Virginia Space Grant Consortium
Student Research Conference – April 19, 2010
Omni Hotel, Newport News, Virginia

Graduate Research Fellows
Oral Presentations – Amphitheater

Structures and Materials

8:50 a.m. **DEVELOPMENT OF A BIOMIMETIC EXCITABLE CELL USING ELECTRO-ACTIVE POLYMERS**
Christina Haden, University of Virginia

Electro-active polymers are being used to develop a biomimetic excitable gel-cell, through which ion species flow to produce excitability and refractoriness, as found in the biological cardiac myocyte (CM). The artificial gel-cell is composed of a thin ionic gating membrane made of polypyrrole (PPy) sandwiched between two areas of ionic liquid polymer gel (ILPG). ILPG is a soft gelatinous material in which ions are suspended and free to move within a polymer matrix. The PPy membrane, acting as a voltage-sensitive gate, confines ions to the upper chamber of the gel-cell and releases them when activated, just as cardiac cells maintain ion gradients across their membrane until threshold signals for activation are received. The characteristics of excitability and refractoriness found in the CM are thus reproduced in the gel-cell through the interplay of these polymers, including a localized ion sensitive probe and an ionic switch detecting activation thresholds. Thus far, a conceptual design for the artificial excitable cell has been produced. In addition, all components necessary for the artificial cell have been produced, and now need to be tested for functionality within the ILPG. Finally, the artificial cell will be assembled and tested for excitability and refractory period duration.

9:05 a.m. **MULTIFUNCTIONAL SELF-CHARGING STRUCTURES FOR ENERGY HARVESTING IN UNMANNED AERIAL VEHICLES**
Steven Anton, Virginia Tech

The development of small aircraft including unmanned aerial vehicles (UAVs) and micro air vehicles (MAVs) has gained tremendous interest in the research community. One particular area of interest involves creating innovative techniques to increase the flight time or endurance of UAVs and MAVs. Energy harvesting technology presents a potential solution for the improvement of flight times by converting ambient energy into electrical energy that can be used to power the aircraft. An adverse effect of adding energy harvesting capability to small aircraft, however, is the added mass associated with such devices. The performance and efficiency of UAV systems is highly dependent on the mass and aerodynamics of the aircraft. Considering the importance of reducing the total mass addition of energy harvesting systems in UAVs, a multifunctional approach is considered in this research in which a single device can generate and store electrical energy and also carry structural loads. The proposed *self-charging structures* contain both power generation and energy storage capabilities in a multilayered, composite platform consisting of active piezoceramic layers for scavenging energy, thin-film battery layers for storing scavenged energy, and a central metallic substrate layer. The compact nature of the devices allows easier integration into UAV systems and their flexibility provides the ability to carry load as structural members. This paper addresses several aspects of the development and evaluation of the proposed self-charging structures including details of the design, fabrication, evaluation, and strength testing of the devices.

9:20 a.m. **HYDRODYNAMIC PERFORMANCE OF A MANTA RAY INSPIRED OSCILLATING FIN**
Keith Moored, University of Virginia

Myliobatidae is a family of large pelagic rays including the manta ray, *Manta birostris*. They are extremely efficient swimmers, can cruise at high speeds and can perform turn-on-a-dime maneuvering, making these fishes excellent inspiration for an autonomous underwater vehicle. Manta rays have been studied from a biological perspective; however, the hydrodynamic performance of their large-amplitude oscillatory-style pectoral fin flapping is unknown. An experimental robotic flapping fin has been developed. Three different kinematic modes that range from simple and artificial to complex and biologically-based are tested to determine the performance benefits of different kinematic features exhibited by the manta ray. The thrust and efficiency performance are quantified. Span-wise curvature is found to improve efficiency by a factor of two. A flat mode of swimming is found to have higher efficiency for higher swimming speeds. Finally, tip lag is found to neither improve nor degrade efficiency performance. Implications for a bio-inspired artificial pectoral fin are discussed.

9:35 a.m. **THE BUSH PLANE: A SYMBOL OF ALASKAN IDENTITY**
Jennifer Camp, College of William & Mary

Alaska's people and history have been shaped by flight. Alaska, arguably the least-connected state in terms of road transportation, contains some of the busiest airport facilities and has more pilots and aircraft per capita than any other place in the country. The airplane, specifically the bush plane, truly carved the face of the Last Frontier and is still the number one choice for Alaskans who want or need to reach remote villages, coastal towns, or off airstrip gravel bars and hilltops. Overall, the bush plane has become an iconic symbol within Alaska. This project traces its history and evolution in order to illustrate the unique relationships between flying, pilots, and aircraft.

9:50 a.m. **ROBUST CONTROL OF SPINNING TETHERED SATELLITE SYSTEM PENDULAR MOTION**
Joshua Ellis, Virginia Tech

We develop control laws for the pendular motion of a spinning tethered satellite system. The control laws are developed using a simplified system model that contains unknown disturbance terms that account for unmodeled dynamics in the simplified model. Principles of sliding mode and adaptive nonlinear control design are used to develop control laws that drive the pendular motion to a desired reference motion in spite of the effects of unmodeled dynamics. The effectiveness of the control laws is tested by applying them to a much more physically realistic system model than that used in their derivation. In all cases tested, the control laws are successful in controlling the pendular motion of the more physically realistic model about the desired reference motion. The main disadvantage of the control laws is that they require relatively large steady-state control inputs to account for the unmodeled dynamics and hold the pendular motion on the reference motion. Any problems associated with these large steady-state inputs could be avoided by simply turning the control off after the reference motion has been reached and accepting the small deviations from the reference motion due to unmodeled dynamics.

Aerospace

10:40 a.m. RELIABILITY DATA ANALYSIS FOR DESIGNED EXPERIMENTS
Laura Freeman, Virginia Tech

Product reliability is an important characteristic for all manufacturers, engineers and consumers. Industrial statisticians have been planning experiments for years to improve product quality and reliability. However, rarely do experts in the field of reliability have expertise in design of experiments (DOE) and the implications that experimental protocol have on data analysis. Additionally, statisticians who focus on DOE rarely work with reliability data. This talk is an attempt to bridge that divide. We provide a new analysis technique for reliability data from designed experiments. The technique is illustrated on a popular reliability data set. This paper discusses implications of using previous analysis methods versus our new approach to the analysis problem.

