June 2020

GEORGIA PATHWAYS
MAGAZINE

Back To Space
Falcon 9 and Dragon

Set Up For Success
Georgia State University

Particle Detectors
Oak Ridge National Lab

TAG
Technology Association of Georgia

TAG | TAG-Ed
Education Collaborative

The Technology Association of Georgia Education Collaborative (TAG-Ed) strengthens the future workforce by providing students with relevant, hands-on STEM learning opportunities and connecting them to Technology Association of Georgia (TAG) resources. Formerly the TAG Foundation, TAG-Ed is a 501(C)(3) non-profit organization formed by TAG in 2002. Later, the organization's name was re-branded to TAG Education Collaborative to facilitate our role as the leaders for K-12 STEM education in Georgia.

President / CEO
Larry K. Williams

TAG / TAG-Ed Executive Director
Heather Maxfield

Publisher
Wayne Carley
wayne@tagonline.org

The Technology Association of Georgia (TAG) and
TAG Education Collaborative
4400 North Point Parkway
Suite 155
Alpharetta, Ga. 30022

http://www.tagedonline.org

To understand STEM...

...you must DEFINE STEM, but you cannot define an acronym using the words it stands for; *you must define the words the acronym stands for.*

Universities and organizations around the world continue to debate what a STEM career is. There is no doubt that "every career" uses STEM skills and this observation remains the focus of STEM Magazine.

SCIENCE: "The systematic accumulation of knowledge" (all subjects and careers fields)

TECHNOLOGY: "The practical application of science" (all subjects and careers)

ENGINEERING: "The engineering method: a step by step process of solving problems and making decisions" (every subject and career)

MATHEMATICS: "The science of numbers and their operations, interrelations, combinations, generalizations, and abstractions" (every career will use some form[s])

For a moment, set aside any preconceived notions of what you think a STEM career is and use the above dictionary definitions to determine the skills used in any career field you choose.

These definitions are the "real" meaning of STEM and STEM careers.

Set Up For Student Success

by Michael Davis

"The student support systems in place at Georgia State before the pandemic have proven invaluable during it, says Timothy M. Renick, who leads the university's student success initiatives."

A lot of our students are facing extreme hardships right now. Any given semester, 85 percent of Georgia State undergraduates are working, and many of their jobs — at restaurants, in retail — were the first to be eliminated as the economy began to decline.

We enroll one of the largest low-income student populations in the country, and this spring we had almost 29,000 Pell Grant-recipient students at Georgia State. That's three times more than the entire Ivy League.

In an interesting way, though, our unique student body has become an advantage during the pandemic. Because almost all of our students are non-traditional in some sense of the word, we've already built the systems to serve students who may have difficulty finding time for face-to-face meetings with staff.

One of our signature programs is academic advising based on predictive analytics. We're tracking every student for 800 risk factors every day and reaching out to them when a problem is identified. Last year we had 60,000 meetings between advisers and students that were not initiated by student but by advisers.

As the pandemic unfolded, we were able to keep our advising of students going without missing a beat because we were already set up for video conferencing and for tracking students electronically. The first two weeks we were delivering instruction entirely online, we had more than 8,000 meetings between advisers and students, and that was almost the same pace as when we were operating normally in the early part of the semester.

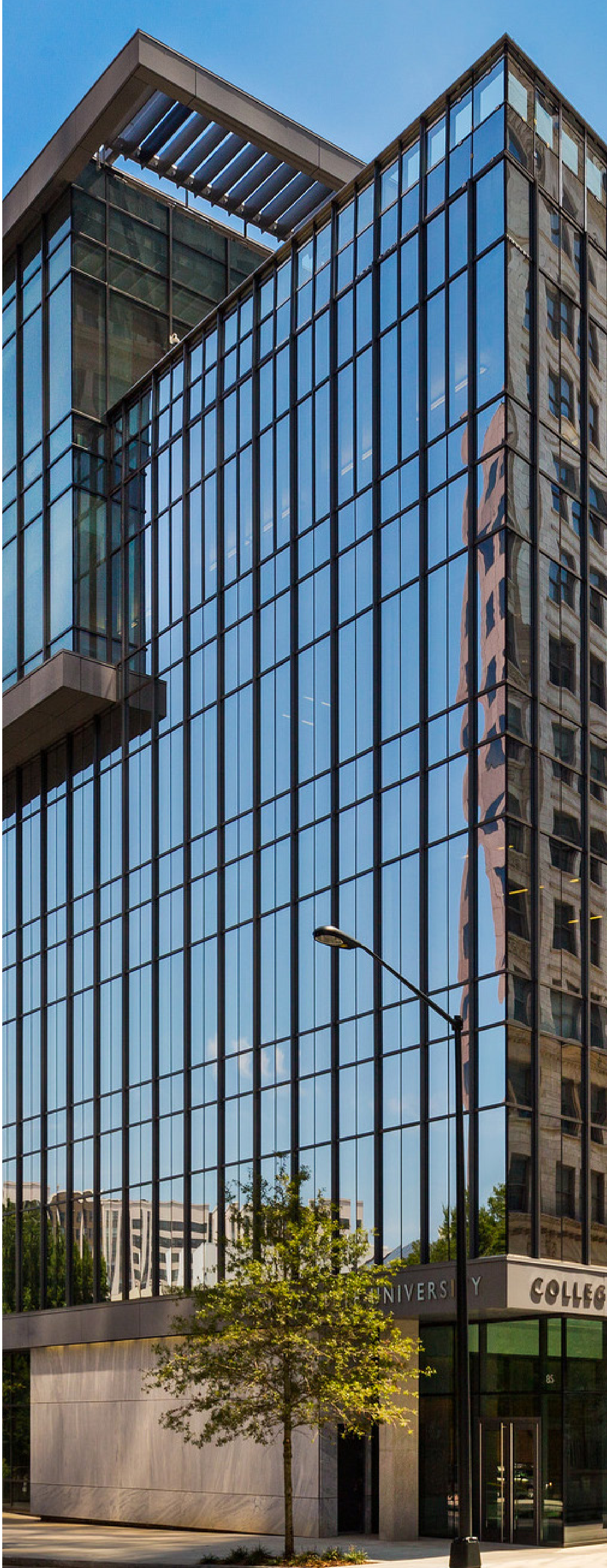
We've also added some new alerts to our predictive analytics tracking system. If students are not logging on to their classes, advisers are reaching out.

The advisers determine what the issues may be — trouble with technology, the course material, financial difficulties — and then connect the students to help. Because of these efforts, 98 percent of our undergraduates were logging on to their online classes every week.

In our Counseling Center, we're also having hundreds of virtual meetings every week between counselors and students. In Career Services, we had a job fair scheduled for the week we came back and started online. We had already set up a virtual system, so students could come in that day and hear pitches from major employers such as State Farm and Amazon in a large chat room, and then ask for a private interview if they were interested. About 170 students participated in that virtual job fair.

Our Admissions Office had already set up a system for virtual campus tours because a lot of our prospective students and parents have trouble coming to our Atlanta Campus in the middle of the day. When we had to suspend in-person campus tours, we moved to virtual tours, and in one week we had 1,700 prospective students and parents participate.

We've also established an Emergency Assistance Fund for students, using some of the same principles, techniques and technologies in place for the last eight years to administer our Panther Retention Grant program. If students are facing food insecurity, for example, we have a process that allows us to give them resources in a very short time, often on the spot.



Since last March, we've awarded grants to more than 2,000 students from this emergency fund.

Over the last couple years, we've built up a large student Financial Management Center with dozens of financial counselors. A lot of our students have not had the

experience of dealing with big financial decisions, so it's that kind of advice that can be just as important as the dollars in helping students navigate this crisis. There are so many distractions right now. Many of our students are trying to lead or are part of families that are under incredible duress due to economic strains or health issues. These things further challenge their ability to complete their degree programs and their courses. That's why Georgia State's student support services are so important.

We've created these supports because it's the right thing to do and what our students need to graduate. But amid the COVID-19 pandemic, these kinds of wraparound services delivered at scale have become more important than ever.

https://counselingcenter.gsu.edu/

https://deanofstudents.gsu.edu/student-assistance/emergency-assistance/

STEM Success is NOT just about *"activities"*.

STEM success is about-

"Connecting the intellectual dots between curiosity and investigation in preparation for a career path."

That is why EVERY teacher in every subject is a STEM teacher.

Please make this is available to students, their parents, friends and anyone in Georgia.

wayne@tagonline.org

Back to Space

Saturday, May 30th, 2020, 3:22PM ET.

SpaceX's Crew Dragon leapt into the sky marking the first private spacecraft to carry humans into orbit. This was not just any ordinary space shot, but the opening of a new "business" door to the cosmos for America and the world.

The mission is the culmination of nearly a decade of development and partnership between SpaceX and NASA.

For the last nine years, all of NASA's astronauts have launched to the International Space Station on Russian rockets from Kazakhstan. It may be necessary to continue using the Russian resources from time to time, but this successful venture is far more than just encouraging.

This mission was the final test for SpaceX's Crew Dragon as part of NASA's Commercial Crew Program. The biggest goal was to have private companies, not NASA, create the next generation of spacecraft that can take US astronauts into orbit.


SpaceX's first astronaut crew: NASA astronauts Bob Behnken (L) and Doug Hurley (R). Photo: SpaceX

These commercial vehicles would be cheaper than what NASA could make, saving taxpayer billions of dollars annually. Companies like SpaceX could make a profit by selling seats on their vehicles to paying customers, both private and governmental globally. NASA wanted to bring capitalism to human spaceflight since private companies are often much better at business matters than government institutions.

