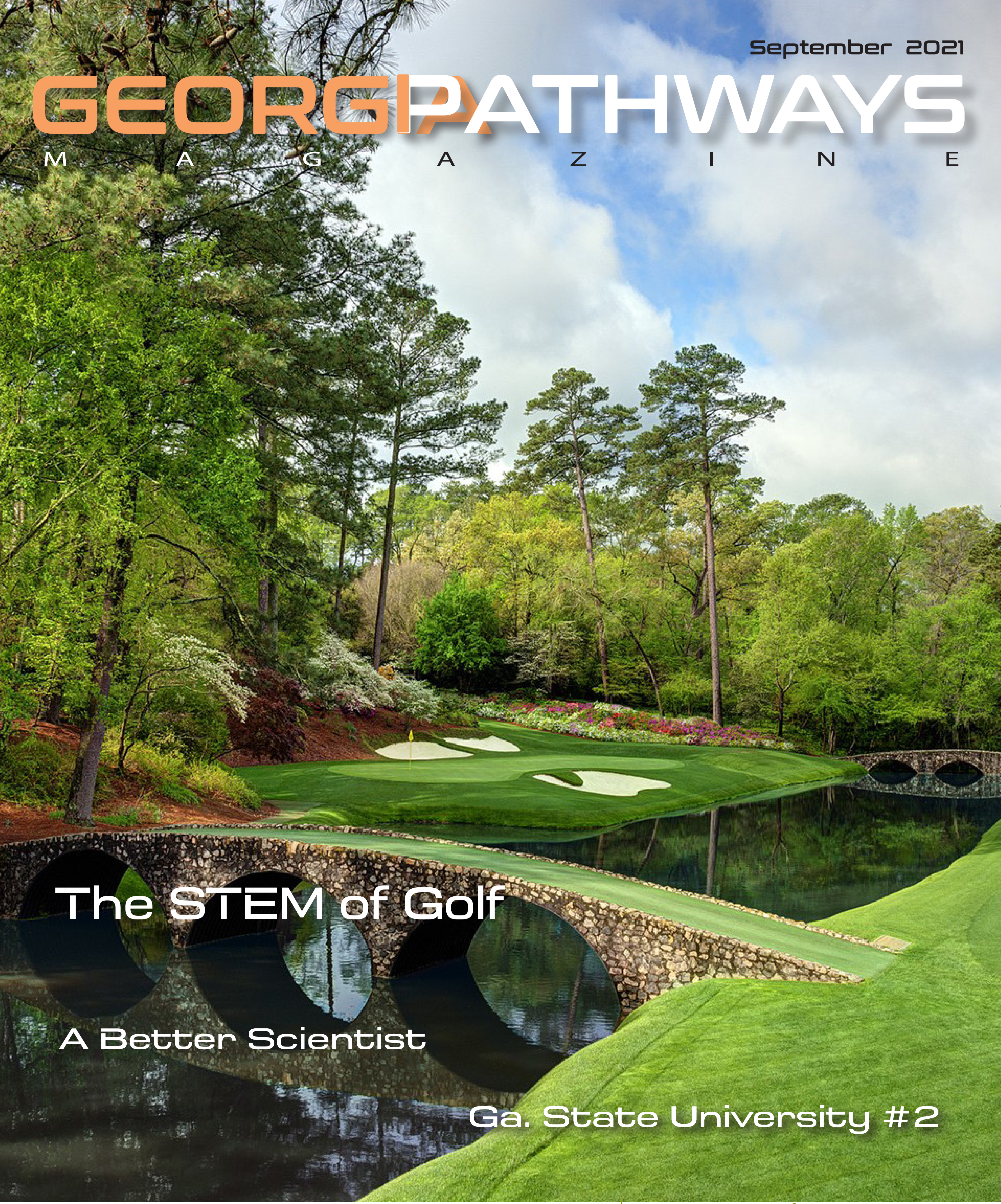

September 2021

GEORGIA PATHWAYS

MAGAZINE

The STEM of Golf

A Better Scientist

Ga. State University #2

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 2000. 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.

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Welcome to the September issue of Georgia Pathways Magazine.

TAG's annual TAGit Golf Tournament is the state's most prestigious golf tournament for technology stakeholders and was a resounding success with a day filled with networking, fun, prizes and awards. What better way to support the TAG Education Collaborative (TAG-Ed) than a day of STEM activity in the form of an energetic round of golf with friends, peers, and supporters.

