Broadcom MASTERS®
2014 Finalists

Washington, DC
October 24-28, 2014

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About Broadcom MASTERS

Broadcom MASTERS® (Math, Applied Science, Technology and Engineering Rising Stars), a program of Society for Science & the Public, is the premier middle school science and engineering fair competition.

SSP affiliated science fairs around the country nominate the top 10% of 6th, 7th and 8th grade students to enter this prestigious competition. After submitting the online application, 300 semifinalists are selected and 30 finalists are brought to Washington, DC for the final round of competition. Finalists present their research projects and compete in team hands-on STEM challenges to demonstrate their skills in critical thinking, collaboration, communication and creativity.

Broadcom Foundation and Society for Science & the Public thank the following for their support of 2014 Broadcom MASTERS:

- Samueli Foundation
- Science News for Students
- Deloitte.
- Allergan
- Sally Ride Science
- Q?rius, at the Smithsonian’s National Museum of Natural History
- The JASON Project
- Wolfram Research
- Affiliated Regional and State Science & Engineering Fairs
- Parents, Teachers and Mentors of the 2,054 Broadcom MASTERS entrants
Broadcom MASTERS (Math, Applied Science, Technology and Engineering for Rising Stars), a program of Society for Science & the Public, inspires and encourages scientists, engineers and innovators of the future.

The national science, technology, engineering and math competition for 6th, 7th and 8th graders, Broadcom MASTERS features top students nominated from SSP-affiliated fairs throughout the U.S.

The top 30 young scientists and engineers will be celebrated for their achievements in Washington, DC, where they compete for awards and prizes, including the Samuei Foundation Prize of $25,000, a gift of the Samuei Foundation.

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Brevard Mainland Regional Science and Engineering Fair
State Science and Engineering Fair of Florida – Ying Scholars

Nikhil Behari
Ingomar Middle School
Pittsburgh Regional Science and Engineering Fair

Daniel S. Bruce
The Rhoades School
Greater San Diego Science and Engineering Fair
California State Science Fair

Benjamin J. Chrepta
Friedell Middle School
Rochester Regional Science Fair

Joshua Courtney
Carmel Hill School
Louisiana Region VII-Science and Engineering Fair

Arnob Das
Stoller Middle School
Beaverton-Hillsboro Science Expo
Intel Northwest Science Expo

Leo Deng
ACCESS Academy
Intel Northwest Science Expo

Caroline Edmonds
Talbert Middle School
Orange County Science and Engineering Fair

Linus Freyer
George Washington Carver Middle School
State Science and Engineering Fair of Florida – Ying Scholars

Raghav Ganesh
Joaquin Miller Middle School
California State Science Fair

Makayla Gates
Peralta Elementary School
Central New Mexico Regional Science and Engineering Challenge
New Mexico Science and Engineering Fair

Alden Giedraitis
Triton Middle School
Massachusetts Region IV Science Fair

Floyd S. Greenwood
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Massachusetts Region IV Science Fair

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Aditya Jain
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Chythanya Murali  
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ScienceMontgomery

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Pikes Peak Regional Science Fair  
Colorado Science and Engineering Fair
**Why Middle School?**

Broadcom MASTERS® is the premier competition for 6th, 7th and 8th graders, where students demonstrate their mastery of math, applied science, technology and engineering through science fair competition.

Participants in Broadcom MASTERS are inspired, mentored and encouraged to stay with math and science through high school and beyond so that they are able to pursue exciting careers in science, technology, engineering and mathematics.

Students who participate in Broadcom MASTERS will be better prepared through project-based learning to meet the challenges of the future as tomorrow’s innovators. They will lead the way with scientific breakthroughs, engineering advancements and technological know-how.

These middle schoolers are invited to compete for prizes and awards in Broadcom MASTERS when they are top performers at their local SSP-affiliated science and engineering fair.

The national finals for Broadcom MASTERS are held in Washington, DC. The winner is awarded the $25,000 Samueli Foundation Prize.

**The Process**

To participate in Broadcom MASTERS, 6th, 7th and 8th grade students must complete an independent science or engineering project, then compete in their local SSP-affiliated science fair. The top 10% of these students, a total of more than 6,000 in 2014, may be nominated by the fair for Broadcom MASTERS.

Nominees complete the Broadcom MASTERS application. Entries are judged during the summer, and in the Fall, SSP and Broadcom announce the top 300 national semifinalists.

From among the semifinalists, 30 students are then selected as finalists for an all-expense-paid trip to Washington, DC to showcase their projects, compete in teams and visit historical sites and organizations that celebrate innovation through science, technology, engineering and mathematics.
Awards
The top finalist receives the Samueli Foundation Prize of $25,000, which recognizes the finalist from this premier group of 30 finalists who demonstrates mastery of science, technology, engineering and math. He or she exemplifies how research, innovation and teamwork come together to achieve STEM goals that impact our everyday lives.

Other awards include:
- One finalist will be awarded the Marconi/Samueli Award for Innovation of $10,000. This finalist demonstrates both vision and promise as an innovator, and ideally, in the spirit of radio inventor Guglielmo Marconi, has applied concepts from electrical engineering.
- Eight finalists (two in each of the disciplines represented by STEM) will win a combined $30,000 in experiential or product awards for their ability and promise in each of the disciplines. Society for Science & the Public and the Broadcom Foundation welcome Allergan in their support of one of these awards in 2014.
- Two finalists will receive Rising Star Awards to represent the United States as Broadcom MASTERS International delegates. They will travel with their local science fair’s delegation as student observers to the Intel International Science and Engineering Fair in Pittsburgh, Pennsylvania, in May 2015. These Rising Stars will be among a select group of Broadcom MASTERS International delegates from around the world.
- All finalists receive a $500 award from Broadcom Foundation to recognize their advancement to the Broadcom MASTERS finals.

Awards Honoring Schools and Teachers
In recognition of the important contributions of teachers to STEM education and the project-based learning of Broadcom MASTERS competitors, each of the 30 finalists’ schools will receive $1,000 from the Broadcom Foundation. Additionally, their teachers will be awarded with a classroom subscription to Science News magazine.
Muhammad Uğur oğlu Abdulla, 15
Melbourne, Florida

Deterministic and Stochastic Analysis in Biomedical Engineering: Fractal Geometry vs. Brownian Motion

Project Background: Doctors use electrocardiograms to record the heart’s electrical activity. Their patterns can help diagnose heart failure, heart attacks or problems with heart rhythm. Muhammad Abdulla saw the electrocardiogram as a chance to apply some advanced mathematics. His goal was to contribute to the early diagnosis of heart disease. “Mathematics, and the way it can bring order to a random universe, has fascinated me for years,” says Muhammad. In his project, he applied two statistical methods to the analysis of actual electrocardiograms. Muhammad hypothesized his methods would be more accurate than the currently used method in detecting abnormal electrical activity. The result could point to serious heart problems, years earlier than now possible.

Tactics and Results: “My passion is the practical application of medical research to contemporary problems faced by our society,” Muhammad says. That led him to apply two statistical methods, fractal geometry and Brownian motion, to the analysis of electrocardiograms. With the first method, he wrote an equation to analyze electrocardiograms from anonymous patients. The equation looked in particular at the patterns in electrocardiograms, and defined a healthy range. For the second method, Muhammad defined the percent chance that a patient was either healthy or unhealthy. Muhammad found the latter method was more accurate when measuring data over time, because of how simple and straightforward it was to observe trends that suggested a patient was unhealthy. In a test case using old patient data, the two methods were able to detect evidence of a heart disorder in electrocardiograms up to five years before a doctor had eventually diagnosed the problem.

Other Interests: Muhammad’s favorite pastime is judo, which tests his strength, endurance, technique and precision. “What sets judo apart is the fact that you need a tremendous amount of mental strength to excel at it. The entire basis of judo is ‘maximum efficiency with minimum effort.’ This can only be achieved by understanding the opponent’s patterns of motion to the point that you can calculate the opponent’s future attacks and defenses. Once this has been completed, overcoming the opponent is just a matter of maneuvering their motion into an attack for yourself,” Muhammad explains.
Project Background: Given Nikhil Behari’s interest in computers, the news of major data breaches at different retail chains caught his attention. “I wondered if it was possible to create a security system that is easy to use, versatile and effective when protecting online data,” Nikhil says. Beyond entering a user name and password, some websites also rely on secondary authentication. Sometimes that means entering a PIN or answering a previously asked question, such as providing a best friend’s name. Nikhil wondered if keystroke dynamics could be used to distinguish one user from another. That means measuring and analyzing the timing, pressure and pauses associated with a user’s every keystroke.