The Commercial Crew Program has a mixed record on achieving its goals, but most experts agree that it has lead the way for both NASA and commercial enterprise to explore space.

This will change what the space economy looks like in decades to come. As long as humans have been flying to space, the government has been in charge of getting them there. For the last fifty years, NASA hired contractors to make its rockets while retaining complete control over every aspect of production and design. When the vehicles were complete, NASA owned and operated the hardware.

The result was usually a really expensive rocket. NASA's budget ballooned in the 1960s in order to develop the Saturn V rocket that took astronauts to the Moon.

NASA had hoped that its next vehicle, the Space Shuttle, would be more cost-effective, but that program cost NASA about $1.6 billion per flight.

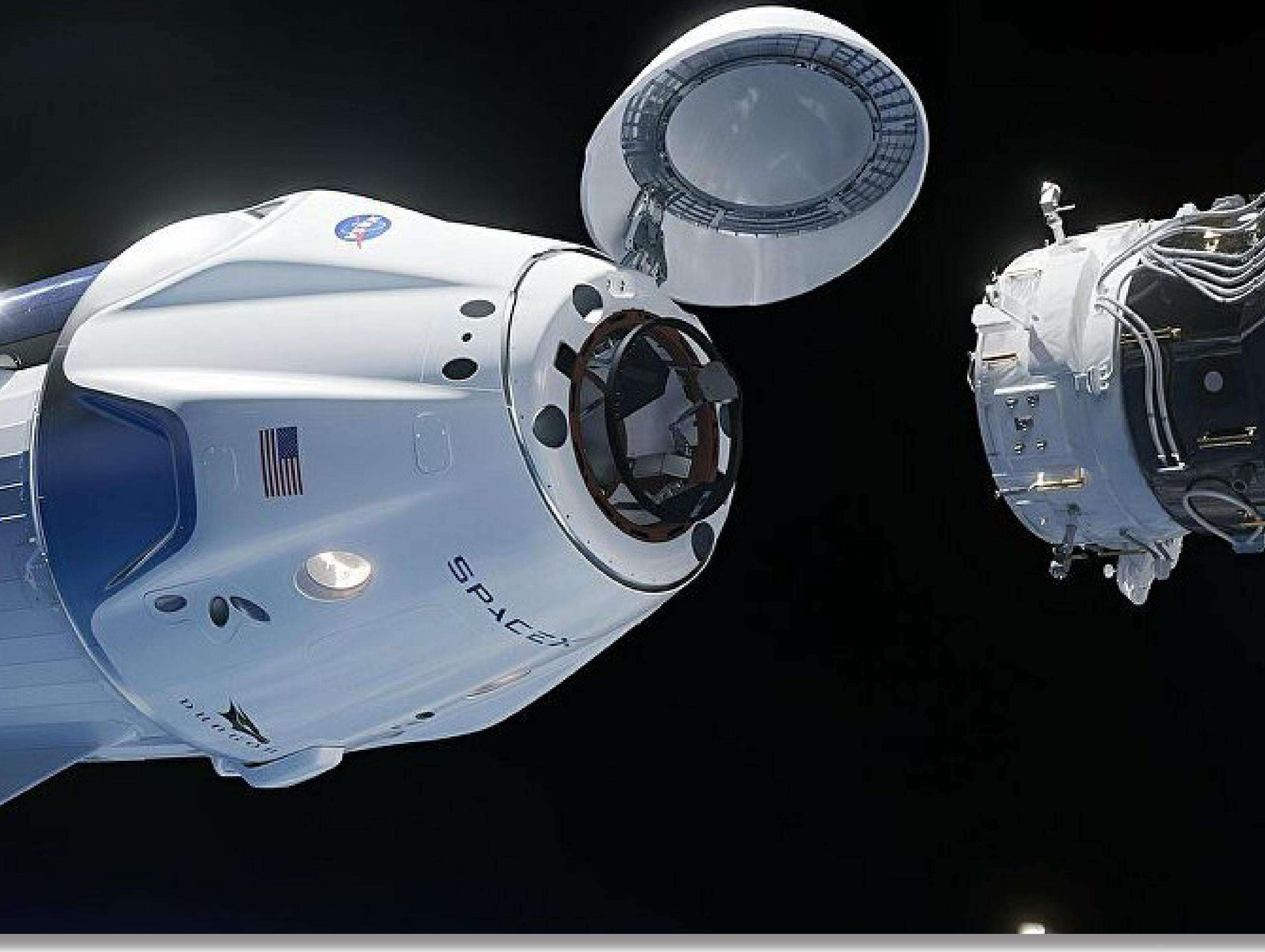
With the cancellation of the Shuttle Program in 2004, officials established a new space business model called Commercial Orbital Transportation Services (COTS). Through COTS, NASA would become an investor instead of the overseer. NASA would tell the companies what kinds of rockets or spacecraft it wanted to invest in for that project. The companies would be responsible for the design and construction of their vehicles.

To keep costs down, companies that participated would have to pay some of the development costs, incentivizing them to find ways to make things cheaply. NASA wanted multiple companies involved to inspire competition. As the costs come down, which they inevitably will with more competition, that's going to allow NASA to do the harder farther things. In the end, NASA would be a regular customer just buying a service, like a passenger buying a ticket on an airplane.

The Crew Dragon and their competitor, the Boeing Starliner, are relatively simple vehicles, quite different from the complex, deep-space vehicles that NASA has developed in the past. It may not be fair to compare one against the other when they have such different missions and different capabilities.

Both Boeing and SpaceX are a type of shuttle services. They're effectively cargo-carrying vehicles, much like the Russian Soyuz capsule.

In the process of creating these streamlined, serviceable spacecraft, the Commercial Crew Program also met its goal of creating competition. Both the cargo and crew programs helped SpaceX become a major player in a field that's been dominated by the same contractors for decades.



NASA's safety advisers are of the opinion that SpaceX and Boeing could not have gotten to this point independently, as there were "strong interventions" to help both of the companies throughout the process. NASA will continue to have significant expertise that will continue to be used for the success of the nation's most complex and challenging space system development program.

As NASA looks ahead to its next project, it's uncertain if there is a market for the Commercial Crew vehicles beyond NASA.

The reason this model worked so well for the COTS program is because there was already an established market and need for rockets to launch satellites needed by a wide variety of private companies and government departments.

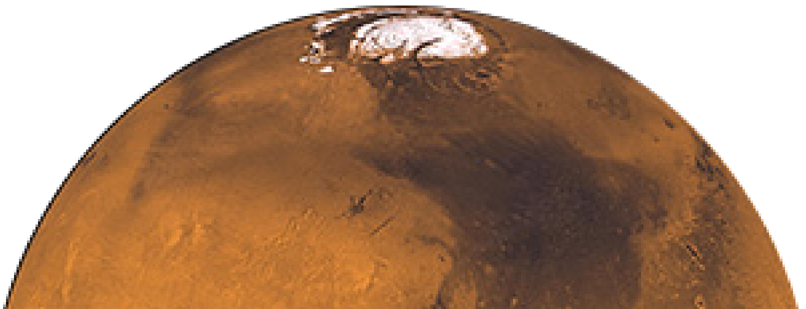
There aren't that many businesses currently operating in orbit, leaving SpaceX and Boeing with limited destinations for their shuttle services. One of the reasons there is no business in orbit is because the transportation costs were so high. With lower costs to get into space, it will be interesting to see who steps up with an

interest in launching.

SpaceX has announced that there is some interest in private citizens riding on the Crew Dragon. The company has sold four seats to passengers who will take a trip around the Earth on the vehicle in 2021. They also plan to eventually send customers to a private space station developed by a commercial company called Axiom.

Could we see a Hilton or Marriott Hotel in orbit as a holiday destination? SyFy has always suggested that future for mankind. It appears as if things are moving in the right direction for private space flight. As with any new market, time is needed to see if a pattern forms and if these kinds of trips are sustainable. But for todays students, it's certain that career opportunities within the private space market will continue to develop and become accessible in a way that government jobs never were.

At this point, the imagination, interest and creativity of young Americans is all that's needed to continue along this exciting path laid out by the Dragon crew, SpaceX and NASA.



How to Inspire *(and Secretly Educate)* Your Kids this Summer

"These innovative, hands-on experiments from Two Bit Circus Foundation and Annenberg Learner use only common household items to ignite curiosity"

Leah Hanes, CEO and Chief Juggler of Two Bit Circus Foundation. Bio: Dr. Leah Hanes is the CEO and Chief Juggler of Two Bit Circus Foundation, where she oversees all non-profit initiatives, including strategy, budget, mergers, and acquisitions. Before joining the Foundation, Leah worked for more than two decades in the entertainment industry. She holds a Master's Degree in Organizational Management and a PhD. in Leadership and Change, both from Antioch University. You can find Leah on Twitter at @LeahHanes.

by Leah Hanes
CEO and Chief Juggler of Two Bit Circus Foundation

Many parents are racking their brains trying to find ways to entertain their kids this summer, while many educators are struggling to find activities suitable for the new reality of distance learning. With the virtual school year coming to an end and the majority of summer camps closed or moving to virtual spaces, it's been a continually stressful year!

