FAMU/FSU College of Engineering

Department of Mechanical Engineering

Sponsors:

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Restated Project Scope and Plan

Team 24: Intercollegiate Rocket Engineering Competition

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Abstract

Team 24 of the 2016-2017 Senior Design class has committed to designing and building a competitive rocket for the Experimental Sounding Rocket Association's Intercollegiate Rocket Engineering Competition (IREC). This competition requires that a sounding rocket be designed, built, and flown to 10,000 ft above ground level; and be safely recovered. For this purpose, we have determined that a rocket with fixed fins and composed of fiberglass, should be created. Housed inside of this should be two recovery systems, our payload and our flight computer. This should all be propelled by a solid grain rocket motor and the delayed black powder gas generator should be used for our recovery system. Once all things have been deemed satisfactory, Team 24 will participate in the IREC held at Spaceport America.

1. Introduction

The Experimental Sounding Rocket Association (ESRA) annually hosts the Intercollegiate Rocket Engineering Competition (IREC). This competition requires teams from over a dozen universities to design, build, and launch experimental sounding rockets. A key point of the competition is that the vehicles must carry a payload which performs a scientific experiment.

It is the goal of Team 24 to compete in this competition and create a rocket capable of reaching an apogee of 10,000 ft above ground level (AGL), while simultaneously performing a useful scientific experiment. Team 24 aims to conduct all activities as safely and professionally as possible, while delivering a vehicle with truly outstanding performance.

1.1 Constraints

The Basic Category of the Intercollegiate Rocket Engineering Competition has a set of rules and requirements pertaining to the design of the vehicle and its payload. In addition there are numerous safety requirements imposed for the launch of the vehicle.

1.1.1 Vehicle & Payload Requirements

- The vehicle must attain an altitude of 10,000 ft AGL
- The payload must be at least 8.8 lbs
- The vehicle and payload must be recoverable
- The payload must not be used to alter the stability of the rocket
- The vehicle must have an altimeter and record data using a fight computer
- A maximum of one propulsive stage is allowed
- Propulsion must use non-toxic fuels
- Payload may not contain hazardous materials or live animals

1.1.2 General Requirements

In addition to the rules regarding the design of the vehicle and payload, several other rules should be observed regarding the flight and launch preparation.

- The vehicle must be able to return to a safe-mode after arming

- The vehicle should attain a speed of 100 ft/s before leaving the launch rail
- The vehicle and payload must have a recovery system
- Main parachute should slow rocket to at least 30 ft/s by 1,500 ft AGL

2. Project Scope

The sounding rocket developed through the course of this project should fulfill the competition requirements imposed by the IREC. Additionally, the research payload should provide useful data for researchers at the FAMU-FSU College of Engineering. Nearly all components of the rocket shall be recoverable and reusable for any subsequent flights, if additional experimental flights are desired.

A number of elements of the launch vehicle can be purchased, however the body, fins, nose cone, software, and experimental payload will require design, development, and some components may require in-house manufacturing. Our major purchases will be the rocket motors required for test flights and validation.

As per the IREC evaluation criteria, the launch vehicle produced by Team 24 will be evaluated based upon the altitude the rocket is capable of reaching as well as the damage levels to components during flight. Our vehicle development process will be completed when, following a thorough test flight program, (1) the rocket consistently reaches the target altitude, and (2) all components are recovered without damage. Beyond that point, group resources will largely be dedicated to optimizing the data obtained through the experimental payload of the rocket, which will be evaluated based upon the quality and accuracy of the data obtained.

In June of 2017 the team will travel to participate in the Intercollegiate Rocket Engineering Competition held at Spaceport America and hosted by the Experimental Sounding Rocket Association. It is our aim to place highly at this competition and bring further prestige to our university.

Finally, it is the hope of Team 24 that successful participation in the Intercollegiate Rocket Engineering Competition will result in an increased level of enthusiasm and usher forth a wave of interest in rocketry and spaceflight at the FAMU-FSU College of Engineering. We sincerely hope that this project will become a yearly venture for the College of Engineering and that, in later years, more advanced vehicles can be developed and entered into competitions.