10:55 a.m. TECHNIQUES WHICH ASSIST IN IMPROVING THE QUALITY OF SOFTWARE SYSTEMS
Malcolm Gethers II, College of William & Mary

Coupling metrics capture the degree of interaction and relationships among source code elements in software systems. A large majority of coupling metrics in the literature rely on structural information, which shows relations such as usage relations between source code elements (e.g. class, method, etc.). Those metrics lack the ability to identify conceptual relationships, which, for example, specify relationships encoded by developers in identifiers and comments of source code. We propose a new coupling metric for object-oriented software systems, which uses Latent Dirichlet Allocation (LDA), an unsupervised probabilistic topic modeling technique. LDA, a novel Information Retrieval method, identifies latent topics associated with documents (e.g. source code elements). We use similarity of latent topics of documents to measure coupling, thus capturing key conceptual relationships. In order to evaluate our novel metric, we compute both established and our LDA-based coupling metrics on a set of open source software systems. We compare the performance of coupling metrics for impact analysis, an important software maintenance task. While other coupling metrics have been successfully used for impact analysis in the literature, we conjecture that proposed conceptual coupling metric not only provides good accuracy but also identifies relevant source code elements not captured by other coupling metrics.

11:10 a.m. **WAVE EQUATION WITH POROUS NONLINEAR ACOUSTIC BOUNDARY CONDITIONS GENERATES A WELL-POSED DYNAMICAL SYSTEM**

Philip Graber, University of Virginia

We consider a structural acoustic wave equation with nonlinear acoustic boundary conditions. This is a coupled system of second and first order in time partial differential equations, with boundary conditions on the interface. Both a linear and a nonlinear version of the problem are considered. In each case, we prove wellposedness in the Hadamard sense for strong and weak solutions. The main tool used in the proof is the theory of nonlinear semigroups. We present the system of partial differential equations as a suitable Cauchy problem dw/dt = Aw. Though the operator A is not maximally dissipative, we are able to show that it is a translate of a maximally dissipative operator. The obtained semigroup solution is shown to satisfy a suitable variational equality, thus giving weak solutions to the system of PDEs. The results obtained (i) dispel the notion that the model does not generate semigroup solutions, (ii) provide treatment of nonlinear models, and (iii) provide existence of a correct state space which is invariant under the flow--thus showing that the physical model under consideration is a dynamical system. The latter is obtained by eliminating compatibility conditions which have been assumed in previous work (on the linear case).

11:25 a.m. **ON THE DETECTION OF SYMMETRIES IN COMPOSITIONAL MARKOV MODELS**

Ruth Lamprecht, College of William & Mary

A model-based evaluation of a system's design often considers to what degree components need to be available multiple times in order to reach a desired level of availability, reliability or dependability. Multiple components of the same kind then lead to models with regular structures and symmetries. In stochastic models, especially Markovian models, such regularities have been used to establish lumpability results. In this paper, we propose a procedure to detect symmetries in a Markovian model that is built in a compositional manner by sharing state variables. The symmetries give insight into a model and help to achieve a significant state space reduction, which alleviates the effects of the infamous state space explosion problem. The results extend existing work of Obal, McQuinn, and Sanders; in particular, we focus on variables in functional transition rates that commute in order to take additional symmetries into account. The overall approach contributes to Möbius, a multi-paradigm, multi-solution framework for the model-based dependability and performance assessment of systems.

11:40 a.m. **DESIGN AND DEMONSTRATION OF A MINIATURE LIDAR SYSTEM FOR ROVER APPLICATIONS**
Benjamin Robinson, Old Dominion University

A basic small and portable lidar system for rover applications has been designed. It uses a 20 Hz Nd:YAG pulsed laser, a 4-inch diameter telescope receiver, a custom-built power distribution unit (PDU), and a custom-built 532 nm photomultiplier tube (PMT) to measure the lidar signal. The receiving optics have been designed, but not constructed yet. LabVIEW and MATLAB programs have also been written to control the system, acquire data, and analyze data. The proposed system design, along with some measurements, is described. Future work to be completed is also discussed.

2:45 p.m. **A LOW COST FLIGHT TEST TO INVESTIGATE THE EFFECTS OF FACILITY VITIATION**
Michael Smayda, University of Virginia

The Short Duration Propulsion Test and Evaluation (SDPTE) Program and the Hy-V Program have recently been combined with the aim of examining the influence of ground test facilities on scramjet performance. The combined program includes both research and educational activities that are being conducted by a consortium of university, industry and government participants. The objectives of the combined program are to: 1) Resolve ground testing issues related to the effects of test medium on dual-mode scramjet engine performance; 2) Resolve ground testing issues related to the duration of the test flow on dual-mode scramjet engine performance; and 3) Educate and motivate a new generation of aerospace engineers through student participation and research. The program will conclude with a Mach 5 flight experiment of both scramjet flowpaths aboard a sounding rocket such that differences between ground and flight performance data can also be isolated.

3:00 p.m. **DEVELOPMENT OF A ONE-DIMENSIONAL ANALYSIS PROGRAM FOR SCRAMJET AND RAMJET FLOWPATHS**
Kathleen Tran, Virginia Tech

One-dimensional modeling of dual mode scramjet and ramjet flowpaths is a useful tool for scramjet conceptual design and wind tunnel testing. Due to the inherent three-dimensional nature of the physics, most one-dimensional codes such as the Ramjet Performance Analysis Code (RJPA) separate the flow path components into connected control volumes. In the present paper, the addition of a modeling tool that enables more detailed analysis of flow physics within the combustor is developed as part of a MATLAB based model known as VTMODEL. The development of VTMODEL enables analysis of multiple injectors along with multiple analysis stations within a combustor. The model also integrates overall cycle analysis to parameterize physical effects on total thrust and engine performance. Using the functions within the model, components can be easily changed and modified to anchor to wind tunnel data.

