2017 National Engineering and Science Academy

Introduction

Figure 1: Lucas Baranski, Matthew Yothers, and Hannah Yothers working on a bright idea.

This National Engineering and Science Academy develops the awareness of career choices in Engineering & Science fields. It is for young men and women who are entering the 8th Grade Fall of 2017 or older. Our program provides an opportunity for them to be aware of different technology career opportunities, insight into the excitement and challenges in these careers, and guidance on planning through high school and beyond to achieve this goal.

The theme of the 2017 academy was careers in science, engineering, and technology. The students participated in a series of modules, each focused on a specific career area. These modules provided introductory material for specific careers, hands-on activities to experience the thinking process a professional would use when tackling typical problems, and ties back to the classes the students would take in college or high school, to prepare them. Some modules involved design challenges; this gave students an opportunity to understand the and use the engineering problem solving approach. They learned how to meet design objectives, in the face of constraints, and how to make decisions involving trade-offs associated with constraints. The academy concluded with a keynote presentation on Design Thinking, the structured approach used by industrial design teams creatively solve problems.

National Engineering and Science Academy General History

During the 1990's, a national committee was formed in Washington, D.C., named the National Engineering & Technology Exploring Committee, a part of the Learning for Life program of the Boy Scouts of America. The mission of this committee was to assist youth, boys and girls between the ages of 14-20, in helping them to find and develop a technical career path for their future development.

The first Academy was held at Marshall University in Huntingdon, WV, and in the following years, under a separate program held at the Westmoreland-Fayette Council's Learning for Life Council. Since its inception within the Ohio Valley Region and in other parts of the United States, over 2,500 students joined the program. A high percentage of these students have gone on to technical careers after graduating from colleges or universities. Students have also been introduced to technical career opportunities available through trade schools.

Committee Members

Dr. Theodore Davi, F-SAME	Fellow, Society of American Military Engineers
	Founder & Chairman, National Engineering and Science Academy
Mr. Charles S. Fuller	Service Manager, Westinghouse
Mrs. Lisa Fuller	Special Education Teacher
Dr. Christopher Seaman	Technical Specialist, Arconic
Mr. Louis R. Grobmeyer	Consulting Engineer, Westinghouse
Mr. Martin Barbie	Scout Executive, Westmoreland-Fayette Council

Additive Manufacturing

The students were introduced to additive manufacturing. Instruction included:

- Examples of products designed and manufactured with 3D printing;
- Choice and use of materials;
- Structure of materials, final properties, and the impact on design;
- Factors involved in multicolored designs;
- Cost of engineering and design;
- Cost and speed of manufacture;

The goal was to give the students an appreciation of both the possibilities and challenges associated with additive manufacturing. The instructor discussed the process in depth, and led an engaging dialogue about the future of additive manufacturing as a delivery mechanism for tools or parts that would otherwise need to be physically transported.

Figure 2: Additive Manufacturing -- From virtual design to manufactured part.

West Point Bridge Design

Students were introduced to computer-aided design and simulation tools through a bridge design challenge. The objective was to design a bridge spanning a river that could meet or exceed carrying a specified load. The bridge was tested, in simulation, by having a truck drive across the bridge. Along with the load requirement, bridges were judged on overall cost of construction materials as well as the weight of the bridge.

The bridge CAD system allowed the students to learn about strength of materials, bending moments, loads, and weight of beam construction. The students learned firsthand how CAD allows one to rapidly iterate on design, and were encouraged to take a structured approach in the design and testing of their iterations, before submitting a final design. The design software for this module can be found at https://www.cesdb.com/west-point-bridge-designer.html.

Each student team had to present their results and explain their design decisions to the group. They then had to demonstrate the ability of their design to meet all objectives.

Figure 3: Applying engineering problem solving.

Welding Technology

The students were introduced to the science of welding, as well as the innovative use of technology for welding training.

In class instruction included a review of joining technologies and the challenges faced by designers incorporating welded structures as part of the design, as well as those of the welders responsible for making the completed parts. Topics included an introduction to metallurgical issues such as weldability of different materials, the impact of the heat affected zone, and how both the designer and welder must manage these.

