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Physical Sciences Department **News**

Engineering Physics Space Physics Astronomy & Astrophysics

2018 - 2019

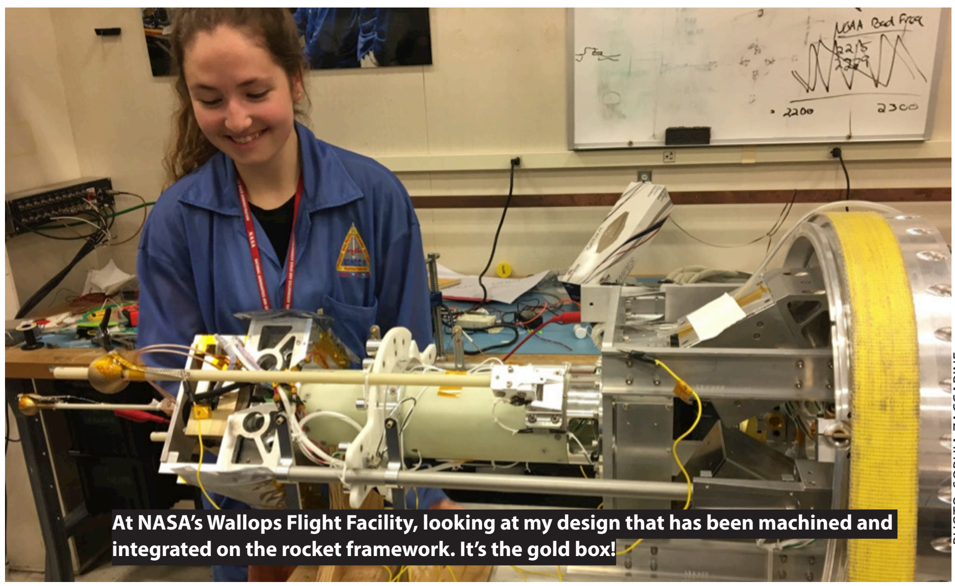
Applying Engineering Physics at NASA

EP student prepares for rocket launch with team from NASA's Goddard Space Flight Center

Sophia A. Zaccarine

NASA's Goddard Space Flight Center is the largest organization in the United States of scientists and engineers studying Earth, the sun, our solar system and the universe. Within Goddard there are four main branches of science; Heliophysics, Astrophysics, Planetary Physics, and Earth Science. Home to 10,000 employees combining civil servants and contractors, some of the most famous projects developed and worked on at Goddard are the James Webb Space Telescope, the Hubble Telescope, the Parker Solar Probe, the Curiosity rover, MAVEN, Cassini, and Juno.

I first started working at NASA Goddard the summer after my sophomore year of my undergraduate degree in the Heliophysics division, and have since completed two summer internships and a fall co-op. Heliophysics is the study of how our Sun affects our solar system. I met my NASA mentor, Dr. Douglas Rowland, when he visited Embry-Riddle to give a talk about his work through the PS Department colloquium series (students – take advantage of the amazing speakers we host in our colloquium series!). He is the principal investigator of a team that includes my ERAU mentor Prof. Zettergen.



At NASA's Wallops Flight Facility, looking at my design that has been machined and integrated on the rocket framework. It's the gold box!

PHOTO: SOPHIA ZACCARINE

The work we do concerns ion outflow from the atmosphere of the Earth; when energized coronal mass ejections are released from the sun, they interact with the earth's magnetosphere, causing an influx of energy resulting in a "boiling off" phenomenon of Earth's atmosphere. By learning how our atmosphere interacts with our sun, we will hopefully be able to better understand the atmospheres of other bodies in space such as Mars or exoplanets, to interpolate what happened to their atmospheres to make them unlike Earth. Additionally, understanding our magnetic system helps us protect all of the assets we have in orbit and beyond. Astronauts,

Continued on back page

Student Research

Probing lunar emissions
Recent graduate Sarena Robertson (BSAA '18) together with doctoral student Dona Kuruppuaratchi (BSSP '11, MSEP '15) , graduate student Margaret Gallant (BSEP '16), BSAA student Christina McFarland and PS professor Mierkiewicz presented a poster entitled "High-Resolution Spectroscopic Observations of Potassium Emissions in the Lunar Exosphere" in National Harbor, MD at the January 2018 meeting of the American Astronomical Society.