Tactics and Results: “The question for my experiment was, can the manner in which people type be used as a means of secondary authentication?” explains Nikhil. To measure pressure, Nikhil used piezoelectric sensors connected to an Arduino microprocessor he had programmed. A separate program measured action and pause time as users typed on the pressure-monitoring keyboard. Nikhil painstakingly recruited 50 volunteers, and had them type in five different passwords, including “hexagon” and “Y9y64w0!”. Once the data was organized, he ran four analyses to prove the possibility of this method. The results of his experimentation and analysis suggest that keystroke-based authentication is a powerful technique for distinguishing individuals. For example, a T-test, which proves whether a certain factor was effective when distinguishing among the typing styles of different users, suggested each of the three factors had some role in successfully distinguishing typing styles.

Other Interests: “My interests include soccer, biking and solving Rubik’s cubes. I enjoy soccer and biking because I like to keep active and stay healthy. I like to solve Rubik’s cubes because it gives my brain a fun ‘mental exercise’ and it keeps my reflex and hand-eye coordination skills sharp,” Nikhil says. He also loves robotics, engineering and computer science. He has spent years fostering this love by experimenting with Snap Circuits and LEGO® MINDSTORMS® NXT. “I one day aspire to achieve a high level of greatness in the field of engineering and computer science,” says Nikhil.
**Project Background:** Daniel Bruce’s fascination with peregrine falcons led him to visit a coastal marsh near his home. While a mating pair of the falcons was known to hunt there, it wasn’t the birds of prey that ended up catching Daniel’s eye. “It was on a bird watching expedition to Los Peñasquitos Lagoon that I noticed a significant human presence and began speculating as to the possible effect this could have on the lagoon birds,” he says. He developed three hypotheses, and then spent more than 35 hours conducting fieldwork in four lagoons scattered along the coast of Southern California. He relied on his keen observational skills and a suite of scientific instruments to conduct his research.

**Tactics and Results:** Daniel hypothesized that the distance at which light-footed clapper rails and other marsh birds took flight when disturbed would be inversely associated with human activity along nature trails through lagoons flanked by development. He also hypothesized this so-called flight initiation distance would vary among bird species, and that urban noise would be inversely associated with species diversity. He visited the lagoons multiple times, tallying average visitors per hour and bird species observed. He also used a laser rangefinder to measure the distances at which birds flew off when disturbed. Other instruments let Daniel log noise, temperature and other levels. He found the more visitors to a lagoon, the shorter the flight initiation distance. That suggested the birds had grown used to people. He also found waterfowl and wading birds didn’t flee. And overall, he observed that the more visitors, the fewer bird species. “No relationship was noticed between noise and bird species diversity,” he notes.

**Other Interests:** “I greatly enjoy bird watching for multiple reasons,” Daniel says. “Birds’ diversity, grace and beauty are unparalleled in my mind.” When not in the field, observing the birds in the salt marshes near his home, Daniel volunteers at the San Diego Natural History Museum. There, he works in its birds and mammals facility. By far, peregrine falcons are the birds he admires the most. “Not only do they wield the grace and beauty of most birds, they also have the power of raptors and fly at speeds unrivaled by any living being,” he explains.
Project Background: “When I saw a news report about the devastating injuries to soldiers in the Iraq War from improvised explosive devices, I thought about whether robots could be used in hazardous situations to reduce risk to human life,” Benjamin Chrepta says. So he built a prototype of a robotic arm that could be controlled with gestures from a safe distance. Relying on gestures would make the arm easier and more natural to control. It also would eliminate the need to write code for each movement. Benjamin worked hard to make the system cheap, durable, fast and efficient. He combined a robotic arm, which he built and modified, with other readily available parts and some custom programming.

Tactics and Results: Benjamin leveraged his experience in robotics to build and modify a robotic arm. He programmed an Arduino microcontroller to move the arm to certain angles at a constant speed. Next, he programmed the Xbox Kinect to map the movements of his own arm — information that he could then feed into controlling the robotic arm. Benjamin sought out a mentor for support, but couldn’t find anyone locally. Instead, his grandfather — a World War II veteran and physicist — encouraged him to tackle the project on his own. “I learned how problems can be solved by iteration, which is making small changes, observing the effect of those changes, and then making further changes based on those effects,” he says. Benjamin ran repeated timed trials to record the robotic arm’s movements, averaging and graphing the results. “The consistency of the robot arm movement suggested that this control system was reliable and reproducible,” he says.

Other Interests: Benjamin is an award-winning digital music composer and plays percussion with the Southeastern Minnesota Youth Orchestra. In the future, he hopes to build a 3D printer, an autonomous drone and even more musical instruments, beyond the flutes and finger piano he’s already crafted. Benjamin is also exploring artificial intelligence in robotics. “It would be great to integrate sensors and machine-learning technology to make a ‘smart’ robot,” says Benjamin, a FIRST Robotics competitor and volunteer robotics teacher at Ronald McDonald House. “This could be combined with gesture control to allow even more versatility of robot function.”
Joshua Courtney, 13
Baton Rouge, Louisiana

*Condition Factors in Fish as Bioindicators of Oyster Over-harvesting in the Calcasieu Estuary*

**Project Background:** It’s only natural that a future ichthyologist like Joshua Courtney should enjoy learning about fish. That’s why he took such interest in what his father and sisters reported from their fishing trip. They had been fishing in the Calcasieu estuary along the Gulf of Mexico. Joshua’s family visits several times a year to catch spotted seatrout, red drum and other fish. On this latest trip, the fish appeared thin. That prompted a family discussion about probable causes. Among them was overharvesting of oysters (and the destruction of oyster reef habitat important for fish). Joshua began planning an experiment to confirm the hypothesis — an experiment that took several years to complete.

**Tactics and Results:** Joshua’s experiment required measuring hundreds of fish. Rather than catch them himself, he stayed on the dock and asked other anglers if he could measure the fish they’d caught. In a field notebook, he recorded the weights and lengths of fish representing four species. “Over three years I collected over 700 data points,” Joshua says. To assess an individual fish’s health, he used its relative condition factor. That assumes a fish’s weight should be proportional to the cube of its length. He hypothesized the condition factor for fish taken from the estuary would be lower than 100% of the long-term average. Graphing this information allowed Joshua to note declines in body condition, especially among black drum and gafftopsail catfish. Separately he obtained oyster stock assessments. “Though unfortunate, oyster overharvesting has provided an opportunity to observe corresponding reductions in relative condition factors of fish with steep decline in oysters,” Joshua concludes.

**Other Interests:** Joshua plays the clarinet and the bassoon, and enjoys biking and playing video games. And yes, he also likes fishing, though he may be more scientific about it than most. “I like the ‘hands-on’ type of research, which fishing has, and I get to look at the anatomy, size, shape and diversity of fish that are caught,” he explains. Joshua’s interests sometimes overlap, such as when he edited the Wiki page for his favorite video game about fish, adding details about the actual species. His additions earned him the compliments of the Wiki’s administrators.
Project Background: Arnob Das knew a six-year-old girl who experienced multiple seizures daily. Doctors implanted a device under her skin to stimulate an important nerve and reduce her symptoms. Unfortunately, after about a month, the device began causing inflammation and malfunctioned. "Replacement required multiple surgeries and despite everything, the device simply wasn't compatible and required an emergency removal," Arnob recalls. "This incident led me to think if the failure would have occurred at a more vital location (e.g., brain), there would've been potentially deadly consequences. The situation’s urgency inspired my project." Arnob began to design an inexpensive but strong material that wouldn’t cause inflammation when used to make medical devices to be implanted in the body.