The highlight of this module was practicing using a virtual welder. After basic welding instruction, the students were able to test what they learned by welding a virtual assembly. Initial practice was done without a welding mask, and watching simulation of the welding pass. This included automated scoring of each weld, with the results displayed on the welder screen, as well as projected in the classroom lab. This allowed the instructor to critique each weld and proved students feedback on technique. The final test had each student weld a virtual assembly. This was scored by the automated system; if an 80% proficiency rating, which would qualify the student to use a real arc welder. If they chose, the student could use a welding mask that provided an augmented reality visualization.

One unique opportunity in this module was for the students to see how one technology was applied to support another. They were all very familiar with video games, and had an appreciation for the technology behind gaming. In this case, they saw how this technology is applied to create a much safer and lower cost training environment to learn a complex skill.

Figure 4: Virtual reality supports manufacturing skills development.

Automation

The students were given an opportunity to learn the basics of hard automation. This included learning about and using training systems for robotics, hydraulic control, pneumatic control, thermal control, and PLCs. In this module students were shown how these systems are used to develop basic trouble shooting skills.

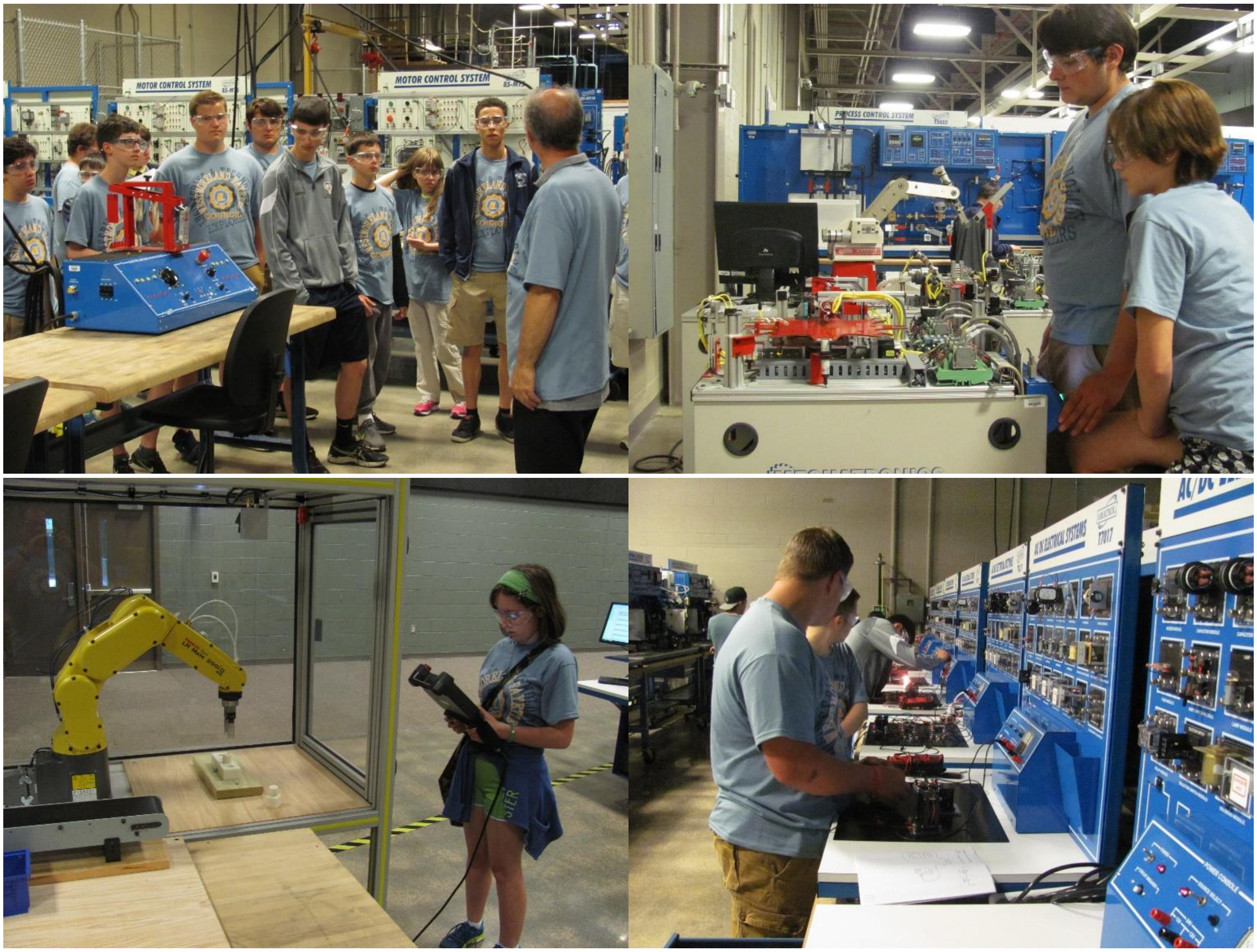


Figure 5: Students gain an understanding of the building blocks and career opportunities in automation.

Rocketry

Students were given an introduction to the theory of rocket flight, and what is important for a stable, controlled flight. Students learned hands-on by assembling and launching their own single-stage, low power model rocket. Topics covered included:

- Safely building and launching model rockets;
- The importance of center of gravity and the center of pressure in designing a stable rocket;
- Use of parachutes and streamers for safe recovery of a rocket;
- The functions of the rocket motor include thrust, delay, and ejection charges.
- Discussion of rocket motor thrust curves and motor classifications;
- How to size the rocket motor to your rocket;
- How the rocket motor ignition system works;
- Setting up a safe launch site;