Fusion sciences/plasma physics Internship
BSAA student Grant Johnson spent the Spring 2018 semester and all of summer 2018 at Lawrence Livermore National Laboratory where his research involved theory and simulation of the physics of plasmas interacting with solids. The results directly contribute to ongoing efforts to create an energy profitable magnetic fusion reactor known as a Tokamak.

Monitoring Mars with MAVEN

Continued on next page

Research *continued*

EP Ph.D. student Andrea Hughes gave a talk and presented a poster on "Variations in Martian Proton Aurora as observed by MAVEN/UVS" at the Coupling, Energetics and Dynamics of the Atmospheric Regions (CEDAR) meeting in Santa Fe in June 2018. Also presenting at CEDAR was alumna Margaret Gallant (BSEP'16) on "Comparisons of Diurnal Asymmetry in Observed Geocoronal Balmer Series Intensity and Modeled Line-of-sight intensities using model atmospheres". Both students are working with Prof. Mierkiewicz.

Student wins 1st place on Discovery Day

BSAA student David Pequeen's poster "Characterizing Giant Exoplanets through Multi-wavelength Transit Observations" based on research from his Research Experience for Undergraduates (REU) at the University of Wyoming won 1st place at ERAU's Discovery Day in April .

Thermospheric wind speeds probed by REDDI

Robert Kallio (MSEP '18) successfully defended his master's thesis entitled "Recommissioning REDDI: Reviving a Doppler Asymmetric Spatial Heterodyne (DASH) Spectrometer" under the direction of Prof. Mierkiewicz. REDDI is the REd-line DASH Demonstration Instrument. REDDI precisely measures thermospheric wind speeds by measuring the doppler shift of the red line of neutral oxygen (wavelength 630 nanometers) REDDI is part of the the INSpIRe (Investigating Near-Space Interaction Regions) trailer.

Chair's Message

Greetings, Earthlings! It is my privilege to welcome you to the newest issue of the PS Newsletter. We're into our first semester as this is being written and it's shaping up to be a very busy year. First, we welcomed our largest incoming class ever, over 70 engineering physics, space physics and astronomy/astrophysics majors! Many of you already know the Department is the most research-active department on campus. We reached another high-water mark this year: over $12 million in active competitively awarded research grants. Most of these projects involve undergraduate students. Many of our students also win prestigious research internships at national labs. Case in point: see the article about Sophia Zaccarine's experience at NASA Goddard Space flight Center on page 1. Congratulations to our 2017-8 undergraduate Outstanding Scholar awardees: Sergei Bilardi, Matt Caixiero Maxx Miller, and Sarena Robertson (page 7) and to our newest Ph.D. recipient, Dr. Meghan Burleigh (page 6). We also welcomed three new faculty members this year: Dr. Bryan Armentrout, Dr. Matthew Haffner (see page 3), and Dr. Katherine Moran. Finally, have a look at page 7 to see what space physics alumnus Bunty Shah is up to. If you're one of our EP, SP or AA alumni, we'd love to do a profile of you, too in a future issue. Meanwhile, keep in touch on our Department's FaceBook page, OK? One last note--this newsletter can only touch a few of the high points. I hope you will come visit us sometime soon to see more of what is going on here these days. If it's been a while since you were here last time, you will hardly recognize the place!

Students study spaceflight dynamics in Germany

Dr. Anthony Reynolds took 10 students to Munich during the Summer A 2018 semester as part of ERAU's study abroad program. In addition to classwork, the group took many fields trips in and around Munich. Participating students included SP students Dan Williams and Ben Byrd and EP student Peter Douglass.