But even during these hardships, there is opportunity to grow. We now have the chance to teach our youth how to learn, explore, discover, and build new things on their own — to build up a foundation of skills that lead to a lifelong love of learning. Creating a better future means equipping the next generation with the tools they need to build it.

We don't yet know the problems that our kids are going to face in adulthood, so the best way we can prepare them is to encourage them to embrace curiosity, think differently, and be confident in their ability to find or create solutions. And those solutions stem from science, technology, engineering, art, and math — or STEAM education.

When grouped together, these skills not

only spark curiosity, they also provide an outlet for creative expression and build critical thinking, which leads to innovation. And they are perfect learning environments for quarantined families to cultivate.

Pursuing STEAM education is critical, engaging, and it can also be a sustainable educational solution for virtually anyone because it can be taught with either free or re purposed materials that can be found almost anywhere. Cardboard, for example, is free, available virtually anywhere, and can be bent, cut, colored on, and glued together to become anything you want it to be (after it's sanitized, of course).

Enter, Two Bit Circus Foundation and Annenberg Learner — Two Los Angeles non-profit organizations that are joining forces to provide free access to over 150 hands-on STEM/STEAM projects designed for educators, parents, and children of all ages.

Two Bit Circus Foundation has been creating innovative STEAM content for over a decade, while Annenberg Learner has funded and distributed multimedia resources for K-12 classroom instruction and teacher professional development for nearly 30 years. In order to help all the kids, educators and parents who have been affected by the recent global pandemic, Two Bit Circus Foundation and Annenberg Learner sped up their collaboration and worked to address the overwhelming need for creative and accessible STEAM resources.

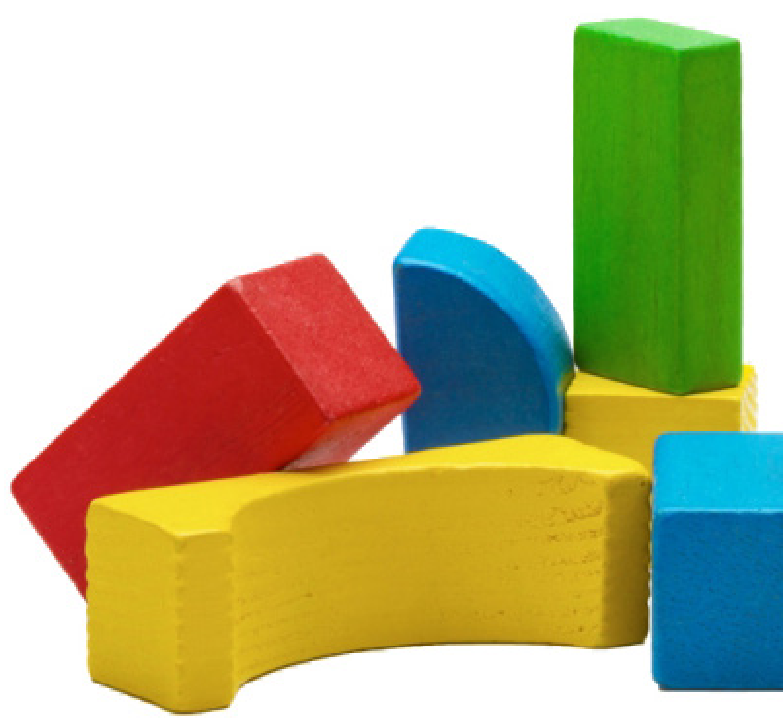
Together, they share a passion for innovative education solutions that ignite curiosity and spark a lifelong love of learning, which is brought to life in the new STEM/STEAM section on Learner.org.

All projects come in easily digestible formats and require only easy-to-find, common household items. Designed to inspire the next generation of inventors, these projects combine fun and entertainment with the STEM/STEAM skills that are critical to engaging young minds.

You can check out all the projects in the new STEM/STEAM section of the Annenberg Learner website, or go to Learner.com/twobitcircusorg.

Project 1: Run Brick Run

For kids in Kindergarten through 8th grade



Objective: Understand how various forces work to amplify or impede movement.

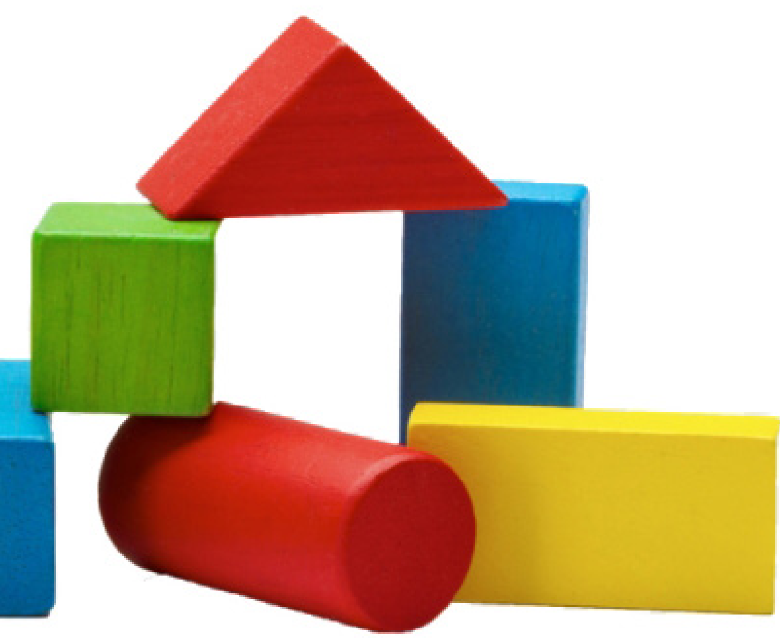
Materials:

- Toilet paper tubes
- Marbles
- Bricks (or building block toys) in a variety of sizes

------- Project Structure -------

Engage/Explain:

- Ask your child if they've ever played with a marble run before, or marbles in general.
- What makes a marble go?
- How does a marble steer?
- In a marble run, what sorts of things influence the marble?



Directions:

1. Work together with your child to build towers of varying heights with the bricks or building blocks.

2. Start by constructing the tallest, biggest tower and then make smaller towers to guide the marble back down to earth.

3. Put the towers together in groups, line them up and connect them with toilet paper tubes and start testing! Make top connectors to hold the tubes in place and corner turns to keep the marble on track.

- Questions to consider:
- How far does the marble go?
- Why does it get stuck where it does?
- What happens when you change the order of the towers?
- If there's a marble of a different size, how does that impact things?
- What's the minimum height difference necessary to make the marble go?

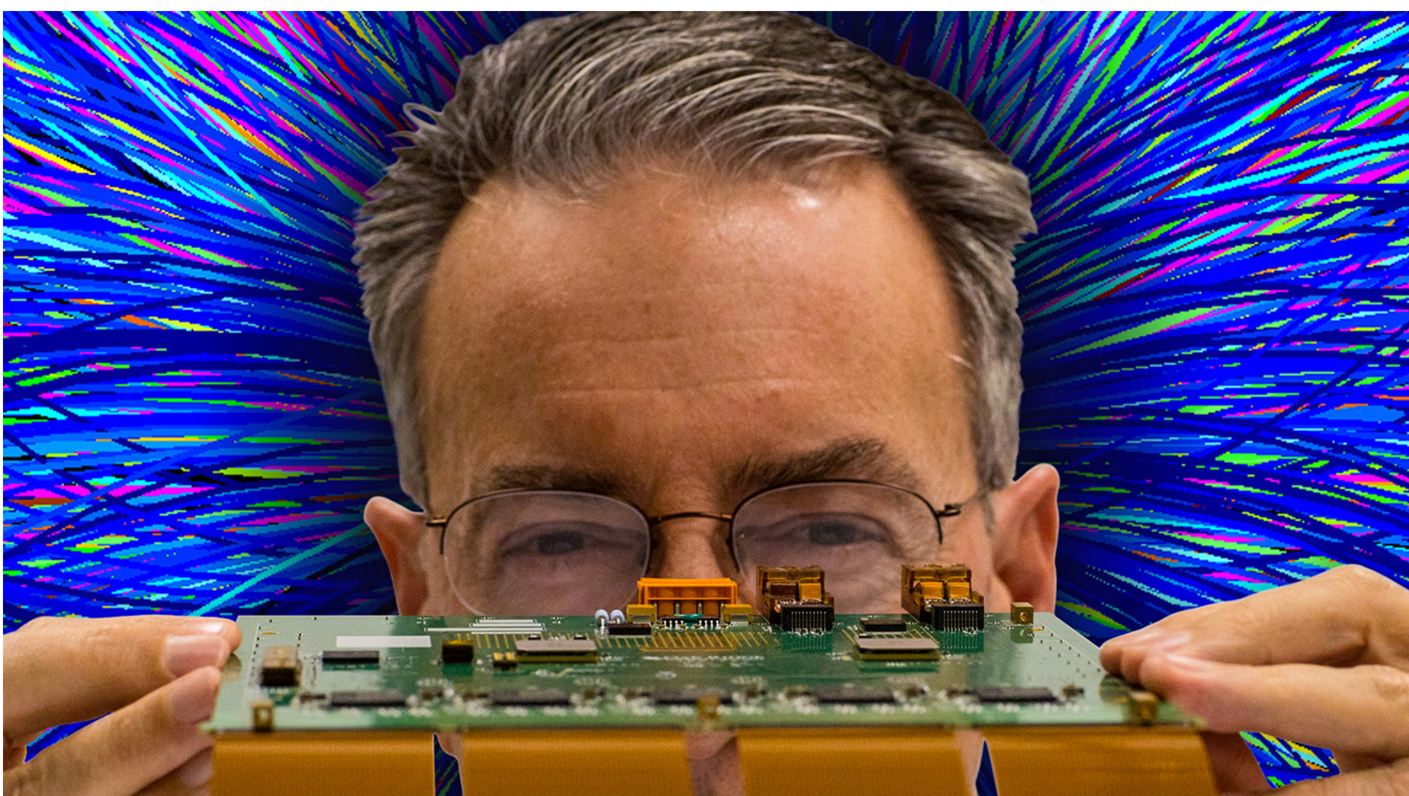
- Another fun marble activity

This interactivity with your child has value far beyond education, so make it fun and enjoy the quality time.

