Structures and Materials

8:50 a.m.  SELF-HEALING BIOLOGICAL MOLECULES FOR USE IN ENGINEERING MATERIALS  
Austin Creasy, Virginia Tech

Phospholipid molecules are one of the fundamental building blocks of cell membranes in many living organisms. These molecules are amphipathic with two hydrophobic fatty acid chains (tails) linked to a phosphate containing hydrophilic group (head) by a glycerol molecule. A bilayer lipid membrane (BLM), which is two phospholipid molecules thick, is 6-10 nm thick membrane and can be used to seal a porous material that has water on both sides. This paper presents how a specific phospholipid, 1-Stearoyl-2-Oleoyl-sn-Glycero-3-Phosphocholine (SOPC), is used to seal a single square aperture (25 x 25 μm) of a silicon substrate. The phospholipids self-assemble into organized structures in the presence of water and will form a bilayer across the aperture when deposited on the aperture and substrate and inundated in water. Mechanical failure is induced using a pressure gradient across the substrate and the amphipathic nature of the phospholipids reconstructs the failed BLM and seals the aperture, introducing the concept of a self-healing biological molecule. This paper will also present testing done on a BLM formed using a method called the Droplet Interface Bilayer (DIB). This method uses water droplets placed in oil to form a monolayer of phospholipids around the droplets. Once the monolayer is formed around the droplet, a bilayer can be formed by connecting two droplets.

9:05 a.m.  BIOMOLECULAR NETWORKS FOR NOVEL PROTEIN-POWERED ACTIVE MATERIALS  
Andy Sarles, Virginia Tech

Biological molecules, including phospholipids and proteins, offer scientists and engineers a diverse selection of materials to develop new types of active materials and smart systems based on ion conduction. The inherent energy-coupling abilities of these components create novel kinds of transduction elements. Networks formed from droplet-interface bilayers (DIB) are a promising construct for creating cell mimics that allow for the assembly and study of these active biological molecules. The current-voltage relationship of symmetric, “lipid-in” droplet-interface bilayers are characterized using electrical impedance spectroscopy (EIS) and cyclic voltammetry (CV). “Lipid-in” diphytanoyl phosphatidylcholine (DPhPC) droplet-interface bilayers have specific resistances of nearly 10 MΩ·cm² and rupture at applied potentials greater than 300 mV, indicating the “lipid-in” approach produces higher quality interfacial membranes than created using the original “lipid-out” method. The incorporation of phospholipids into the droplet interior allows for faster monolayer formation but does not inhibit the self-insertion of transmembrane proteins into bilayer interfaces that separate adjacent droplets. Alamethicin proteins inserted into single and multi-DIB networks produce a voltage-dependent membrane conductance and current measurements on bilayers containing this type of protein exhibit a reversible, 3-4 order-of-magnitude conductance increase upon application of voltage.
9:20 a.m.  NOVEL PIEZOELECTRIC ENERGY HARVESTING DEVICES FOR 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. Adding the necessary components to perform energy harvesting can, however, add a significant amount of mass to the aircraft, which often have small payload capacities. The additional mass can hinder the performance of the aircraft and, in fact, result in a decreased overall endurance. A novel concept is presented in this paper involving the combination of piezoelectric devices and new thin-film battery technology to form multifunctional self-charging, load-bearing energy harvesting devices for use in UAV systems. 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. A potential application of the self-charging structures is use in the wing spars of UAVs or as the entire wing of an MAV. This paper addresses several aspects of the development and experimental evaluation of the proposed self-charging structures. Details of the design and fabrication of the self-charging structures and appropriate energy harvesting circuitry are given. Results of experimental testing to evaluate the energy harvesting performance of the devices under harmonic loading are also presented.

9:35 a.m.  ARTIFICIAL INTELLIGENCE ALGORITHMS FOR THE ULTRASONOGRAPHIC PERIODONTAL PROBE
Crystal Bertoncini, College of William and 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 show 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.

9:50 a.m.  WETTING LAYER FORMATION OVER ALUMINUM AND RELEVANCE TO HYDROGEN EMBRITTLEMENT
Michael Francis, University of Virginia

Ab initio density functional theory methods are used to analyze the energetics and structure of water over aluminum. Inserting energetics calculated here and elsewhere into a kinetic Monte Carlo to simulate all water vapor chemistry, it is determined that wetting layer formation occurs around 1% relative humidity. This water pressure is coincident with experiments showing changes in the slope of crack growth rates with water partial pressure at around 1% relative humidity. These results combined suggest that above 1% relative humidity wetting layer chemistry is activated and below water vapor chemistry. It is found at pressures before wetting layer onset, water adsorbs in the form of water clusters and not in grains of water wetting layers. In these calculations in which coadsorbates and defects were not considered, no uptake is predicted, suggesting the critical role these effects have in generating hydrogen entry.
**DEVELOPMENT OF A COMPRESSED CARBON DIOXIDE PROPULSION UNIT FOR NEAR-TERM MARS SURFACE APPLICATIONS**