- The importance of a stable pad or platform;
- Rules to be observed for launch and recovery safety;

Students were also introduced to high power model rocketry and the use of electronics to control parachute deployment and start additional motors while the rocket is in flight.

Figure 6: Model rocketry: theory and practice.

Designed Experiments and Empirical Modeling

The students were introduced to the challenges of designing and executing an experiment, and using data to develop empirical models. This module used Aerolab, an activity developed by the Academy of Model Aeronautics (AMA) where students learn the principles and physics of flight. Detailed information can be found at http://www.modelaircraft.org/education/aerolabs.aspx. Students use a JetStream balsa airplane, powered by a rubber motor, and tethered to a central pylon. This allows the students to run controlled experiments on the airplane and develop simple models of plane behavior.

The students designed and executed experiments measuring plane behavior, creating models, and predicting results. Activities were designed such that students made specific changes to their plane, hypothesize a result, measure and quantify, and then assess their hypothesis. Activities were:

1. Calculate average speed by measuring time aloft and distance flown. Perform replicates and determine spread of results and reason for outliers;
2. Put different amounts of power into the rubber motor (600, 800, and 1000 turns), and measure average speed and time aloft. Use linear regression to develop a model relating turns to speed and time aloft. Identify and explain potential data outliers.
3. Add drag to the airplane and repeat Experiment 2. Compare results, and the model to the one developed for Experiment 2.
4. Add weight to the airplane and repeat Experiment 2. Compare the results to Experiments 2 and 3. Suggest a hypothesis to explain the difference.
5. Given a target speed and time aloft, use models developed in 2, 3, and 4 to adjust drag, weight, and number of motor turns to achieve the target. Run the experiment and evaluate the results.

This provided a very hands-on approach to the experimental method, design of experiments, empirical model building and system identification, and application of statistics. Students were also encouraged to evaluate their experimental methods and revise as necessary to improve the accuracy and repeatability of their experiments.

