BamaSPACE: The University of Alabama's Student Space/Astronautics Programs

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Abstract

Space and astronautics related undergraduate student projects at The University of Alabama (UA) are outlined. The use of experiential learning opportunities has been chosen by UA as a focus for quality enhancement. The unprecedented growth in the size of UA's undergraduate engineering programs has resulted in a dramatic increase in the number of students involved in space/astronautics related activities. This increase in the number of students interested in space/astronautics has brought with it both challenges and opportunities. From providing student design space to instructional support to simple logistical issues, the challenges are matched only by the passion our students continue to display for all things space. Six different undergraduate student teams (2 competition/capstone design teams, 1 competition team, 1 capstone design team, and 2 multidisciplinary space technology teams) and two relatively new on-campus student organizations, are discussed.

Keywords

CubeSat, microgravity, robotics, rocketry, space systems

Introduction

Experiential learning opportunities play a key role at The University of Alabama (UA), being the focus of the University's Quality Enhancement Plan[1]. The belief is that such opportunities enhance our students' ability to define and develop solutions to "real-world" problems by challenging them to put the knowledge gained throughout their studies to use in an environment that transcends the traditional classroom environment. In the UA College of Engineering, experiential learning has historically manifested itself primarily in the establishment of a number of extracurricular undergraduate student projects and teams, some of which participate in externally sponsored competitions. The UA College of Engineering has invested heavily in facilities to support these teams, from student project space and the undergraduate student machine shop (including student access to machinists in the College of Engineering Machine Shop) to the creation of the Cube (a facility that provides undergraduate students with access to additive manufacturing and other state-of-the-art fabrication facilities). This investment has been in response to the unprecedented growth in enrollment experienced by the UA College of Engineering. During the 2004-05 academic year, undergraduate engineering enrollment was 1,540 students. For the fall 2015 semester, undergraduate engineering enrollment was 5,301 students and it is expected that enrollment growth will continue. In parallel, the mean ACT of the freshman class has also continued to increase, from a composite ACT of 25.6 in AY 2004-05 to 29.8 in the fall 2015 semester. Needless to say, providing experiential learning opportunities to so many students has been a challenge especially in light of the increase quality of the students (as measured by mean ACT scores). A decade ago, the UA College of Engineering would not have been able to support as many space/astronautics related student teams as it does now. As it stands, even the current number of space/astronautics related student teams is expected to grow due to increasing demand by students for such opportunities.

The purpose of this paper is to provide a brief summary of on-going experiential learning activities in the UA College of Engineering that have a direct relationship to the fields of space and astronautics. The activities, collectively known as BamaSPACE, represent an outstanding opportunity for our students and faculty to blur the boundaries between undergraduate education and research. BamaSPACE undergraduate student project teams are involved in a wide range of space related projects and, unfortunately, not all of the organized efforts have been included in this paper.

Alabama Astrobotics Team

Alabama Astrobotics is a student organization at the University of Alabama (UA) dedicated to research and development of advanced, autonomous robotic technologies for space-based applications.

Project Goals: The primary goal of Alabama Astrobotics is to stimulate interest in robotics at the undergraduate and graduate levels. One related goal is to develop robotic systems to participate in various competitions including the NASA Robotic Mining Competition (RMC), PISCES Robotic International Space Mining competition, and the NASA Sample Return competition. A second related goal is to serve as a "seed" project to stimulate graduate-level research in robotics.

Project Background: Alabama Astrobotics had a very humble beginning. The organization was formed in Fall 2009 specifically to compete in the inaugural NASA Lunabotics Mining Competition in May 2010, hence renamed the NASA Robotic Mining Competition. The team originally consisted of five members, four from Electrical and Computer Engineering and one from Mechanical Engineering. This group of students had no infrastructure dedicated to the project, including no lab space, no test equipment, no testing area, and no hand tools. From these humble beginnings, Alabama Astrobotics has grown into a large, multidisciplinary organization supporting various competition teams as well as graduate-level research projects. The following paragraphs detail each of the competitions in which Alabama Astrobotics has or plans to participate.