Major Upgrades Of Particle Detectors
and electronics prepare CERN experiment to stream a tsunami of data

by Dawn Levy / ORNL

For a gargantuan nuclear physics experiment that will generate big data at unprecedented rates—called A Large Ion Collider Experiment, or ALICE—the University of Tennessee has worked with the Department of Energy's Oak Ridge National Laboratory to lead a group of U.S. nuclear physicists from a suite of institutions in the design, development, mass production and delivery of a significant upgrade of novel particle detectors and state-of-the art electronics, with parts built all over the world and now undergoing installation at CERN's Large Hadron Collider (LHC). "This upgrade brings entirely new capabilities to the ALICE experiment," said Thomas M. Cormier, project director of the ALICE Barrel Tracking Upgrade (BTU), which includes an electronics overhaul that is among the biggest ever undertaken by DOE's Office of Nuclear Physics.



Kenneth Read led design, fabrication and assembly of ALICE's upgraded electronics hardware. Background: CERN. Foreground: Oak Ridge National Laboratory, U.S. Dept. of Energy; photographer Carlos Jones, composition Brett Hopwood.

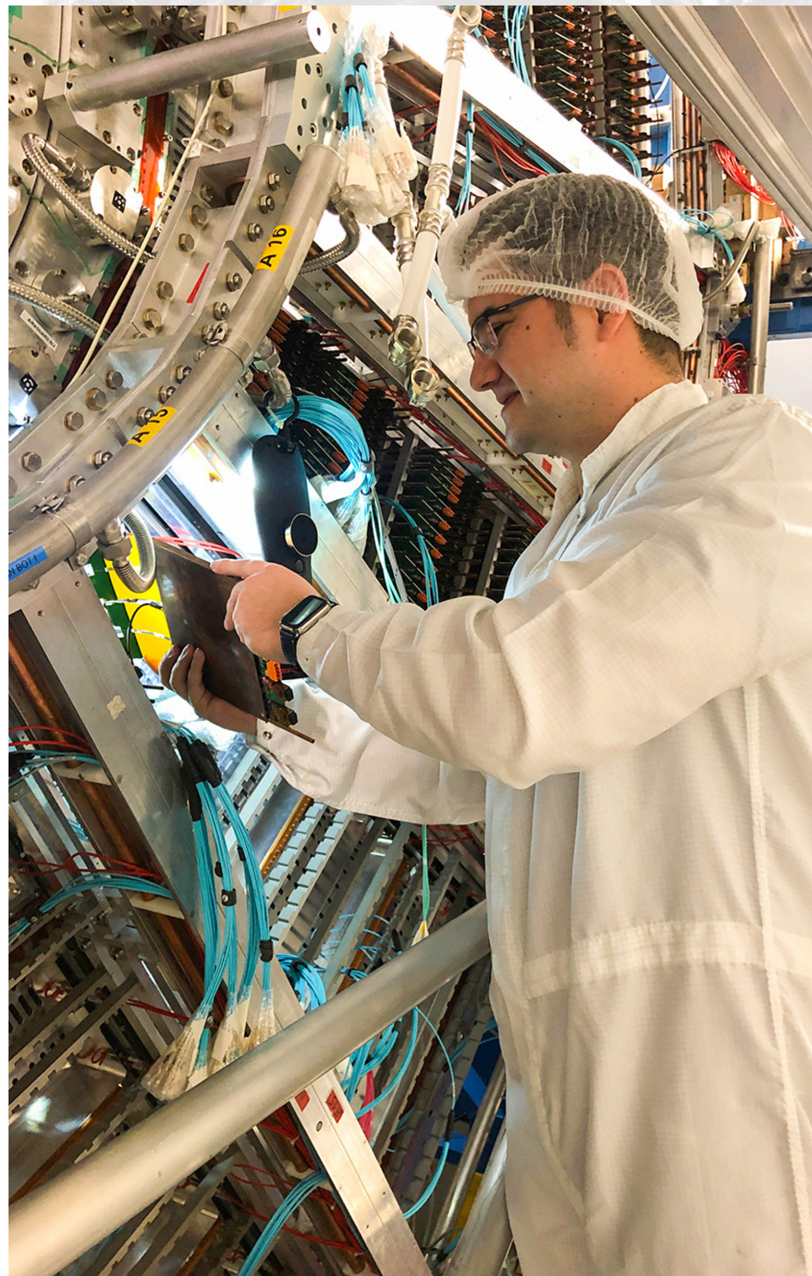
ALICE's 1,917 participants from 177 institutes and 40 nations are united in trying to better understand the nature of matter at extreme temperature and density.

To that end, the LHC creates a succession of "little bangs"—samples of matter at energy densities not seen in the universe since microseconds after the Big Bang. ALICE's detectors identify the high-energy particles and track their trajectories, interactions and decays that produce lower-energy daughter particles, daughters of daughters, and so on. The upgrades enable ALICE to more efficiently track particles at high rates, digitize their weak analog electronic signals continuously and stream the tsunami of readout data to high-performance computing (HPC) centers around the world for analysis.

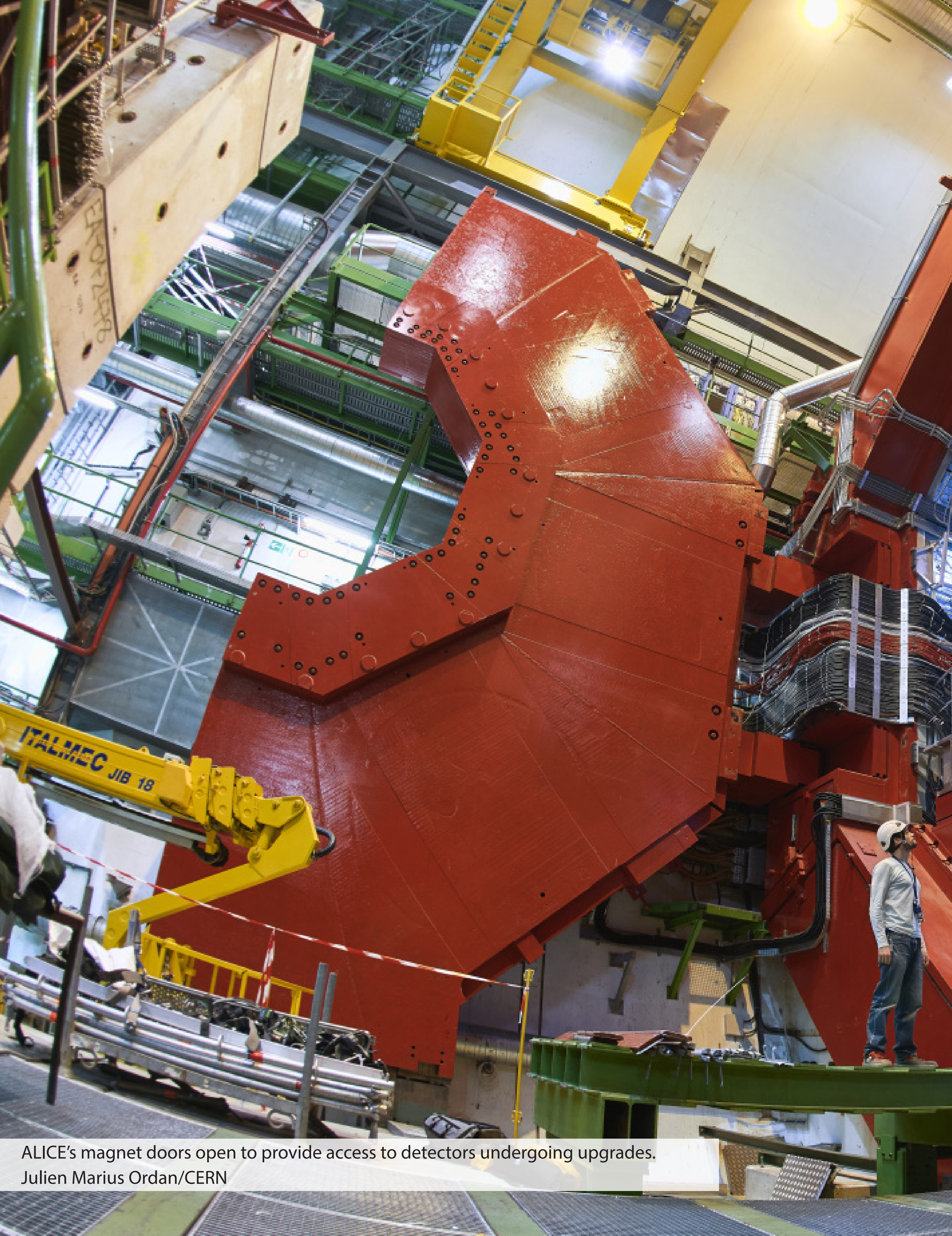
"Revising the instrumentation lets us expand the window of the science that ALICE can look at," said Cormier, who is a physicist at ORNL and professor at the University of Tennessee at Knoxville. "A lot of things are waiting out there to be discovered if we just have the sensitivity to see them." Combined with upgrades to the LHC accelerator, the BTU will increase sensitivity tenfold, enabling greater differentiation of the underlying science.