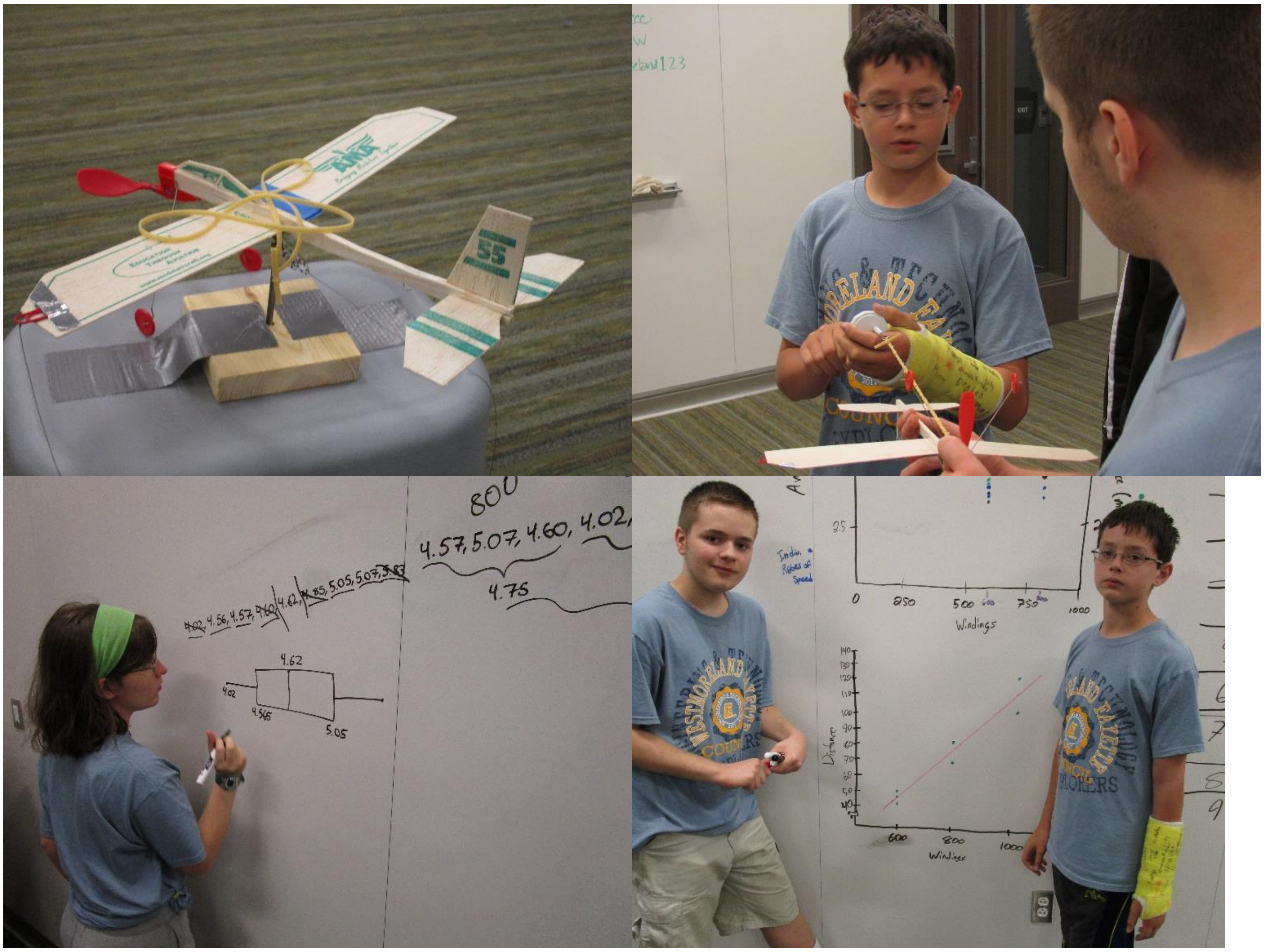


Figure 7: Students experience the process of building models using designed experiments and empirical data.

Quadrotors and Closed-Loop Control for Stabile Flight

Students were introduced to the basics closed-loop control, and the components of a control system using QuadLugs Box Quad STEM Kit. Details of the kit can be found at https://quadlugs.com/.

The system has the following components:

- Actuators – 4 brushless DC motors with integrated velocity sensors.
- Electronic Speed Control – This system implements tunable PID control for each of the DC motors, using the velocity feedback. It is also used to coordinate the motor control based on commands from the flight controller.
- Flight Controller – This system receives flight commands from the RC receiver, and coordinates the control to the electronic speed control, using an integrated 3 axis accelerometer.
- RC Transmitter / Receiver Pair – This system provides radio communications to the quadrotor and sends throttle and attitude control commands to the flight controller.

Libre Pilot, https://www.librepilot.org/site/index.html, was used for calibration and controller tuning of the quadrotor. This software provides a graphical user interface to each of the quadrotor subsystems, and visualization of quadrotor data to provide an understanding of the flight behavior, and how the quadrotor behaves as a system.