NASA Robotic Mining Competition: This competition started in May 2010 and attracts some of the top engineering and mining programs in the country. It has been listed as one of the top ten engineering student competitions in the world[6]. The competition is held each May at the Kennedy Space Center and is typically limited to domestic teams, although in previous years international teams have participated. This competition is sponsored by the Kennedy Space Center Exploration Systems Mission Directorate Higher Education Project. The competition involves the design, fabrication, and operation of a robot capable of excavating simulated Lunar or Martian soil, also known as regolith. Excavation is seen as a major first obstacle to the construction of permanent Lunar or Martian bases. "NASA will directly benefit from the competition by encouraging the development of innovative robotic excavation concepts from universities which may result in clever ideas and solutions which could be applied to an actual excavation device or payload. The unique physical properties of basaltic regolith and the reduced 3/8th of Earth gravity make excavation a difficult technical challenge. Advances in Martian mining have the potential to significantly contribute to our nation's space vision and NASA space exploration operations7".

Participating robots can be controlled remotely or can be designed to operate autonomously. Each robot is given ten minutes to collect and deposit the simulated Lunar regolith into a designated collector, with a minimum excavation requirement of 10.0 kg to qualify for victory. Competition points are also awarded based upon the mass of the robot, how much autonomy it demonstrates, the amount of communication bandwidth required to control it, the robot's ability to monitor its power usage, the extent of the community outreach performed leading up to the competition, team spirit, and technical presentations and papers submitted as part of the competition. Additional information about the NASA RMC can be found on the website:

http://www.nasa.gov/offices/education/centers/kennedy/technology/nasarmc.html.

PISCES Robotic International Space Mining: The PRISM competition is very similar in its goals to that of the NASA RMC. The competition is held each July in Hilo, Hawaii and includes university teams from around the world. PRISM makes use of NASA analog test sites on Mauna Kea that are superb substitutions for both Lunar and Martian environments. Additional information about the PRISM competition can be found on the website:

http://pacificspacecenter.com/prism-competition

NASA Sample Return Centennial Challenge: Alabama Astrobotics plans to complete for the first time in Sample Return in 2016. Sample Return is a NASA Centennial Challenge and is held each June at the Worcester Polytechnic Institute in Massachusetts. In this competition, all robots are tasked with autonomously finding and retrieving various samples randomly located in a predetermined search area representing an open, unstructured outdoor environment. Robots are required to complete specific tasks to advance to more difficult competition levels. Additional information about Sample Return can be found on the website:

http://www.nasa.gov/directorates/spacetech/centennial_challenges/sample_return_robot/index.html

Accomplishments: Alabama Astrobotics has a history of successful participation in the NASA RMC. In previous years, overall UA placed 6th in 2010 (out of 60 domestic teams), 4th in 2011 (out of 72 international teams), 1st in 2012 (out of 72 international teams), 3rd in 2013 (out of 50 international teams), 2nd in 2014 (out of 42 domestic teams), and 1st in 2015 (out of 47 domestic teams). In addition to these overall awards, Alabama Astrobotics has won multiple first place trophies in many different categories. Alabama Astrobotics is the most decorated team in the history of this competition and is the only team to have won the overall championship more than once[8].

Alabama Astrobotics participated in PRISM in 2014 finishing with two second place trophies and a third place finish in the various categories.

Research results include one publication[2], three MS theses[3,4,5], one MS thesis in progress, and one PhD dissertation in progress.

Student/Faculty Participation: Alabama Astrobotics is faculty-led. The faculty leader is a member of the Electrical and Computer Engineering faculty. Student participants include all levels of undergraduates as well as MS and PhD level graduate students. The major areas of study for current student members include Aerospace Engineering, Computer Engineering, Electrical Engineering, Mechanical Engineering, Computer Science, Mathematics, Physics, and General Business. Past members have also represented Chemical Engineering, Civil Engineering, Early Childhood Development, and Geology.

Financial Support Structure: Alabama Astrobotics is funded externally through the Alabama Space Grant Consortium (ASGC), NASA, and various corporate sponsors. Internal funds are also provided via the UA College of Engineering, The Department of Electrical and Computer Engineering, The Department of Mechanical Engineering, the Student Government Association, and the UA Graduate School.

Facilities: Currently, the 40+ student members have dedicated on-campus lab space provided by the UA College of Engineering including an indoor test area that is a one-to-one scale replica of the RMC competition arena, a remote control operation center, and a test chamber containing various simulants of Lunar soil.