In this issue of Georgia Pathways, we've included an interesting and enlightening article on the STEM of golf. This content is a great reminder of how we include STEM skills and concepts in the activities we enjoy as well as professionally at the office, not to mention its economic impact in the state.

Historically, Georgia has a rich heritage of golf events, personalities and magnificent courses of which we are proud. But in addition to that, golf provides a significant economic impact to our state with more than 350 golf courses administered by the Georgia State Golf Association. As of 2019, Golf supported $4.859 billion in annual economic impact on the Georgia economy, which includes $2.9 billion of direct economic activity, which supports more than 45,000 jobs and $1.610 billion in wages and benefits, as well as $233.2 million in state and local taxes.

Golf equipment manufacturers proliferate the state from Atlanta to Valdosta, offering career opportunities and innovative tech applications that will impact the South East U.S. and beyond. To say that the golf industry is a Georgia Technology Industry is an understatement. From UGA to Kennesaw State, golf management degrees and programs offer exciting career paths for those who love the game and just spending time on the fairway.

Once again, a resounding thank you to those who participated and supported TAGit this year. Your support of education in Georgia is incredibly powerful.

Larry K. Williams
President
TAG / TAG-Ed

Larry K. Williams serves as the President and CEO of the Technology Association of Georgia (TAG) and President of the TAG Education Collaborative (TAG-Ed). TAG-Ed's mission is to strengthen Georgia's future workforce by providing students with relevant, hands-on STEM learning opportunities by connecting Technology Association of Georgia (TAG) resources with leading STEM education initiatives.

The STEM of Golf

By Wayne Carley

In the continuing revelation of what STEM really means in our lives, let's continue to explore the STEM skills necessary to participate and excel at a sport so many enjoy. Regardless of your sport of choice, this article on golf translates to any sport, career or hobby you can imagine. In the midst of our summer and in honor of the Ryder Cup, let's dig into the STEM of Golf.

Golf is intensely mathematical, with strong engineering applications. The math and engineering are physical in application, with the technology being primarily in the equipment. The science of Golf (the systematic accumulation of knowledge) permeates all aspects.

What is really interesting is that we don't actually learn these math applications to be effective at golf. For successful golfers (low scoring), we seem to be born with many of these practical applications and experiential knowledge of the following mathematics.

Math is defined as, "The science of numbers and their operations, interrelations, combinations, generalizations, and abstractions". Golf is certainly all of this and includes the math domains of geometry, analysis, topology, combinatorics, number theory, algebra, math physics and more. If you enjoy any sport, but say you hate or don't understand math, this is a real contradiction.

What I hope you will consider and better understand is that you already know so much math, you just don't realize it or see it in your daily life. That being said, let's consider the geometry of golf.

Geometry

noun
ge•om•e•try |
Definition of geometry

1a : a branch of mathematics that deals with the measurement, properties, and relationships of points, lines, angles, surfaces, and solids

Golf is three dimensional and requires three dimensional thinking to solve golf's primary problem: Getting the ball in the hole with as few swings (strokes) as possible. Geometric considerations include:

- ***the flight of the golf ball*** (apex or height reached, distance desired, possible obstacles to be avoided, velocity of ball flight to get from point A to point B).