Tactics and Results: Arnob hypothesized an implantable material treated with plasma — that gaseous state of matter in which electrons separate from the atom — would reduce any toxicity. The material would be more compatible with the surrounding tissue. Plasma treatment would enable that by increasing how easily a material can be wetted. Arnob improvised a device to expose oxygen at low pressure to high-power radio waves, creating plasma. Working at home and in a university lab, he bombarded five polymers with plasma. The polymers included cellulose and several materials used in implants. Arnob next measured how evenly a drop of water would sheet on each surface. Cellulose proved best. Arnob realized the plasma treatment would allow a water layer to form on the cellulose’s surface. In an implant, the layer would separate the device from the surrounding tissue, reducing inflammation. The project “really taught me to think outside the box,” Arnob says.

Other Interests: “I like playing the piano, violin and saxophone and compose moving pieces that have tinges of classical and modern aspects,” says Arnob. He aspires to be a biotechnologist (and is already well on his way). “The one important thing to me is how to make the world a better place for everyone. By choosing my career as biotechnologist, I can discover new means to stop detrimental diseases,” he explains. In his free time, Arnob enjoys weightlifting, swimming, Tae-Kwon-Do and running. He also mentors a group of elementary school students.
Leo Deng, 14
Portland, Oregon

Development of Forest Fire Prediction Tool for the State of Oregon

**Project Background:** While learning about the effects of climate change in biology class, the threat of forest fires struck a note with Leo Deng. That’s in part because he lives in heavily forested Oregon. Leo learned how fires damaged much more than just trees. They also can harm the broader environment, as well as people and property. The family of one of Leo’s classmates experienced that firsthand. Separately, Leo was growing interested in machine learning. He knew it had many practical applications. So he hypothesized he could develop a machine-learning tool that could build on past fire and weather data to accurately predict future forest fires in Oregon.

**Tactics and Results:** Leo used a programming language called MATLAB® to create a forest fire prediction tool he could test by analyzing past fires. “When verifying the tool, it will accurately describe the past fires’ intensities with a reasonable accuracy of about 80%,” he hypothesized. Leo gathered 30 years of fire data from four institutions. The dataset included wind, temperature and other weather attributes, as well as fire intensity. He then processed the data, looking for which attributes correlated with fire intensity, using the total area burned as a proxy. He then tested the various attributes, individually and in combination. Using all of the ten weather attributes he’d previously selected in combination proved most accurate. That is probably because each has a role to play in fire intensity. The tool is the first, Leo says, to predict the specific intensities of forest fires.

**Other Interests:** “I’ve been playing chess since I was little. It’s the sort of game that tests your focus, your patience, and basic problem-solving skills — it’s a war of the mind,” Leo says. “I also really love playing soccer — it helps me to train my skill and discipline and at the same time I improve my teamwork skills (and social skills) by communicating and working together with my team as one. In both of these as well as other activities and skills, I love the idea that every loss is a win, and I can always improve on my previous effort.”
Project Background: Caroline Edmonds has spent more than three years volunteering at a Southern California aquarium, where the giant flashlight fish (*Anomalops katoptron*) gave her a bright idea. The fish cover and uncover bioluminescent patches under their eyes. That “lighting up” gives the fish their name. Inspired by the marine scientists and engineers she’d met through her volunteer work, Caroline decided to study the flashy fish to learn when and why they light up most. “I created a sampling method to quantify their light-ups, which has never been done before. Not much research has been done on these deep-sea creatures, so I was discovering some undocumented behaviors and quantifying light-up counts,” she says.

Tactics and Results: Caroline hypothesized the flashlight fish would light up the most when feeding, as they supposedly blink to spot or attract prey. Caroline devised a sampling method to consistently count the number of light-ups. She did so by shooting dozens of observational videos. Caroline then examined the footage at five-second intervals, logging her data in a spreadsheet. If the work sounds tedious, that’s because it was: Each of her 94 five-minute videos required 60 counts. She also recorded time of day, diet and fish behavior. She found the fish light up the most during feeding, and the least when resting at night. “This has not been quantified before in flashlight fish studies,” Caroline says. She also learned the fish light up more in the morning, possibly because they’d adapted to feeding times in the aquarium. They also lit up more when fed frozen crustaceans — but less when hunting live prey.

Other Interests: “I love anything ocean related,” says Caroline. Volunteering at the Aquarium of the Pacific in Long Beach, California, has allowed her to wade with sharks, pet octopuses and feed otters. “I love all types of sea creatures and enjoy learning how to care for them and how they live,” says this future ocean explorer. During a special aquarium camp, she even designed and built a remotely operated vehicle. The underwater robot successfully collected a sediment sample. Away from the water, Caroline enjoys volleyball, basketball, LEGO®, reading, hanging out with friends and playing with her dog.
Linus Freyer, 13
Pinecrest, Florida

Who Wants to Eat Horse?: Accuracy of Meat Declaration in Lasagna

Project Background: In 2013, while Linus Freyer was still living in Germany, a food scandal struck Europe. DNA testing revealed horsemeat mixed into some frozen beef sold in United Kingdom supermarkets. Soon, further testing found even more horsemeat in other food products sold across Europe. “Although not per se harmful the sheer scope of horsemeat adulteration sparked heated discussions over transparency of food preparation and food safety,” Linus explains. The scandal prompted Linus to investigate two questions: Was horsemeat also illegally present in processed foods being sold in the United States? And, how accurate and comprehensive were the labels detailing the meat content of frozen lasagna sold in Miami supermarkets?

Tactics and Results: Linus hypothesized genetic testing would reveal meat from animals not listed on the lasagna labels. “If the meat of horse, pig, cattle or chicken is present in a sample, then a specific DNA band would be visible on an agarose gel after species-specific DNA amplification,” explains Linus. Amplification required making millions to billions of copies of DNA segments. Linus used those copies to identify variations in cytochrome B gene CYTB and then identify different animal species. At a genetics laboratory, Linus tested eight lasagna samples, as well as one salami. As a control, he tested pure samples of various meats. The good news: Linus found no horsemeat. The bad news? Three of eight samples contained animal meats not listed on the label. This included pork and/or chicken in two supposedly “pure” beef lasagnas. Additionally, the all-pork salami also contained beef.

Other Interests: Linus loves a good racket, whether it’s playing tennis or the violin. His interest in science and engineering stems from an early — and ongoing — passion for LEGO®. As a kid, he used LEGO®s to build increasingly complicated machines, including differentials. At the same time, Linus started taking apart laptops and other devices to see how they work. He likes to use parts from older electrical devices to build new ones. He once used parts from a cheap disposable camera to build an electroshock device—much to his parents’ chagrin.
Raghav Ganesh, 12
San Jose, California

A Low Cost, Adoptable, User Tested Add-on Device for the White Cane Facilitating Safer Mobility of the Visually Impaired

Project Background: Raghav Ganesh loves innovation, especially when creative solutions can improve the lives of others. He founded the innovation club at his school, and likes to watch TED talks featuring inventors. A chance to meet a blind activist, who was among the first test users of Google’s self-driving car, got Raghav thinking about other ways to safely increase mobility among the blind. He learned that most visually impaired people are elderly, unemployed and still rely on a decidedly low-tech tool to get around. “This inspired me to develop a low-cost, add-on device to the traditional white cane, with real blind users as evaluators,” Raghav explains.

Tactics and Results: Raghav’s engineering goal was to create an add-on device that gives a white cane some real smarts. “My device would extend the white cane’s range while users continue to get terrain information by tapping the cane,” Raghav says. The device eventually used both ultrasonic and infrared sensors, coupled with an Arduino microprocessor, to compute the distance to furniture and other obstacles. Early tests showed the sensors, when used individually, failed to detect some obstacles. The device flags obstacles for blind users by vibrating the cane’s handle. Repeated experiments, and revisions, helped Raghav perfect his prototype. It costs about $55 to make and just ten minutes to master. “My results show that a low-cost, detachable, lightweight, and responsive device can be added to work with the traditional white cane’s usage model of sweep and tap,” says Raghav, who wants to start making — and giving away — the devices.