Erin Blass, Old Dominion University

This work has focused on the development of a reusable rocket propulsion system for near term Mars surface applications by utilizing Mars atmosphere as a propellant source. Mars atmosphere is more than 95% carbon dioxide and its low ambient temperatures mean that it is relatively easy to condense dry ice out of the atmosphere. Furthermore, the low critical temperature of carbon dioxide enables the production of a supercritical fluid by heating dry ice at constant density to temperatures only slightly higher than terrestrial ambient temperatures. The goal of this research is to develop a supersonic nozzle for reusable high-thrust propulsion. Due to the complex behavior of supercritical carbon dioxide gas, it is not possible to use the standard linear method of characteristics for nozzle design, via the ideal gas-based, Prandtl-Meyer function. Instead, a Method of Characteristics (MOC) for isentropic axisymmetric flow of a real gas has been used to develop the streamline contour of a supersonic nozzle. The boundary layer that develops along the wall of the nozzle is also taken into consideration and then combined with the non-ideal gas method of characteristics to complete the supersonic nozzle design. A Mach 2 nozzle design has been selected because it is possible to achieve relatively high (though modest) specific impulse over longer durations before predicted performance degrades due to recondensation of carbon dioxide.

**OXYGEN IN THE ATMOSPHERE OF SATURN’S RINGS AND INNER MAGNETOSPHERE**

Meridith Elrod, University of Virginia

The main rings and the ice grains in the tenuous F and G rings are a source of O$_2^+$ ions for the inner magnetosphere (Tokar et. al 2005). These ions are formed from neutral O$_2$ through the decomposition of ice by incident radiation (Johnson et. al 2006). As the principal source of O$_2^+$ ions is from the ionization of the neutral O$_2$ molecules through photo-ionization and electron interactions, O$_2^+$ becomes a marker for the radiation induced decomposition of ice and the presence of O$_2$ neutrals. Recently, Martens et. al (2008) described O$_2^+$ beyond the orbit of Enceladus, noting the possibility that Rhea is a source. Here, we focus on O$_2^+$ inside the orbit of Enceladus. Through simulations of the neutral cloud created by photo-induced decomposition of the ice in the main rings and the tenuous F and G rings (Johnson et. al 2006, Tseng et. al 2008) it is possible to calculate the column density of the neutrals and the O$_2^+$ source rate in the inner magnetosphere. Using the Cassini Plasma Spectrometer (CAPS) data, we describe the density of the O$_2^+$ ions from the rings out to the orbit of Enceladus. The largest source of O$_2$ neutrals is expected to be the main rings. However, here we examine whether or not the energetic ion irradiation of grains in the F and G rings are significant sources of O$_2$ and if ion-neutral reactions in the Enceladus plume are a possible source.

**THEORETICAL AND COMPUTATIONAL STUDIES OF INTERSTELLAR C$_{2n}$H AND SiC$_{2m+1}$H**

Ryan Fortenberry, Virginia Tech

This work focuses on computation of simulated spectra in the C$_{2n}$H family (n = {1, 2, ...,}) of carbon chain radical molecules and their silicon analogues, SiC$_{2m+1}$H (m = {0, n}), that are potential carriers of the Diffuse Interstellar Bands (DIBs). High-level quantum chemical computations for the ground- and excited-states of these radicals indicate agreement with experimental data that the ground-state of C$_2$H is $^2\Sigma^+$ while that of C$_6$H, SiCH, SiC$_3$H, and SiC$_5$H is $^2\Pi$. On the other hand, most of the theoretical models employed in this work indicate that the ground state of C$_2$H is $^2\Pi$, in disagreement with previous spectroscopic interpretations. Simulations of the electronic spectrum of the short chains considered here exhibit a strong $\pi\rightarrow\pi^*$ transition that is too high in energy for these chains to be carriers of any of the DIBs, though longer chains remain viable candidates.
SEARCHING FOR EVIDENCE OF PLANET ACCRETION IN RAPIDLY ROTATING K GIANT STARS
Joleen Miller, 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 Li and $^{12}$C (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.

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 detection. Finally, I present preliminary results on the direct detection of the relative velocity between two equal mass clusters currently undergoing a major merger in the Cygnus A cluster. The geometry and thermal structure of the clusters agree well with the merger scenario hinted at by previous observations of the thermal gas and the galaxy velocity distribution.