3. Design Updates

3.1 Avionics

The team has moved forward with the selection of our avionics systems. The avionics system will measure the altitude of the vehicle during flight, emit signals to jettison the parachutes, and serve as a beacon for locating the vehicle after the flight. The competition requires teams to have redundant flight computer systems. One of these is required to be purchased commercially off the shelf and the other may be developed by the team in fulfillment of the SRAD component of the competition. For the COTS system, the team has decided to make use of the `StratologgerCF` altimeter.

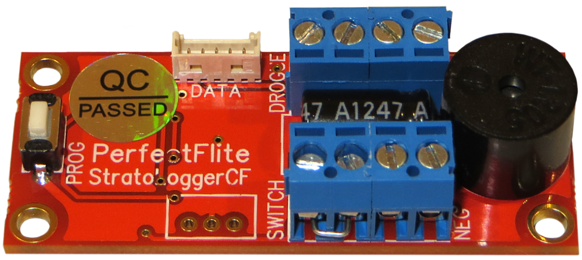


Figure 1: StratologgerCF flight altimeter.

A generic radio beacon that does not require a central processing system will be used in conjunction with the `StratologgerCF` altimeter and a battery to complete one of the avionics systems. For the SRAD avionics system, the configuration of the system will include a motherboard, central processing unit (CPU), inertial measurement unit (IMU), RF beacon, battery, and various switches to control the computer. The motherboard selected is a `Freescale Freedom` motherboard as shown in Figure (2):

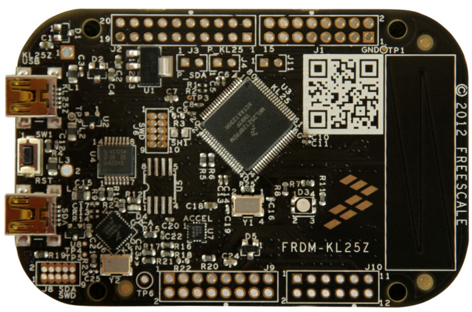


Figure 2: Freescale Freedom motherboard and processor.

The `Freescale Freedom` board also includes the CPU. Connected to this is a point-to-multipoint telemetry device. For this we intend to use the `XBee s3b` unit. This has a transmitting power of up to 250mW.

Figure 3: XBee RF beacon.

The IMU chosen is the SparkFun ADXL345. This measures the acceleration experienced by the device over 6 degrees of freedom. Using this data it will be possible to integrate the data twice with respect to time and determine the altitude achieved by the vehicle. Both of the avionics systems will utilize the type of battery specified by the competition.

3.2 Centering Rings

Previously team 24 had intended to construct and fabricate the centering rings for the motor assembly from 6061 aluminum. However to reduce fabrication time, a decision has been made to scrap this plan and instead fabricate the centering rings from Finnish birch wood. The new design will be similar to the old one, however it will be made from a stack of $\frac{1}{8}$ inch thick birch. Fins will then be epoxied to these rings and the whole unit will be placed around the motor housing. As mentioned this will ultimately have the benefit of being significantly faster to machine than the AL6061 design. For the wood design, one only needs to laser-cut the design from wood sheets, then epoxy and stack the cuts until the desired thickness is attained.

4. Issues

Currently Team 24 is facing a small number of issues. The most pressing of these is the procurement of fiberglass fabric. We have made a couple of attempts to procure the fabric and resin we need, however the first vendor we submitted an order for would have charged us over $330 for shipping from Washington state. The second vendor we contacted does not supply the neede material. We could get the material from McMaster

Carr, but their pricing is significantly higher than the standard price for the material. We are currently pursuing other options and intend to have finalized this by the end of the 27th of January.