Other Interests: Flying — and crashing — a remote-controlled airplane in fifth grade kindled Raghav’s interest in engineering. “As I usually do, I disassembled the plane and figured out how each part exactly worked. With the parts from the plane and some additional components, I created a solar car,” he says. Raghav has also played soccer since first grade, and is now on a competitive club team. “I enjoy the strategic passes and real-time decision making done on the field,” he says. When not spending time outdoors, Raghav enjoys singing and playing the violin. He also designs computer games using Java.
Makayla Gates, 12  
Peralta, New Mexico  

Acoustic Levitation: The Wave of the Future

Project Background: While reading the Harry Potter book series, Makayla Gates wondered if levitation was even possible. A visit to a NASA website confirmed it is — and also revealed details of experiments on acoustic levitation. The method uses sound waves to lift — and remove — dust. NASA has used it to keep spacecraft and astronauts clean on the moon and Mars. About that same time, Makayla visited a vast solar array near her home. Her mother commented how hard it must be to keep the several hundred thousand panels clean of billowing sand. “I began thinking about trying to use acoustic levitation to clean the solar panels,” Makayla says.

Tactics and Results: Makayla made her own acoustic levitator, using a transducer to generate standing, ultrasonic-frequency sound waves. A plate reflected the waves back on themselves, creating the standing wave and pressure nodes that make acoustic levitation possible. Makayla then levitated different sizes of sand grains at different frequencies. Finding the most versatile frequency, Makayla says, would make it work best in removing sand from solar panels. Grain by grain, she started. “If I couldn’t find a place where the sand grain would float, I adjusted the reflector up or down as needed,” she explains. Makayla measured each grain, experimenting across five different frequencies. “I determined that in order for the sand to be levitated, each grain must measure between one-third to one-half the wavelength of the frequency,” she explains, adding that the 20 kilohertz transducer was able to levitate the widest range of grain sizes.

Other Interests: “I enjoy doing beadwork and crafts because I use my creativity to make beautiful things, and reading because I can go on adventures learning about the world around me,” Makayla says. “I like playing music in nursing homes and community service programs because I feel I help lift people’s spirits. As Youth Representative of Cherokee Southwest Township, I represent and increase community awareness of Cherokee culture.” Makayla also enjoys finding scientific solutions to problems. Her current “hobby” is figuring how to use a type of mushroom to clean up oil spills.
Alden Giedraitis, 15
Byfield, Massachusetts

Project A.I.P: An Introduction to Artificial Intelligence and Autonomous Navigation

Project Background: “From the time I could speak, I was always fascinated with robotics,” says Alden Giedraitis. Alden started building robots at age six, after receiving a LEGO® MINDSTORMS® NXT robotics kit. His robots walked and rolled — all thanks to his growing skill in programming. More recently, Alden set himself a new goal: create a machine capable of making decisions on its own. “I have always wanted to take on this challenge so that not only would I be advancing in what I like to do, but I’d also be able to contribute to the development of Artificial Intelligence,” Alden explains. That led to the creation of A.I.P. — the Artificial Intelligence Platform.

Tactics and Results: Alden wanted to create a robotics platform that could navigate autonomously. “Long story short, robotics for me is taking electronics and giving them a mind of their own,” Alden explains. The A.I.P. combined an iRobot® Create programmable robot, a sensor from an Xbox Kinect gaming system, a laptop computer, a voltage regulator, a little simple carpentry and some advanced programming. Alden hypothesized the A.I.P. would be able to perform a series of trials and tests that demonstrated Artificial Intelligence can be implemented in the field of robotics. Working in his living room, Alden put A.I.P. through the paces, testing its ability to negotiate obstacles, follow a human, map its surroundings and follow voice commands. He scored and logged his results for later display in graphs and charts. The results: A.I.P. was 87% accurate in demonstrating its purpose (and that’s despite its hard drive failing halfway through the experiment).

Other Interests: For a decade, Alden has strived to become the best roboticist he can. He has diligently learned more advanced programming languages to drive his creations. “To me, the idea that you can take different stringlets of lettering, numbers and symbols and give them meaning seems amazing, as the sky is the limit,” he says. Three years ago, Alden started his own robotics company, ARI Robotics. For now, Alden runs it out of a garage — just like his hero, Steve Jobs, did with Apple® in its earliest days.
Floyd S. Greenwood, 13
Andover, Massachusetts

*Selectively Breeding Nannochloropsis Microalgae to Become a Healthier Feed Stock for Freshwater Rotifers*

**Project Background:** As a student, Floyd Greenwood didn’t just read about Gregor Mendel’s early contributions to genetics; he also undertook his own experiments in selective breeding. In sixth grade, he bred algae to become more resistant to bleach. A year later, he met a biologist who developed algae that consume oil spills. “We talked about how scientists use algae to improve aquaculture and create healthier food for humans,” Floyd says. Floyd then began a new project: the selective breeding of an improved strain of algae useful both in feeding farmed fish and in producing biofuels. “I wanted to work on a problem with real-life benefits to people,” Floyd says.

**Tactics and Results:** To measure the beneficial elements of *Nannochloropsis* algae, Floyd fed them to rotifers — microscopic animals commonly found in ponds and puddles. He started with master samples of rotifers and algae, splitting each into five. Working in his basement, he got the algae to bloom under artificial light. He then fed the algae to the rotifers. After about a week, he counted the rotifers in each sample. “Once it was clear that one population was doing better than the others were, I declared it the winner,” Floyd says. He then split the winning group in five, and repeated the experiment. It took months, as Floyd struggled with contamination and other problems. “The populations peaked and crashed,” he explains. Eventually, the logged data revealed a subtle increase in the effectiveness of the algae in raising rotifers from one generation to the next, he says.

**Other Interests:** Floyd participates in robotics and engineering challenges, including Destination Imagination® and FIRST® LEGO® League. He’s built electronic cars and devices to shut off a home’s electricity during a flood. Floyd also used an Arduino microcontroller to build an automated rotifer feeder. “The Arduino is an important invention because it enables creative thinking, creative building and helps to turn big ideas into reality,” Floyd says. In his spare time, Floyd likes to browse for coins, stamps and other collectables in antique stores. “I enjoy the history they show and the stories they tell,” he says.
Project Background: Ever since fourth grade, Holly Jackson has loved to sew. She has sewn dolls, dresses, shirts and more. It shouldn’t be a surprise she decided to test the strength of, and the best applications for, various stitches — two questions she had long pondered. Her project taught her stitch strength is crucial, and not just in clothing. “Sewing is important in parachutes, air bags, space suits, blimps, seat belts and anything that requires pieces of fabric to be connected together,” Holly explains. “It is important that a seam is as strong as can be. In devices like parachutes and seat belts, a person’s life may be dependent on the strength of a seam.”

Tactics and Results: Holly asked which type of lockstitch, a stitch made from two interlocked threads, would be strongest: straight, stretch, zigzag or three-point zigzag. She used nylon or polyester thread to stitch together identical swatches of cotton, denim or nylon fabric. Holly hemmed the opposite ends of her 120 samples and passed a steel rod through each loop. She connected one rod to a winch and nestled the other atop a bathroom scale to measure the downward force. A high-speed camera recorded when each sample failed. Holly measured, recorded and graphed the force it took to pull apart each sample. She also compared fabric, thread and stitch strength. Holly found polyester thread failed, as hypothesized, and that the straight stitch was strongest on average — at least in samples that paired nylon thread and denim fabric. Other combinations were inconclusive due to overlapping measurement errors.

Other Interests: Holly doesn’t just sew — she also makes candles and bath products. “And, really, who doesn’t enjoy mixing things together?” she asks. “I also like mixing ideas, emotions and words. I wrote a 100-page science fiction novella that explores the concepts of free will and determinism. I have also played piano for eight years, and I have learned to entwine meaning by just changing the emphasis of a note. But emotions are sometimes confusing. For lucidity, I revert to math. I meet with a math club every other week and do challenging problems in geometry, algebra and logic.”
Aditya Jain, 14  
Portland, Oregon

It’s a Matter of Life & Breath: An Improved Automated Diagnostic Tool for Lung Cancer Solitary Pulmonary Nodules (SPN) Detection towards Population Based Screening

Project Background: It all started in fourth grade, when Aditya Jain’s grandma got pneumonia. He grew curious about the disease and the lungs. Aditya began researching lung function and experimenting with lung capacity, entering his projects in school science fairs. Then, in sixth grade, a family friend died of complications related to cancer. “This event inspired me to research lung cancer. I realized that if early detection of lung cancer was possible, we could save millions of lives,” Aditya says. By leveraging his love of programming, he developed a diagnostic tool for the early detection of lung cancer. It reads patient lung scans and accurately pinpoints spots, called lesions, most likely to be cancerous.