Aerospace Systems

PROGRESS REPORT FOR HY-V SOUNDING ROCKET PROJECT
Matthew Bitzer, Virginia Tech

The Hy-V Sounding Rocket Project is a collective effort of four senior design teams from the Departments of Mechanical and Aerospace Engineering at Virginia Tech to design, build, test, and fly a scramjet on a sounding rocket. After three years of preliminary design work, a complete system design is coming closer to a reality. The Mechanical Engineering Senior Design Team (MESD) is nearing the completion of a full scramjet flow path design. This includes an inlet, a shock isolator, a combustion chamber, an ignition system, a control system, a fuel system, and a nozzle. The Aerospace Engineering team will complete two tasks by the end of May. The first task is to design a system that will test scramjet instrumentation, including attitude, pressure, and temperature sensors, on a sounding rocket as part of the RockSat...
program. The second task is to complete a preliminary design of an airframe around the MESD flow path. The scheduled completion date for the project is Spring 2011.

9:05 a.m. SENSOR MODELING AND FLOWS OVER A FROZEN WAVEFORM
William Eberhart, 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 focuses on a cantilever beam hair-like sensor capable of detecting disturbances in a flow field. Such sensors are imbedded in an often turbulent boundary layer and must provide useful information concerning the external flow field. Numerical modeling of the sensor under imposed flow oscillations is investigated. An examination of both turbulent and laminar boundary layer flows over a fixed frozen waveform of varying amplitude has been performed.

9:20 a.m. EVIDENCE THEORY AND FAULT TREE ANALYSIS TO COST-EFFECTIVELY IMPROVE RELIABILITY IN SMALL UAV DESIGN
Justin Murtha, Virginia Tech

Inexpensive small unmanned aerial vehicles (SUAVs) are plagued by alarmingly high failure rates. Because the systems are small and built at less cost than their full-scale counterparts, redundancy and high fidelity modelling is often sacrificed for cost savings. This paper addresses this problem and proposes a process to “design-in” reliability in a cost-effective way. Fault Tree Analysis is used to evaluate a system’s (un)reliability and Dempster-Shafer Theory (Evidence Theory) is used to deal with large amounts of uncertainty in failure data. Finally, sensitivity analyses highlight the most cost-effective improvement for the system.

9:35 a.m. EXPERIMENTAL STUDIES OF INJECTOR ARRAY CONFIGURATIONS 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. Two cylindrical injector array models were developed which represent state of the art scramjet combustion chambers. One model uses an array of fuel injectors distributed around the wall of a circular duct whereas the other model uses an array of injectors distributed across four struts within a circular duct. The two injector models were experimentally studied to assess performance and mixing behavior. The experiments were conducted at a freestream Mach number of 4 using helium as the injectant to safely simulate hydrogen fuel. Experimental results for the flush-wall injector model showed a reasonable rate of mixing, but modest penetration of the injectant across the combustor cross-section resulting in a substantial region of pure air along the duct centerline. Experimental results for the strut injector model showed good penetration of the injectant, but the rate of mixing was somewhat slow. This experimental data will be used to upgrade turbulence modeling and quantify the uncertainty of CFD predictions used for scramjet engine design.

9:50 a.m. STEREOSCOPIC PARTICLE IMAGE VELOCIMETRY MEASUREMENTS FOR SCRAMJET ENGINE DEVELOPMENT
Chad Smith, University of Virginia

Measurement of the three-component velocity field inside the combustor section of a scramjet would significantly improve the understanding of this complex flow. Unfortunately, no instantaneous, three-component, spatially resolved velocity measurements in scramjets during fuel combustion are reported in the literature. Three-dimensional Particle Image Velocimetry (3DPIV) is an optical measurement technique that is capable of determining three-components of velocity simultaneously with virtually no impact on the flowfield. 3DPIV has the additional capability of providing instantaneous or time-averaged velocity measurements. In recent years, work has been conducted to apply the 3DPIV technique to the
scramjet combustor facility at the University of Virginia. Particle Image Velocimetry has been used to obtain instantaneous three-component velocity measurements in a scramjet combustor. Some background of the 3DPIV technique and the experimental assembly are presented along with information about the supersonic combustion facility at UVa. Measured 3D velocity fields and some plots derived from these measured velocity fields are presented. The data obtained shows successful implementation of the 3DPIV technique to the scramjet combustor at the University of Virginia.

10:40 a.m.  AVIATION IN THE LAST FRONTIER
Jennifer Camp, College of William & Mary

The image of a Piper Super Cub or a de Havilland Beaver on a glacier, or with rugged mountains as a backdrop, has become iconic within Alaskan culture and identity. There are very few places in which aviation is so tightly integrated into society. Alaska has more pilots per capita and more aircraft per capita than any other place in the United States; but despite the importance of aviation within the state, little anthropological or archaeological research has been conducted on this topic. By examining the cultural, social, and material aspects associated with flying in this distinct area of the world, this research creates a more complete understanding of aviation within the social history of the Alaskan frontier.