Completed ahead of schedule and under budget, the project relied on participants from DOE's Oak Ridge (ORNL) and Lawrence Berkeley (LBNL) National Laboratories and seven universities: California at Berkeley, Creighton, Houston, Tennessee at Knoxville (UTK), Texas at Austin (UT

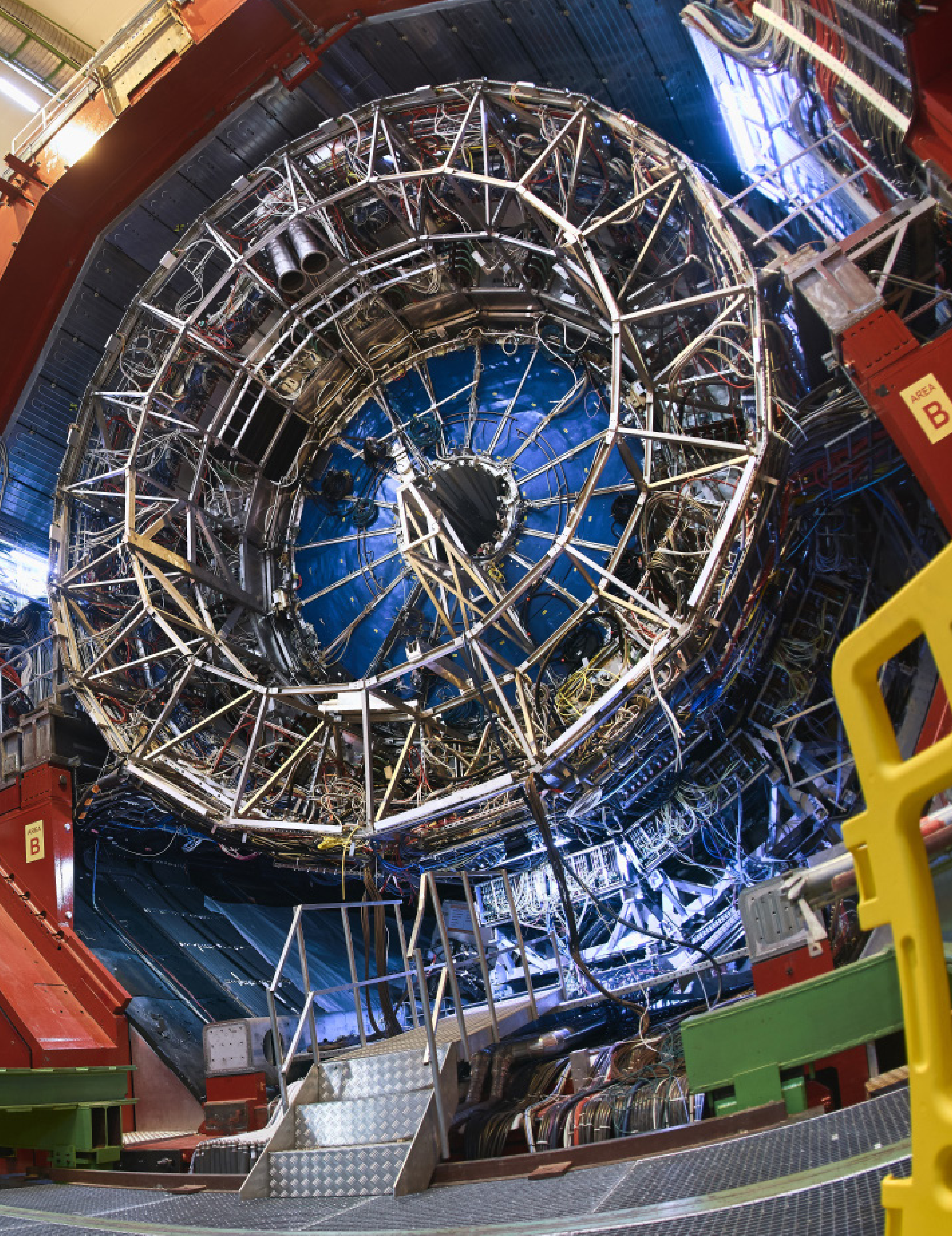
"A Wonderland In Alice"



ORNL electronics engineer Alex Rusu performs installation steps on the Time Projection Chamber in the clean room at the ALICE site. Oak Ridge National Laboratory, U.S. Dept. of Energy



ALICE's magnet doors open to provide access to detectors undergoing upgrades.
Julien Marius Ordan/CERN


AREA
B
AREA
B

Austin), Wayne State and Yale.

The upgrade effort began in April 2015 and ended in November 2019, delivering a suite of advanced detectors and electronics to CERN. Researchers anticipate the completion of installations this spring.

Considering the scale, this is no easy feat. Sited underground at the Franco-Swiss border, ALICE is heavier than the Eiffel Tower. A 52-foot-tall magnet is its front door. Behind it, nuclear physicists have rolled out one of the world's biggest barrel instruments, housing many detectors arranged in concentric cylinders. LHC's beam line runs through its center axis.

Significant effort went into improving two ALICE detector systems. One is the Time Projection Chamber (TPC), a gas-filled cylindrical apparatus the size of a shuttle bus. As charged particles speed through the gas, a magnetic field bends their paths, creating curved trajectories that reveal their momenta and masses and, in turn, their identities. Each endcap of the TPC cylinder is covered with two concentric rings of novel inner and outer readout chambers that receive the ionization charge and amplify it using an innovative four-layer system of micro-pattern perforated Gaseous Electron Multiplier foils. A system of nearly a half million, millimeter-scale pads spreads across the ends of the TPC cylinder to collect the amplified charge and create an electronic image of the charged particle tracks.

The second detector system to receive an upgrade is a seven-layer Inner Tracking System. LBNL collaborated with UT Austin to develop its middle layers, which include a strong-but-lightweight carbon-fiber frame to support seven layers of staves holding 24,000 silicon-pixel sensors for high-precision particle tracking. Each pixel is 30 × 30 micrometers squared—finer than an average human hair. This detector will have a total of 12.5 billion pixels—making it the largest "digital camera" ever built.

Processing the biggest of data

The upgrade dramatically increased the number of events per second that ALICE can sample and read out. Kenneth Read, manager of BTU's electronics upgrade, led a huge undertaking in design, fabrication and assembly of electronics hardware. Read, an experimental nuclear physicist with expertise in high performance computing, holds joint appointments at ORNL and UTK.

Ultimately, Read's team delivered 3,276 circuit boards (plus 426 spares) for readout of the half a million TPC channels. The electronics upgrade makes it possible to digitize and distribute 5 million samples per second per channel.

"Non-stop data output totaling 3 terabytes per second will flow from the Time Projection Chamber, 24/7, during data taking," Read explained. "Historically, many experiments have dealt with megabyte per second, or even gigabyte per second, data rates. Real-time processing of streaming scientific data at 3 terabytes per second is approaching unique in the world. This is a big data problem of immense proportions."

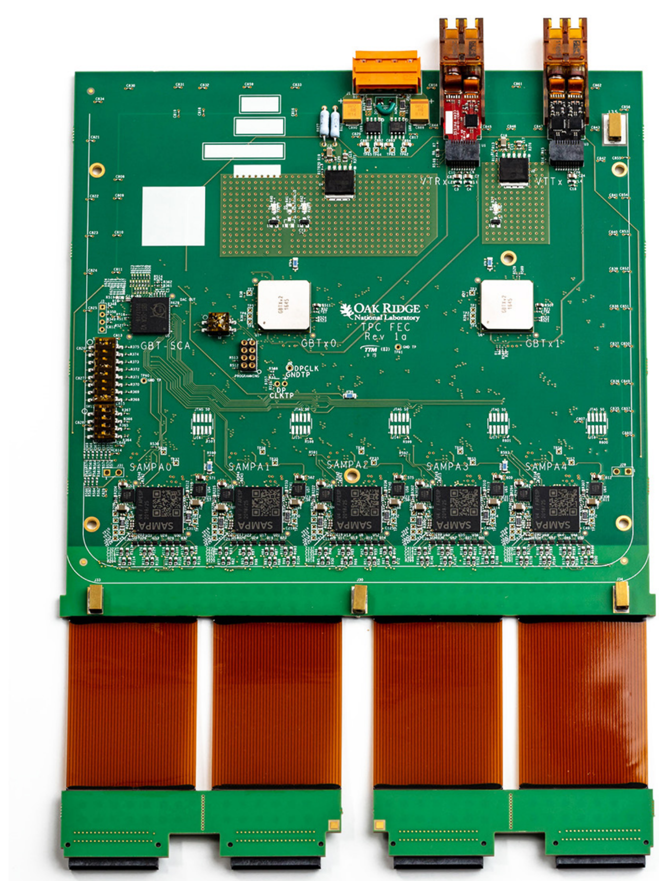
That data provides a snapshot of the quantum system known as the quark–gluon plasma—the matter of the very early universe first discovered at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and subsequently studied at both RHIC and the ALICE detector at the LHC. Such a plasma is produced here on Earth when a powerful collider, such as the LHC, accelerates heavy ions, each containing many protons and neutrons, and collides these heavy ions with so much energy that their protons and neutrons "melt" into their elementary building blocks—quarks and gluons—in a plasma more than 100,000 times hotter than our sun's core.