Additional information about Alabama Astrobotics can be found at:

http://www.alabamaastrobotics.com

Alabama Rocket Engineering Systems (ARES) Team

ARES (Alabama Rocket Engineering Systems) is a senior design team in the Department of Aerospace Engineering and Mechanics (AEM) participating in the 2015-16 NASA Student Launch competition. More information about the NASA Student Launch competition may be found at:

http://www.nasa.gov/audience/forstudents/studentlaunch/home/index.html

Project Goals: The specific goal of the team is to compete and place in the student launch competition annually sponsored by NASA. The proposed 2015-16 mission is to deploy a landing hazards detection payload and a guided descent system payload after a launch to an altitude of one mile. The locations of detected landing hazards will be stored onboard and transmitted to a ground station, and the detection payload will be steered away from hazards using a servo-controlled parafoil. This effort is conducted as one of the B.S. in Aerospace Engineering capstone design projects. The broader learning goals of senior design are to

- apply accumulated knowledge of aerospace engineering sciences,
- apply new knowledge from in-course special lecture topics,
- engage in teamwork and simulation in the development of the preliminary design of an aerospace system,
- plan simulations or experiments to test design concepts,

- conduct productive and regular work meetings,
- manage activities and time devoted to team meetings including brainstorming, division of labor, scheduling (agendas, time keeping), and presentations,
- produce regular progress documents and design reports,
- and assess societal impact of system designs or understand and follow safety regulations of build-and-compete competitions.

Project Background: The selection of a BSAE capstone design topic or competition starts the prior year, when the students are completing their junior-level course work. At that time, the juniors in the BSAE degree program are required to complete and submit a questionnaire covering their design interests, relevant experience, and prior research or design participation. Early in the summer, the senior design instructor along with faculty mentors place the rising seniors on teams to allow the students to start preparations as needed for their respective design projects. Every effort is made to place students on their first-ranked team. ARES is one of four senior design teams this year and the only one with a space or rocketry theme. The history of the team dates back to the 2010-11 competition when an all-female team (the *Rocket Girls*) was formed in the Department of Mechanical Engineering and recruited students from mechanical, aerospace and electrical engineering. Over the following years, the team expanded to be co-ed and renamed as Yellowhammer Rocketry. Yellowhammer Rocketry (again recently renamed the Alabama Rocketry Association) is still a sanctioned student-group on campus and will be discussed later in this paper. The 2015-16 academic year is the first year the team has been included as part of the capstone design course.

Accomplishments: The team has competed and launched the last five years they have submitted a proposal. The competitive proposals are due near the beginning of the academic year and reviewed and accepted or rejected by NASA. In each of those years, the team has completed and passed preliminary, critical and final design reviews by NASA which includes sub-scale and full-scale test launches, allowing them the launch in the competition.

Student/Faculty Participation: Teams are capped with ten seniors; however, juniors and underclassmen are actively recruited by the seniors at AIAA club meetings, presentations in AEM 121 Introduction to Aerospace Engineering, and the University of Alabama “Get Onboard Day”. The team is advised by two departmental faculty members: the senior design professor and another professor that has a background or strong interest in astronautics and/or rocketry. Finally, due to safety requirements and regulations of handling high-powered rocket motors, the team must be monitored by a certified mentor from the National Association of Rocketry at all launches. This individual is usually recruited from local high-powered rocketry clubs within the state.

Financial Support Structure: The team generally seeks funding through four avenues: the Alabama Space Grant Consortium (through a larger proposal that partially funds this effort and other programs described in this paper), the university’s student government, the AEM department, and other industrial sponsors or fund raising events. A typical budget, depending on the scope of the project and travel needs (competition location), ranges between $4000 and $8000.

Facilities: The team shares undergraduate laboratory space (~400 ft^2) with the Alabama Rocketry Association club. It also has access to the AEM Undergraduate Computer Lab and simulation software, the Hardaway Hall wind tunnels, the Student Machine Shop, the College of Engineering Machine Shop, the Cube (a 3D printing lab and design studio), and a video teleconferencing room for design review presentations with NASA personnel.

Built-By-Bama Satellite (B^3Sat)

The development of miniaturized satellites, i.e. CubeSats, has dramatically enhanced access to space for university student teams. With the advent of CubeSats, there has been an ever increasing interest in miniaturization of spacecraft technology and the use of such technology for a wide range of applications. Initiated in 2015, the B^3Sat program established the first formal UA CubeSat program.

Project Goals: The B^3Sat is an integral part of the Aerospace Engineering curriculum at the University of Alabama with the primary goal of providing students with a multi-disciplinary, hands-on space systems experience. The vision is to create end-to-end, science-driven solutions to satisfy real-world space system needs.