10:55 a.m.  PARTICLE IMAGE VELOCIMETRY AND COMPUTATIONAL FLUID DYNAMICS STUDY OF A DUAL-MODE SCRAMJET INLET NOZZLE
Jason Howison, University of Virginia

Stereoscopic particle image velocimetry (PIV) data near the exit plane of an overexpanded Mach 2 nozzle have been collected. The flow created by this nozzle is used as an inlet flow for ground-based testing of a dual-mode scramjet (DMSJ) combustor. This flow characterization serves as a means of quantifying the upstream boundary conditions in the DMSJ isolator and supporting CFD validation efforts. The PIV results were compared with CFD calculations conducted at NASA Glenn Research Center using the Wind-US Reynolds-averaged Navier-Stokes (RANS) solver. Only PIV results in the core flow upstream of the oblique shock waves were deemed valid due to particle tracking issues associated with the shock waves. The CFD results were within the experimental uncertainty for some areas of the core flow, but the CFD did not capture the saddle-shaped structure of the velocity field apparent in the PIV results. Underprediction of the boundary layer thickness and sparse data of the temperature field upstream of the nozzle, which was used to define the boundary conditions in the CFD, were deemed likely causes for the disagreement. The turbulence intensity within the core flow was found to average 9% using an ensemble of the instantaneous PIV data.

11:10 a.m.  A HYBRID METHOD FOR MEASURING HEAT FLUX
David Hubble, Virginia Tech

This paper reports on the development and evaluation of a novel hybrid method for obtaining heat flux measurements. By combining spatial and temporal temperature measurements, it is shown that both the time response and accuracy of a heat flux sensor can be improved. This hybrid method was shown to increase the time response of a heat flux sensor mounted on a high conductivity material by a factor of 28 compared to a standard spatial sensor. Furthermore, this analysis allows the heat flux sensor to be much less sensitive to the material to which it is mounted. It was shown that changing the thermal conductivity of the backing material four orders of magnitude caused only an 11% change in sensor error. This method is validated both numerically and experimentally and demonstrates significant improvement compared to operating the sensor as a spatial or temporal sensor alone.
11:25 a.m.  OPTIMIZATION OF NONLINEAR UNSTEADY AERODYNAMIC DYNAMIC TESTING
Brianne Williams, Old Dominion University

NASA Langley Research Center (LaRC) and Old Dominion University (ODU) Department of Aerospace Engineering are collaborating to develop a methodology for dynamic modeling of aircraft using wind tunnel measurements. Aircraft experience unsteady and nonlinear aerodynamics that are currently misunderstood and difficult to model mathematically. NASA LaRC has developed the hardware for a dynamic test rig for using the NASA Langley 12-foot Wind Tunnel (LaRC 12-FT WT). However, software development has been fraught with difficulty. Currently the software is being worked on by a NASA engineer. The software will be uploaded, bench tested, and implemented on the larger scale dynamic rig (DR) in the LaRC 12-FT WT. Concurrently, ODU is working on a model simulation of the DR in order to determine possible sources of error in the rig. The second objective is to leverage the power of Design of Experiments (DOE) and Response Surface Methodology (RSM) to exercise, validate, and examine the sources of error on the DR. These methods will also allow for optimization of the rig to be conducted. The final objective is to develop a general dynamic test modeling method for an aircraft using the DR and ultimately using a DOE/RSM approach to develop the necessary empirical models of aircraft unsteady aerodynamics.

Structures and Materials

11:40 a.m.  CORROSION FATIGUE CRACK PROPAGATION AND INHIBITION IN Al-Zn-Mg-Cu VS Al-Cu-Mg/Li ALLOYS
Jenifer Warner, University of Virginia

Age-hardenable aluminum alloys used in aerospace structures are susceptible to environment-assisted fatigue crack propagation (EFCP), limiting component durability and safety. The objective is to quantitatively understand EFCP and its inhibition for important aerospace alloys: 7075-T651 (Al-Zn-Cu-Mg), 2024-T3 (Al-Cu-Mg), and 2090-T8 (Al-Cu-Li). EFCP is understood through the hydrogen embrittlement mechanism (HEE) where crack tip dissolution creates H which is absorbed and promotes fatigue damage accumulation at a crack tip. For full immersion in aqueous chloride solution, crack growth rate (da/dN) typical of this mechanism is independent of loading frequency (f) or increases with decreasing f. This is observed for 7075; but for 2024 and 2090, the opposite behavior is seen: decreasing da/dN with decreasing f. The 2000 series dependence is similar to 7075 when the crack growth inhibitor molybdate (MoO$_4^{2-}$) is added to chloride solution. MoO$_4^{2-}$ effectively inhibits EFCP in 7075-T651; understood by MoO$_4^{2-}$ promoting crack tip passive film formation, reducing H uptake. MoO$_4^{2-}$ inhibition increases with decreasing f which acts to increase crack tip passive film stability. Therefore, 2000 series aluminum alloys are capable of self inhibition and a metallurgical difference must be present between 2000 and 7000 series allowing for inhibition in 2000 series alloys without passive inhibitor addition.