Physical Sciences Department **News**

A newsletter of the Physical Sciences Department

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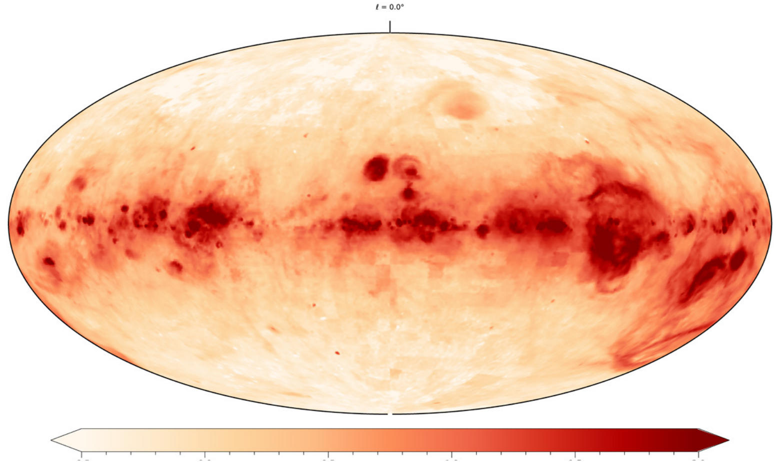
“Surprisingly, scientists have discovered that H-alpha can be seen in every direction in the sky”

PHOTO: CREDIT: MATT HAFFNER



GRAPHIC:MATTHEW HAFFNER

Warm hydrogen gas pervades the disk of our Milky Way Galaxy. The WHAM instrument brings this gas in to focus

Haffner brings WHAM! to ERAU!

New professor studies gases between the stars

Interstellar and Galactic Correspondent

For those of us in the northern hemisphere, Orion is one of the most recognizable constellations in the winter sky. The middle “star” that makes up his sword is actually not a star at all, but one of the brightest nebulae in our sky, Messier 42 (M42). There, intense ultraviolet and X-ray radiation from nearby hot stars is ionizing the abundant hydrogen gas throughout the nebula, separating electrons from their proton nuclei. But the attraction between the charged particles often brings them back together again. As the hydrogen atom reforms, it emits a distinctive pattern of light at very specific colors. One of these red “spectral lines” is known as Balmer-alpha or H-alpha. Whenever we see H-alpha emission from interstellar gas, we know it is being ionized by some source of energy.

Surprisingly, scientists have discovered that H-alpha can be seen in every direction in the sky—not just near hot stars like in M42. Our eyes, and many traditional astronomical instruments, are just not quite sensitive enough to see it. For over 20 years, Dr. L. Matthew Haffner has been studying this diffuse ionized gas throughout our Galaxy, the Milky Way. He joined the Department of Physical Sciences this fall as an Assistant Professor of Physics and Astronomy.

While Dr. Haffner’s astrophysical interests include the interstellar medium, Galactic structure, and the evolution of spiral galaxies, his research efforts have focused on characterizing the distribution, conditions, and environment of diffuse ionized gas. For the past 14 years, he has been the principle investigator of the Wisconsin H-Alpha Mapper (WHAM) project, an astronomical facility tailored to observe any faint light spread out across the sky. WHAM is so sensitive, it routinely detects H-alpha emission more than 10 million times fainter than M42. Dr. Haffner and colleagues used this unique facility from Arizona and Chile over the last two decades to study our local universe, the solar system, and even the Earth’s atmosphere. Their work has been funded primarily by a series of awards from the National Science Foundation.

As a graduate student at the University of Wisconsin, Dr. Haffner designed software to make WHAM one of the first remotely-controlled observatories in the mid-1990s. His team operated the facility from Wisconsin while it was located on Kitt Peak in Arizona and completed a northern-sky survey of the Galactic H-alpha emission in about 18 months.

Unfortunately, the whole Galaxy can’t be seen from just the northern hemisphere. So in 2009, Dr. Haffner and his team moved WHAM from Arizona to Cerro Tololo in Chile. While there, it has been able to finish the survey of the whole Galaxy. Now with the full-sky survey in hand, the team has a three-dimensional perspective of the ionized gas throughout the Galaxy.