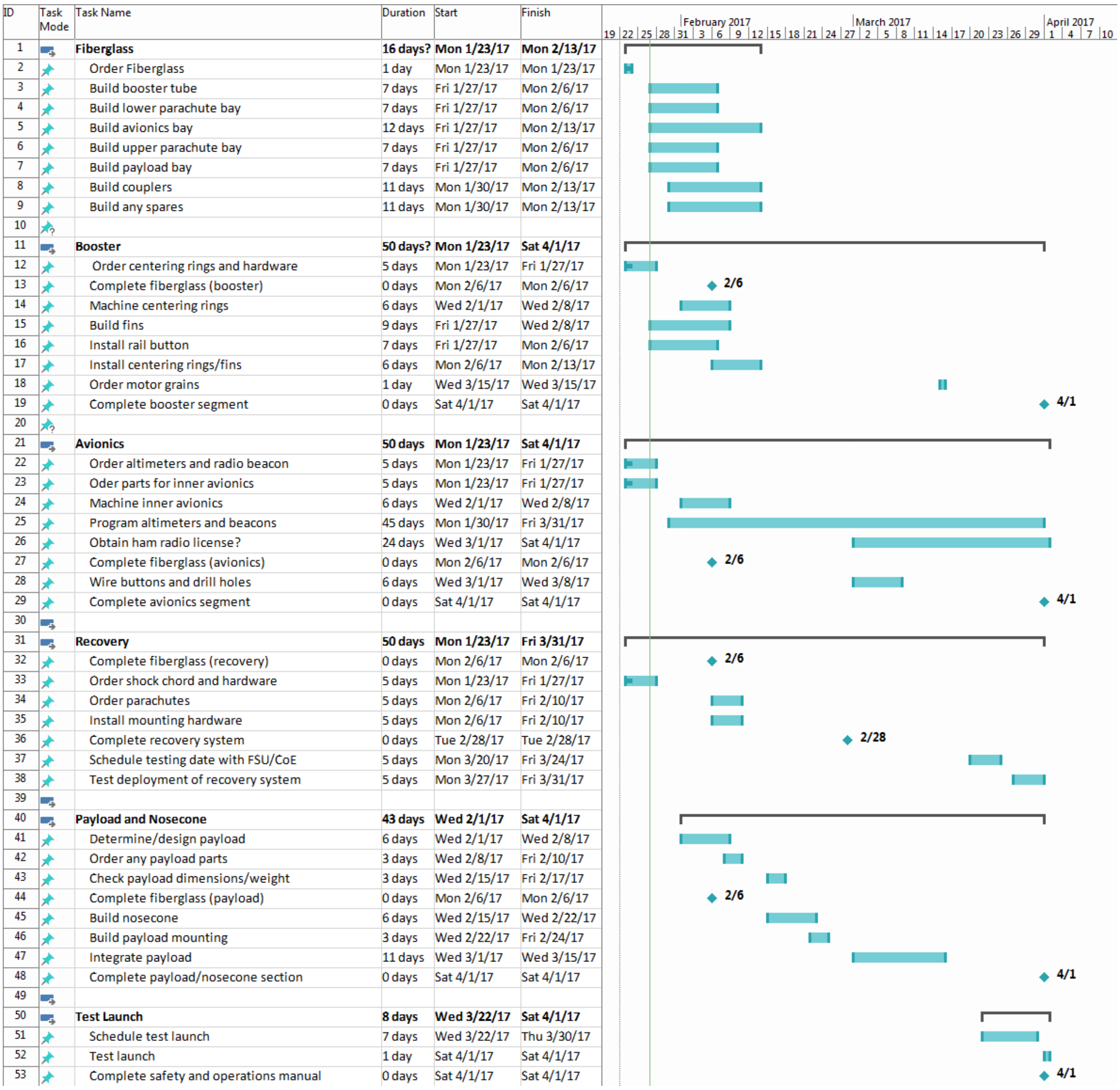
Secondly, we are expecting a disagreement between our calculated rocket mass and our actual rocket mass. This is due to the fiberglass body. The mass for this section was calculated by approximating the mass of a one foot squared section and multiplying this through to the amount of square feet we would have of our intended thickness. The reason this is problematic is primarily due to the resin being added to the fiberglass. There is no feasible way to determine precisely the quantity of resin added to the fiberglass until actually constructing a section of the rocket and taking measurements from this section. Additionally, we intend to have a 10 ply body tube, and the thickness of this tube may deviate slightly from the thickness we had initially calculated.

Lastly, if the weight of our finished rocket is significantly different than our original predictions, then our motor selection may need to be reevaluated. If so we may need to select a a more powerful set of fuel grains that will fit into the same motor housing we are designing for. We don't anticipate this to be a major issue.

5. Schedule

This semester this team will begin and complete the construction of the rocket. The schedule was made with the intention of a test launch happening in early April. Early April was chosen because most rocketry clubs meet at the beginning of each month. At the moment, the team's budget does not allow a test launch, but the team did not want to completely rule out the possibility of a test launch.