Project Background: Currently, the program is establishing its initial membership. Students are being actively recruited at AIAA club meetings, presentations in Introduction to Aerospace Engineering, the University of Alabama “Get Onboard Day” and at the SEDS club meetings (SEDS to be discussed later in this paper).

The B^3Sat framework uses the same architecture as space asset mission planning and deployment. The University of Alabama Space Mission Architecture currently includes two major components: spacecraft (bus and instruments/mission payload), and a ground station (command/control of the spacecraft and mission operations). The third requirement of a mission, launch segment, will be handled by outside organizations requiring close coordination with the Air Force, NASA and industry.

Accomplishments: The mission of the current spacecraft is to improve the pointing accuracy of CubeSat sized satellites through better control software and advanced momentum management. Current state-of-the-art for CubeSat pointing accuracy approximately 2 degrees. Larger satellites with active attitude control systems are capable of 0.1 degrees for prolonged periods. Miniaturization of the delicate control mechanisms (torque rods, momentum wheels, thrusters) has proven to be a significant challenge. Improving the pointing accuracy of CubeSats from 2 to 0.1 degrees enables these nano-satellites to provide significantly more utility in space. Specifically, the improved accuracy will enable CubeSats to use laser communications with the ground, capture images with better than one meter resolution, increase the signal-to-noise ratio without increasing power requirements, and perform maintenance missions (intercept).

Student/Faculty Participation: The current management structure has been established as a student-led organization, primarily comprised of undergraduate aerospace engineering students. Faculty accomplishes the overall coordination and advising.

The University of Alabama is currently partnering with the Air Force Institute of Technology (AFIT) and NASA. AFIT has built, validated and launched a 3U CubeSat. The Attitude

Determination and Control System (ADCS) will be tested and validated at the NASA Marshall Space Flight Center (MSFC). Thrusters for the ADCS will be developed under the guidance of NASA Glenn Research Center. The program is also working to establish cooperative activities with both Alabama A&M University and the University of South Alabama.

Financial Support Structure: The Alabama Space Grant Consortium has provided initial funding. These funds are sufficient to cover raw material costs and initial infrastructure but not sufficient to fully establish the equipment needed to field a fully space-rated satellite. In addition, the University has active Cooperative Agreements with NASA and the US Air Force which may ultimately provide additional support. The program is also seeking industry partners (e.g. Boeing, Aerojet, SpaceX). These connections will better enhance internship opportunities, provide mentors at the top of the field as well as provide direct pathways for UA graduates to enter the scientific workforce.

Facilities: Currently, the CubeSat program has several functional engineering models to use for training. These models were provided by AFIT. The current effort is focused on creating the facilities needed for the program. These facilities include a ground station, soldering station, printed circuit board design station, vibration testing facility, Faraday cage, attitude determination and control station, and thermal/vacuum testing facilities. The manufacture of the structure will be accomplished in the student machine shop. Printed circuit boards will be printed in the University shared facilities (the CUBE). Currently, vacuum facilities are available for the environmental testing (2.0 m x 3.0 m vacuum chamber capable of pressures lower than $1.x10^{-4}$ Pa)

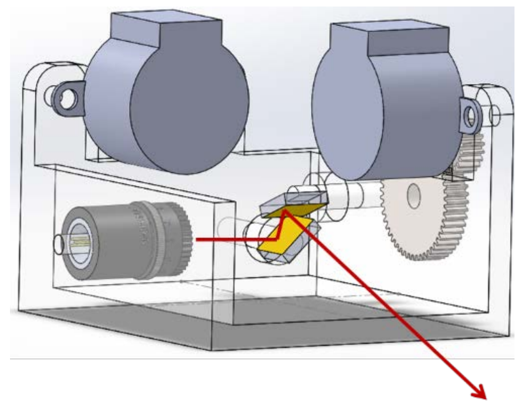
CubeSat Laser Satellite Communications Team

The CubeSat Laser Satellite Communications team is a capstone student design team comprised of students in the UA Department of Electrical and Computer Engineering.