Although WHAM continues to produce great data for research projects today, it is lagging behind other surveys in one important aspect. The size of the “pixels” in a WHAM map are one-degree in diameter—twice the diameter of the full moon. Dr. Haffner is looking forward to designing and building a new instrument at Embry-Riddle, opening a new era of sharper views of the diffuse ionized gas.

Lab News

Space Physics Research Lab (SPRL)

Global Navigation Satellite Systems (GNSS), such as the Global Positioning System (GPS), provide essential services for multiple industries, such as the financial services sector, the military, and the aviation industry. GNSS signals when passing through the ionospheric structures experience fluctuations known as phase and amplitude scintillation. In the most severe cases a GNSS receiver may lose lock on the signal. A study of ionospheric scintillation can reveal information of the ionospheric irregularities, their occurrence, formation and relation to the geomagnetic storms, and their impact on navigation.

Dr. Kshitija Deshpande and her team of students have two GNSS receivers (Novatel-GPStation6) deployed in the SPRL lab collecting data since June 2017. These receivers are capable of measuring low rate, high rate (50Hz) phase and amplitude scintillation as well as total electron content (TEC) measurements.

One of these receivers was relocated to Clemson to take measurements during the total solar eclipse on 21 August 2017. We noticed no scintillation relating to absence of irregularities during totality, a dip in the TEC and comparable values to those modeled using an ionospheric model by University of Michigan (GITM). Physics minor Nick Gachancipa (photo above) at Clemson University with our GNSS antenna on the roof of Kinrad Hall. After Nick left for a year-long coop with Rockwell Collins, 6 undergraduate students (4 current) have since worked on a few different projects associated with the data collected at SPRL.

Swarm Alert

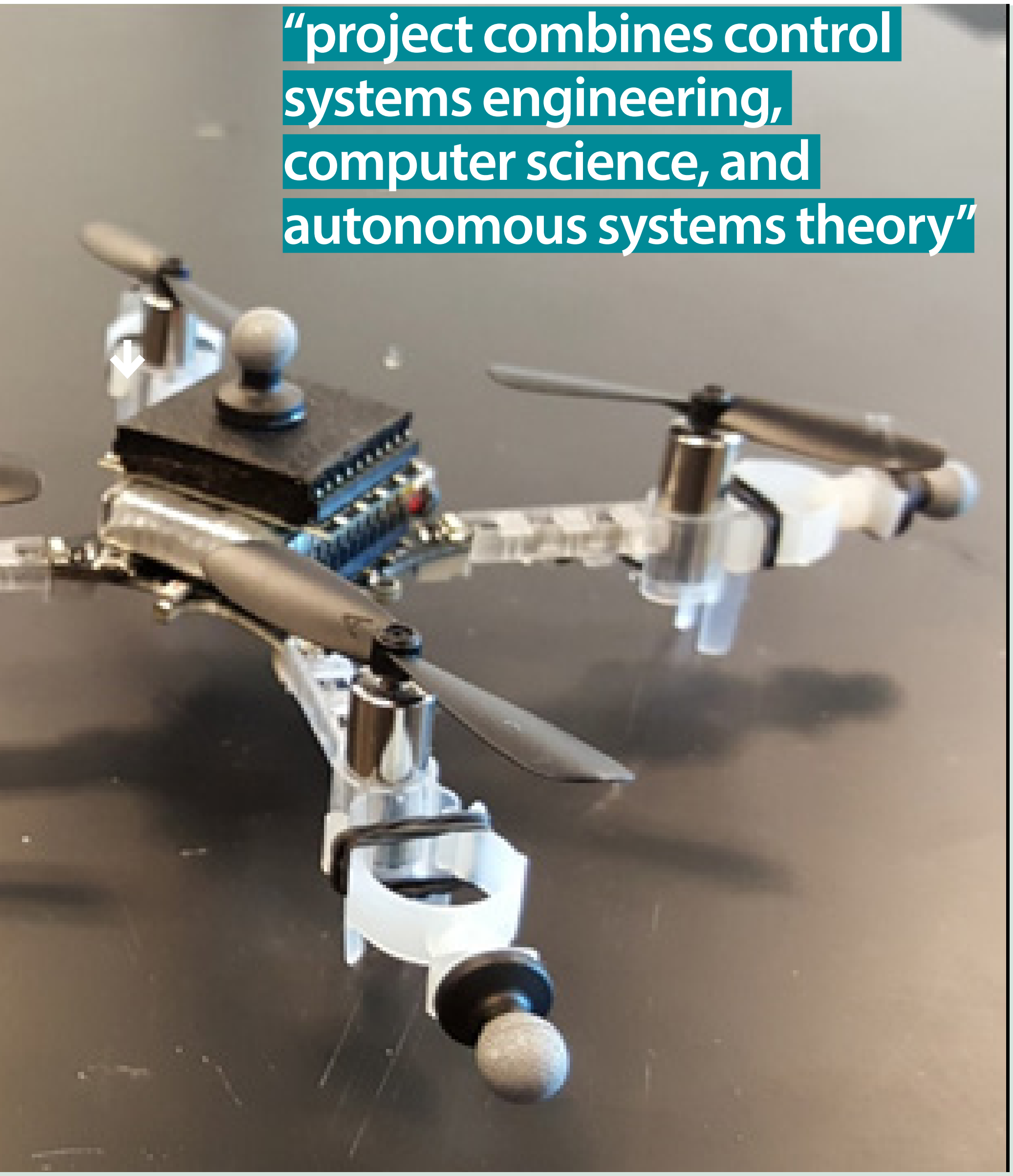
QUASAR brings control to arrays of unmanned aerial vehicles