Tactics and Results: “Current lung cancer diagnosis methods are prone to error, due to the need for human intervention, and are unable to find solitary pulmonary nodules at an early stage of development,” says Aditya, using the scientific term for lesions. He developed algorithms, using the MATLAB® programming language, to process and analyze a scan of a patient’s lungs. “These algorithms analyze the image and form the brain of the program, intelligently searching for cancerous nodules,” says Aditya, who performed some research at Oregon Health & Science University. After preliminary testing, he ran the program on ten biopsy-confirmed scans. Aditya then calculated true positives, true negatives, false positives and false negatives. The program “performed very well overall,” says Aditya, noting its 88% accuracy. “Although some obstacles remain to be overcome, my tool could eventually serve as an everyday tool for the interpretation of chest CT images,” he concludes.

Other Interests: Aditya has devoted four years to researching the lungs. His interest in computers and programming stretches further back, to when he was just nine. That is about when he started programming his own games — and mastering a growing list of programming languages. He has since created a handful of Android apps available for download on the Google Play store (just look for his app development company, WizWon Studios). Aditya is also an active Boy Scout, and is currently a Life Scout. He enjoys writing and blogging, and even started his school newspaper.
Project Background: Reading an article about the effects of ocean acidification on the world’s coral reefs got Gelsey Jaymes wondering: What would the effects be on her local environment, namely the oyster beds right off her neighborhood dock? “I thought I would investigate the effect on oysters since they are a foundation species of our local salt marshes,” Gelsey says. Specifically, she wanted to learn whether increasing ocean acidity, due to the increase in levels of atmospheric carbon dioxide, would cause significant harm to oyster shells. By tinkering with pH levels, Gelsey simulated how oysters fared at the start of the Industrial Revolution, fare today — and will fare in the future.

Tactics and Results: Gelsey hypothesized lower ocean pH levels would lead to a greater oyster shell weight loss rate. That’s because acidic water erodes the calcium carbonate in the shells. She collected oyster shells and creek water from near her home. She then used seltzer and baking soda to adjust the pH of some samples so they matched past, current or future conditions. “I ran this experiment for eight weeks, adjusting the pH daily and changing out the creek water weekly. I dried and weighed the shells weekly as well,” she explains. Gelsey found the current 1.3% shell weight loss rate is 82% greater than what occurred in 1750. In 2100, it would be 62% greater than the current rate — and 72% greater in 2250. “This data supports the experiment’s hypothesis,” she says. Gelsey predicts thinner and smaller oyster shells (and fewer oysters) as ocean acidification continues.

Other Interests: Oysters aren’t all that gets Gelsey into the water. She belongs to a year-round competitive swim team and enjoys sharing the excitement at swim meets with her friends and teammates. “Six years of daily violin practice pays off when I get to perform Bach or Gaelic folk music with my quartet,” she adds. And Gelsey, after five years of work, is steadily progressing in written and spoken Mandarin ahead of a future China trip. She is also an amateur birder with a count book of Southeastern coastal migratory birds.
Sahar Khashayar, 14  
Laguna Niguel, California  

**Wildfire Early Warning System Using Computer Science**

**Project Background:** Lightning sparked Arizona’s deadly Yarnell Hill Fire in 2013. Tragically, 19 firefighters died battling the wildfire. “The mixture of long-term drought, record triple-digit heat and strong winds was a recipe for disaster,” says Sahar Khashayar. The deaths moved Sahar. “I couldn’t stop thinking, ‘What if?’ What if we could somehow detect the fire before it spread out of hand?” she says. She explored whether a mix of hardware and software could spot the early signs of a fire better than humans could. Such a device would be cheap, easy and efficient. Most importantly, it would provide an early warning that could prevent or reduce the loss of life and property.

**Tactics and Results:** Sahar created a device to detect the three main signatures of fire: heat, smoke and infrared radiation. Levels of each don’t rise in lockstep in a fire, so she chose to measure all three. To do so, Sahar mated SparkFun temperature and gas sensors, along with an Arduino infrared sensor, to an Arduino processor board. “My solution must use a temperature sensor, gas sensor and IR sensor, respectively, to continuously collect and measure data, then compare them to the threshold for given parameters,” she explains. She then tested the sensors individually, using a lit candle, propane lantern and propane stove to simulate wildfire. Sahar also wrote a program to send a warning via Bluetooth® to a smartphone if her detector measured any values suggestive of a fire. Deploying a network of her $60 early wildfire detection devices could save lives and property, she concludes.

**Other Interests:** Sahar loves playing the piano, reading and writing. “Honestly, I don’t know where I’d be without the invigorating, yet peaceful world of music. I’ve been playing since I was 5; the piano never fails to calm me down, no matter how I’m feeling,” she says. With reading, she won’t put down a good book until she’s finished it — only to sometimes read it again. And she calls writing “my addiction.” “One word, one sentence, and I’m off into my own little world. My wonderland, my mind palace, whatever you want to call it,” Sahar says.
Preventing Excessive Blood Sugar Levels in Type 2 Diabetes Patients: An in vitro Inhibition Mechanism of Alpha-Amylase with Flavonoids

Project Background: Rajiv Movva’s grandparents, aunts and uncles all live in India. They also all have type 2 diabetes. Their bodies do not make or use insulin well, sending their blood sugar levels soaring. “Ever since their diagnoses, they have had to strictly limit their carb intake, rice in particular,” Rajiv explains. This can be difficult, since rice is a staple food in India. During a visit to India a few summers ago, Rajiv discovered his diabetic relatives were more upset about drugs than diets. They didn’t want to take medicine to control their disease. “As a result, my research aims to take a step forward into finding a natural remedy for type 2 diabetics,” Rajiv explains.

Tactics and Results: Rajiv learned alpha amylase breaks down complex carbohydrates to simple sugars, playing a role in blood sugar levels. He asked whether plant compounds called flavonoids could inhibit the action of alpha amylase. He chose to test three flavonoids (naringin, hesperidin and quercetin) widely found in commonly eaten fruits and vegetables. Working in beakers, Rajiv tested each flavonoid on a starch solution to which he then added alpha amylase. He next measured glucose levels as a proxy for blood sugar levels. Mistakes and missteps forced him to constantly revise his procedure. “I learned firsthand that failure is a required step for success,” he says. The quercetin worked best, as Rajiv had hypothesized. “Ultimately, I concluded that flavonoids are viable amylase inhibitors and therefore could help control the rapid post-meal blood sugar spike,” says Rajiv, adding that eating fruits and vegetables rich in flavonoids would best serve less severe diabetics.

Other Interests: Rajiv is not just interested in science; he relies on it to quench his curiosity. That’s why he spends hours reading science, technology, engineering and math articles on Wikipedia. Rajiv also competes on his school’s Science Bowl team. “The fact that I can answer science trivia questions with my like-minded peers makes it a no-brainer for me to compete,” he says. Rajiv coaches up-and-coming 6th graders who show strong potential in representing his school in future MATHCOUNTS® and Science Bowl competitions. Outside of school, he enjoys writing and playing both basketball and tennis.
Chythanya Murali, 13
Little Rock, Arkansas

Saving the Aquatic Ecosystem from Oil Spill Cleaning Agents: A Non-Conventional Approach

Project Background: A 2010 oil spill in the Gulf of Mexico prompted a massive cleanup. It also moved Chythanya Murali to investigate new and better ways to clean up future spills. “The destruction wreaked in the aquatic realm was truly devastating, as many plants and animals suffered or were killed within a short time after the spill,” Chythanya says. “I decided to investigate the types of chemicals used to clean these events and found that the chemicals used for cleaning oil spills have positive and negative impacts on the marine life.” Chythanya didn’t just want to find a better method of cleaning up oil spills — she wanted to find one that wouldn’t harm the ecosystem either.