Graduate Research Fellows
Oral Presentations – Theater

Planetary Science

8:50 a.m.  IMPROVING SOFTWARE TESTING THROUGH CODE PARSING
Carl Arrington, Hampton University

A common technique in completing software tests is the design and implementation of test cases, detailed procedures that test particular features and aspects of the software. Testers are often required to have extensive understanding of the function or technology being tested. This research seeks to achieve better testing results by developing a testing application for the AIM Advanced Data Search tool that emphasizes the development of test cases only from the comments within the program. Code comments and documentation are structured to model the Doxygen code documentation syntax. The comments are
parsed and organized to allow the test developer to design tests based on code documentation without having to look at the source code. This allows developer and tester independence by eliminating the necessity of the tester requiring access to, and understanding of, the source code to develop tests. The tests therefore promote organized and more detailed code documentation from the developer.

9:05 a.m.   DEVELOPMENT OF THE HAMPTON UNIVERSITY LIDAR SYSTEM AND THE REALM LIDAR NETWORK
Kevin Leavor, Hampton University

Lidar offers a plethora of information on atmospheric aerosols and chemical constituents. However, lidar systems typically work in vacuums, applied to specific applications, such as validation efforts, and with little collaboration with other institutions. In order to alleviate these limitations, the Hampton University lidar has made steps to join the Crest Lidar Network (originally the REALM lidar network) and greatly increase its measurement capabilities. Frequent, coincident measurements with the CALIPSO lidar are made with the aid of an orbital overpass predictor. Meanwhile, regular measurements of water vapor mixing ratio over Hampton University using a rotational Raman technique have been added to the lidar’s repertoire. Furthermore, strides toward adding rotational Raman temperature sensing have been taken as well. The Hampton University lidar system aims to gather information on the development, motion, and interaction of aerosol, water vapor, and cloud systems to better describe the atmospheric system as a whole.

9:20 a.m.   A STUDY OF AIR QUALITY IN THE SOUTHEASTERN HAMPTON-NORFOLK-VIRGINIA BEACH REGION WITH AIRBORNE LIDAR MEASUREMENTS AND MODIS AOD RETRIEVALS
Jasper Lewis, Hampton University

A study of air quality was performed using a compact, aircraft aerosol lidar designed in the Science Directorate at NASA Langley Research Center and MODIS aerosol optical depth (AOD) retrievals. Five flights of lidar measurements conducted in the Hampton-Norfolk-Virginia Beach region showed complex regional aerosol distributions. Comparisons with MODIS AOD at 10x10-km and 5x5-km resolutions show good agreement with correlation R-squared values of 0.82 and 0.88, respectively. Linear regressions of PM2.5 and AOD within the range of 5-40 μg m⁻³ and 0.05-0.7 result in R-squared values ~0.71 and ~0.82 for MODIS and CAL respectively. The linear regressions reflect approximately 54 μg m⁻³ to 1 AOD. These relationships are in agreement with previous findings for air pollution aerosols in the eastern US and in northern Italy. However, large vertical variation is seen case by case with planetary boundary heights ranging between 0.7 and 2 km and uncertainties between 0.1 and 0.4 km. The results of the case studies suggest that AOD can be used as an indicator of surface measurements of PM2.5 but with larger uncertainties associated with small aerosol loading (AOD <0.3).

9:35 a.m.   INFLUENCE OF SAHARAN AIR LAYER (SAL) ON THE DEVELOPMENT AND INTENSITY OF ATLANTIC HURRICANES
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 and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) are examined.
DETECTION OF NEARLY SUB-VISUAL CIRRUS CLOUDS IMPACT ON THE SPECTRAL DISTRIBUTION OF THE INFRARED RADIATIVE COOLING OF THE ATMOSPHERE

Melissa Yesalusky, Hampton University

This research aims to look at the identification of subvisual cirrus clouds (SVC) using remote sensing techniques. These ice clouds tend to transmit and forward-scatter the incoming solar radiation, they act to absorb, and therefore greatly reduce, the infrared radiation which would otherwise exit our atmosphere. These processes play an important role in our weather and climate as they modify the radiation balance of our planet. The objective in this study is to validate a technique for detecting the infrared radiative properties of SVC from Earth-orbiting satellites. This study utilizes lidar, multi-spectral visible and infrared, and hyperspectral infrared measurements from the CALIPSO, MODIS and AIRS satellite instruments concurrently. An analysis 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 optical properties. Initial findings indicate that the majority of SVC and thin cirrus clouds are located in the tropics with low effective emissivity and optical depth values while lower level clouds are observed more frequently at higher emissivity values.

