544	Magnetic Bearings for Space Flight Applications
Morgan	Ian	*Judith Racusin*	661	Very High-Energy Gamma Rays from Gamma Ray Bursts: Predictions for New and Current Telescopes
Morgan	Rachel	*Calinda Yew*	549	Space Simulation Testing for the James Webb Space Telescope
Moscato	Teresa	*Mark Steiner*	592	GPM Mission Evolution
Mosley	Graham	*Jacqueline Le Moigne*	580	Earth and Planetary Image Processing for IMAGESEER Database
Munoz	Rai	*Keith Gendreau*	662	NICER Pointing System
Murphy	James	*Jacqueline Le Moigne*	580	Improving Feature Extraction for Image Registration with Shearlets
Murphy	Kaitlin	*Ron Shiri*	551	EM Field Propagation through Lithography Masks for Assessment of Intensity Suppression
Nasipak	Zachary	*John Baker*	663	Analyzing and Visualizing Black Hole Binary Simulations
Natarajan	Aparna	*Pamela Clark*	695	SPACE Interactive Tool
Neely	Aaron	*Brain Roberts*	408	Robotic Arm Controller Evaluation Report
Nettey	Miranda	*Charles Rogers*	428	Safety Training Database
Newheart	Anastasia	*Michael Collier*	695	Thermal Ions and Ion Cyclotron Wave Activity

Intern		*Mentor*	Code	Title
Nichols	Rebecca	*Patricia Boyd*	660	Characterizing the Long-Term Variability of X-ray Binary 4U1705-44: Evidence for an Underlying Double-Welled Nonlinear Oscillator
Nie	Alexander	*Alice Harding*	663	Visualization of Particle Trajectories in Magnetospheric Pair Cascades around Rotation-Powered Pulsars
Nwaogbe	Jessica	*Jeffrey Dalhoff*	350	Investigating Indoor Air Quality in GSFC
Ogard	Lindsay	*Gary Crum*	587	Doppler Shift Compensation in Satellite-to-Ground Station Communication
Ohi	Nicholas	*Ricky Forquer*	180	Robotics Image Processing and Interpretation
Okel	Dalton	*Joelle Loretta*	180	SGSS Fault Management Analysis Abstract
Oparaocha	Destiny	*Terry Hurford*	693	Imaging Europa with Clipper
Ortiz	Javier	*Manuel Vega*	555	Modeling, Fabrication, and Testing of D3R Arbitrary Waveform Generator and Low-Cost Doppler Radar Design Definition
Owrutsky	Rachel	*Michael Novak*	616	Measurements of Particulate Organic Carbon in Estuarine, Coastal, and Offshore Waters of the Gulf of Mexico
Paynter	Ian	*Miguel O. Román*	619	Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems
Pearson	Blair	*Jentung Ku*	545	Testing a Cryogenic Heat Transport Device for Satellite Temperature Control
Peck	Dakota	*William Truxton*	750	Enterprise Virtualization with Failover Clustering
Peri	Francesco	*Miguel O. Román*	619	Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems
Perlin	Michael	*James Thorpe*	663	Micronewton Thruster Modulation and Analysis for the LISA Pathfinder
Pfeifle	Ryan	*Richard Barry*	667	Detection of Exoplanets Using Microlensing for the Wide-Field Infrared Survey Telescope (WFIRST)
Pirtle	Bradley	*Rafael Rincon*	555	Digital Beamforming Synthetic Aperture Radar, 2nd Gen. (DBSAR-2)

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Plave	Aaron	*Christopher Lynnes*	610	MyGiovanni: Online analysis and Visualization with User Contributed Shapefiles
Pleitez	Caesar	*Jaime Esper*	592	Atmospheric Aerocapture through Saturn/Titan
Pontius	Rebecca	*Mark Hasegawa*	546	Improving Adhesion of Thermal Coatings through Oxygen Plasma Exposure
Potter	Alyssa	*Barbara Milner*	583	Goddard Mission Services Evolution Center Wiki
Pruitt	Alexis	*Robyn King*	564	Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller
Racine	Nicole	*Fred Minetto*	695	Development of a Gentle Non-Tactile One Terrestrial Atmosphere Contamination Mitigation Tool
Randolph	Austin	*Paul Mirel*	665	Mechanical Design and Construction of the Primordial Inflation Polarization Explorer (PIPER)
Reginauld	Shawn	*Mark Hasegawa*	546	Analysis of Thermal Optical Properties regarding the Degeneration of Z93C55 Substrate
Reid	Katherine	*Edward Meek*	180	Kennedy Space Center Automated Subsystem Software Evidence Tool (KSC-ASSET) Development Project
Reid	Piper	*Padi Boyd*	660	Search for Optical and UV Variability in Be/X-ray Binary Transient Swift J1626.6-5156
Reinert	Chris	*George Bussey*	566	Web-based Communications Design Agent Development
Reisman	Shaina	*Padi Boyd*	661	X-ray Bursts in the Bright Low Mass X-ray Binary, Cygnus X-2
Reyes	Coral	*Evelyn Baskin*	220	Energy Management at Goddard Space Flight Center
Reyes	Coral	*Evelyn Baskin*	220	Building Energy – Efficiency Profiling and Assessment
Robertson	Gabrielle	*Larry Hess*	553	Characterizing the Thermal Conductivity of Porous Silicon