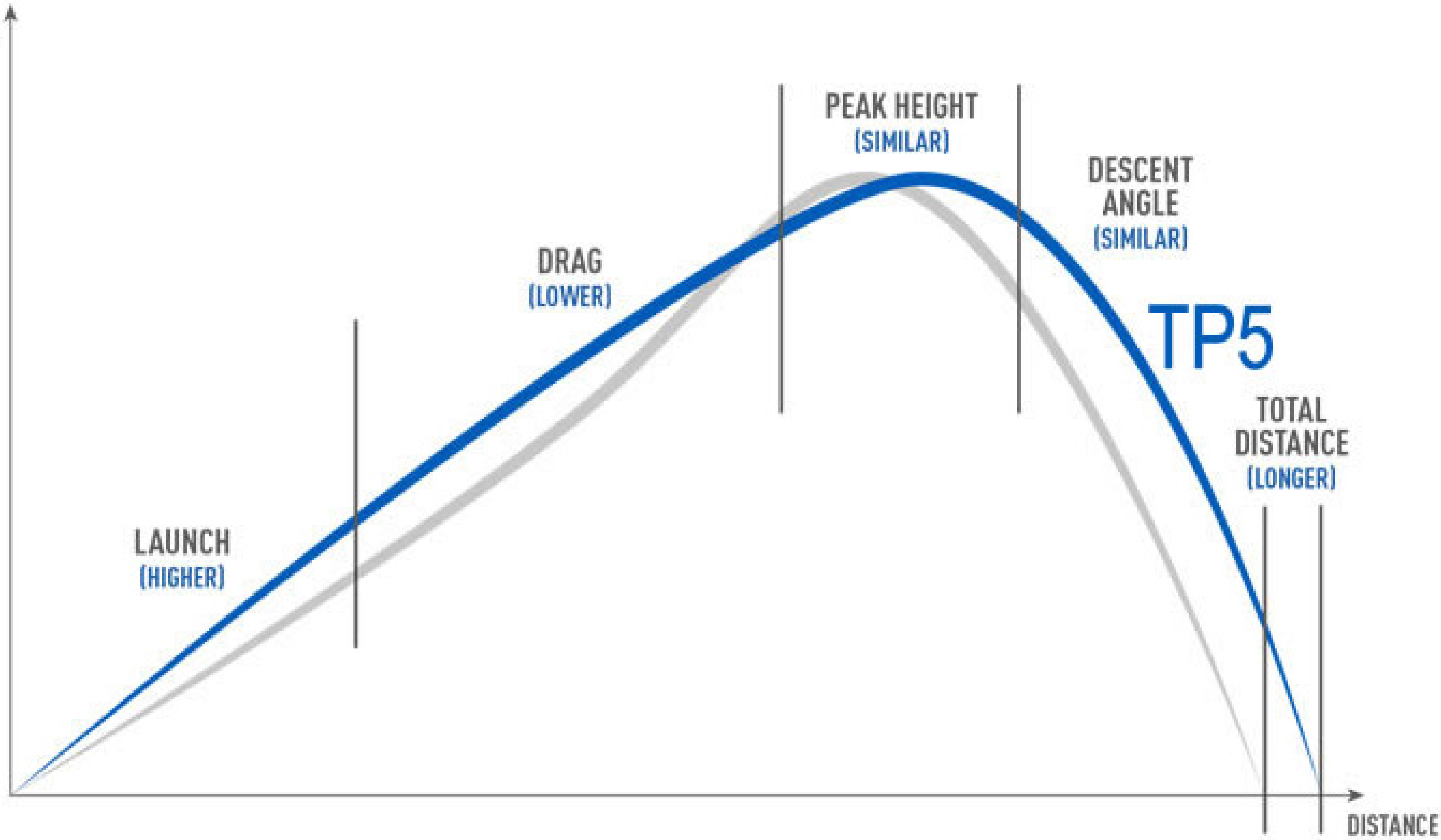
This geometric problem can only be solved by the golfer using the engineering method that we will cover later, in conjunction with the technology in the golf bag, the golfers ability to use it well, and a dozen questions that need to be asked for each and every golf shot.

The golfer must visually determine where they want the golf ball to land for the first shot. Once decided, the distance needs to be estimated, usually in yards.

A golf club must be chosen with the correct angle of attack for the desired ball flight. Proper physical alignment toward target must be decided, usually in degrees. The speed of the golf swing must be estimated to drive the ball along the chosen flight path. Just when you thought we were done, other factors must be considered for success.

Air temperature or density directly impacts ball flight and affecting distance and accuracy. This is also measured in degrees. The hotter the air, the thinner the air, thus less resistance to flight requiring another recalculation of club use and strike force required. The humidity of the air is important and often in direct contradiction to air temperature.

If there is wind, the direction and speed of the wind needs to be evaluated. Will a head wind slow the forward movement? If so, how much? Will a tail wind speed the flight progression? If so, how much? Will a cross wind cause a deviation in the alignment of the shot? If so, how much?



Relative humidity is the most common consideration and is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain.

For practical purposes, we have to simply observe:
"Is it humid today? How did I play this shot last time it was this humid?"