Applied Physics

ULTRASOUND SIGNAL PROCESSING FOR AUTOMATED MEDICAL MONITORING

Cara Campbell, College of William and Mary

Ultrasound is a safe, non-invasive technique that can be used in various medical applications to improve patient quality of life. In this paper we discuss the current status of two ultrasound-based medical projects. The techniques we are developing can in the future be applied to medical monitoring in rural or space settings. Urinary incontinence affects a large percentage of the population. We are developing a wearable ultrasound device that can measure bladder fullness and alert the wearer or caretaker of the need to void. We have collected ultrasound data from a phantom bladder and are planning in the near future to collect data from human subjects. The data will be used to develop algorithms that can detect bladder fullness in real-time. Increased embolic load to the brain is a concern in high-altitude flight, deep water diving, and open heart surgery. Acoustic radiation force can be used to push emboli out of the blood flow path. We are currently developing simulations to accurately model acoustic radiation force on spherical emboli in a viscous fluid. These models will be used to help establish an experimental technique for efficient emboli removal.

QWEAK – A SEARCH FOR NEW PHYSICS

John Leckey, College of William and 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).

GREEN’S FUNCTION TECHNIQUE FOR RADIATION TRANSPORT IN THREE DIMENSIONS

Candice Rockell, Old Dominion University

In the near future, astronauts will be sent into space for longer durations of time compared to previous missions. The radiation that they will be exposed to, which includes Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE), are of great concern to the health and wellness of these astronauts. A study
of the mathematics behind radiation transport through shielding materials will be described in this paper where the equation of interest is the Boltzmann equation. In order to solve this equation, a few modeling assumptions are made. We will make use of the straight ahead approximation for the primary beam in which it is assumed that after an initial interaction of particles occurs, the fragments produced continue to move in the same direction as the primary ion. Additionally, we will use the continuous slowing down approximation in the final representation of the Boltzmann Equation. We will then be able to effectively turn the Boltzmann equation into a Volterra integral equation, which will be solved by the Neumann series method. This solution consists of a series of Green's functions. We will be addressing the Zero Order Green's function in this paper, which models the primary flux of the particle. Future work will include investigating the rest of the Neumann Series where a non-perturbative approximation will be used.

11:25 a.m. **AN EXPLORATORY STUDY ON ASSESSING FEATURE LOCATION TECHNIQUES**
Meghan Revelle, College of William and Mary

This paper presents an exploratory study of ten feature location techniques that use various combinations of textual, dynamic, and static analyses. Unlike previous studies, the approaches are evaluated in terms of finding multiple relevant methods, not just a single starting point of a feature's implementation. Additionally, a new way of applying textual analysis is introduced by which queries are automatically composed of the identifiers of a method known to be relevant to a feature. Our results show that this new type of query is just as effective as a query formulated by a human. We also provide insight into situations when certain feature location approaches work well and then they fall short. Our results and observations can be used to guide future research on feature location techniques that will be able to find near complete implementations of features.

11:40 a.m. **CLUSTER CALCULATIONS OF NUCLEAR MAGNETIC RESONANCE CHEMICAL SHIELDING IN PIEZOELECTRIC SOLID ALLOYS**
Daniel Pechkis, College of William and Mary

High performance piezoelectric materials are expected to play an important role in the next generation of sensors and actuators, used for example, in aircraft for active vibration and noise control. Piezoelectric materials can transform mechanical to electrical energy (and vice versa). Piezoelectric properties are related to a material's local structure. For example, B-site alloys with the perovskite structure ABO3 such as Pb(Zr,Ti)O3 and Pb(Mg,Nb)O3 have extremely different piezoelectric characteristics. Nuclear magnetic resonance (NMR) has been shown to be a sensitive experimental probe of the local structure, but it is difficult to interpret the measurements without theoretical modeling. I will demonstrate first-principles quantum mechanical calculations of chemical shielding can accurately predict oxygen NMR full chemical shielding tensor for the prototypical perovskites BaTiO3 and SrTiO3. We then report comparisons of the O and Ti isotropic shielding component for PbTiO3, PbZrO3, and for the 50/50 alloy Pb(Zr1/2Ti1/2)O3 where only NMR powder spectra are available. The δiso(O) values are relate to variations in the Ti-O and Zr-O bond lengths and used to interpret recent experimental measurements.

**Graduate Research Fellows**
**Oral Presentations – Cyber Lounge**

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**Astrophysics**

2:45 p.m. **THE BIRTH OF SUPER STAR CLUSTERS**
Amy Reines, University of Virginia

Super star clusters (SSCs) are the most extreme star forming environments in the local universe. Packed with massive stars, these clusters have a major impact on the energetics and morphology of galaxies. Massive stars ionize the interstellar medium and power the infrared radiation of dust and their stellar winds and supernovae release mechanical energy that can trigger further star formation. In addition, the
most massive and dense SSCs are the likely progenitors of ancient globular clusters. For all of these reasons, there is wide-spread interest in the birth and evolution of SSCs. The goal of my research is to improve the current understanding of SSC formation and early evolution by combining observations of starburst galaxies spanning the radio to ultraviolet wavelength regimes. This work capitalizes on the unique capabilities of the Hubble and Spitzer Space Telescopes and the Very Large Array to probe the gaseous and dusty sites of star formation at high resolution.