3:15 p.m. **INVESTIGATION OF PROPULSIVE DECELERATION JETS ON A MARS SCIENCE LABORATORY AEROSHELL**

Joshua Codoni, University of Virginia

Propulsive deceleration (PD) technologies to slow entry vehicles on Mars, first conceived and tested in the 1970's, is once again a significant research topic to NASA, as currently used Viking technology reaches its limits with the launch of the Mars Science Laboratory (MSL) in 2011. Planar laser-induced iodine fluorescence is utilized to obtain qualitative flow visualization images of single on-centerline and 4-jet peripheral PD jet models in Mach 12 flow. The models are 0.22% MSL frontal body with 0.5 mm jets drilled into the frontal aeroshell of the model. The interactions of PD jets with a Mach 12 freestream flow are visualized with Coefficients of Thrust (C_T) varying from 0.5 to 3.0. It is found that as C_T increases the shock stand-off distance also increases for both model configurations. However, the increase in shock stand-off is less pronounced for the 4-jet case. The results for the single jet model agree with previously collected experimental data from 1971; the bow shock from the PD jet interaction is oblique at lower C_T's and becomes normal as C_T increases. However, data collected for the 4 peripheral jet model demonstrates that the shock stays more normal for the full range of C_T's tested.

3:30 p.m. **EXPERIMENTAL STUDY OF A STRUT INJECTOR FOR CIRCULAR SCRAMJET COMBUSTORS**

Christopher Rock, Virginia Tech

Supersonic combustion is a major challenge in scramjet engine design. Supersonic fuel injection and mixing research contributes to the effort to make the scramjet a viable option to power hypersonic aircraft, economical and reusable launch vehicles, and hypersonic missiles. An experimental study of a strut injector configuration was performed for application to high-Mach-number scramjets with circular combustion chambers. The strut injector has sixteen inclined, round, sonic injectors distributed across four struts within a circular duct. The struts are slender, inclined at a low angle to minimize drag, and have two injectors on each side. The strut injector was experimentally studied under Mach 4, cold-flow conditions using two different molecular weight injectants, helium (molecular weight = 4) and air (molecular weight = 28.97). The primary goal of this study is the refinement of turbulence models for these complex mixing flows. Furthermore, injectant molecular weight has been identified as a parameter of critical importance in the development of the turbulence model upgrades. Experimental data such as presented here will be used to guide the continuing upgrade of turbulence modeling in a closely integrated program.

3:45 p.m. **SPATIAL VARIABILITY OF N OXIDIZING ORGANISMS IN ENGINEERED SYSTEMS**

Joseph Battistelli, University of Virginia

Water is a limiting factor for space exploration. Tidal flow wetlands (TFW) are a viable means of water treatment in space because they have low energy and operations requirements, and a small footprint. TFW in this study are vertical columns, packed with a light-weight shale aggregate (LESA), that fill and drain with water. The fill-and-drain cycles of the TFW create a unique temporal juxtaposition of aerobic and anaerobic phases of microbial growth. This encourages growth of bacteria capable of anaerobic ammonium oxidization (anammox), as well autotrophic and heterotrophic nitrifiers, and denitrifiers. This study will quantify the distribution of organisms responsible for the oxidation of N species and relate it to parameters that can be manipulated to control functioning of TFW. Preliminary research has used fluorescence *in situ* hybridization (FISH) to gain an understanding of the distribution of bacteria within the TFW columns. Bacterial abundance peaked 30 cm below the upper surface of the column packing. This biofilm-rich region of the reactors was comprised of aerobic nitrifying bacteria as well as heterotrophic organisms. Abundance data of different clades of N-processing organisms within our reactors will enhance our understanding of bacterial behavior and enable us to better optimize the TFW.

4:00 p.m. **WATER AS AN EFFICIENT ATOMIC HYDROGEN SOURCE FOR THE EMBRITTLEMENT OF ALUMINUM**
Michael Francis, University of Virginia

Water acts as an efficient source of atomic hydrogen for the embrittlement of aluminum while molecular hydrogen does not. *Ab initio* density functional theory methods are used to investigate the mechanism responsible for hydrogen production via H_2O and H_2 adsorption and decomposition as well as subsequent desorption and ingress. It is found that water substantially outcompetes molecular hydrogen as an atomic hydrogen source as a result of a near zero H_2O apparent activation barrier to dissociation. A simple analytical model for hydrogen entry from a water environment is constructed in which it is demonstrated that there is an effective barrier to hydrogen entry of $E_{effective}=E_{ingress}+½E_{H2O^*\rightarrow OH^*+H^*}-½E_{2H^*\rightarrow H2^*}$.

Graduate Research Fellows
Oral Presentations – James River Room A

<u>Astrophysics</u>

8:50 a.m. **THE PHYSICS OF STATE TRANSITIONS IN BLACK HOLE DISKS**
Jacob Simon, University of Virginia

Accretion disks around powerful black holes in orbit with a companion star appear to undergo state transitions; the accretion rate can drastically change episodically. The underlying mechanism for these state transitions is unclear, but one promising hypothesis is that the strong dependence of the accretion rate through the magnetorotational instability (MRI) on the magnetic Prandtl number (i.e., the ratio of viscosity to resistivity) leads to a thermal-type instability. However, this Prandtl number dependence is still not well-defined as previous studies have focused on a limited set of initial conditions. Via a series of local shearing box simulations, we systematically examine the effects of the Prandtl number on the MRI in the presence of a net azimuthal field, which is a more likely field geometry for accretion disks. We find that the accretion rate depends strongly on the magnetic Prandtl number, and if the resistivity is large enough, the MRI-induced turbulence decays away, leading to no accretion. This work serves as an essential stepping stone to constructing simulations where the viscosity and resistivity are temperature-dependent and are thus controlled by turbulent heating, radiative cooling, and vertical gravity.