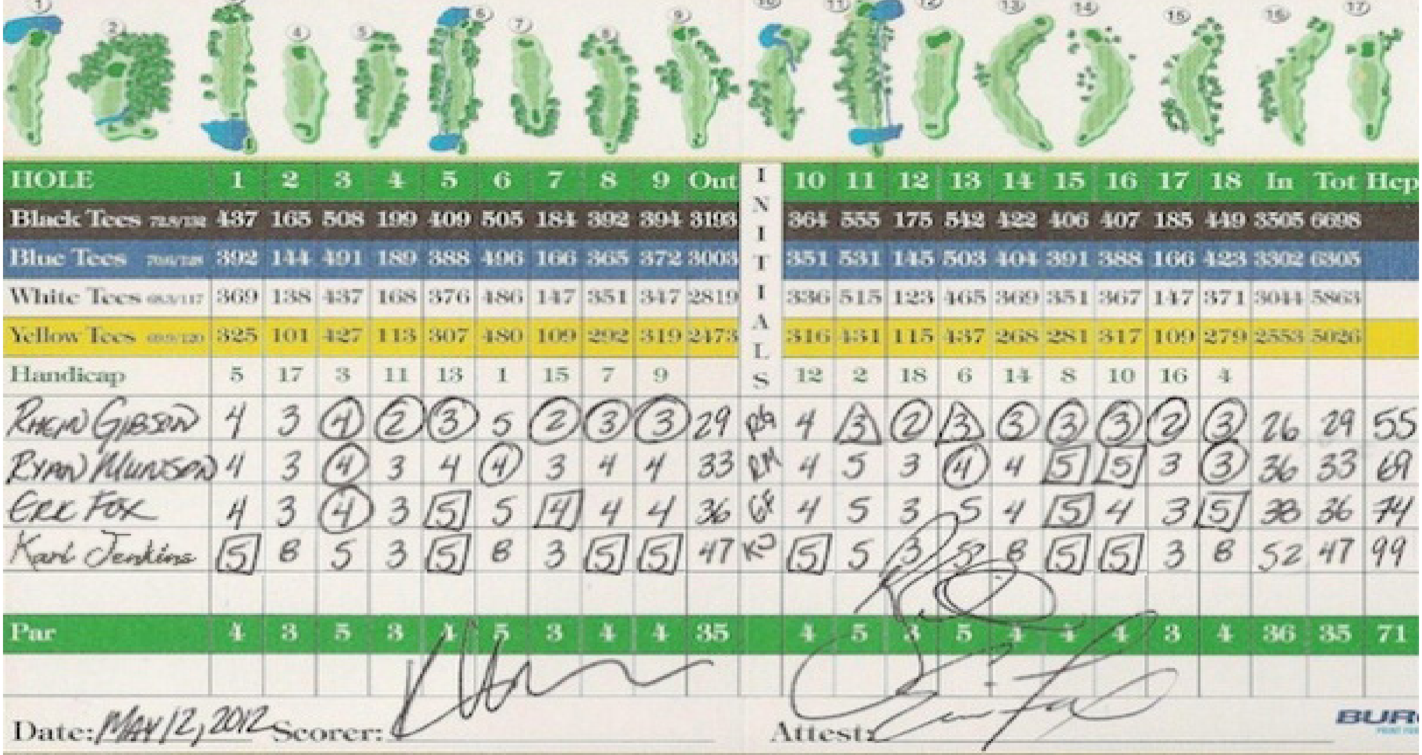
"Is the grass wet? How will that affect the ball roll out?"

"Did it rain yesterday? Is the ground soft or hard?"

This is considered throughout your play this round.

Let's not forget altitude, measured in feet above sea level for golfing purposes. Air density or thickness at sea level is greater than air density at higher altitudes. Therefore, the distance a golf ball travels at the beach is less than the distance it travels in Denver, Colorado at 5,280 feet above sea level. Under similar atmospheric conditions using the same club, same ball, and same striking force, the ball in Denver will travel significantly further.

The math and geometry of golf is very complicated and we've only scratched the surface. When all of the aforementioned aspects are decided, the human golfer must physically execute a golf swing that allows for the calculations to be accurately realized. This is where the challenge really exists. The brain has done its work, and now the body is called upon to execute the mental decisions.