Tactics and Results: Some of the chemical agents used to clean up oil spills are toxic to the environment, Chythanya explains. She proposed using biodegradable enzymes and bacteria instead. When used individually, the two methods have a so-so effect. Chythanya hypothesized using the two natural agents in combination would yield much better results. Equally importantly, the unconventional combo would cause less damage to an ecosystem’s flora and fauna. Chythanya created miniature oil spills in five small aquariums hosting plants, various microorganisms and two kinds of crustaceans. A sixth aquarium served as a control. She added a chemical dispersant, enzymes, bacteria or the enzyme-bacteria combination to four of the polluted aquariums. Over a month, she monitored the life and water quality in each aquarium, repeating the whole experiment three times. Chythanya’s results supported her hypothesis: The combination treatment was fast acting and long lasting, as well as ecofriendly.

Other Interests: Chythanya likes to use her mind and body to do things that are productive, enjoyable and truly worthwhile. “I enjoy many activities that require physical exertion and critical thinking. Karate gives me a chance to cool myself down by requiring much exercise and structured discipline. Activities such as spelling bees, clubs such as Science Olympiad®, and simple daily activities require critical thinking and analytical skills,” she explains. Chythanya also enjoys learning more about anatomy. “I feel absorbed when reading about the structural components of our bodies,” she says.
Caroline Nolan, 14
Stuart, Florida

Filtering Agricultural Effluent with Fungal Mycelium

Project Background: Runoff rich in nutrients fueled a bloom of toxic algae on the Indian River Lagoon, near Caroline Nolan’s home on Florida’s east coast. The lagoon is the most diverse estuarine ecosystem in North America. It is also the heart of Caroline’s community. “The bloom resulted in massive fish kills and bacteria levels that made it unsafe for any type of recreational activities,” remembers Caroline. Fishing was out. So was boating. “The Lost Summer,” people called it. Caroline began researching a potential remedy. “I wanted to find a way that I could help my community and the ecosystem by filtering out one of the main causes of the algae — nitrogen and phosphorus,” she says.

Tactics and Results: Caroline hypothesized biological filters incorporating either roundhead or oyster mushrooms could filter farm runoff, since fungi need nitrogen and phosphorus to grow. She cultivated 16 filter bags, growing the two mushrooms separately on either straw or wood chips. She also created eight control filters. Caroline collected runoff from a dairy farm. “Using recycled gutters, sawhorses and a bucket system, I built a filter platform that allowed me to run the agricultural effluent through each filter bag at a constant rate,” Caroline explains. She repeated the experiment every 14 days for six weeks. Once filtered, Caroline found the nutrient levels remained too high to measure using standard test kits. So she sent the samples to a state laboratory. The results partially supported her hypothesis. Oyster mushrooms grown on wood chips proved to be the most promising, cutting total nitrogen by 5.45%, and total phosphorus by 2.43%.

Other Interests: Caroline enjoys boating because it allows her to spend time with her family. “I also love to do art, any type of art. I am currently taking oil painting classes, creating paper cuttings and doing pencil drawings,” she says. Caroline also is a whiz at using Adobe® Photoshop, the image-processing software, and is getting more into photography. “I often go out with a newspaper photographer to her assignments and take photographs along with her, which have been printed,” she explains. Caroline is also learning computer animation to create a videos for other competitions.
To See or Not to See: A Foray into DIY Quantum Entanglement

Project Background: Reading two library books sparked Jonathan Okasinski’s interest in the weird and wonderful world of quantum entanglement. Quantum entanglement involves correlations between the physical properties of two objects, even when separated. Measurements of one object instantaneously influence the other — if they are entangled. That is why it’s famously called spooky action at a distance. Jonathan read about a simple experiment to demonstrate quantum entanglement, then set himself the goal of improving upon the experiment. Even better, Jonathan would attempt to do so for less than $1,000. Jonathan just missed that second goal — but reached the first. To do so, he relied on surplus parts he machined and assembled himself.

Tactics and Results: At the heart of Jonathan’s experiment was a disc of radioactive sodium-22. The sodium decays to produce entangled pairs of gamma-rays. His goal was to use a pair of scratch-built detectors to measure any simultaneous hits from the entangled rays. To confirm the effect was real, Jonathan used three checks: 1) The entangled gamma-rays would initially be traveling in opposite directions; 2) They would have equal energies; and 3) The gamma-rays would scatter off hundreds of hand-cast aluminum cubes in perpendicular directions. Jonathan ran the experiment twice, once with his detectors in parallel and once with them placed at right angles. Only the latter detected pairs of signals, as expected given the perpendicular movement of entangled gamma-ray pairs. “I was able to demonstrate quantum entanglement,” says Jonathan, adding the experiment ended up costing roughly $1,360. Who says a seventh grader can’t do quantum physics?

Other Interests: Jonathan is a Maker — and has been ever since he got a Snap Circuits kit for his fifth birthday. Outside of science, he enjoys cooking. “I don’t subscribe to the ‘take-it-out-of-a-can-and-throw-it-in-the-microwave’ theory, and always cook from scratch, usually without electronic implements,” says Jonathan, whose repertoire includes everything from éclairs to meringues. He recently started metalworking. He cast the aluminum cubes used in his experiment — and the aluminum paperweights he gave his dad for Father’s Day. Outside of academics, Jonathan applies his sharp analytical skills to mastering the game of water polo.
Annie Ostojic, 12
Munster, Indiana

Wave Goodbye to Energy Loss

Project Background: Yuck! Annie Ostojic and her father grimaced as they bit into the microwave dinner. Each bite was either partly soggy or partly frozen — and completely awful. Worse, the meal had wasted both time and energy. “No doubt our 30-minute battle with this frozen entree had increased our carbon footprint and depleted more energy than it was worth,” Annie says. “Loving challenges, I decided to figure out how food could be microwaved more efficiently with optimal operating conditions and a new container design.” Annie did so, but it took eight months of microwaving hundreds of cheese cubes, marshmallows and potatoes. What she discovered should be of interest to anyone who’s ever struggled with a microwave.

Tactics and Results: Annie got cooking on three hypotheses: 1) Food with a high surface area-to-volume ratio would cook more quickly in conventional and microwave ovens; 2) Food would cook more evenly in certain positions inside a microwave; and 3) Food microwaved in geometrically shaped containers would cook more evenly and efficiently. She sequestered part of her house and ran hundreds of experiments, graphing her results. “Perseverance and dedication are essential for successful scientific research,” she says. Annie discovered cheese cubes with a lower surface area-to-volume melt more slowly in microwaves (but not conventional ovens) as heat is lost to the unwarmed air. Also, food cooks more evenly on the perimeter of a microwave turntable. Lastly, she designed a geometric microwave container shaped like half of a soccer ball. It sits in a ceramic bowl partly filled with water, creating an insulating steam chamber. “It really works!” she says.

Other Interests: People tell Annie she must have been born with goggles and a beaker in her hand. “Although it’s obviously an exaggeration, it’s true that I’ve had a passion for science and math from very early on in my life. I don’t just participate in science; I live it!” Annie also has a thirst for adventurous hobbies. These include zip-lining, parasailing, and indoor sky diving. “It is thrilling to meet the physical challenges that these activities provide,” she says. In addition, she also enjoys swimming, running and biking.
James Peter Roney, 14
Santa Barbara, California

Can Ant Pheromones Communicate Food Quality?

Project Background: James Roney grew increasingly interested in ants and other social insects through reading science fiction. “That and my mom’s constant complaints about ants invading our house made me curious about ant communication,” James says. For humans, word of a new place to eat might spread online or by word of mouth. With ants, it’s different. They lay down tracks of chemicals called pheromones to communicate the presence and location of a food source. “I wanted to know whether these pheromone trails could also communicate the quality of a food source,” James says. Luckily, he didn’t have to look beyond his own home for enough tiny subjects on which to experiment.