9:05 a.m. EXOPLANET DETECTION PROSPECTS WITH LMIRCAM

Jarron Leisenring, University of Virginia

The L/M-band mid-InfraRed Camera (LMIRcam) will image the coherently combined beams of the Large Binocular Telescope's twin 8.4-meter primary mirror, achieving an unprecedented high angular resolution of 26 and 34 milliarcsec (mas) at the respective operating wavelengths of 3.6 and 4.8 microns. The incorporated 1024x1024 Teledyne HAWAII-1RG detector array provides a pixel scale of 10.9 mas per pixel and a field of view of 10 square arcsecs. A suite of broad and narrow-band filters have been optimized for specific applications such as imaging planets around nearby stars, probing dust and ice features around young stars, and detecting atomic gas emission lines from astronomical objects. In addition, LMIRcam will contain grisms for low-resolution spectroscopy, and serve as a test-bed for novel pupil masks to enable high-contrast imaging. The unique opto-mechanical design and anticipated performance provide the capability to detect young warm Jupiters and older "super"-Jupiters around nearby stars as well as characterize protoplanetary disks in unparalleled detail.

9:20 a.m. THE MAGNETOSPHERES OF EXTRASOLAR GIANT PLANETS

George Trammell, University of Virginia

The atmospheres of extrasolar giant planets are subject to high levels of radiation and strong tidal forces from their parent star, and thus represent a unique laboratory to study atmospheric dynamics that is not found within our own solar system. In contrast to previous purely hydrodynamic studies of thermal outflows driven by photoionization heating, we include magnetic and tidal forces for the first time, and we discuss how the modulated wind structure has observational consequences. Our motivation comes from exciting discoveries by NASA’s space-based instruments, most notably those aboard the Hubble Space Telescope (HST). Our work continues to be further motivated by the rapid pace of exciting scientific discoveries (e.g., new exotic planets being uncovered by NASA’s Kepler Mission). The extreme environment of a particular class of extrasolar giant planets with very tight orbits around their host stars (i.e., the “hot Jupiters”) is described, which demonstrates that, along with a new magnetohydrodynamic treatment of dynamics in the upper atmospheres of these planets, allows us to probe an entirely new regime of exoplanet physics.

9:35 a.m. **O_2^+ FROM OVER THE MAIN RINGS INTO THE INNER MAGNETOSPHERE OF SATURN**
Meredith Elrod, University of Virginia

The detection of a stable O_2 atmosphere over Saturn's main rings was one of the first major discoveries of the Cassini mission. The primary source of neutral O_2 for this ring atmosphere was suggested to be due to solar UV photons that produce O_2 by decomposition of H_2O ice particles in the main rings. This process, as well as charged particle radiation, can also produce O_2 from ice grains in the tenuous F and G rings. The O_2 ring atmosphere is very thin to the point of being nearly collisionless with the O_2 primarily interacting with the ring particles, causing changes in the trajectories so that O_2 produced from the optically thick B and A rings diffuses throughout the inner magnetosphere as well as Saturn's atmosphere. Once formed, the O_2^+ ions follow the field lines, collide with the ring particles, and re-neutralize, which effectively limits the ion density. As a result the ion density is seen to be greater over the Cassini Division and the area between the F and G ring, regions with low grain density. This study re-analyzes the ion data from Cassini's orbits in the ring region and compares the resulting ion densities to the neutral sources.

9:50 a.m. **THEORETICAL PREDICTION OF A 443 NM TRANSITION: A POTENTIAL CARRIER OF A DIFFUSE INTERSTELLAR BAND**
Ryan Fortenberry, Virginia Tech

The carriers of the diffuse insterstellar bands (DIBs) is one of the longest standing problems in astronomical spectroscopy. This completely unattributed absorption spectrum stretches from the UV to near-IR and can be seen in multiple interstellar sightlines with the strongest features at 443 nm and 578 nm. Additionally, the number of known features grows with every observation. No known molecular spectra have been comparable to the DIBs as seen in the interstellar medium. It has been hypothesized that the molecular carriers of the DIBs may play a role in many aspects of astrochemistry including the potential for better understanding of the origins of the chemical building blocks of life. The current approach to answering this problem, a form of experimental guess and test, has yet to prove fruitful. The use of chemical theory and computation in answering this problem seems promising due to the ease of molecular creation (simple input of the atomic nuclei and their coordinates), but has been held up by development of the necessary computing capabilities. With state-of-the-art computational techniques we have examined several proposed carriers of the DIBs. In this work, we report on our findings including a molecule that our methods predict to have a strong transition at 442 nm.

10:40 a.m. **SEARCHING FOR EVIDENCE OF PAST PLANET ACCRETION IN THE RAPIDLY ROTATING GIANT STARS**
Joleen Miller-Carlberg, University of Virginia

Rapid rotation in red giant stars may signify a violent past if the unusually large angular momentum was gained through the engulfment of a planetary companion; we explore the feasibility of this spin-up mechanism both theoretically and observationally. By modeling the tidal interaction of known extrasolar planets and their host stars, we have found that many of these exoplanets will indeed be engulfed during future stellar evolution. Furthermore, the orbital angular momentum of these accreted planets is, in some cases, sufficient to cause red giant rapid rotation. Planets accreted during the red giant phase should leave behind a chemical signature in the form of unusual abundance patterns in the host red giant's atmosphere. Proposed signatures of planet accretion include the enhancement of lithium and carbon-12 (which are both depleted in giant stars' atmospheres) and a preferential enhancement of elements with higher condensation temperatures (which are thought to be enhanced in planets themselves). We are performing a chemical abundance analysis of both rapidly rotating and normally rotating red giant stars to look for these expected chemical signatures. Our preliminary results show evidence for an enhancement of the average Li abundance in the rapid rotators when compared to the slower rotators.

10:55 a.m. **UNDERSTANDING THE PHYSICS AND OBSERVATIONAL EFFECTS OF COLLISIONS BETWEEN GALAXY CLUSTERS**

Daniel Wik, University of Virginia

Galaxy clusters, the largest gravitationally bound objects in the universe, form over time from collisions and mergers between clusters and between clusters and smaller galaxy groups. The results of these collisions can be detected in a variety of ways. In one case, I have found that clusters which have recently undergone a merger will have an enhanced Sunyaev-Zel'dovich (SZ) Effect. Another result of these mergers is the acceleration of relativistic particles, which produce non-thermal emission that should be observable in X-rays. In the Coma cluster, the brightest merging cluster in the sky, detections of this emission have been claimed, though these findings are controversial. Using observations of Coma with the Hard X-ray Detector onboard Suzaku, I find no conclusive non-thermal emission and derive an upper limit on the emission that excludes the most recent previous detections. Using data from the Swift/BAT instrument, which is also sensitive to hard X-rays, I reject the hypothesis that the discrepancy is due to the non-thermal emission being extended. Also, I present results on the direct detection of the relative velocity between two equal mass clusters currently undergoing a major merger in the Cygnus A cluster.