3:00 p.m.  EXPLORING EXTINCTION AND STRUCTURE IN THE MILKY WAY DISK
Gail Zasowski, University of Virginia

The interstellar dust permeating our home galaxy, the Milky Way, strongly affects astronomical observations and creates difficulties for studies of the Galaxy on both large and small scales. Our ability to accurately characterize both the large-scale structure of the Galaxy, and the smaller regions embedded within it, relies on our knowledge of the intrinsic nature and distribution of the intervening dust. In this project, we measure the effects of dust as a function of position within the Galaxy, and we find hitherto unknown variations that suggest a more complex and variable interstellar environment than previously assumed. We are developing a technique that uses these findings to obtain simultaneous, robust distance and extinction information towards individual stars. When this technique is applied to large infrared stellar catalogs, the enormous quantity of data produces two- and three-dimensional Galactic structure maps with high angular and spatial resolution and good signal-to-noise ratio. The newly-discovered extinction variations and the improved stellar and dust maps will explore such diverse and crucial questions as, e.g., the location of spiral arms, the chemical gradient of the Galactic disk, and the kinematics of stars and interstellar gas clouds.

3:15 p.m.  STATE TRANSITIONS IN BLACK HOLE X-RAY BINARY DISKS
Jacob Simon, University of Virginia

In order to investigate the mechanism for state transitions in black hole X-ray binary disks, we have proposed a series of local shearing box simulations. These simulations will systematically examine the impact of various physical effects on the MRI-driven angular momentum transport in these disks. In particular, nonzero viscosity and resistivity and their ratio, the magnetic Prandtl number, have been shown to have a strong effect on the angular momentum transport. Previous studies have focused on a limited set of initial conditions. We expand on these initial conditions in this paper in order to gain a deeper understanding of exactly how viscosity and resistivity affect the accretion flow. We find that for a purely azimuthal magnetic field configuration, which is more applicable to real accretion disks, the angular momentum transport depends strongly on the resistivity, but is nearly independent of the viscosity. 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.

3:30 p.m.  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 Curtin University in Western Australia. 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. We have been using a prototype array in Green Bank, West Virginia, which has expanded from eight to sixteen antennas this year. This larger array presents new calibration challenges and opportunities, including a look at the impact of the ionosphere on our astronomical observations. I plan to expand the Green Bank array to longer baselines in the near future to further this exploration and aid in making a catalog of the sky at our telescope's receiving frequencies around 150 MHz.
Structures and Materials

2:45 p.m. DEVELOPMENT OF A BIOMIMETIC EXCITABLE MEDIA TUBE PUMP USING IONIC FLUID POLYMER GEL
Christina Haden, University of Virginia

The purpose of this research is to create a biomimetic excitable medium using synthetic polymers based on the characteristics of an actual excitable cardiac myocyte. The heart is a highly efficient biological pump composed of millions of electrically excitable cells that contract in unison to send blood throughout the body. These excitable cells, known as cardiac myocytes, were the inspiration for this project, which consists of producing artificial excitable polymer-based cells which will ultimately combine to form a synthetic tissue capable of electrical and mechanical wave propagation. The development of such an artificial excitable medium has never been done before and the possible applications for its development are very broad – including the creation of peristaltic tube pumps. We propose to achieve this goal using electroactive polymers in combination with electrodes to drive and control the flow of ions within an artificial polymer gel cell. The polymer cell consists mainly of ionic fluid polymer gel (IFPG), a medium which mimics the intra and extracellular spaces in vivo by being rich in mobile ions. Although several different ions are available in living cells, our setup only uses potassium cations as a tracer ion. The incorporation of an electroactive polymer gating membrane called polypyrrole (PPy) allows for the control of ion flux within our cell, and electrodes made from polymers filled with carbon nanotubes provide electrical fields to direct the ions to flow, thus reproducing the cellular characteristics of excitability, refractoriness and resting state. The preliminary work for a novel synthetic excitable cell has been demonstrated. We have shown the conceptual design of the cell, the ability to deposit PPy onto bucky gel as well as the incorporation of carbon nanotubes into PPy to increase its gating speed. More experiments on the feasibility of each component are currently underway.

3:00 p.m. DESIGN, CALIBRATION, AND IMPLEMENTATION OF A HIGH TEMPERATURE HEAT FLUX SENSOR (HTHFS) FOR HYPersonic FLIGHT RESEARCH
Clayton Pullins, Virginia Tech

Recent advances in heat flux measurement have produced a robust thermopile heat flux sensor intended for use in hypersonic flight research. The High Temperature Heat Flux Sensor (HTHFS) is capable of operation at sensor temperatures up to 1050°C with simultaneous measurement of thermopile surface temperature and heat flux. Customization of the sensor design allows implementation in a broad range of measurement scenarios. Output temperature dependence up to 600°C is calibrated with a new tabletop radiation system, ensuring accurate output with the sensor placed in either cold wall or hot wall boundary conditions.