HOLE	1	2	3	4	5	6	7	8	9	Out	INITIALS	10	11	12	13	14	15	16	17	18	In	Tot	Hcp
Black Tees	437	165	508	199	409	505	184	392	394	3193		364	555	175	542	422	406	407	185	449	3505	6698	
Blue Tees	392	144	491	189	388	496	166	365	372	3003		351	531	145	503	404	391	388	166	423	3302	6305	
White Tees	369	138	437	168	376	486	147	351	347	2819		336	515	123	465	369	351	367	147	371	3044	5863	
Yellow Tees	325	101	427	113	307	480	109	292	319	2473		316	431	115	437	268	281	317	109	279	2553	5026	
Handicap	5	17	3	11	13	1	15	7	9			12	2	18	6	14	8	10	16	4			
Rhein Gibson	4	3	4	2	3	5	2	3	3	29	[illegible]	4	3	2	3	3	3	3	2	3	26	29	55
Ryan Munson	4	3	4	3	4	4	3	4	4	33	RM	4	5	3	4	4	5	5	3	3	36	33	69
Eric Fox	4	3	4	3	5	5	4	4	4	36	[illegible]	4	5	3	5	4	5	4	3	5	38	36	74
Karl Jenkins	5	8	5	3	5	8	3	5	5	47	[illegible]	5	5	3	5	8	5	5	3	8	52	47	99
Par	4	3	5	3	4	5	3	4	4	35		4	5	3	5	4	4	4	3	4	36	35	71

Date: May 12, 2012 Scorer: Attest:

This was the first shot of our round of golf. Everything we've just calculated must be done again, an average of 100 times for the typical golfer. Your results may vary.

Golf science -

Golf science, or the *"systematic accumulation of knowledge"* about golf, is very experiential. With every swing of the golf club, every hole, every course on every day, your experiences in decision making, weather conditions, course conditions, physical interaction and more, are building a complex and varied mental catalogue of accumulated knowledge that you can use moving forward. Aside from physics that will be covered later, this science definition and application is the most used in your golf game.

Along with the accumulation of knowledge about your game, we should remember to consider the psychology and physiology of your body as it applies to this knowledge.

How do I feel today? What did I eat? How did I sleep? What's my frame of mind right now?

The answers to these physical and ultimately psychological questions will affect your quality of play today, your mental state in response to that play and your decision making about everything. This is the physical science part of the golf equation. If you play the game even occasionally, no doubt you'll agree that this aspect is often more important than the hours of practice, the expensive new driver or the high tech golf balls potentially destined to go for a swim.

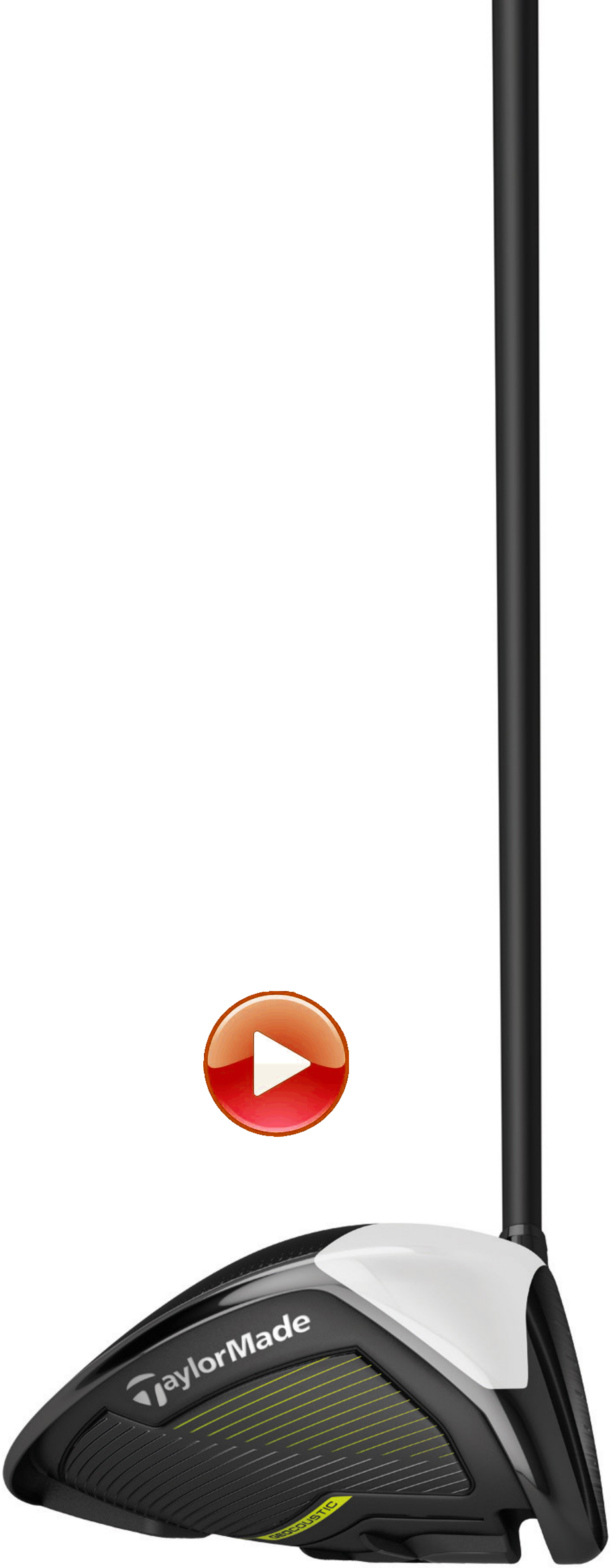
Golf is a "head game" as much as anything, and the STEM of your brain and body can impact your round tremendously.