11:10 a.m. **EXPLORING THE IONOSPHERE WITH PAPER: THE PRECISION ARRAY TO PROBE THE EPOCH OF REIONIZATION**

Nicole Gugliucci, University of Virginia

The Precision Array to Probe the Epoch of Reionization is a collaborative effort between the University of Virginia, the National Radio Astronomy Observatory, the University of California at Berkeley, the University of Pennsylvania, and SKA South Africa. This array of low frequency radio antennas will be used to detect neutral hydrogen in the universe from a time before it was ionized by the first stars and galaxies. The refractive and sometimes turbulent ionosphere is a challenge for interferometers working at these frequencies. This work will present an update on the ongoing work to characterize the effects of the ionosphere as seen from the PAPER engineering array in the radio quiet zone of Green Bank, West Virginia.

11:25 a.m. **A *SPITZER* SURVEY FOR DUST IN TYPE IIN SUPERNOVAE**
Ori Fox, University of Virginia

The source of the large amounts of dust observed in high redshift galaxies has remained uncertain for nearly 40 years. Despite the success of models in producing dust within supernova explosions, only a handful of supernovae show direct observational evidence for dust condensation, and these examples all yield 2-3 orders of magnitude less dust than predicted by the models. Recent observations suggest Type IIn supernovae may condense more dust than typical core-collapse events. Few Type IIn observations, however, exist. The few dust forming Type IIn supernovae show late-time infrared emission sometimes more than five or six years following their initial detection, making remnant archeology possible. A Spitzer/IRAC follow-up survey of all observable Type IIn supernovae from the past ten years will determine the extent to which this subclass produces dust. Ground-based observations are insufficient. Spitzer/IRAC provides the necessary sensitivity at wavelengths spanning the peak of the blackbody emission from the warmest grains, as well as the tail-end emission from colder dust. I present here a preliminary overview of an ongoing *Spitzer* survey of 71 Type IIn supernovae from the past 10 years.

Planetary Science

2:45 p.m. **DETECTION OF NEARLY SUBVISUAL CIRRUS CLOUDS**
Melissa Yesalusky, Hampton University

This research aims to identify subvisual cirrus (SVC) clouds using remote sensing techniques. These ice clouds tend to transmit and forward scatter the incoming solar radiation. They also act to absorb and therefore reduce, the infrared radiation, which would otherwise exit our atmosphere. These processes play an important role in our weather and radiative climate as their variations modify the radiation balance of our planet. The objective of this study is to validate a technique for detecting SVC and their infrared radiative properties from Earth orbiting satellites. This study utilizes simultaneous and geographically coincident lidar, multi-spectral visible and infrared, and hyperspectral infrared measurements from the CALIPSO, MODIS, AIRS and CloudSat satellite instruments. An assessment of the radiative heating impact of SVC was determined by comparing clear and cloudy fields of view through radiative transfer calculations for typical atmospheric conditions to help identify and quantify the cloud optical properties. Initial findings indicate that the frequency of occurrence of SVC clouds globally is between 2.11 and 4.32%. They are observed more frequently (4.38-8.61%) in the tropics in all case studies. The subtropic and polar regions reveal frequency of occurrences between 0.42-1.13% and 0.59-1.40% respectively.

3:00 p.m. **CHARACTERIZATION OF THE SAHARAN AIR LAYER (SAL) FROM RADIOSONDE AND SATELLITE DATA OVER THE TROPICAL ATLANTIC OCEAN**

Christopher Spells, Hampton University

The Saharan Air Layer (SAL) is a layer of warm, dry, dusty air which normally overlays the cooler, more humid surface air of the Atlantic Ocean. Over the Saharan Desert from late spring to early fall, air moving across the desert becomes warm and dry forming a deep mixed layer in the troposphere. This layer can extend from 1.5-6.0 km in the atmosphere, be traced as far west as the Gulf of Mexico, and is characterized by mineral dust, dry air, and strong winds. The SAL has been shown to help increase vertical wind shear and allow for the entrainment of dry air into a tropical wave, which aids in weakening tropical disturbances. The dry air aloft forbids the moist air along the ocean's surface from rising and condensing to form thunderstorm squalls. Evidence suggests that the SAL was a reason for the lack of tropical storm and hurricane development over the Atlantic during the 2006 hurricane season. Observations from radiosondes, FORMOSAT-3, and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) are examined.

3:15 p.m. **THERMALLY INDUCED ESCAPE: MONTE CARLO SIMULATIONS FOR THE ATMOSPHERES OF PLUTO AND TITAN**

Orenthal Tucker, University of Virginia

Recent models of the atmospheres of both Pluto and Titan estimate large escape rates of the principal atmospheric species in comparison to their respective Jeans theoretical rates. However, these continuum models were applied to the transition region of the atmosphere where the local Knudsen number approaches 1. In particular, the 'slow hydrodynamic escape' model requires assumptions about the thermal conduction, temperature and local speed distributions of atmosphere at the exobase which favors large escape rates. Tucker and Johnson (2009) tested the results of the slow hydrodynamic model in Strobel (2008b) using a Monte Carlo model and concluded that thermal escape of N_2 and CH_4 from Titan and N_2 from Pluto should occur similar to Jeans rate. In this paper, we provide a summary on the DSMC model and current results.