Prof. Will MacKunis

In recent years, autonomous quadrotor unmanned aerial vehicles (UAVs) have become widely implemented in a variety of practical applications, such as meteorology, aerial package delivery, emergency and rescue services, professional cinematography, and recreational uses. While quadrotor UAVs are being used in various applications already, there has recently been a surge of interest in autonomous multi-agent UAV arrays or swarms. The purpose of the QUASAR project is to design and test a proof-of-concept experimental test bed for autonomous formation flight control of multi-agent quadrotor swarms.

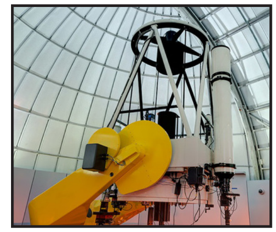
The focus of QUASAR is on the design of a decentralized hardware-in-the-loop (HIL) system comprised of a motion capture system, a wireless inter-agent communication system, and a robust attitude determination and control system (ADCS). Together these provide reliable formation control of multiple quadrotors in the presence of unpredictable operating conditions and uncertainty in the quadrotor dynamics. The QUASAR project combines control systems engineering, computer science, and autonomous systems theory to develop a versatile and comprehensive solution for autonomous UAV formation control, which can be used in myriad real-world applications.

In the broadest formation control approach used in QUASAR, the quadrotor UAV swarm is endowed with a robust nonlinear feedback control algorithm, which “project combines control systems engineering, computer science, and autonomous systems theory”



utilizes real-time UAV position measurements from the motion capture system (i.e., cameras) to enable the swarm to automatically track desired flight trajectories that are pre-programmed by a human user. In more advanced formation control methods, the QUASAR project will investigate new algorithms for online, real-time machine learning-based strategies, which will enable the quadrotor UAV agents in the swarm to automatically optimize future flight control actions based on past experience. To develop the machine learning-based formation control strategies, the QUASAR project will employ multi-level neural network (NN)-based reinforcement learning methods, which utilize real-time (current) sensor data with “snapshots” of previously recorded sensor data (i.e., experience) to mimic brain-like experiential learning.

The end goal of the QUASAR project is experimental demonstration of new reliable formation control methods for multi-agent groups of autonomous quadrotor UAVs using the motion capture arena. A secondary goal is to demonstrate that reinforcement learning-based control methods can be utilized to deliver a new level of versatility in autonomous multi-agent UAV formation flight, which provides reliable control performance over a wide range of unpredictable, time-varying, and potentially adversarial operating conditions. It is expected that this goal will be achieved in QUASAR through the intelligent synthesis of sensing, planning, and action in autonomous multi-agent UAV control.