The Tech and Engineering of Golf

Using this golf tech in modern golf clubs is still the responsibility of the player, but technology has had a huge impact on golf in the last 20 years. Changes in clubs, balls, shoes and the equipment that helps make the game easier and more enjoyable have altered the game dramatically. For the amateur golfer, these changes can be enjoyed without restriction. But for the professional golfer, strict regulations are imposed to level the playing field and not allow for secret or unusual technology applications.

Manufacturers' boast that you will be able to make huge strides in your game and lower your scores just by using their new equipment. It is possible that improved equipment will turn an average golfer into a better one, a good golfer into a great one and help the top amateurs consider making a run at the pro's. But several things are certain; STEM is deeply woven into the game and the equipment. If you really want to improve your game, recognize and learn the science, technology, engineering and math of golf.

STEM skills and concepts are the bones of any sport you participate in. Embracing these can only improve your results as well as give you a more complete appreciation of what STEM really is in your daily life, at home, work or play.



The Driver –

Not that long ago, the shafts and head of the drivers were made of different types of wood before being replaced by hickory in the middle of the 19th century. The varieties of woods included ash, purpleheart, orange wood, and blue-mahoo. Despite the strength of hickory, the long-nose club of the mid nineteenth century was still prone to breaking at the top of the back swing. The club heads were often made from woods including apple, pear, dogwood, and beech in the early years of golf until persimmon became the primary material for drivers.

Today, changes in aerodynamics, weight, materials, club shape and shaft flexibility are allowing golfers to hit the ball longer and straighter than ever before. These innovations are the result of manufacturers employing engineers, designers, mathematicians and materials experts, some from the aerospace industry. Engineers are problem solvers, so their task in golf is to help the player get the ball in the hole with fewer strokes, which is the primary problem facing the golfer. Mechanical engineering and industrial engineering should be your focus if interested in careers in the golf manufacture industries. Strong interest in metals, materials and physics would be helpful.

The head of the driver is now built with aerodynamics in mind to allow for a faster swing and a uniform swing path. New technology in this area results in less wind resistance and more club head speed, both primary factors in distance. The components inside the golf club are lighter and stronger than they were just two or three years ago. Today's average driver may weigh 50 grams lighter than previous generations of equipment, and that will result in more distance. Drivers of old were made of solid wood, whereas new drivers are often very hollow, and much larger. This provides for a faster swing and a better chance of hitting the ball well with a larger club face.

Weight distribution on the club itself, in the form of small threaded weights, can be adjusted to the golfers swing or personal preferences. This can greatly impact your personal swing for the best personal results.

Innovative alloys used in the construction of modern drivers and golf clubs in general include titanium, carbon fiber, aluminum, carbon graphite, carbon steel, vanadium, tungsten and zinc; titanium being the lightest and most expensive. Often, several of these alloys are used in combination for specific driver designs and expectations.

Each of these alloys varies in cost, weight and durability which are considerations for the golfer. Collaboration between engineers and designers provide a marketable and appealing product for the market.