3:30 p.m. **DEVELOPMENT OF THE HAMPTON UNIVERSITY LIDAR SYSTEM AND THE CREST LIDAR NETWORK**

Kevin Leavor, Hampton University

As a remote sensing technique, lidar is a staple of atmospheric measurement techniques. Short-wavelength scattering allows measurements from molecular and particle or aerosol components of the atmosphere. These features are of particular importance to studies of weather, climate, and the underlying radiative transfer processes that drive them. Furthermore, these quantities or the scattering processes themselves may be linked to other quantities, such as temperature, which can then yield dynamic and thermodynamic information about atmospheric layers, such as the planetary boundary layer, and the general atmosphere. Hampton University, in order to further knowledge and understanding of the atmosphere, air quality, climate, and lidar techniques, continues to make lidar measurements of aerosols and clouds, but has also added rotational Raman temperature sensing to its list of capabilities. Furthermore, its steps to develop and join a network of similar lidar stations in the United States and the rest of the world have advanced into a regime of simultaneous measurements between a number of stations. Finally, an automated satellite observation program for tracking volcanic emissions is presented to showcase the possibilities of combining measurements from multiple satellites with ground-based measurements.

3:45 p.m. **CONTINENTAL SCALE VALIDATION OF A DYNAMIC FOREST MODEL WITH REMOTELY SENSED SATELLITE IMAGERY**

David Lutz, University of Virginia

The Russian boreal forest is one of the largest terrestrial biomes on the planet and its behavior has significant consequences for global and regional climate, the Russian economy, and the global carbon cycle. Ecological forest models have successfully been applied to investigate how forests will respond to changes in climate and disturbance. In order to make projections about the future of Russian forests, a fine-scale dynamic forest model FAREAST was run and tested throughout the country under a variety of climate and disturbance scenarios. To validate this model output, remotely sensed data derived from satellite imagery was used as a comparison with the results of FAREAST model runs. Baseline model output was matched with an empirically derived forest biomass product for nearly 33,500 sites at various year-steps of model functioning. This model output was also compared to a MODIS leaf area index product for the same sites. After removing disturbed and immature stands from the analysis, model biomass output and the remotely sensed product were comparable, albeit with a lower r^2 than expected. This error was likely a result of the difficulty in comparing stands with unknown ages. The leaf area index comparison fared much more favorably, signifying high accuracy of the FAREAST model to ground conditions. The results of this study suggest that the FAREAST model is fit to model Russian boreal and temperate forests on a continental scale with acceptable accuracy for the scientific community.

4:00 p.m. **DIKE EMPLACEMENT AND HYDROTHERMAL PROCESSES ON MARS**

Kathleen Craft, Virginia Tech

Many features on the surface of Mars indicate that water contributed to their formation. Hydrothermal salt deposits and mineral hydrates discovered on Mars by the rovers Spirit and Opportunity at the plateau, Home Plate (Squyers et al., 2008), provide evidence that subsurface water from hydrothermal systems may have played a role in surface feature formation. Here we investigate hydrothermal systems on Mars by emplacing a dike below the surface and analyzing the stresses surrounding it as it propagates to the surface. We then relate the stresses to change in permeability and discuss future work. Results from our initial models show that horizontal stresses surrounding the dike are on the order of 10^5 to 10^6 Pa for a range of Young's modulus (E) of 10^9 to 10^{11} Pa. These stresses correspond to changes in permeability of 1.0068 for E =

10^{11} Pa and crack aspect ratio (ε) = 10^{-2} to about 27 for E = 10^9 Pa and ε = 10^{-3}. Therefore, dike emplacement increases permeability adjacent to the dike. Further research will determine the resulting flux from the increased permeability and will relate this flux to feature formation. Additionally, an overlying ice layer will be investigated to determine fluid flux contribution to the system.

Graduate Research Fellows
Oral Presentations – James River Room B

Applied Physics

8:50 a.m. **PATTERN CLASSIFICATION TECHNIQUES FOR THE ULTRASONOGRAPHIC PERIODONTAL PROBE**
Crystal Bertoncini, William & Mary

Periodontal disease, commonly known as gum disease, affects millions of Americans. The current method of detecting periodontal disease is painful, invasive, and inaccurate. As an alternative to manual probing, the ultrasonographic periodontal probe is being developed to use RF ultrasound waveforms to measure periodontal pocket depth, which is the main measure of periodontal disease. The methods employed use wavelet transforms and pattern recognition techniques to develop artificial intelligence routines that can automatically detect pocket depth. Results with pattern classification showed that as much as 86.6% of the periodontal pocket depths can be predicted within the manual probe's 1mm tolerance. Applying ultrasound to dentistry in this way is useful for long-term flight situations in the space industry. The same techniques have been applied to several other applications, including using dental ultrasonography to detect cavities in the hard tissue of teeth, indicating flaw severity in pipes, and predicting seismic activity in mines.

9:05 a.m. **DEVELOPMENT AND EVALUATION OF THE TIME-RESOLVED HEAT AND TEMPERATURE ARRAY**
David Hubble, Virginia Tech

The development and evaluation of a differential style heat flux gauge is presented. The sensor is constructed from spot-welded foils of copper and constantan on either side of a thin Kapton® polyimide film and is capable of measuring the heat flux and surface temperature at ten locations simultaneously. Analytical modeling was performed to estimate the sensor's sensitivity and time response. Calibrations were performed in conduction, convection, and radiation yielding an average heat flux sensitivity of 210 $\mu V/(W/cm^2)$. Time response measurements were also performed which gave an average first-order time response of 169 milliseconds. The capabilities of the sensor are demonstrated by showing its use in on-going convection research.

9:20 a.m. **USING DATA FUSION AND WEB MINING TO SUPPORT FEATURE LOCATION IN SOFTWARE**
Meghan Revelle, College of William & Mary

Software maintenance is the process of modifying a software system after its initial development and deployment. Software systems undergo changes for a variety of reasons such as to fix problems, to improve performance, to add new functionalities, or to adapt the system to a new environment. The software maintenance process is often triggered by a bug report or a feature request. Bug reports typically describe problems related to incorrect system behaviors or functionalities. These program behaviors or functionalities are known as *features*. In the literature, a feature is more formally defined as "a requirement of a program that a user can exercise and which produces an observable behavior." For instance, an example of a feature from a web browser is the ability to save a bookmark to a web page. As another example, features of a word processor include the abilities to spell-check and print a document. Since many maintenance tasks are initiated by bug reports, and most bug reports are expressed in terms of features, it is the goal of this work to support software maintenance tasks at the feature-level. This work focuses on two software maintenance activities in particular: feature location and impact analysis.