This exploding "soup" of liberated quarks and gluons forms particles that decay into myriad other particles. The detector array identifies and maps them so nuclear scientists can reconstruct what happened and gain understanding of the collective phenomena.

Capturing that plethora of particle collision events required a team of institutes to develop a custom-tailored chip that could digitize and read out the biggest of data. Enter "SAMPA."

At the heart of ALICE's massive electronics upgrade, this chip began as the PhD thesis project of Hugo Hernandez, then at the University of Sao Paolo.

SAMPA chips and other electronic components were shipped to Zollner Electronics in Silicon Valley for assembly onto printed circuit boards fabricated by electronics manufacturing giant TTM Technologies. The team of ORNL PhD-level electrical engineers making critical contributions throughout the electronics upgrade—lead designer Charles Britton with N. Dianne Bull Ezell, Lloyd Clonts, Bruce Warmack and Daniel Simpson—also developed a high-throughput station to test the boards right at the assembly factory. Whereas it traditionally took 1 hour to diagnose and debug a complex board, the ORNL team's automated process did it in a mere 6 minutes.



Circuit boards were customized with SAMPA chips (five black squares) and fast, radiation-tolerant optical transceivers (two components protruding at top right). Oak Ridge National Laboratory, U.S. Dept. of Energy

"It used to be, you'd order a thousand widgets, receive them at Oak Ridge and test them," Read reminisced. "You'd send the bad ones back to the factory and the good ones on to CERN." The ORNL test stations allowed the assembly factory to ship passing boards directly to CERN in small "just-in-time" batches for quicker installation than possible when waiting on large lots.

The researchers will calibrate the BTU using cosmic rays. Then, the upgraded equipment will be ready for the high-luminosity LHC Run-3, anticipated in 2021. Several runs of various collision data sets are planned—lead-on-lead, proton-on-lead and proton-on-proton—to illuminate emergent features of the quark-gluon plasma.

Even one year of collected raw data will be far too big to archive. The readout system winnows the streaming data to petabyte scale by processing it on the fly with hardware acceleration using field-programmable gate arrays and graphics processing units (GPUs)—considered a best practice. The reduced data is distributed over high-speed networks to HPC centers around the world, including ORNL's Compute and Data Environment for Science, for further processing. As experiments get larger, physicists build the case for also using centralized resources, such as the Oak Ridge Leadership Computing Facility's Summit supercomputer for GPU-accelerated data processing.

"Other large experiments at the LHC using different particle detectors—notably ATLAS and CMS—will confront some of the same data challenges as ALICE in 2027 and beyond," said ALICE researcher Constantin Loizides of ORNL. "The world-leading capabilities of the BTU electronics will likely benefit future physics experiments like the planned electron–ion collider, a top priority for U.S. nuclear physics."

The Department of Energy's Office of Science funded the U.S. contribution to the BTU.

Drones in STEM Education

By David C. Hook

Few activities capture imaginations like flying. Whether watching the takeoff of an airplane at a local airport or witnessing the spectacle of a USAF Thunderbirds' precision formation flyby, fantasies of flight hold the attention of young and old alike. Therefore, involving aviation in the learning process is an effective method to create imaginative pathways to learning. Many might see an unmanned aircraft—a drone—as merely a toy.

However, the same principles of flight apply at the micro-level of aviation as they do at the airliner's macro-level. The advantage for the educator is that introducing these concepts using a drone is far less costly, and the risk to student and educator safety is driven down to an acceptable level by using the smaller aircraft.

Drones, as it turns out, are an easily scalable teaching resource. A single drone can be controlled strictly by the educator and used as a springboard for science, technology, engineering, and mathematics (STEM) topics. Multiple drones can provide students a hands-on experience that can take lessons even further by engaging a student's hands and imagination. Drones can be used in a twenty-plus student classroom as easily as a single-student home-schooled or private tutor setting.

Capturing the learner's imagination and keeping their attention on-topic using a drone is more about how the drone is introduced and what the educator chooses to do with it in the classroom than the drone itself. Furthermore, the drone does not have to be a big, expensive video camera drone. The drone does not have to be a zippy little racing drone. The drone needs to be flown by its pilot in such a way that it focuses the learner's attention and leads into the topic. Now, let's look at some examples of drone use and unmanned aviation topics that can enhance STEM learning.

The Science

The science topics embedded in a small unmanned aircraft are staggering. Consider the chemistry involved in the Lithium Polymer Battery that powers the drone. https://www.explainthatstuff.com/how-lithium-ion-batteries-work.html

The bane of many a high school sophomore or junior is electro-chemistry. Discussing anions and cations and the movement of electrons along a circuit can be really boring with students nodding off and teachers becoming frustrated. Enter the drone.

Suddenly, this little machine remaining airborne becomes a chemistry mascot by making the topic of anodes and cathodes real. After flying the drone to battery exhaustion, take the battery out of the drone, pass it around the class, and pose this question, "Why is the battery warmer than the room?" Now you have a practical example of a battery pushing electrons through a circuit, encountering resistance, and generating heat as a byproduct of powering the drone.

You can also discuss the concept of power density, examining why the drone manufacturers chose a Lithium Polymer battery instead of the Lead-Acid battery found under the hood of most cars and trucks.

Another element of science that can be adapted for elementary, middle, and high school learners is Newtonian motion using a drone. Here are the three basic principles;

1. Objects at rest tend to stay at rest and objects in motion tend to stay in motion unless acted upon by an unbalanced force.

2. Force equals mass times acceleration.

Georgia Agricultural drone use

3. For every action, there is an equal and opposite reaction.

For the elementary classroom, a simple path maintaining level flight and allowing the drone to decelerate can lead an introduction to the four forces involved in flight: lift, weight, thrust, and drag.

The middle school students can observe the pilot (teacher) make the drone rotate about its vertical axis. This flight input serves as a springboard for introducing the concept of torque and the difference between balanced and unbalanced forces.

As for high schoolers, fly the drone from relatively cool air over a warm hot plate or other heated surface and watch the drone's altitude decrease until the pilot intervenes by adding power. This short flight involving the need to increase rotor speed to regain the needed force of lift to maintain altitude is a natural segue for discussions on atmospheric pressure and how Charles' Law applies to real-world situations.

The Technology

Drones are chocked full of technology. If there's a challenge, it's where to begin. A common approach to teaching elementary and middle school students about the Earth's magnetic field is to use a simple magnetic compass, however, using a hovering drone takes the topic up a notch.

The drone maintains a constant nose point by balancing the torque produced from propellers spinning in opposite directions.

Unfortunately, over time that noise point drifts left or right. So, drone manufacturers install magnetic sensors that allow drones to know which way they are pointing and if they need to correct for drift. To prove this, have a student take a strong magnet and move it around the compass, observing how the needle moves. Now, take that magnet and move it around the hovering drone and note how the drone gets confused and rotates under the influence of the magnet.

Secondary school educators will find a hovering drone useful when teaching wave theory. While some drones maintain a constant hover altitude using a barometric pressure sensor, other drones also make use of a SONAR sensor—favorite drones for this demonstration are the Ryze Tello™ and Parrot Mambo™.

Attenuation of wave energy, otherwise known as signal loss, can be demonstrated by taking a flat, reflective surface like a book or hard, smooth plastic and raise it from directly underneath the drone to observe the drone climb as the surface gets closer. Now use a piece of shag carpet and do the same. Students will see that the carpeting gets much closer before the drone begins to climb. The drone is a simple alternative to the typical wave tank.

A follow-on question for student learning might be, "What makes a material stealthy?"