Irons –

The majority of clubs in the bag are irons which are used for the majority of golf shots once the driver has launched the ball as far as desired, if you've made a few good decisions. These include a variety of clubs with varying degrees of loft or angle of the club face. The greater the loft, the higher the ball flight will be. This still relys on the players decision making about the math of the shot. The decision making is at the heart of the engineering method, or problem solving process.

The golfer must evaluate and imagine the desired golf shot and choose which loft of club will get them from here to there as visualized; the chosen spot for the ball to land.

The engineering method (for golf) is comprised of the following steps:

Idea –

I want to hit the golf ball from here to there.

Concept-

I will accomplish this by using my chosen golf club, swing speed and aiming.

Planning-

Based on my observations of wind, topography, distance, humidity, obstacles, and other considerations, my choice of club is……?

Design-

I've chosen my club to accomplish my goal. I'm visualizing how I will line up and aim, how I will swing to hit the ball, (the force, speed, shape of the shot) and how it will fly to my target.

Development-

(For golf, this step is much like the Design step)

Launch-

It's time to hit the ball as I have imagined with the club I have chosen, keeping in mind all of the concepts, planning and design steps I've decided upon.

* Your results may vary….

This is the STEM of Golf.

The engineering method is used for each and every golf shot, including the putt. Yes, you are a golfing engineer!

Irons typically have shorter shafts and smaller club-heads than drivers. The head is made of solid iron or steel, and the head's primary feature is a large, flat, angled face, usually scored with grooves to grip the golf ball. Irons are used in a wide variety of situations, typically from the fairway or off the tee on shorter holes. Irons do vary somewhat in their design such as:

Muscle Back - A muscle back is the more traditional design and consists of a solid metal head, typically made of forged iron or steel. The design of the club typically distributes the metal more evenly around the club head.

Cavity Back - Cavity back, or perimeter weighted irons, are usually made by investment casting, which creates a harder metal allowing thinner surfaces while retaining durability, and also allows for more precise placement of metal than forging techniques.

The cavity created in the rear of the club head due to the removal of metal from the center of the club head's back, is then redistributed very low and towards the toe and heel of the club head. This has the general effect of lowering the club head's center of mass placing it underneath that of the ball allowing for a higher launch angle for a given loft.

The perimeter weighting also increases the moment of inertia, making the club head more resistant to twisting on impact with the ball. The end result is a club head with a larger "sweet spot" that is more forgiving of slight mis-hits.

These two examples are on-going engineering and design challenges tasked to employees of golf manufacturers to be competitive with other companies since they have to continue to create something to sell; a new "must have" innovation for you to buy and be a better golfer than last year.

The Hosel

For irons, the hosel is very noticeable, forming a barrel shape on the inside face of the club and the "heel" of the sole of the club. Many modern irons have a more offset hosel, integrated into the club head at a lower point and further from the hitting area of the club. This, combined with the perimeter (edge) weighting of modern irons, gives a club the lowest possible center of gravity and the highest possible usable club face. (engineering)

The Shaft

The shaft is critical to the performance of the iron. The right shaft for your swing style will determine your individual result, potentially increasing distance and accuracy, while a poorly suited shaft can lead to inconsistent, inaccurate shots and reduced distance. (mathematics)

Although graphite shafts made from composite materials such as carbon fiber are now standard in many drivers, shafts for irons are still most often made from steel, which has lower torque than graphite, allowing less club head twisting, which gives better accuracy. Graphite shafts are not uncommon for numbered irons, as the increased distance conferred by the shafts flexibility is advantageous to many older players, and shorter hitters.

Golf balls –

Golf ball technology is perhaps the most varied and advanced of any golf hardware. For hundreds of years, a golf ball was simply a leather case stuffed with boiled goose feathers. In the 1800s gutta-percha, a natural rubber extract, was used to construct the first hard-covered ball. In 1898 Coburn Haskell, working in a Goodrich tire plant in Ohio, devised a method of building a golf ball with a solid core wrapped tightly with rubber threads. The Haskell ball was the prototype for golf balls into much of the next century.