Tactics and Results: James hypothesized if he baited ants with sugar solutions of varying sweetness, the insects would lay down a more attractive pheromone trail to the most sugary food source. This would draw more workers and increase foraging efficiency. Relying on wild colonies of Argentine ants, James found sweeter solutions consistently drew more ants, whether presented individually or simultaneously. James also placed pure and diluted sugar solutions accessible only through straws. Halfway through, he switched straws — and counted more ants in the straw that had led to the pure solution, even though it now pointed to the diluted solution. His last experiment started the same way, except James relocated the two straws so they both now led to solutions of equal sweetness. Still, more ants traveled along the straw that had led to the sweeter solution. Hypothesis confirmed, all thanks to the participation of 26,256 ants.

Other Interests: “I love reading, especially science fiction. I enjoy science fiction because the future still remains ambiguous, so many science fiction stories could contain aspects of the actual future,” James says. He also writes short stories, plays piano and performs stand-up comedy and freestyle raps.
Hafsa Naseem Saeed, 14
Fort Pierce, Florida

Nitrogen Levels from the Agricultural Fields to the Indian River Lagoon

**Project Background:** The Indian River Lagoon, to the north of Hafsa Saeed’s Florida home, is in trouble. Runoff flows into the lagoon, fertilizing the explosive growth of algae. These blooms in turn choke the lagoon and kill marine life. Hearing about pollution’s impact on the local environment and economy, Hafsa researched its cause. She zeroed in on nitrogen. Nitrogen is heavily used as a fertilizer, including in the citrus groves for which Florida is famous. Hafsa spent a year collecting and analyzing water samples to learn how nitrogen levels varied along the waterways that drain the groves and flow into the lagoon. She looked at different types of nitrogen, including nitrates, nitrites and ammonium.

**Tactics and Results:** Hafsa routinely sampled storm water from 12 sites. These included ditches draining grapefruit groves and a canal funneling runoff into the lagoon. She used methods established by the Environmental Protection Agency to test her samples. Using an ion chromatograph and other equipment in a University of Florida laboratory, Hafsa measured levels of everything from organic nitrogen to ammonium in her samples. “All of these different types of nitrogen pollute our natural community, creating wastelands and killing animal and plant life,” she says. She found levels of total nitrogen (NO$_2$, NO$_3$ and NH$_3$) were highest. NO$_3$, or nitrate, easily dissolves in water. It fertilizes algae, causing blooms. When the algae die, bacteria decompose them. That uses up oxygen, killing fish. Hafsa also discovered that total nitrogen concentrations declined as the waterways neared the lagoon. That suggests bacteria were taking up some of the nitrogen.

**Other Interests:** “At the age of 2, I already owned a doctor kit and performed very serious check-ups on my grandmother,” says Hafsa, in explaining her lifelong love of medicine. She hopes to become an ophthalmologist. For now, she keeps busy — and fit — with various hobbies. Usually it’s reading. “Other times, in order to avoid fatigue and enjoy life, I often exercise with my mom and my brother. After running, stretching and weightlifting, all that is left to do is eat!” Luckily, Hafsa enjoys cooking exotic dishes, as well as baking delicious pastries.
Alex Shelby, 14  
Fishers, Indiana  

Gre-Cycling

**Project Background:** The more than one billion pizzas delivered each year may cause more headaches than stomachaches. That is because pizza grease soaks into the delivery boxes. When the boxes are recycled, the grease keeps cardboard fibers from bonding correctly. That can ruin whole batches of recycled cardboard. Alex Shelby thought if an efficient way could be found to recycle pizza boxes, it would save resources — and landfill space. Alex quantified the effect of grease on the strength of recycled cardboard. He also experimented with how different additives or processes counteracted that effect. What he learned is no pizza pie in the sky. Instead, it offers a simple, inexpensive solution to a $700 million problem.

**Tactics and Results:** Alex applied homemade grease in equal measure to cardboard samples from a restaurant chain. He then created a slurry by mixing the cardboard with water and different additives, including dish soap and drain cleaner. Alex also tried boiling the slurry and skimming off the grease. He then shaped the slurry samples. Once dried, Alex cut the freshly recycled cardboard into test strips. He clamped each cardboard sample to a rig, and hung from it a weighted bucket. He added weights until the cardboard tore, to measure its tensile strength. The testing revealed grease has a major effect on recycled cardboard, decreasing its strength by more than 83%. Meanwhile, the different additives and the skimming all increased the cardboard’s strength. Dish soap, formulated to cut grease, worked best. The cheap and easy solution increased threefold the strength of cardboard recycled from greasy pizza boxes.

**Other Interests:** Alex enjoys Boy Scouts, marching band and service work with his church. He is also interested in biomedical engineering, for one very personal reason: his brother, Eric. “Inspired by my younger brother with autism, I am planning to help enhance the lives of special needs children and adults throughout my engineering career by building devices and programs that can impact these individuals,” Alex says. He hopes to study biomedical engineering, and apply his interests, abilities and skills in math and science to helping others.
**Aditya Sivakumar, 14**  
Beaverton, Oregon

*An Acoustical Investigation of Western Classical Music Theory*

**Project Background:** Aditya Sivakumar loves math, physics and especially music. He studies piano and is an active composer. “When composing music, I have been fascinated by dissonance and consonance in Western harmony,” Aditya says. He learned the rules of harmony but wondered why the rules are what they are. Aditya knew some of the human perception of harmony is physiological — it just sounds good — but suspected there was more to it. That quest led to his project to determine the physical and mathematical basis for consonance and dissonance in Western music. He hypothesized the frequency difference between the two notes forming a chord determined whether it sounded consonant or dissonant.

**Tactics and Results:** Aditya used a two-tone signal generator to study two-tone chords, analyzing 57 frequency intervals. He classified each chord by acoustical quality, as well as by the frequency difference between its two constituent notes. He found chords formed by notes with a frequency difference less than a critical value were dissonant, while those with a larger difference were consonant. However, as the difference widened, the chords again grew dissonant. In phase two, Aditya looked at overtones, or frequencies higher than the fundamental frequency heard when a note is played. He found the overtones of one note would interact with the root note and the overtones of the second note, forming numerous two-note chords. Aditya says as long as enough of the chords were dissonant, based on his findings in phase one, the overall chord would be dissonant. The analysis explains all two-note chord behavior, he concludes.

**Other Interests:** Aditya loves mathematics. “When I was very young, my parents bought me a wonderful book on mathematics called *The Number Devil.* I loved reading that book. It had various chapters about dreams that a boy, not unlike myself, has every night,” Aditya explains. “After I read that book, I had my own dreams about mathematics.” Aditya’s second passion is music. He takes lessons in both piano performance and composition. He’s composed several pieces for solo piano and chamber ensembles. Aditya also runs cross-country with a club named for the coach who founded Nike, Inc., based in his hometown.
Talar Victoria-Grace Terzian, 13
Gainesville, Florida

Churn It Up: Off-the-Grid Laundry Agitators

Project Background: A 120-year-old device for hand washing clothes, purchased in an antique shop, got Talar Terzian’s mind churning. Curious, she learned how the manual device could agitate a sudsy tub of dirty clothes. The device works when plunged, over and over, into a laundry tub. That sets the different layers of the wash water in motion at different velocities, creating what’s called shear. It also creates suction, helping to vigorously agitate the dirty clothes. Talar then set out to improve on the design of the 1894 agitator. She tested her invention against the one antique and two other modern hand agitators. Talar since has received a provisional patent for her invention of a simple, green and reliable way of washing clothes by hand.

Tactics and Results: Talar first tested how well the three commercial agitators cleaned tomato-stained T-shirt fabric, using only water and lemon juice. “I constructed a lever-driven shaft to maintain constant control over each agitator’s movements up and down,” she explains. She then built an agitator, fitting a plunger inside a funnel with the help of her grandparents in their garage workshop. Inside the plunger, Talar nested the three halves of progressively smaller wiffle™ balls. Three hundred controlled tests later, Talar recorded the stain remaining on each swatch by comparing it to a color gradient scale. Overall, her “Whiffle Baffle Ball Plunger” worked best. “I then used the same lever system with each agitator to demonstrate the hydrodynamic shear force using an ice cube test,” Talar explains. For each agitator, she counted the plunges it took to melt the ice cubes in a bucket of water. Again, her invention worked best. Talar now seeks to motorize her device using a bicycle-driven shaft.