The initial focus was on PID control for the individual motors and the importance of having the motor responses being matched. Libre Pilot was used to calibrate each of the motors responses; this allowed the students to see that each of the motors had a different open-loop behavior, and the importance of matching the responses for a controlled flight. This was highlighted by discussing what happens during power up for take-off. Students were asked to describe the quadrotor response if one of the motors was producing less lift than the others.

The next stage involved calibration of the accelerometers, and discussion of how the three sensors are used to coordinate the commands to individual motors. Libre Pilot provided a visualization of a virtual cockpit that responded in real-time to manual movement of the quadrotor. This allowed the students to verify the calibration. We then purposefully miscalibrated the accelerometers and evaluated the changes to the virtual cockpit visualization. The students were asked to hypothesize the effect they would observe if the quadrotor were to be flown with the miscalibrated sensors.

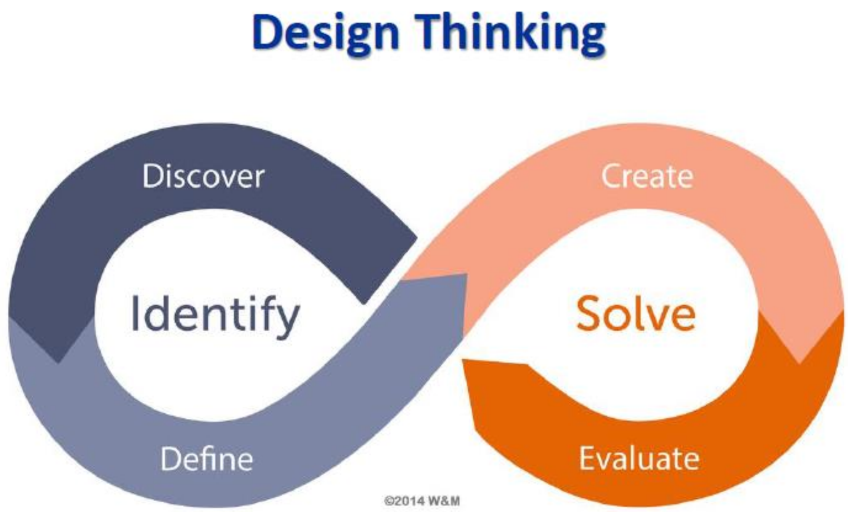
With the on-board sensors calibrated, the next stage was to calibrate and verify operation of the RC transmitter. Correct mapping and operation of the throttle, roll, pitch, and yaw controls is critical to safe and controlled flight. Again, visualizations provided by Libre Pilot allowed the verification of proper mapping of these controls.

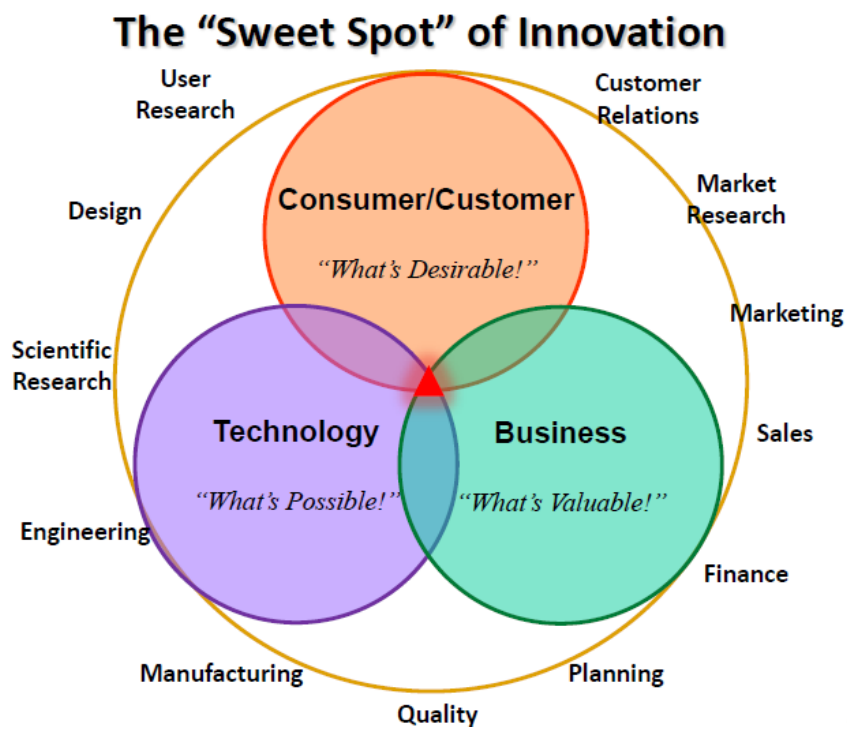
Finally, the students were led through the pre-flight checklist to ensure a safe flight. The exposed propellers move at very high speed, and present a very real safety risk. The pre-flight checklist is used to ensure there is a very specific procedure followed when preparing for a flight. The transmitter has both a hardware switch and a software switch using the throttle / rudder control that must both be engaged, in sequence, to allow the motors to be energized. The students were challenged to think of reasons why this redundancy is important, and the role a safety plays in designing and using systems.