9:35 a.m. **OPTICAL SECOND HARMONIC GENERATION IN A WHISPERING GALLERY MODE RESONATOR**
Matthew Simons, College of William & Mary

We are developing high quality factor whispering gallery mode resonator (WGMR) disks for use in quantum information experiments. Our polished lithium niobate disks can achieve a quality factor on the order of 10^7. We report the use of Type-I noncritical phase matching in a lithium niobate whispering gallery mode resonator disk to produce optical second harmonic generation at $\lambda = 532$nm. This process can be used to create both squeezed light and a single photon source, which are important steps toward quantum memory scheme.

9:50 a.m. **SENSOR DEVELOPMENT: LEARNING FROM NATURE**
William Eberhardt, University of Virginia

Biological hair fluid motion sensors can be found in a variety of animals such as arachnids, insects, crustaceans, fish, and mammals. These sensors display a wide range of geometrical sizes and dynamical characteristics affecting their sensitivity depending on their purpose. This paper compares vibrissae (whiskers) of a California sea lion and a harbor seal. The vibrissae of each specie are unique in its form and function, demonstrating differing material properties and reactions when placed in a free stream flow and in the presence of a wake.

10:40 a.m. **UNDERSTANDING AND IMPROVING PERFORMANCE IN MULTIHOP WIRELESS MESH NETWORK COMMUNICATION SYSTEMS**

Jonathan Backens, Old Dominion University

As the demand for flexible non-homogeneous wireless communication systems increases, there remain significant challenges in achieving optimal network performance. With varying number of communicating nodes, configurations and highly fluctuating spectrum conditions, we seek to provide a decentralized method for approaching optimal system performance. We are motivated by the reduction in performance traditional cognitive wireless networks face as they increase in number of nodes and have greater variance in inter-node spacing. Therefore we apply the theoretical techniques from non-cooperative game theory combined with the capabilities found in cognitive radio devices to develop a more optimal solution which avoids needing to have a centralized spectrum and rate allocation method. In addition we develop new metrics for wireless mesh network performance based on individual traffic demand and fairness. Our improved DRWF algorithm improves network fairness by an order of magnitude and while better meeting individual node traffic demands. Finally, we discuss various implications multihop mesh structures have on wireless network performance.

10:55 a.m. **A STUDY OF CHARGE TRANSPORTATION AT ORGANIC/ METAL OXIDE INTERFACES IN BULK HETEROJUNCTION SOLAR CELLS**

Patrick Boland, Jr., Old Dominion University

Charge carrier transport within bulk heterojunction organic solar cells has been simulated with the goal of extending the insights gained to analysis of transport between organics and metal oxides. In turn, this information will be applied to the metal oxide/metal electrode interfaces. Recent discoveries have shown that optimizing interfaces between the various layers in organic solar cells serves to improve overall device power conversion efficiency. Metal oxides can be a beneficial component when included within devices as they can improve spectral absorption, facilitate carrier transport, and have unique energy bandgap properties that make conduction between cell layers more energetically favorable. With the knowledge gained thus far, our group has begun expanding our simulation methods as they apply to metal oxide/organic interfaces. The focus of this report is to describe current understanding of oxide/organic interfacial characteristics.

11:10 a.m. **ADVANCED COMMUNICATIONS SPECIFIC EMITTER IDENTIFICATION**

Corey Miller, College of William & Mary

Radio Frequency Identification (RFID) tags are used to track inventory and for automatic recognition of ID cards and passports. Reproduction of the electronic equivalent of an FID chip, commonly known as RFID cloning, is a straightforward process and can lead to serious security breaches. A cloned RFID badge can allow for unauthorized access to secured areas. Specific Emitter Identification (SEI) uses unintentional modulations of the electromagnetic signal of RF

emitters to identify individual sources of signals, and allows for the detection of cloning of RF chips. A method for determining a spoofed RFID tag from the original RFID tag based on SEI is presented here. Features are extracted using the Dynamic Wavelet Fingerprint (DWFP) and supervised pattern classification techniques are used to identify the unique RFID tags.

11:25 a.m. **REMOTE SATELLITE AMPLIFIER PREDISTORTION USING THE INDIRECT LEARNING ARCHITECTURE**

Jakob Harmon, University of Virginia

Power amplifiers (PAs), an integral component to most wireless communication systems, are inherently nonlinear devices that introduce out-of-band spectral intermodulation to the amplifier output, which can exceed regulatory limits. One solution is to operate the PA in a highly backed-off state to achieve quasi-linear performance. Operating in this region requires a higher-saturated power rating for a given output power and reduces DC-to-RF efficiency. A more effective, low-cost solution is to apply digital predistortion which pre-compensates for the harmful nonlinear effects. A common framework for identifying the predistortion system is known as the indirect learning architecture. Typically this predistortion architecture is applied to accessible ground-based systems, i.e. a cell base station or wireless repeater. The objective of this study was to develop an architecture to apply predistortion remotely to inaccessible PAs on-board orbiting communication satellite systems, such as the NASA developed Tracking and Data Relay Satellite System (TDRSS). Several complications arise when attempting predistortion remotely including uplink/downlink additive noise, signal accessibility, and time-varying satellite round-trip delay which are not encountered when predistorting accessible amplifiers. Several techniques are introduced and simulated to solve these unique challenges to remote predistortion.

11:40 a.m. **A WHISKER-LIKE ARTIFICAL SENSOR FOR FLUID MOTION SENSING**

Jonathan Stocking, University of Virginia

This research aims to develop a whisker-like artificial fluid motion sensor capable of detecting both fluid direction and velocity for use in hydrodynamic wake detection and tracking. Our current design utilizes a cone-in-cone capacitive sensing mechanism attached to a 4 cm rigid whisker used to detect and transduce fluid motions. Numerical and finite element modeling of the design demonstrated the feasibility of such a mechanism and predicted capacitive changes of 1-2 pF for flows of up to 1.0 m/s. Experimental characterization of the fabricated whisker showed a significant performance improvement over the predicted behavior. In particular, the typical capacitor quadrant showed a resting signal nearly 6 pF higher than predicted and a range of up to 3 pF. In fact, one quadrant showed a resting capacitance nearly 7 pF higher than predicted and a range of up to 8 pF, owing to its slightly off-center position and thus smaller initial gap size. The experimental validation showed the sensor’s excellent discriminatory ability for both flow direction and magnitude under steady flow conditions.