The Engineering

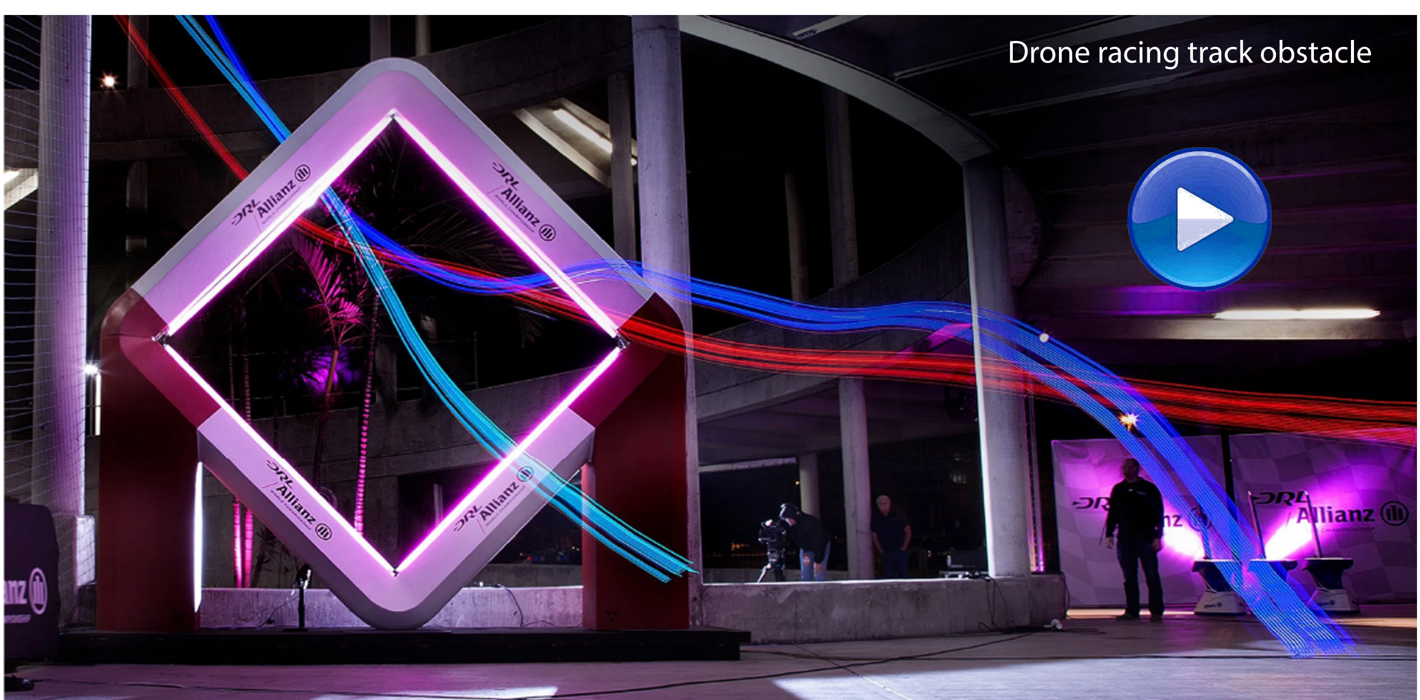
I love teaching the principles of engineering using drones. Engineering takes science and makes it useful. Engineering is messy and filled with testing, failures, reflection, refinements, and ultimately success. Visionaries come to the forefront of the class when that light bulb suddenly comes on in their heads.

Elementary school students love to get their turn flying a drone (I have found that bird netting is suitable for creating a safe drone cage for young student flying). A great way to teach the concept of engineering tolerance is by having students fly a drone through a cardboard gate (a box with large holes cut in it to allow the drone to fly through). Have the students measure the drone's height and width and then the height and width of the holes in the box.

Using some addition and subtraction, have the students figure out how far off they can be from the center of the hole and still get the drone through it. This understanding of tolerance is useful to examine the wiggle room for other tasks in daily life, say the size of a car versus the width of the road.

Middle school students can learn the concept of safety factor planning by maintaining a drone in a hover for a minute. An excellent place to try this is an empty gym, auditorium, or other large room because you will want a fair amount of space.

Have students fly in teams of three. One flies the drone, one measures flight deviations, and the other records the results. Given a dot on the ground, have students determine how close each team's pilot keeps the drone over the dot (Note: The experiment can get interesting when the air conditioning or heat cycles on). Retiring to the classroom with the data, take a class average of the results.



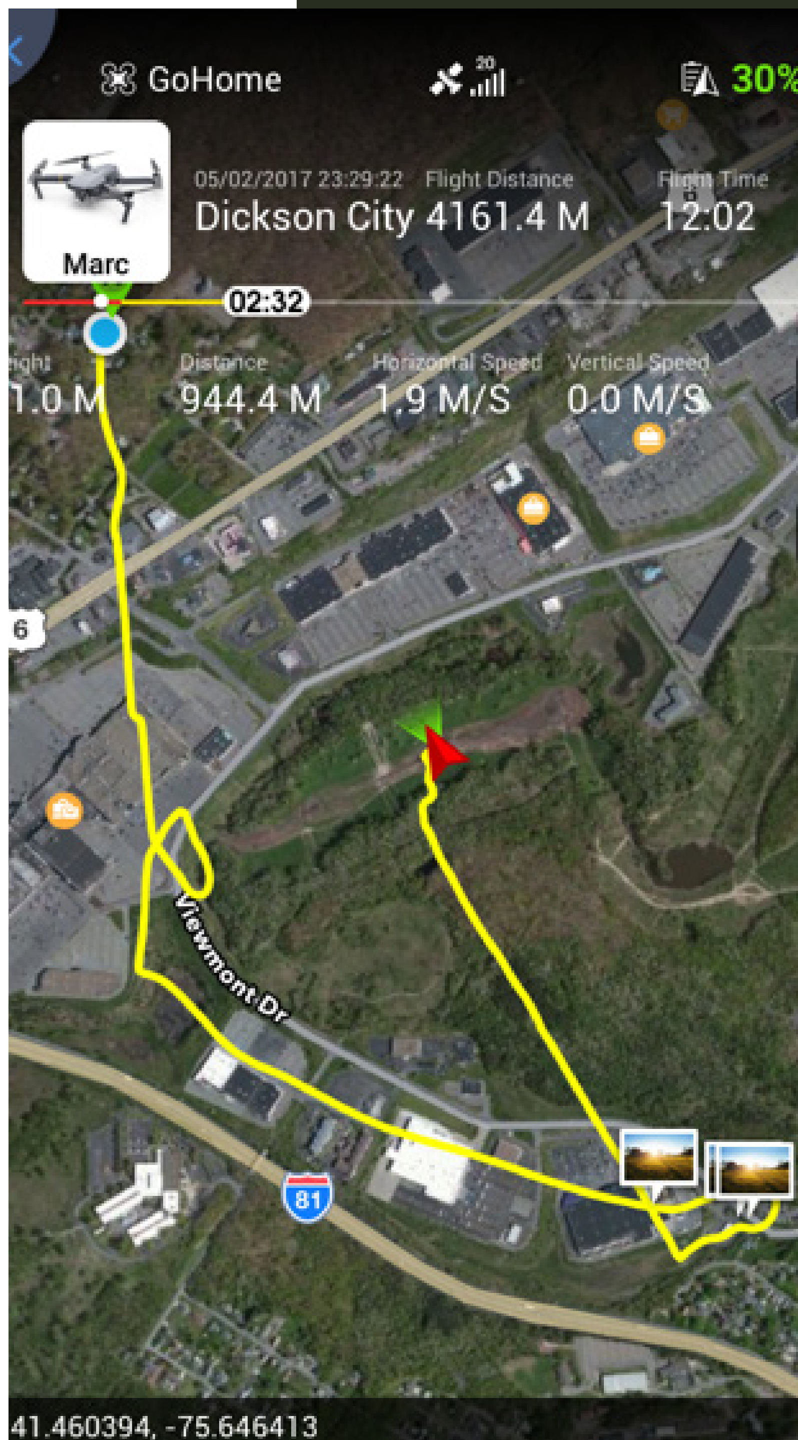
Drone racing track obstacle

Now, ask the students how close they would be willing to fly the drone near someone or something. That safety distance plus the average drone flight deviation, all divided by the flight deviation, becomes the safety factor. Ask them why they think airports build their runways so much wider than the wheelbase of an airplane's main landing gear. Now they have an appreciation of the safety factors engineered into our daily lives.

High school students who are learning to drive will appreciate this bit of engineering learning. Using a drone that can receive a sufficient number of Global Positioning Satellites (GPS) to be able to hover in place, have the drone maintain its position in the front of the classroom. Have students observe over a one- or two-minute period how far the drone strays from its initial position and estimate an average distance.

Knowing that GPS is a bunch of orbiting clocks that broadcast a highly accurate time from their locations, these multiple times allow the receivers in our car navigator or the guidance navigation system in our drone to know where they are. Have students determine the time difference between the drone's desired location and the average distance it strayed using the speed of light for the broadcast signals.

For a drone that strays one meter, based upon a speed of light of 299,792,458 meters per second, the GPS time difference between the desired position and the furthest it deviated is approximately 3.34 nanoseconds. Suddenly, a drone that stays within one meter looks to be doing a pretty good job.



The Mathematics

Unless a student has a natural inclination towards numbers and number-crunching, mathematics can seem a dry and lifeless set of concepts with no practical application to fun stuff. However, nothing could be further from the truth. Keeping an airplane loaded correctly involves arithmetic skills for the average 5th grader. Here is an example using a favorite piece of school playground equipment, the see-saw.

A simple outdoor activity involving students sitting on a see-saw becomes a science lesson involving weights, arms, moments, and centers of gravity. Taking that lesson a little bit further into the realm of aviation, educators can have their students using addition, subtraction, multiplication, and division to determine if an airplane is correctly balanced and safe for takeoff. Toss in a YouTube video showing the consequences of a misloaded jet, and rudimentary mathematics practice suddenly transforms into a critical analysis of aircraft loading.

This concept of weight and balance can span elementary, middle, and high school. Introducing multiple loads and locations is easily adapted to support the pre-algebra learning concepts in middle school math classes. Creating a more open-ended equation for numerous weights and strap-down positions, known as flight stations among pilots and flight crew, allows for practice using algebraic concepts.

Tired of teaching students how to figure out when two trains will pass one another? What about "Will your drone make it home?" The wind is a force that has consequential effects on a flight. Asking students to figure out how far they can fly their drone and get it back before it runs out of battery power when dealing with headwinds and tailwinds provides similar algebraic manipulations as the typical train problem.