Observatory News

Spectrograph upgrade and EP student work to design filter system for telescope’s biggest camera

Observatory Engineer Dr. Steve Gillam and Observatory Director Dr. Ted von Hippel maintain the ERAU 1-meter campus telescope for both teaching and research. The observatory’s high-resolution fiber-fed spectrometer now has an upgraded collimator, extending the simultaneous wavelength range of the instrument. EP seniors are working this year to design multi-filter system for the observatory’s largest CCD camera, which contains 16 million pixels.

The College of Arts and Sciences building houses the 1-meter Ritchey-Chrétien telescope built by DFM Engineering. This telescope is the largest university-owned research telescope in the state and possibly the largest optical telescope in the southeast United States. Nearly 165,000 pounds of steel support this telescope five stories off of the ground. The 560 pound, 1-meter diameter primary mirror collects so much light that looking at the moon without special filters will hurt your eyes. The state-of-the-art control room also provides real-time images from the four refractor telescopes attached to the primary scope.

Astronomy Open House Dates

Astronomy Open House nights during the academic year are hosted in collaboration with ERAU’s Amateur Astronomy Club. Remaining dates and speakers for 2018-2019

Nov 16 - Dr. Michael Chaffin

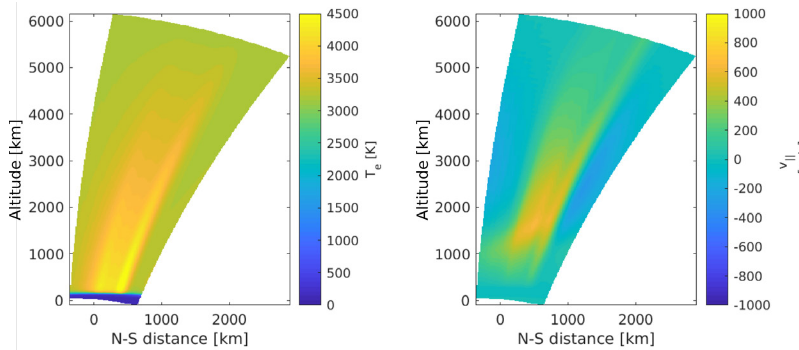
Feb 22 - Speaker TBD

Mar 22 - Speaker TBD

Apr 12 - Speaker TBD

"This solar storm remains the largest experienced at Earth in the last 500 years"

PHOTO: MATTHEW KARL.



GRRAPHICS: MEGHAN BURLEIGH

Models for elevated electron temperatures (left) and ion up flows and down flows (right) due to auroral activity.

Winds, plasmas & currents, oh my!

Former Ph.D. student now ionosphere specialist

Space Weather Correspondent

Early morning of September 1st, 1859, Richard Carrington, working on recording sun spots, observed an enormous solar flair that is speculated to have contained the energy of 10 billion atomic bombs. That night, the aurora was seen across the nation and as far south as Hawaii. The following day, American Telegraph Company employees, unable to send and receive regular dispatches, discovered that if they unplugged their batteries they could send telegraphs across the country using the storm induced currents alone. This solar storm remains the largest experienced at Earth in the last 500 years. If our modern infrastructure is on the receiving end of another such storm the damage is estimated to be trillions of dollars.

Modeling and predicting these geomagnetically induced currents, and their potential threat, is important and Meghan Burleigh, a recent EP PhD graduate, has joined the research group at the University of Michigan as a Postdoctoral Fellow to do just that. Her PhD research focused on the Earth's ionosphere and the effects of atmospheric motions, solar variations and the aurora. This background was instrumental to her joining the U of M research group; they needed an ionosphere specialist.

The Earth's ionosphere is an exciting and dynamic environment. At high latitudes, plasma is often transported by atmospheric winds and auroral precipitation, accelerated by wave-particle interactions, and propelled to escape into the magnetosphere. In order to accurately model this exciting environment Meghan developed a new model, GEMINI-TIA, that includes these processes along with photoionization, electron-impact ionization, and interactions with the neutral atmosphere. The new model is ideal for studies of ion upflow/outflow and calculates the density, velocity, and energy of ion species.