Design Thinking

The week was capped off with a presentation on Design Thinking, a structured approach identifying the problem developing creative solutions. Steve Leonard, Senior Innovation Leader at Arconic, showed how these approaches are used to solve industrial design challenges and unleash creativity of teams. He provided examples based on products he developed with S. C. Johnson as well as Arconic.

Design thinking is a continuous activity designed to be iterative and repeatable. It integrates the various disciplines to enable the creation of innovative solutions. It is an inclusive process; all disciplines on the team contribute equally in the development effort in order to achieve success. The process of design thinking brings structure and time to the “fuzzy front end” to broaden and deepen concepts. It forces development teams to abstract and reframe problems to get at meaningful issues and integrates design throughout the development process.





Technology & Science • What technologies or scientific breakthroughs can be applied? • What IP does the firm possess that brings differentiation?	**Business Factors** • What new business models can be considered. • How can value be captured in the value chain.
User Factors • Physical, Cognitive, Emotional, Social & Cultural. • Lifestyles, Experiences & social trends.	**Personal Life Experience** • "Gut" instincts. • Past experience to draw on.

Figure 8: The process of Design Thinking

The students were presented an example of the design thinking process in the evolution of Apple products from the iPod to the iPhone to the iPad. The initial design challenge was focused on “enjoying music”. Mr. Leonard described how the design thinking process created a new device, a new business, and a series of banked ideas that became the core of the smart phone and tablet industry we know today. Using this, and other product development examples, he also discussed how ideas and creativity from all disciplines are used.

Summary

The overall goal for the National Engineering and Science Academy is to introduce late middle and high school students to the challenges and rewards of a technical career. Students experienced a range of hands-on activities from computer-aided design and manufacture, to hard automation, to experimenting and measuring with systems they designed themselves. They learned how courses they are taking now, or will take through high school, form the foundation for the technical career they are interested in pursuing. The activities, and discussions of the fundamental concepts behind these activities with the technical professionals leading them, provided guidance and context to plan their career.

Appendix – Expenses

ENGINEERING & SCIENCE ACADEMY Expenses for 2017		
Program Supplies	Planned	Actual
QuadLug Quadrotor STEM Kit	$1000.00	-
Rocket kits, motors, launch pads	$640.00	$242.64
Youth Recognition and Awards, Advertising	$450.00	$306.62
Mousetrap Racer Kits	$440.00	$214.00
Transportation	$1,470.00	-
Site rental/equipment	$1,000.00	$2159.00
Total	$5000.00	$2922.26

Explanation of Changes from Planned Expenses:

- QuadLug Quadrotors were donated by the Academy of Model Aeronautics.
- Transportation costs were eliminated because the program was revised to stay on-site at the Advanced Technology Center. This allowed time for more hands-on activities for the students.
- Site rental costs doubled; four days were spent at ATC, rather than the planned two. Due to the change in plans, we were able to negotiate a 20% reduction, leading to further savings.
- All other costs were reduced because of lower than planned attendance; the budget was planned for 40 students, but only 14 attended.