Educator Flight Training

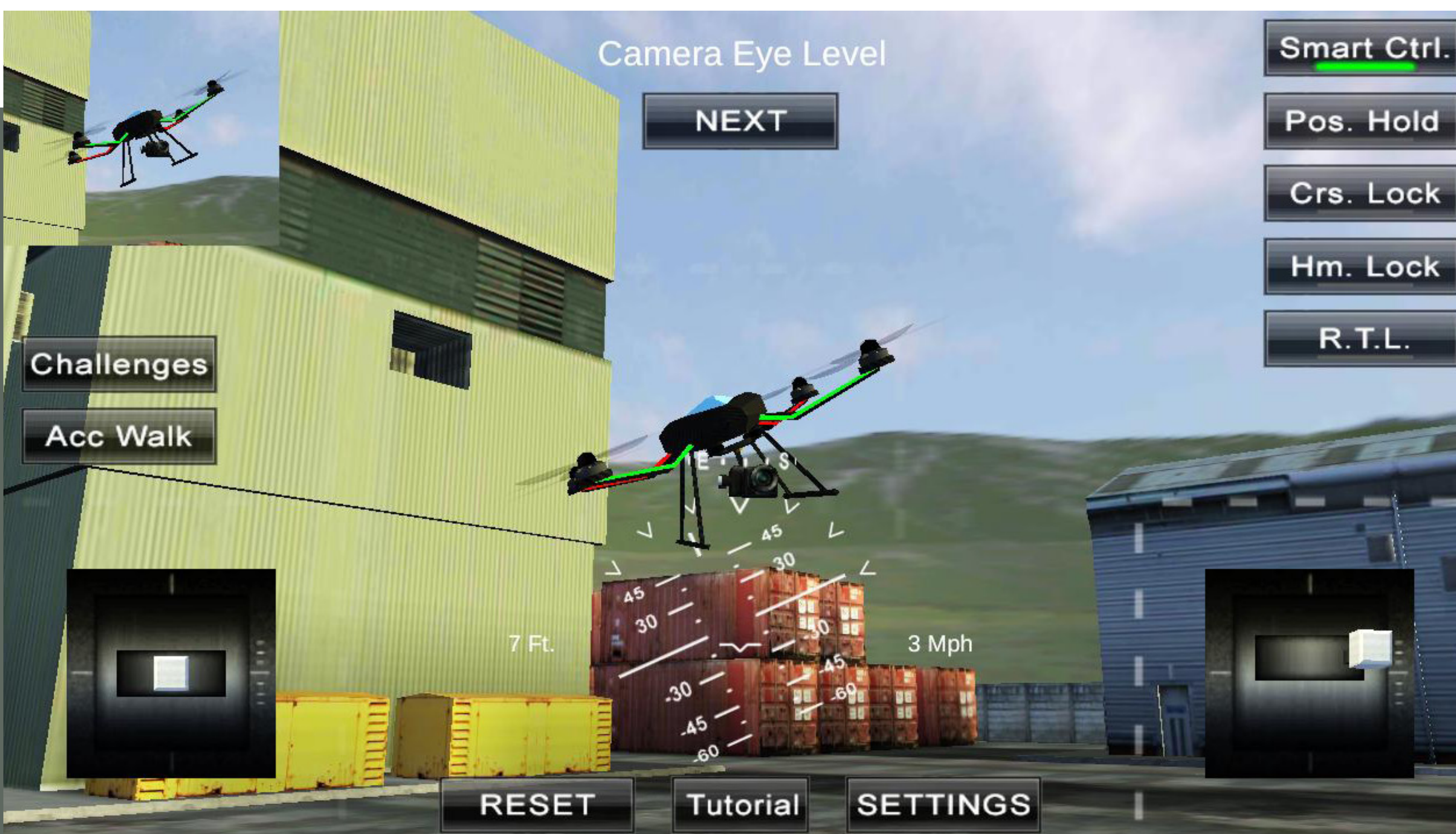
Learning to fly a drone isn't that difficult. Like learning to throw and catch a baseball, it's all about practice. Most modestly priced small drones are packed with technology to make their pilots look like flying gurus. Always read the manufacturer's flight manual before flying your new drone.

When flying indoors, the rules of the US Federal Aviation Administration (FAA) do not apply. However, make sure that your planned flight activities conform to your school's policies too.

When flying outdoors, the FAA's rules apply. For an online primer, you can watch Rules to Fly By on YouTube™. You can peruse the FAA's Advisory Circular 91-57B Exception for Limited Recreational Operations of Unmanned Aircraft. Flyers in the Great State of Texas should know that there are specific laws involving the recording of imagery—still or video—and the overflight of critical infrastructure.

Should the flying of an actual drone exceed your appetite for risk, a reasonable alternative is the use of a drone simulator. There are many app-based drone simulators available for your smart device.

David C. Hook is an experienced entrepreneur and long-time aviation educator. Dave entered flying by earning his Private Pilot license in high school. He graduated from the US Air Force Academy with a Bachelor of Science degree in Astronautical Engineering and the Webster University of St. Louis, Missouri with a Master of Arts Degree with Honors in Acquisition and Procurement Management.



GEORGIA PATHWAYS
M A G A Z I N E

Content Invitation

Georgia Pathways™ STEM Magazine requests the privilege of including your content or the content of your students in upcoming issues. This is a great opportunity for students to be published and for educators and industry professionals to share their insights and wisdom regarding careers across Georgia.

If you have questions, please contact the publisher at:

wayne@tagonline.org

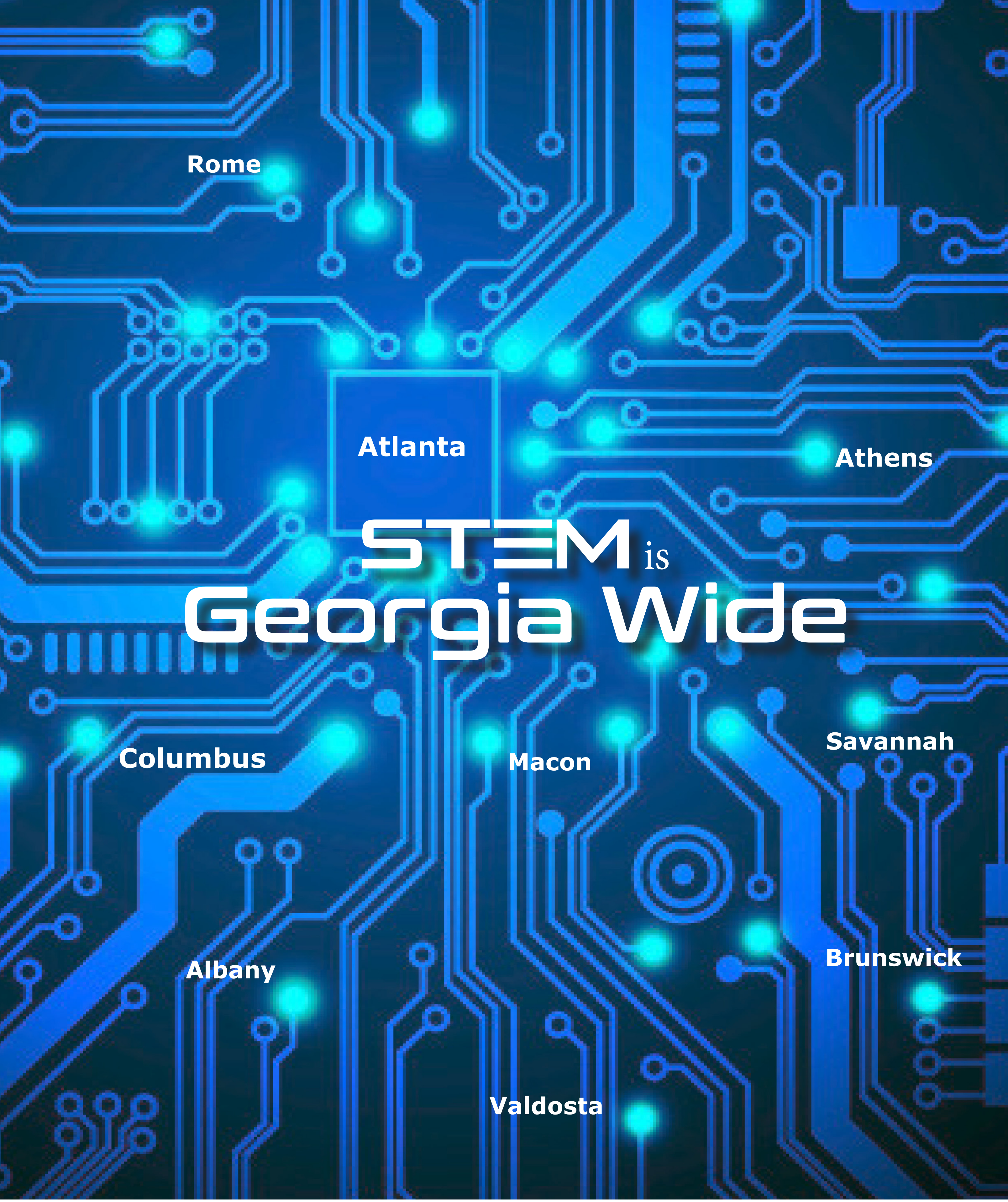
770.370.1905

Content submissions:

- Word.doc format
- **Completely** revised and spell checked.
- Everything as an attachment.
- Unlimited electronic distribution to everyone in Georgia.

Advertising:

- Full page ads are available monthly at a very low cost.



TAG Technology Association of Georgia

TAG TAG-Ed Education Collaborative