Project Background: The use of lasers for long distance space communications promises to enable significantly higher data transmission rates (exceeding Gbps) compared to more conventional radio frequency communication approaches. This is in large part due to their higher directionality, lower power needs and higher security link capability. One example of such a system is NASA's Lunar Laser Communication Demonstration (LLCD) that was carried out using the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft, which achieved a ground-to-satellite laser link at data rate near 625 Mbps[9]. Achieving this at shorter distances, with low Earth orbit (LEO) satellites, has been reported with bidirectional ground-to-satellite data rates up to 5.625 Gbps by The Aerospace Corporation[10]. At the same time, there is a growing effort to implement a similar technology in CubeSats[11]. This is a result of the rapid advances in integration and the growing complexity of such small satellites, which calls for an increasing desire to achieve higher data rate satellite-to-satellite (S2S) communications in order to enable greater autonomy and alleviate the need for long range ground-to-satellite links. But implementation in small satellites presents design and integration challenges.

Project Goals: The goal of this project is to study and realize a basic laser communication system with design requirements relevant to CubeSats. This project is part of the B.S. in Electrical Engineering curriculum and consists of a 2-semester capstone senior design project. In addition to the design of the hardware, the current effort will lay the foundation for planned subsequent development work by student teams in collaboration with the B^3Sat project.

Accomplishments: The team of 7 students was originally tasked with the research, design, realization, and testing of a simple free-space communication laser system which can be integrated into a 1U CubeSat for the laser transmitter with a separate 1U receiver. Power generation/storage capabilities were not part of the set of requirements, but the design was constrained to using standard CubeSat power specifications. The electronics would have to be SMD PCBs matching the PC/104 standard, and both transmitter and receiver would have to operate autonomously and independently. To date, the design of the major sub-systems has been completed, with assembly and testing about to commence. Four major sub-systems are being designed: laser/photodetector and optics (one for each of the 1U CubeSat modules), beam steering (only transmitter), signal processing (one for each 1U CubeSat), and power (one for each 1U CubeSat module). One part of the design work encompasses investigating proper selection of commercial OEM lasers and photodetectors in terms of optical and spectral characteristics, efficiency, power needs, and cost in a limited available volume. The beam steering sub-system (Fig. X) is aimed at providing some ability to precisely steer the laser beam. The signal processing sub-system involves all coding/decoding aspects of the transmitted/received signal, as well as power control and decision making. The power sub-system takes charge of regulating and distributing the power throughout each 1U CubeSat module.



3D CAD schematic of the designed laser beam steering system.

Student/Faculty Participation: This project is led by the student team, with the faculty mentor guiding and training on topics not learned in courses (e.g. laser and optics) as well as providing continuity for subsequent improvement iterations of the project. Students have and will learn and/or further develop a wide range of topics/skills that are not necessarily learned or as deeply practiced in class, including lasers, photodetectors, optics, analog and digital signal processing, feedback and control, micro-controller programming, surface mount PCB design and fabrication, CAD and 3D printing.

Financial Support: As a senior design team project, this is financially supported by the Department of Electrical and Computer Engineering,

Facilities: Most of the work is being accomplished in the faculty mentor's research laboratory, partially for laser safety reasons and the need for special optical instrumentation.

Firefly Team

The Firefly Project is an undergraduate design effort that spans the entire four year curriculum of the Bachelor of Science in Aerospace Engineering (BSAE) degree program.

Project Background: The genesis of the Firefly project occurred during the fall 2013 semester as an unlikely, somewhat jokingly made, challenge to an AEM 121 Introduction to Aerospace Engineering class after watching a video of SpaceX's Grasshopper Rocket[12]. The challenge, to design and build a small-scale version of the Grasshopper Rocket, was surprisingly taken up by a group of freshmen aerospace engineering students, with the long-term plan of integrating the project into the BSAE capstone design experience during their senior year. From the beginning, it was clear that the project objectives were highly ambitious and that building such a rocket may not be feasible for a group of undergraduate aerospace engineering students. From an instructor's perspective, the Firefly Project provided unique opportunities to observe how engineering students at different levels of their education respond to real-world engineering challenges (both technical and non-technical). As such, the AEM 121 instructor agreed to serve as the faculty mentor for the project.

Project Goals: Since the project was initiated, the goals of the project have significantly evolved. Currently, the Firefly team has 3 goals:

a) design, fabricate, and successfully demonstrate the operation of a micro-descent vehicle (μDV), a small-scale lander with a power descent stage, capable of being redeployed shortly after landing,

b) design, fabricate, and successfully demonstrate the operation of a mobile drop tower (employing a tethered weather balloon to achieve altitude) that is capable of deploying both the μDV or other landers (such as the HAL lander being developed by the ARES competition team), and

c) design, fabricate, launch, track, and successfully recover a buoyant ascent platform (BAP), a balloonsat, to support a future mission that will optically image the total eclipse of the Sun in 2017.