Simulations using the GEMINI-TIA model have been been compared to data from ISINGLASS sounding rocket campaign. These simulations capture the shape and duration of ion upflows/downflows more accurately by containing both time and space variability, but at the loss of the fine scale details that are present in in-situ rocket measurements. One example, during the ISINGLASS campaign, was that the auroral arc pronounced southward drift, not captured in the rocket measurements, which slowly moved the energization regions across the ionosphere generating a finite amount of heating in any given location. Such comparisons help us to better understand the overall ionospheric response to aurora, including the locations and strengths of upflows and downflows, which are highly dependent on the time history of the ionosphere.

In addition to this research Meghan has participated, as one of the student representatives, on the CEDAR Science Steering Committee, responsible for planning the Student Day Workshop; CEDAR greatly values and supports the work of students. Meghan received her Bachelor's Degree in Space Physics from ERAU's Prescott campus before transferring to the Daytona campus for her Master's and PhD in Engineering Physics. On any given day it is likely that you will find her curled up with some coffee and a good book.

Dr. Burleigh completed her Ph.D. work under the direction of Prof. Zettergren. ●

Alumunus **Profile**

Why did you choose to major in Space Physics at Embry Riddle?

I actually applied as AE, but when I saw the SP program I switched before starting. I wanted to learn physics, more about space, space phenomena, and cosmology, and wanted to head towards the physicist career. In the end, I wanted to work for NASA and live somewhere warm mostly year around.

What are your professional interests today?

My professional interests today are tracking space objects such as satellites and rockets, modeling space systems and validating/improving models with real world data, understanding ionospheric models and using them in scenarios, and improving the space-based surveillance system. With what I learned and experienced at Riddle and the Space Physics program, it made things easier to learn new things in the work place since I am usually thrown fire hose of information and I had to figure out what to do with it. Having a passion to continue learning new stuff on your own is important and will help you in the work and graduate school life.

What sage advice would you give a current Engineering Physics, Space Physics and Astronomy & Astrophysics students?

During college, don't overload yourself with too many classes. Actually take time to learn the material and the concepts. It will help when you join the work world or when you take a graduate level class.

Don't stress about not having a 4.0., even though it looks nice on your resume or application. A person with a 3.5-3.9 with research, and internships, will look better in on job application than a person who has a 4.0 and does nothing but study. Join clubs because you have interest in them, like to do projects with them, and not to just fill your resume.

Getting into internships,and doing research will open a doors in your future when it comes to jobs and graduate school. These opportunities will provide new knowledge in different fields, and you will learn to work with other people.

Learn to develop presentations and present them to a wide variety of audiences. After working in a

PHOTO: BUNTY SHAH

Bunty Shah (SP '10) works for Raytheon in California.

research and development lab, I learned that I could be presenting to my technical colleagues one minute, but then I could be presenting to sponsors who could just have a history or political science degree the next.

Learn to be social and work with people outside your major too. In the real working world, they will help you and become your friends. Also, in the real world, you work on teams with various people and not alone all the time.

Learn to have fun in college life. Don't just study and do homework all day. Rest that brain as needed.

Exercise and learn to eat healthy. Your brain and body will thank you. It will help you focus more and stay energized.

Coding is essential nowadays in science and engineering. At a minimum learn. Knowing one coding or analysis language will help you learn others if needed and make it easier to analyze and use data and create models.

Don't just learn to be theoretical in physics. Knowing about instrument/sensor limitations and how to calculate them will help you figure out what data you can collect to use for science.

One last thing, the professors in the Physical Science department do a good job teaching you the material. As a former Riddle student, I wasn't sure at first if I could compete against graduate students in two graduate-level classes. I took at MIT while working. I was able to get an A+ in both classes. If you can handle the junior and senior level classes in the PS department, you can handle MIT classes. Have some confidence!