Team 24 plans to complete the first round of purchases by January 27. Parts that require machining or a great deal of assembly will be ordered first. Components such as the parachutes and motor will be ordered at a later date. This is because the weight of the rocket will greatly influence the chose of motor and parachutes, and the exact weight will not be known until later in the build process.



ID	Task Mode	Task Name	Duration	Start	Finish
1		**Fiberglass**	**16 days?**	**Mon 1/23/17**	**Mon 2/13/17**
2		Order Fiberglass	1 day	Mon 1/23/17	Mon 1/23/17
3		Build booster tube	7 days	Fri 1/27/17	Mon 2/6/17
4		Build lower parachute bay	7 days	Fri 1/27/17	Mon 2/6/17
5		Build avionics bay	12 days	Fri 1/27/17	Mon 2/13/17
6		Build upper parachute bay	7 days	Fri 1/27/17	Mon 2/6/17
7		Build payload bay	7 days	Fri 1/27/17	Mon 2/6/17
8		Build couplers	11 days	Mon 1/30/17	Mon 2/13/17
9		Build any spares	11 days	Mon 1/30/17	Mon 2/13/17
10					
11		**Booster**	**50 days?**	**Mon 1/23/17**	**Sat 4/1/17**
12		Order centering rings and hardware	5 days	Mon 1/23/17	Fri 1/27/17
13		Complete fiberglass (booster)	0 days	Mon 2/6/17	Mon 2/6/17
14		Machine centering rings	6 days	Wed 2/1/17	Wed 2/8/17
15		Build fins	9 days	Fri 1/27/17	Wed 2/8/17
16		Install rail button	7 days	Fri 1/27/17	Mon 2/6/17
17		Install centering rings/fins	6 days	Mon 2/6/17	Mon 2/13/17
18		Order motor grains	1 day	Wed 3/15/17	Wed 3/15/17
19		Complete booster segment	0 days	Sat 4/1/17	Sat 4/1/17
20					
21		**Avionics**	**50 days**	**Mon 1/23/17**	**Sat 4/1/17**
22		Order altimeters and radio beacon	5 days	Mon 1/23/17	Fri 1/27/17
23		Oder parts for inner avionics	5 days	Mon 1/23/17	Fri 1/27/17
24		Machine inner avionics	6 days	Wed 2/1/17	Wed 2/8/17
25		Program altimeters and beacons	45 days	Mon 1/30/17	Fri 3/31/17
26		Obtain ham radio license?	24 days	Wed 3/1/17	Sat 4/1/17
27		Complete fiberglass (avionics)	0 days	Mon 2/6/17	Mon 2/6/17
28		Wire buttons and drill holes	6 days	Wed 3/1/17	Wed 3/8/17
29		Complete avionics segment	0 days	Sat 4/1/17	Sat 4/1/17
30					
31		**Recovery**	**50 days**	**Mon 1/23/17**	**Fri 3/31/17**
32		Complete fiberglass (recovery)	0 days	Mon 2/6/17	Mon 2/6/17
33		Order shock chord and hardware	5 days	Mon 1/23/17	Fri 1/27/17
34		Order parachutes	5 days	Mon 2/6/17	Fri 2/10/17
35		Install mounting hardware	5 days	Mon 2/6/17	Fri 2/10/17
36		Complete recovery system	0 days	Tue 2/28/17	Tue 2/28/17
37		Schedule testing date with FSU/CoE	5 days	Mon 3/20/17	Fri 3/24/17
38		Test deployment of recovery system	5 days	Mon 3/27/17	Fri 3/31/17
39					
40		**Payload and Nosecone**	**43 days**	**Wed 2/1/17**	**Sat 4/1/17**
41		Determine/design payload	6 days	Wed 2/1/17	Wed 2/8/17
42		Order any payload parts	3 days	Wed 2/8/17	Fri 2/10/17
43		Check payload dimensions/weight	3 days	Wed 2/15/17	Fri 2/17/17
44		Complete fiberglass (payload)	0 days	Mon 2/6/17	Mon 2/6/17
45		Build nosecone	6 days	Wed 2/15/17	Wed 2/22/17
46		Build payload mounting	3 days	Wed 2/22/17	Fri 2/24/17
47		Integrate payload	11 days	Wed 3/1/17	Wed 3/15/17
48		Complete payload/nosecone section	0 days	Sat 4/1/17	Sat 4/1/17
49					
50		**Test Launch**	**8 days**	**Wed 3/22/17**	**Sat 4/1/17**
51		Schedule test launch	7 days	Wed 3/22/17	Thu 3/30/17
52		Test launch	1 day	Sat 4/1/17	Sat 4/1/17
53		Complete safety and operations manual	0 days	Sat 4/1/17	Sat 4/1/17