Accomplishments: During the initial semester of the effort, spring 2014, weekly meetings were held where lectures on various topics related to rocketry were provided to the students as part of a pseudo crash course on rocketry. At the end of the spring 2014 semester, the student team was challenged to read (over the summer) the book *The Rocket Company*[13] as a means of providing them with a better appreciation of the challenges associated with building a rocket. The students were also asked to design a gimbal system for the yet to be designed rocket engine.

At the beginning of the fall 2014 semester, the first proto-type gimbal system was 3-D printed using the UA College of Engineering's additive manufacturing facilities. This gimbal system provided the student team, now sophomores, with what would become a critical obstacle to the long-term success of their project and what would ultimately result in an evolution of the overall project objectives. The obstacle was how to control the gimbal during flight. It was recognized that the problem was, simply put, that of an inverted pendulum. For sophomores who had never had a controls class, this was a bit overwhelming and resulted in little progress during the fall 2014 semester. During the spring 2015 semester, the challenge was once again taken up with relatively little success. After much discussion, the team decided to focus on the descent phase of the vehicle, i.e. to focus more on the development of a "lander" with a powered descent stage. Two lander prototypes were created, one simply a 3-D printed model that would serve as a concept model and the second, fabricated using paper and RC servos, served as a working model of an updated gimbal design. Again, autonomous control of the gimbal system proved to be a serious obstacle and stalled progress during the spring 2015 semester. The problem of lander control also resulted in an overall lowering of team morale during the spring 2015. It was at this time that the team decided to reinitiate the UA balloonsat program. The UA BamaSat program had for several years successfully launched and recovered high altitude balloons that carried student designed payloads, i.e. balloonsats, to altitudes of on the order of 100,000 ft. In recent years, the BamaSat program had become inactive, but a significant fraction of the infrastructure remained and a short term focus on balloonsats provided an opportunity to shift focus away from the controls issue. The team produced a preliminary balloonsat design, with a plan for a balloonsat launch during the spring 2016 semester.

The fall 2015 semester saw somewhat of a revival for the Firefly team. While the problem of lander control remained, the addition of the balloonsat effort provided an expanded set of design challenges and opportunities. The make-up of the team expanded and changed, some members leaving to pursue other opportunities and new members interested not just in the lander but also the balloonsat joining the team. While the balloonsat effort continued, it was decided that a tethered balloon, with a deployment payload, would be used to drop test the lander and a new sub-team was formed to design this system. The problem of gimbal control was eliminated by a radical design change in the lander, the lander now structured more like Robert Goddard's original liquid rocket. The new design has a solid rocket motor located "above" the main lander structure. At the time of writing, preliminary designs for all three component efforts have been completed and initial fabrication has begun.

Student/Faculty Participation: The initial project began as a student-led project with the faculty advisor simply providing instruction and guidance related to basic engineering design. Over the past year and a half, the faculty advisor has increasingly taken the lead in the project and the Firefly team would now be best described as a faculty led effort. During the spring 2016 semester, the effort was given a more formal structure, being taught as AEM 491 Astronautics Design Studio (an elective for the B.S. in Aerospace Engineering degree program). The current Firefly team consists of 13 students from aerospace engineering, mechanical engineering, telecommunications and film, and International Studies.

Financial Support: The Firefly team is currently supported by the Alabama Space Grant Consortium and the UA Student Government Association (through an undergraduate research grant). Initial support for the project was provided by the College of Engineering (via free access to the additive manufacturing facilities) and the AEM Department.

Facilities: Currently, the 13 student members have dedicated on-campus laboratory space provided by the AEM Department, free access to multiple additive and subtractive fabrication capabilities through the College of Engineering's Cube facilities, and other resources provided by the University.

Micro-G NExT Team

Micro-G NExT is a NASA experience to design and build a hand-held tool to be tested in a NASA micro-gravity facility, the Neutral Buoyancy Lab (NBL).[14] It is being used at the University of Alabama as Capstone Design Projects.