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Rogoszinski	Zeeve	*John Hewitt*	660	Constraining Cosmic Ray Origins through Spectral Radio Breaks in Supernova Remnants
Rose	Caitlin	*Jeremy Schnittman*	663	Evaluating the Use of Hive and Impala for Storage and Processing of Climate Data
Rosenthal	Jacob	*Pamela Clark*	695	SPACE Interactive Tool
Ross	Caitlin	*Dan Duffy*	606	Theoretical Modeling of Exoplanet Atmospheres
Ross	Issac	*Daniel Mandl*	581	Analyzing Plant Fluorescence with Matlab
Roth	Sarah	*David Benson*	597	Low-gravity Investigation of Propellant Slosh [LIPS]
Rothe	Johannes	*Michael McElwain*	667	Instruments and Detectors for Exoplanet Characterization
Saenz	Edward	*Miguel O. Román*	619	Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems
Sample	Omar	*Tammy Tuttle*	760	Next Generation Voice (NVG) Enhancement Project Voice over Internet Protocol (VoIP) Vs. Private Branch Exchange (PBX)
Saripalli	Pratik	*Eric Cardiff*	597	Systems Engineering Support for NEXT PPU
Schaaf	Crystal	*Miguel O. Román*	619	Ultraportable Terrestrial Lidar in Tropical Forest Ecosystems
Schaefer	Caitlin	*Arlindo Da Silva*	610	Using Geostationary, MODIS and OMPS Data to Determine Smoke Injection Heights during the SEAC4RS Field Campaign
Schiewe	Tyler	*Richard Mullinix*	674	SEA^5: Space Environment Automated Alerts & Anomaly Analysis Assistant
Schoenwald	Adam	*Damon C. Bradley*	564	Designing Modular Electronics for Multiple CubeSAT Missions
Serigano IV	Joseph	*Conor Nixon*	693	Instantaneous Mapping of Titan's Daylight-Hemisphere HC3N Using ALMA
Sharp	Alexander	*Darryl Mitchell*	504	Infuse Tech Transfer with NASA Goddard and Abroad
Sharp	Jared	*Herb Frey*	698	Early Impact History of Mars

Intern		*Mentor*	Code	Title
Sheetz	Hannah	*Jacqueline Le Moigne*	580	Earth and Planetary Image Processing for IMAGESEER Database
Shipp	Nora	*Terri Brandt*	661	Exploring Evidence of Cosmic Ray Acceleration in Westerlund 1
Simmons	John	*Dalia Kirschbaum*	617	A Dynamic Model for Rainfall-Triggered Landslides in Central America
Skinner	Charles	*Jim Loughlin*	540	Pressure Vessel Systems Certification
Smith	David	*Carrie Anderson*	693	Software Optimization for Processing and Interpreting Cassini CIRS Titan Data
Smith	Tyler	*Bill Squicciarini*	408	Performance and Characterization of Helicoil Locking Inserts
Sobel	Emily	*Larry Kepko*	674	The Substorm Gordian Knot: Onset Patterns and Frequencies
Soto	Emmaris	*Jonathan P. Gardner*	665	Diverse Galaxies: Clumpy Regions in The UV HUDF at 0.5<z<1.5
Spagnuolo	Vincent	*Donald Kranz*	180	Defining, Categorizing, and Aggregating Adverse Conditions
Speciale	Amanda	*Patrick Coronado*	606	Climate Change: How do we know?
Starr	Michael	*Eric Stoneking*	591	Slosh Modeling for Spacecraft Applications
Stewart	Noel	*Sara Zhang*	601	First-Look Statistics of Precipitation Estimates from the Global Precipitation Measurement (GPM) Constellation Satellites
Steyert	Vivian	*Cory Powell*	542	Improving Temperature-Dependent Honeycomb Panel Modeling Approaches
Stokes	Eleanor	*Miguel O. Román*	619	Holidays from Space: the urban social data embedded in VIIRS NTL signatures
Suriel	Tommy	*Barbara Grofic*	600	Web Forms for the Sciences and Exploration Directorate
Talkington	Samuel	*Frank Blankley*	180	SLS Engines Program Summary
Tallerico	Thomas	*Joe Nuth*	691	Residence Time of H2O in Analog Regolith Samples of a Carbonaceous Asteroid
Tann	Raymond	*Todd Bonalsky*	549	Cellular Controlled Remote Magnetic Observatory