Spring 2018 Awards **Corner**

Outstanding Space Physics Scholar

Maxx Miller is a graduate of the Space Physics program and is pursing a career as a mathematical physicist.

Outstanding Physical Sciences Student

Sergei Bilardi is a graduate of the Engineering Physics program and is pursuing a Ph.D. degree in Aerospace Engineering at the University of Colorado at Boulder.

Outstanding Engineering Physics Scholar

Matt Caixiero is a graduate of the Engineering Physics program and is working as an engineer at Rockwell Collins.

Outstanding Astronomy & Astrophysics Scholar

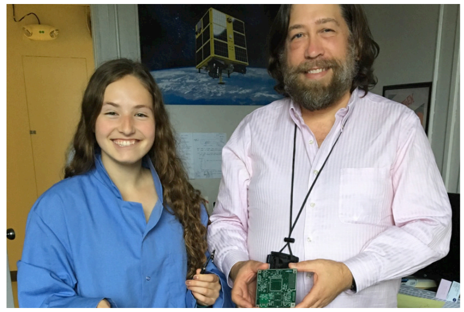
Sarena Robertson is a graduate of the Astronomy & Astrophysics program and now enlisted in the Navy and training to be a Nuclear Power School Instructor.

satellites, and launch vehicles are all subject to radiation once they leave the protection of earth's atmosphere, which can compromise and even destroy many of the systems.

My work at Goddard has been part of a large collaboration known as the Grand Challenge Initiative – an international collaboration intended to advance understanding in space and earth science using sounding rocket investigations, ground based instruments, modeling, and satellites. Dr. Rowland is the PI of the VISualizing Ion Outflow via Neutral atom Sensing (VISIONS) Sounding Rockets – a series of three sounding rockets launched into auroral substorms to understand how ionized oxygen acquires enough energy to escape our atmosphere.

A benefit of using sounding rockets is they provide a more affordable method of testing spacecraft in space rather than using a traditional larger launch vehicle, as well as being time efficient and cost-effective. These sounding rockets range from 7-65 feet tall, and can reach altitudes between 30-800 miles. Part of the testing being done with VISIONS-2 requires electric field measurements of the auroral zone – these E-field sensors are deployed on booms around the rocket.

During the summer of 2017, I did mechanical and electrical engineering. I redesigned the CubeSat Electric Field Instrument (CEFI) to house the electronics for these motor deployers, as well as other electronics concerning communications and the magnetometer on board. After doing the mechanical work to resize and reorder CEFI, I created the motor deployment electronics board by selecting the electronics components needed and drawing the board and traces using computer software. It's like building a circuit board in an electronics lab – except you design it on a computer to minimize manufacturing errors, as well as make a much more refined and miniaturized design. All of this work has led to an updated CEFI design that is more structurally sound, cheaper and easier to manufacture than the original, while remaining within size constraints. This box will be mounted on the inside of the VISIONS-2 rocket launching this winter in December 2018 from Svalbard – and I get to go!



Top: My mentor Doug Rowland and me. He's holding the electronics board we designed. **Center:** Goddard's massive centrifuge, used for simulating launch-time G-forces. **Bottom:** Ny-Ålesund research facilities and launch site in Svalbard, where VISIONS-2 will be launched in December 2018.

This past summer and fall, my work has been a combination of systems engineering and modeling – I am designing the mission for the next sounding rocket, VISIONS-3, as well as writing the mission proposal. I have conducted trade studies to determine the optimal launch site, launch vehicle, trajectory, mechanical sizing, mass budget, science traceability matrix, and instrument access requirements, capped by a monetary budget of 2 million. Additionally, I am creating a data simulation model to simulate what our instruments will see aboard two separate rockets.

Working at NASA Goddard has been an incredible experience. It is the dream opportunity for an Engineering Physicist, being able to design and engineer components while learning and applying the high level physics driving the mission. I learn new concepts every single day, and have needed to apply nearly every skill I have learned at ERAU – which makes for a very rewarding job. I'm beyond excited to wrap up this internship session at the northernmost civilian settlement in the world, hopefully culminating with a successful rocket launch!

Physical Sciences Department **News**

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