Project Goals: Teams of up to six students are invited to propose a device that represented one of five challenges related to asteroid exploration by a human crew. The students develop their proposal which is reviewed by NASA personnel at the Johnson Space Center. If accepted, up to 30 teams are invited to manufacture their tool and do preliminary testing of it. If the tool meets requirements, the team may then go to the NBL and run the test with NASA divers in the NBL facility. More information on the NASA Micro-g NExT program may be found at https://microgravityuniversity.jsc.nasa.gov/theProgram/micro-g-next/index.cfm

The Department of Mechanical Engineering conducts a two-semester capstone design sequence, ME 489 and ME 490 (each course counting for 3 credits). ME 489 includes an introduction to the design process and ancillary material on engineering economics and engineering ethics. Additionally, students begin the major capstone project which is completed the following semester in ME 490. As enrollment has grown, particularly in mechanical engineering, the size of capstone teams has increased depending on the project with a typical project consisting of five students. In fall 2015, 30 projects were needed to accommodate the enrollment. Over a dozen students requested to participate on Micro-g NExT projects.

Project Background: The NBL, adjacent to Johnson Space Center in Houston, Texas, is a swimming pool with dimensions of 202 ft x 102 ft and 40 ft deep. It holds 6.2 million gallons of water. By comparison, an Olympic-sized swimming pool is 164 ft x 82 ft and 10 ft deep[15]. The NBL creates an environment which can simulate the use of equipment in micro-gravity. It is used to train astronauts for spacewalks and for testing some facilities during the construction of the International Space Station.

For the fall 2015 semester, prospective student teams were asked to propose a device that represented one of five challenges: a Float Sample Grabber, a Coring Device for Regolith, a Gap Spanner Boom for an asteroid redirect mission, an Anchoring Device for Regolith, or a Rock Chip Sampling Device for Microgravity. Each of the tools must be manual, have volume and weight constraints, and must be compatible with the chlorine water environment in the NBL. Before is a listing of the design requirements for each of the five challenges:

The Float Sample Grabber is a handheld device that could mechanically collect three loose geological samples from the surface of an asteroid without sample cross-contamination. The Coring Device for Regolith would be used to collect a core sample. Regolith is the loose layer of topsoil on the surface of a planetary body,

The current mission plan for an Asteroid Redirect Mission has the Orion vehicle docked to the Asteroid Redirect Vehicle (ARV). To travel to the asteroid from the Orion, crew members must traverse across a gap. Astronauts must travel between the two vehicles to prevent damage to Orion's delicate thermal protection tiles, and the Gap Spanner Boom is the device which allows this transport to occur, An Anchoring Device for Regolith will be used to anchor to regolith in a microgravity environment, and

The Rock Chip Sampling Device to break off and store chips from the surface of the asteroid.

Two six-person teams were formed from the mechanical engineering students interested in Micro-g NExT program. Teams were formed based on their interest in the various five projects. The teams are UA (Understanding Asteroids) and STRAHL. UA selected the Float Sample Grabber, and STRAHL selected the Gap Spanner Boom.

Their first major task was the development of a working concept for the team's tool and to put this into a proposal for NASA that included plans for testing in the device in the NBL in addition to an outreach plan to bring their work to the general public and particularly into K-12 schools.

Based on the proposals, both teams were selected to participate in the competition. Both teams are currently manufacturing their devices, and this will be followed by preliminary testing. A Test Equipment Data Package with the details of the testing in the NBL will be due within 6 weeks before traveling to the NASA Johnson Space Center in late spring and early summer.

Accomplishments: NASA first offered Micro-g NExT in the 2014-15 academic year. This is the first time that anyone from the University of Alabama has participated in the competition. The UA Team Leader has previously participated in Astrobotics, and the faculty advisor has participated in previous NASA student design competitions, including the University Student Launch Initiative and the Reduced Gravity Student Flight Opportunities Program, another program involving other than earth-normal gravity.

Student/Faculty Participation: Each team is structured with each member having a specific role. Although the project is faculty-led in that it is part of a course, with 30 projects in the class, the faculty member relies on the Team Leader to handle the primary organization and reporting of the team. Other roles include Safety Coordinator, Outreach, Financial, Technical, and Logistics. As Capstone Design, the performance of each team member is evaluated through a brief weekly report on contributions toward the project.

Financial Support Structure: Funding for this project has been provided by several sources. The primary funds are from a Space Grant Workforce Development grant for hardware and travel which includes a match from the College of Engineering. Additionally ASME has provided a Diversity Action Grant which funds supplies and travel for the outreach program. NASA is also providing a small amount of funding for each team as they meet their deliverables.

Facilities: The devices created in this project are hand-held tools that must withstand a swimming pool environment. They are of a size and weight that they can fit into a backpack.