Figure 4: Schedule showing list of items to be completed during the spring semester.

5.1 Fiberglass

The most crucial component to be completed is the construction of the fiberglass body tubes. This portion of the rocket's construction must be completed early in order to compare the expected weight of the fiberglass with the actual weight of the fiberglass components. All fiberglass construction is planned to be completed by mid-February.

5.2 Booster

For construction of the booster, the construction and installation of the centering rings and fins is the most time demanding aspect of the construction. The parts for the centering rings and fins have already been ordered. The machining of the centering rings is scheduled to be completed by February 8. The fin design may be altered depending how accurate the theoretical weight of the rocket matches the actual weight once constructed. The motor grains will be ordered at a later date closer to the date of the first launch.

5.3 Avionics

The most challenging part of the avionics segment will be familiarization and programming of the two altimeters, radio beacon, and other flight computer components. The schedule allocates a month and a half to developing the flight computers, so this task should have ample time to be completed. The construction of the avionics bay is mostly dependent on the completion of the fiberglass components, which are scheduled to be completed by February 6. Once the fiberglass is complete, the final diameter of the avionics bay can be measured, and the wooden parts of the avionics segment can be machined.

5.4 Recovery

The most important components of the recovery system are the parachutes. The purchasing of the parachutes is scheduled for med-February to ensure that the parachute selected will be sufficient for the actual weight of the rocket. Other components such as mounting hardware and shock chord are scheduled to be purchased by January 27. The construction of the recovery system is not expected to be time intensive process, but it needs to be completed in a timely manner to ensure enough time for ground testing of the recovery system. Assuming a test launch in early April, the ground testing is scheduled to be completed by the end of March. The schedule also takes into account the time frame needed to organize the ground testing date with the College of Engineering or FSU.

5.5 Payload and Nosecone

Team 24 is still uncertain of the rocket's payload. The team plans to begin work on the payload in early February. Once the payload is determined the weight and dimensions of the payload must be finalized to match the requirements of the competition. In late February the nosecone will be 3D printed, and the payload will be integrated into the upper segment of the rocket.

5.6 Test Launch

The team is optimistic about performing a test launch if the budget allows. The test launch is most likely to occur in early April, when most rocketry clubs meet, and the completion of all rocket segment is scheduled to meet this date.

6. Safety

Broadly speaking, the significant phases of the project include research, design, construction, validation and testing, and lastly travel. Those parts of the project that present physical risk are inherent to the construction phase as well as the testing phase. Once an adequate design has been approved by our advisor, Dr. Kumar, the components of the rocket will be ordered, and in some cases, machined using the facilities at the College of Engineering. Fuel and any other energetic materials will not be added until just prior to launch at the intended launch or test location.

During the construction of the vehicles airframe, the team would like to ensure that all safety precautions are taken. The construction process involves hazardous adhesives and irritants. To mitigate this, the team will work in a well-ventilated area, wear long-sleeve shirts and pants, and wear thick, protective gloves. It is possible that these materials could cause serious damage to the lungs or eyes: to this end the team will wear proper eye and ear protection following OSHA standards. In addition, the power tools used could potentially cause bodily harm or injury. Eyewear and the use of a stable workstation can help reduce the risk of injury. Respirators will also be worn during the painting, gluing, and sanding processes.