Other Interests: “I enjoy volunteering, fundraising and playing the clarinet in my school band,” Talar says. Each week, she volunteers as a cashier, sorter and pricer at the Alachua County Humane Society’s thrift store. Talar also likes to create green solutions to everyday problems. That passion has inspired more than just her laundry agitator experiment. “Repurposing worn-out household goods, such as turning clothing into tote bags and newspapers into paper pulp ornaments, are some of my recent projects,” explains Talar.
Annika Urban, 13
Pittsburgh, Pennsylvania

The Stethophone

Project Background: Exercise-induced asthma and a nasty cough sent Annika Urban to the doctor, over and over. Sometimes, the problems would vanish before she got there. “These experiences made me aware of the difficulties associated with diagnoses of symptoms that appear and disappear or are triggered by events that don’t typically occur in doctors’ offices,” Annika says. “I envisioned a stethoscope which could record and transmit breath and chest sounds to provide an easier way for a doctor to diagnose patients’ conditions remotely.” Such a device could allow doctors to listen to a patient’s heart and lungs from anywhere. Annika imagined it being useful in developing countries, at sea or on battlefields.

Tactics and Results: “My project’s goal was to engineer a device to allow doctors to diagnose cardiopulmonary conditions such as asthma or heart murmurs remotely using a patient-operated stethoscope diaphragm and recording device,” Annika explains. The device had to be effective, inexpensive and simple. Her first effort combined a stethoscope, microphone and tablet computer. It couldn’t detect a heartbeat. A different recording device could, but was expensive. Then she added a microphone adapter and pre-amplifier to the first setup. “Using this device, I could hear distinct heartbeats and breath sounds,” Annika says. A doctor analyzed recordings she took of her heart and lungs. “He told me that he could definitely see the Stethophone being used in medicine, and that he was amazed with its sound quality and authenticity.” Repeated testing, using sound editing and analysis software, revealed the $50 device amplified the signal and retained lower frequency sounds.

Other Interests: Ever since she first peered through a microscope, Annika’s been enthralled by engineering and science. “To me, engineering new tools that allow us to better see and measure the world around us is a fascinating challenge,” she says. Annika is already brainstorming other mobile medical instruments, including an otoscope and in-home strep test. She also wants to develop a smart phone app to teach patients how to use her Stethophone. And she developed a curriculum to teach elementary students computer programming. Finally, Annika loves to compete — in FIRST® LEGO® League, cross-country, track and science fairs.
Project Background: Katherine Wu’s family always vacations in Florida. One year on the way south, her parents drove late into the night. “From the backseat, I could hear my mom talking to my dad to make sure he wouldn’t fall asleep while driving,” Katherine recalls. She knew falling asleep behind the wheel causes 100,000 crashes a year. She’d also heard of headbands that measure electrical activity in the brain. Inspired, she created a device that could detect drowsiness and alert a driver. “As most accidents occur when a driver is alone, I worked to create a device that acts like a companion and prevents the driver from falling asleep behind the wheel.”

Tactics and Results: Katherine started with a headband that relies on electroencephalography (EEG) to read the tiny electrical signals used by brain cells to communicate. The waves vary depending whether a person’s drowsy or awake. “Frequent eye-blinking is also associated with drowsiness. As a result, I used EEG waves and eye-blinks to determine how drowsy the user is,” she explains. The headset communicates wirelessly with a Raspberry Pi microcomputer that Katherine learned to program in part by watching university lectures online. When the device detects the signs of drowsiness, it alerts the wearer by broadcasting music or beeping a warning. Katherine’s test volunteers wore the headset while driving Mario Kart on her Nintendo® Wii or doing math problems to simulate a wakeful state. Then they did the same while sleeping (or relaxing with closed eyes) to simulate drowsiness. The device accurately detected the early signs of drowsiness, alerting users.

Other Interests: As a young child, Katherine enjoyed swimming, ice skating, gymnastics, drawing and piano. “Growing up, my interests changed but my love for classical music and piano only grew, as I devoted more time to piano,” Katherine says. “Music is a form of art and universal language. It connects people who have diverse backgrounds. After working hard to learn each piece, I put in my understanding of the music, making it unique and personal.” This accomplished pianist has performed solo at Carnegie Hall and with the Washington Philharmonic Orchestra.
**Liam Hayden Young, 14**  
Colorado Springs, Colorado

*The Bubble Effect: How Nozzle Induced Cavitation Reduces Surface Drag on Water Vessels*

**Project Background:** Liam Young had a thought bubble — or rather, a thought about bubbles. He wondered if a ship would move more quickly, and efficiently, if it could sail through a cluster of bubbles. Creating bubbles under pressure at a ship’s prow would result in an area of low pressure, Liam says. That would reduce drag and increase the ship’s efficiency. If Liam could demonstrate how to cut use of the dirty fuel burned by cargo ships by 20%, it would exceed the reduction in sulfur emissions achievable by converting every car in the world to run on electricity. Liam’s backyard experiments took seven months but yielded some promising results.

**Tactics and Results:** Liam built a seven-meter tank to test a torpedo he fashioned from PVC tubing. A pressurized tank delivered a stream of bubbles from a nozzle in the torpedo’s nose. Liam also rigged a weight-and-pulley system that pulled the torpedo through the water along a guide wire. The testing involved ten non-pressurized runs, plus another ten runs at five pressurized levels. During each run, he measured the time the torpedo took to travel a set distance. “The data shows a consistent decrease in time from the non-pressurized control runs to the highest pressure,” says Liam. Overall, his results suggested the bubbles decreased the torpedo’s travel time (or increased its velocity) by 12.8%. However, further analysis revealed that random errors could account for the measured difference. That finding prohibited a conclusive result, Liam says. Undeterred, Liam plans further research, increasing pressures and sample sizes to improve his random-error analysis.

**Other Interests:** Liam enjoys hiking, snowboarding and volunteering on church service projects. He and his family like exploring the canyons of Colorado looking for ancient petroglyphs — and even more ancient dinosaur footprints.
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The Inspiration for the Broadcom MASTERS

In recognition of the importance of STEM education and the importance of sparking insight and passion through project-based learning, the Broadcom Foundation is proud to sponsor the Broadcom MASTERS and congratulates all finalists for their hard work and dedication to following their passion in science, technology, engineering or math.

The inspiration to create the Broadcom MASTERS is found in the personal history of Broadcom's co-founder, Dr. Henry Samueli. Just like the thousands of young people competing in science fair competitions throughout the United States and the world, Henry Samueli's passion to pursue a career in engineering was ignited during the formative years of middle school with a 'hands-on' electronics project in his West Hollywood 7th grade electric shop class.

Henry Samueli convinced his teacher to let him tackle building a vacuum-tube short-wave radio he had read about in a Heathkit catalog, which he worked on every night for an entire semester. When he brought the assembled radio into school, the teacher plugged it in and it worked.

From that moment on, he was hooked. "That became my mission in life, from 7th grade onward, to find out how radios work." He went on earn his Bachelor's, Master's and Ph.D. degrees in electrical engineering at UCLA and his amazing career trajectory as an engineer/innovator led to the founding of Broadcom, which today is an international Fortune 500 company with over 11,000 employees.

Broadcom Foundation and Society for Science & the Public thank Dr. Henry Samueli and his wife Dr. Susan Samueli for their generosity in presenting the Samueli Foundation Prize, the top award of $25,000, at the Broadcom MASTERS.
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Broadcom Foundation is a non-profit charitable organization formed by Broadcom Corporation to advance science, technology, engineering and math (STEM) education by funding research, recognizing scholarship and increasing opportunity by advocating project-based learning and initiating programs like Broadcom MASTERS to inspire young people to pursue STEM careers.

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Society for Science & the Public
Society for Science & the Public (SSP) is one of the oldest nonprofit organizations in the U.S. dedicated to public engagement in science and science education. Established in 1921, SSP is a membership society and a leading advocate for the understanding and appreciation of science and the vital role it plays in human advancement.

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