To create the devices, students will be using The Cube – a relatively new College of Engineering facility where students learn, share, think, fail, succeed, and create by designing, devising, and constructing. It is to promote a culture of innovation and includes a 3D printing lab, electronics prototyping lab, Makerspace lab, ideaLAB, and Apps Lab.

Student Organizations

A discussion of BamaSPACE would not be complete without a discussion of the new student organizations that have been established in recent years that promote an interest in space and astronautics.

The University of Alabama chapter of the Students for the Exploration and Development of Space (SEDS) is currently two years old, preserving space exploration's deep roots in Alabama and inspiring its future development. SEDS is a national organization that seeks to empower students to become involved in the nation's space endeavor. More information about SEDS can be found at:

http://seds.org/

The leadership of SEDS has been instrumental in exposing UA students to the wonders of space and how they can be a part of our activities in space. SEDS currently provides lectures (video, recorded or live) from current space professionals such as Dr. Elizabeth LeBlanc (NASA Johnson Space Flight Center). This year, the SEDS chapter has planned a number of outreach activities. Of note is the water bottle rocket competition at Hillcrest Middle School. The goal this year is to set an altitude record with a single bottle, water-bottle rocket. Additionally, the students in SEDS have the opportunity to participate in the B^{3}Sat activities.

As previously mentioned, the UA participating in the NASA Student Launch competition originally began with the creation of the Rocket Girls team. After several successful campaigns, the Rocket Girls decided to become a co-ed team and to change the name of the team to Yellowhammer Rocketry. Last year, Yellowhammer Rocketry decided to no longer participate in the NASA Student Launch competition. The focus of the team would now be to develop the infrastructure to fabricate high power rocket body components on campus and to increase interest in high power rocketry on the UA campus. Last year, Yellowhammer Rocketry built a facility for the fabrication of fiberglass rocket body tubes and several members used these structural components to become NAR Level-1 certified, the first level of certification offered by the National Association of Rocketry[16]. This year, the club decided to change the name of the organization to the Alabama Rocketry Association so as to be more recognizable to the UA student body. Their primary mission, to teach interested students the basics of high-powered rocketry and help them become NAR 1 certified, remained. The Alabama Rocketry Association and the ARES team have many of the same members and share undergraduate laboratory space and facilities.

UA QEP

As previously mentioned, the University of Alabama (UA) has chosen experiential learning as the focus of its quality enhancement plan (QEP). Each of the respective student projects discussed in this paper embody the fundamental elements of experiential learning. The projects contribute to the UA QEP by involving students in hands-on projects outside the classroom that apply theory and academic principles to solve real-world problems. The lifecycle of these projects is strenuous and structured, preparing students for what they should expect during their post-graduate working career. Additionally, the perception that UA students have of their own education is improved via direct competition with teams from other universities. Currently, there are no assessments performed to quantitatively or qualitatively evaluate the success of the various BamaSPACE projects with regard to contributing to the UA QEP. The UA QEP was formally initiated during the 2014-2015 academic year. It is expected that the manner in which the various BamaSPACE projects contribute to the UA QEP will evolve during the next several years as the full implementation of the UA QEP continues.

Closing Remarks

There is a strong undergraduate community on The University of Alabama campus that is passionate about the exploration and development of space. As with the University as a whole, this community of students has seen unprecedented growth in the past decade. To provide these students with outstanding experiential educational opportunities, multiple space related projects and teams have been established. The below table provides a summary of the teams/projects discussed in this paper.

Table 1: 2015-2016 BamaSPACE Projects

Project	Student Participation	Student Level	Project Type	Sponsor
Alabama Astrobotics	45	G/UG(all levels)	Robotics	NASA/ASGC/UA/Other
ARES/HAL	10	UG(seniors)	Rocketry	NASA/ASGC/UA
B^3SAT	6	G/UG(all levels)	CubeSat	ASGC/UA/Other
CubeSat Laser Comm	7	UG(seniors)	CubeSat	UA
Firefly	13	UG(all levels)	Balloonsat/Space Tech	ASGC/UA
Micro-G NExT	12	UG(seniors)	Space Tech	NASA/ASGC/UA

(G: Graduate | UG: Undergraduate)

As the University continues to grow, it is expected that these and other space-related student project teams will grow and develop. The challenge will be how to effectively assess the worthiness, from an educational perspective, of these new space teams/projects.

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