During the recovery system test the team will assemble the rocket with its recovery system deployment charges (black powder). This test can be performed at a field near the college of engineering. The rocket will be positioned in such a manner that damage to the rocket body can be avoided. The black powder force is great enough to cause the nose cone or body tube to hit objects or persons within the possible trajectory. Therefore, all personnel shall be positioned at least 10 feet away from the nose cone and its ejection path and appropriate protective equipment shall be implemented. Each charge will be activated remotely and handling of the black powder shall be minimal. Delayed or early ejection may cause someone to be injured when ejection occurs. Given that the avionics section is critical to the safe operation of the rocket during flight, team 24 will consult a third party that is knowledgeable in programming and circuitry, to ensure a safe avionics design with a consistent firing mechanism at the time of detonating the black powder charges. The tests shall also be supervised by a member of the FSU Environmental

Health and Safety department with whomsoever they deem additionally required for safe testing and validation.

The flight test will require that the design team contact a local rocketry club and arrange a launch under the guidance of a Tripoli or an NAR certified launch safety officer. Lastly, the design team must travel out to the competition location in Truth-or-Consequences, New Mexico to perform the final launch and participate in the other events of the Intercollegiate Rocket Engineering Competition, hosted by the Experimental Sounding Rocketry Association.

There are many ways in which a launch can go wrong and potentially result in injury or damage. The motor system could lose reaction containment, causing the rocket to explode. If the parachute doesnt deploy, it could cause the rocket to fall freely and potentially injure someone or damage something. If the parachute deploys too early, it could cause the rocket to stray from its safe flight path. If the bulkhead containing the rocket motor is improperly secured, the motor could tear though a section of the rocket and possibly lead the vehicle or motor on a dangerous flight path. To reduce the risk associated with any of these possible mishaps, Team 24 will observe the required safety range policy of remaining 1,500 feet away from the launchpad during launch or flight. A procedure will be developed for interacting with the rocket prior to flight, and this procedure will ensure all planned safety measures will be properly executed. All rockets will be remotely armed and launched from a safe distance via a system incorporated and mandated by the Experimental Sounding Rocket Association. The launch location is in an isolated area with little within the vicinity which may be damaged by falling materials. It is also important to note that the Launch Safety Officer who is required to be present at each launch, will direct the attention of viewers to a rocket with an errant path.

It is the intention of Team 24 to store the solid propellants and all energetic materials in a flame cabinet (certified to hold said materials) provided by the FAMU-FSU College of Engineering. Access to this cabinet is limited to only ourselves and the safety staff of the University. It is also standard practice that the items inside of University Storage be inventoried and all proper signage displayed. This will prevent unintentional movement of the propellants and limit the possibility of bodily harm and fatal injury. Prior notice will be given to College staff before any of the materials are moved.

7. Conclusion

Sounding rockets have been used for the majority of the last century to further scientific knowledge and engineering goals. It is the aim of Team 24 to continue this by creating a sounding rocket capable of reaching 10,000 ft AGL while performing a scientific or engineering experiment safely. To achieve this goal it is imperative that we focus on the stability, reliability, and avionics package of our rocket. These features will maximize the scientific usefulness of the final product as well as emphasize the importance of safety to this group. Design of the overall system will happen in 4 general steps: pre-design, launch vehicle design, payload integration, and finally, verification and validation. Each of these steps contain the most pertinent requirements to proceed to the next. It is the goal of Team 24 that by completing each step, the final product will be adequate for the competition and provide useful scientific data.

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Biography

Tariq Grant is a Florida State University student in his senior year of Mechanical Engineering. He is currently a research volunteer at the Center for Intelligent Systems, Controls, and Robotics. Tariq is also the President of the American Institute of Aeronautics and Astronautics student organization at the FAMU-FSU College of Engineering.

Alex Mire is a Florida State University Mechanical Engineering student. For the past two summers, she has had summer internships with Jacobs Technology in the Kennedy Space Center. She is a member of the American Society of Mechanical Engineers and FSU's Flying High Circus.

Brandon Gusto is a double major in mechanical engineering and applied mathematics at FSU. He is interested in the development of computational fluid dynamics algorithms in the field of aerospace engineering. He spent his most recent summer at the Los Alamos National Laboratory where he worked on parallelizing shock hydrodynamics codes.

William Pohle is a senior Mechanical Engineering student at the FAMU-FSU College Of Engineering. He spent his last summer in Indiana working for Norfolk Southern resolving repair issues and train derailments. Previously William has volunteered his time at the High Performance Materials Institute in Tallahassee where he helped develop a new composite material.