3:15 p.m. DEVELOPING A MORPHING FIN FOR A BIOMIMETIC UNDERWATER VEHICLE
Keith Moored, University of Virginia

Myliobatidae is a family of large pelagic rays including cownose, eagle and manta rays. 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. A synthetic pectoral fin, similar to the fins of myliobatoid rays, is being developed using a tensegrity structural foundation. A tensegrity structure is a truss-like structure composed of cables and struts that only has a stable shape from an imposed state of pre-stress in the structure. Actuation strategies for these contemporary structures have been identified. Theoretical models have been developed to be able to design structures using any of the actuation strategies. Specifically, the models investigate pre-stress states, mechanisms, stability, actuation response and loading response of the structures. Using the identified actuation
strategies, tensegrity beams have been fabricated that can replicate the deformations of myliobatoid rays. The fabricated structures are compared to the theoretical models.

3:30 p.m. **CPG CONTROL OF A TENSEGRITY MORPHING STRUCTURE FOR BIOMIMETIC APPLICATIONS**
Thomas Bliss, University of Virginia

Rhythmic movements associated with animal locomotion are controlled by neuronal circuits known as central pattern generators (CPG). These biological control systems appear to entrain to the natural frequencies of the mechanical systems they control, taking advantage of the resonance of the structure, resulting in efficient control. The ultimate goal is employing these controls in a biomimetic autonomous underwater vehicle so as to capture, and possibly improve upon, the performance capabilities of animals like the manta ray. To this end, this paper investigates the CPG control of a simple tensegrity structure using a reciprocal inhibition oscillator (RIO). The dynamics of a tensegrity structure are linearized about a nominal configuration, and a synthesized RIO is used as the control input. The method of harmonic balance is used to verify the robustness of entrainment. Simulations are used to verify entrainment.

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**Aerospace Graduate Research Fellows Oral Presentations – Theater**

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**Applied Physics**

2:45 p.m. **CHARACTERIZATION OF SIMULATED MARTIAN ATMOSPHERIC ENTRY PLASMA**
Dereth Drake, Old Dominion University

During entry into the Martian atmosphere, the friction between the surface of a spacecraft and the atmosphere will cause thermal ionization of the surrounding air. The plasma parameters associated with this Martian atmospheric entry plasma vary considerably depending on the spacecraft’s trajectory. We evaluated the probable range of these parameters using the existing Martian atmospheric data and recorded spacecraft trajectories. Comparison to the existing simulations will be presented. As an alternative method, a desk-top supersonic flow apparatus is devised for the study of aerothermodynamic and chemical properties of a simulated Martian atmospheric gas (SMAG). We performed detailed laboratory measurements of the excited-species populations in the supersonic flow of weakly ionized SMAG. A cylindrical cavity was used to sustain a discharge in SMAG in the pressure range of 100-600 Pa. A stationary acoustic shock wave was generated by an oblique solid body. Excited state populations of Ar were measured using absolute emission spectroscopy. Comparison of the data was made in a model free flow and across the shock front. The gas and electron temperature were determined from the CO rotational spectra and Ar spectra, respectively. A comparison between the simulations and the experimental results will be presented.

3:00 p.m. **SPATIAL DISTRIBUTION OF AUTOTROPHIC NITRIFYING MICROORGANISMS IN ENGINEERED REACTOR SYSTEMS**
Joseph Battistelli, University of Virginia

Water is a limiting factor in space exploration. Biological systems such as Aerobic Rotating Membrane Systems (ARMS) are eloquent means of water resource regeneration. Bacteria involved in this reactor are identified using fluorescent in situ hybridization (FISH). Distribution of organisms is examined in relation to dissolved oxygen gradients within the reactor. Bacteria within the ARMS are capable of up to 70% conversion of ammonia to nitrate.

New research is now being conducted in benchtop tidal wetland reactors to determine the benefits of this low-yield, low-energy reactor capable of complete nitrogen removal from wastewater. Sequential filling and draining of tidal wetland reactors provides both anoxic and aerobic phases. Simultaneous
nitrification, denitrification, and COD removal are observed in these reactors. Previous research has determined the predominance of heterotrophic nitrifiers and ammonia oxidizers under certain conditions. The presence of anaerobic ammonia oxidizing (ANAMMOX) bacteria is consistent with results under other conditions.

FISH will be used to identify nitrogen cycling bacteria within bench top columns. Benchtop column research will determine the presence of novel nitrogen cycle bacteria such as ANAMMOX. Research within these reactor systems will not only quantify nitrogen-processing bacteria and examine their spatial distribution and but also determine optimum operating conditions for these organisms.