2:45 p.m. **ULTRASOUND SIGNAL PROCESSING AND MODELING FOR AUTOMATED MEDICAL MONITORING**
Cara Campbell, College of William & Mary

My research focuses on the use of ultrasound for medical monitoring applications. Two projects that I will discuss are ultrasonic bladder distention monitoring and emboli removal from cardiopulmonary bypass circuits. In the first topic, ultrasound signal processing methods are used to relate raw ultrasound signals to bladder fullness. Clinical tests have been completed to collect relevant bladder distention data. Further clinical data must be collected to develop adequate bladder fullness algorithms. The second topic involves the implementation of complicated acoustic force models in order to optimize ultrasonic emboli removal in the operating room. Our modeling results show that experimental optimization of a removal system can be based on a simple inviscid fluid model. The techniques we have developed can be applied to various other applications. I will briefly discuss the application of acoustic processing algae for the production of algal biofuels. Algal processing requires not only acoustic force models, but also the investigation of multiple scattering via 3D acoustic finite integration simulations.

3:00 p.m. **QWEAK: A SEARCH FOR NEW PHYSICS, REGION 3 VERTICAL DRIFT CHAMBER PROGRESS REPORT**
John Leckey, College of William & Mary

The standard model of particle physics has been quite successful in the description of the electromagnetic, weak nuclear, and strong nuclear sectors of particle physics; however, it is known to be insufficient to completely describe nature. Qweak is an upcoming experiment at Thomas Jefferson National Accelerator Facility (JLAB) that will use high precision electron proton scattering to measure the weak nuclear charge of the proton. The measurement of the weak coupling will allow the effective probing of the 1.5 to 2.5 TeV region that is believed to contain new physics. To ensure accuracy, there will be tracking devices throughout the full apparatus to measure the positions and trajectories of the scattered electrons. The tracking device that will be further detailed in this report is known as a vertical drift chamber (VDC). All 5 of the VDCs have been built and tested and the resulting data will be presented.

3:15 p.m. **INVESTIGATION OF FLOW EFFECTS AND EXTINCTION LIMITS OF ETHYLENE- AND METHANE-AIR COUNTERFLOW DIFFUSION FLAMES**
Brendyn Sarnacki, University of Virginia

Fundamental flame characteristics derived from counterflow flames are routinely used in chemical kinetic model optimization and validation. This paper reports an experimental investigation aimed at characterizing the extinction conditions of low extinction strain rate methane-air flames and high-extinction strain rate ethylene-air flames and identifying the sources of uncertainties associated with such characterizations. In the experiments, convergent nozzles with exit diameters of 7.95mm were used to inject non-premixed fuel and air to establish a planar flame in the counterflow mixing region. Velocity profiles and extinction data were measured using an LDV setup. Experiments were conducted at various separation distances to investigate potential differences in axial velocity profiles along the axial and radial directions and the corresponding local extinction strain rates. The slope of axial velocity in the axial and radial directions at the air outlet boundary was found to increase with decreasing separation distance. The variation of local extinction strain rate with changes in separation distance was within the uncertainty of experimental data.

Structures and Materials

3:30 p.m. MODELING BILAYER SYSTEMS AS ELECTRCIAL NETWORKS
Austin Creasy, Virginia Tech

Two of the main components of cell membranes are lipids and proteins. Lipids are the passive structure of the membrane that acts as a barrier between the inner and outer portions of the cell. Proteins are the active structure of the membrane that allows signaling, energy conversion, and open channels between the inner and outer portions of the cell. Artificially made membranes, called bilayers, can be made from natural or artificial membrane components at the interface of aqueous volumes. The lipids of the membrane act electrically as a small conductor and capacitor in parallel where the measured capacitance is related to the area of the bilayer. Some proteins act electrically as an additional conductor in parallel to the lipids with varying conductance properties depending on the specific protein. A large system with multiple aqueous volumes and multiple bilayers made of just passive membrane components can be modeled as an electrical network of resistors and capacitors. The addition of proteins to this network increases the complexity of the system model because the proteins usually do not act as a linear conductance and numerical methods are used to approximate what is happening in the system. This paper shows how a system of multiple aqueous volumes and multiple bilayers can be modeled as a system of first order odes, numerically solved, and then compared to the published results of a similar system.

3:45 p.m. IN SITU HIGH TEMPERATURE HEAT FLUX SENSOR CALIBRATION
Clayton Pullins, Virginia Tech

Recent advances in heat flux measurement have resulted in the development of a robust thermopile heat flux sensor intended for use in extreme thermal environments. The High Temperature Heat Flux Sensor (HTHFS) is capable of simultaneously measuring thermopile surface temperature and heat flux at sensor temperatures up to 1000°C. The need for high temperature heat flux calibration of the HTHFS has resulted in the development of a new wide angle radiation calibration system, which operates with the sensor at elevated temperatures. The temperature dependence of the sensor output over the range of 100°C to 900°C has been successfully characterized with acceptable uncertainty limits. The calibrated HTHFS sensitivity agrees well with a theoretical sensitivity model, suggesting that the primary cause for the sensor's output temperature dependence is due to the change in thermal conductivity of the sensor elements with temperature.

4:00 p.m. **RECENT DEVELOPMENTS IN THREE DIMENSIONAL RADIATION TRANSPORT USING THE GREEN'S FUNCTION TECHNIQUE**

Candice Rockell, Old Dominion University

In the future, astronauts will be sent into space for longer durations of time compared to previous missions. The increased risk of exposure to dangerous radiation, such as Galactic Cosmic Rays and Solar Particle Events, is of great concern. Consequently, steps must be taken to ensure astronaut safety by providing adequate shielding. In order to better determine and verify shielding requirements, an accurate and efficient radiation transport code based on a fully three-dimensional radiation transport model using the Green's function technique is being developed.