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Taraschi	Peter	*Paul Mirel*	665	Mechanical Design and Construction of the Primordial Inflation Polarization Explorer (PIPER)
Tarnosky	Grace	*Barbara Milner*	583	Goddard Mission Services Evolution Center Wiki
Teeling	Aran P.	*Debbie S. Watson*	763	Technical Writing Internship
Tepper	Julia	*Terry Hurford*	693	Imaging Europa with Clipper
Terry	Sean	*Richard Barry*	667	Detection of Exoplanets Using Microlensing for the Wide-Field Infrared Survey Telescope (WFIRST)
Torres	Jorel	*Ali Tokay*	612	Snowfall Observations at NASA Wallops Flight Facility
Tran	Aaron	*Robert Petre*	662	Particle Acceleration at the Shock of Tycho's 1572 Supernova
Ullom	Laura	*Rick Hess*	180	James Webb Space Telescope JWST Tool Development
Urriste	Jonathan	*Elizabeth Timmons*	587	Accelerated Space Computing
Van Artsdalen	Kathryn	*Shing Fung*	673	Characterizing Magnetospheric States
Vasquez-Garcia	Guillerma	*Umesh Patel*	544	Magnetic Bearings for Space Flight Applications
Voorhies	Sarah	*Elizabeth Park*	472	Testing a Calibrator for an Earth-Imaging Radiometer
Walker	Iman	*Robyn King*	564	Microcontroller Interfacing and Software Programming: Using the ARM MBED Microcontroller
Wang	Thomas	*Richard Harman*	444	ST-5: A Spacecraft Dynamics Simulation
Wang	Xiyu	*Lixa Rodriguez-Ramon*	250	Hazardous Waste Minimization Project
Warner	Katherine	*Frederick Beamer*	180	Comparison of IV&V and MPCV Program Software Testing Environments
Waterman	Dylan	*Stephen Rinehart*	665	The Balloon Experimental Twin Telescope Infrared Interferometry (BETTII): Near-Space, Far-Infrared Astronomy

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Wells-Weitzner	Christopher	*Richard Harman*	444	ST-5: A Spacecraft Dynamics Simulation
Wheeler	Aaron	*Darryl Mitchell*	504	Infuse Tech Transfer with NASA Goddard and Abroad
Wheeler	Anthony	*Darryl Mitchell*	504	Infuse Tech Transfer with NASA Goddard and Abroad
White	Shunafrica	*Matthew Showalter*	547	Mechanical Design of Coronagraph CubeSat
Wildenstein	Fabian	*Dave Leisawitz*	605	Optical Modeling of the Wide-Field Imaging Interferometry Testbed (WIIT)
Wilkins	Jocelyn	*Milton Davis*	596	R/F Board Design for Space Cube in Navigator
Williamson	Tyler	*Jeremy Perkins*	661	Simulation Studies of a Small, Cost-Effective TeV Cherenkov Observatory
Willmot	Kathleen	*Charles Ichoku*	613	Investigating the Link between Biomass Burning and the Water Cycle in Northern sub-Saharan Africa
Wolfe	Isaak	*Darilyn Dunkerley*	180	Technical Quality and Excellence
Wolfe	Michael	*Keith Gendreau*	662	NICER Pointing System
Woodman	Jennifer	*Paul Racette*	550	Slow Down, I'm Not a Scientist: A Field Guide to Science Writing
Woods	Aaron	*Bonnie Seaton*	581	Point Spread Functions in Astronomy
Wright	Alexander	*Bryan Blair*	694	Computation Intensive and Parallel Data Applications Solved with OpenCL
Wu	Lisa	*Keith Gendreau*	662	NICER Pointing System
Yao	Ellen	*Mark Secunda*	546	The Impact of Different Parameters on the Effectiveness of the Nitrogen Purge
Yewer	Tabitha	*Keith Gendreau*	662	NICER Pointing System
Zhao	Kerry	*Guangning Yang*	554	Laser Communications Relay Demonstration Laser Vibration Qualification
Zhu	Frances	*Alvin Yew*	596	NanoSat Star Scanner for Next Generation Precision Attitude Determination
Zink	Jenna	*Yihua Zheng*	674	Space Weather Forecasting: Analyzing the July 8, 2014 Event

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Zoldak	Kimberly	*Judith Racusin*	661	Exploring Biases in the Measurement of Isotropic Equivalent Energies of Gamma-Ray Bursts with the Fermi Telescope