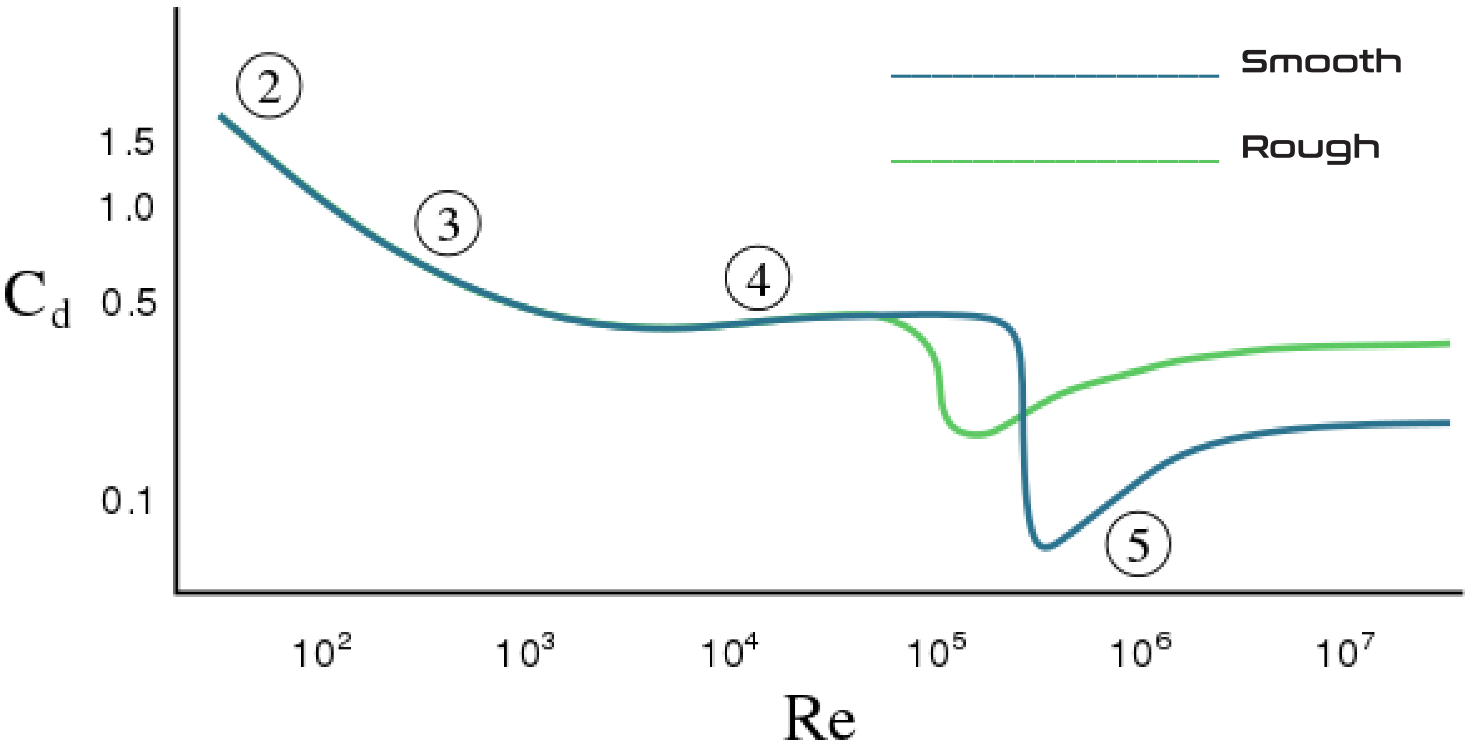
Under the rules of golf, a golf ball has a mass no more than 1.620 oz (45.93 grams), has a diameter not less than 1.680 in (42.67 mm), and performs within specified velocity, distance, and symmetry limits. These restrictions apply to professionals of course, but what wonders are available to the casual golfer?

When a golf ball is hit, the impact, which lasts less than a millisecond, determines the ball's velocity, launch angle and spin rate, all of which influence its trajectory and its behavior when it hits the ground. (math / physics)

A ball moving through air experiences two major aerodynamic forces; lift and drag. Dimpled balls fly farther than non-dimpled balls due to the combination of these two effects. Aside from lift and drag, the ball creates turbulence and turbulence reduces energy, thus speed and distance.

The Reynolds number (Re) is an important dimensionless quantity in fluid mechanics used to help predict flow patterns in different fluid flow situations such as air which behaves much like a liquid. At low Reynolds numbers, flows tend to be dominated by laminar (sheet-like) flow, while at high Reynolds numbers, turbulence results from greater differences in the fluid's (air) speed and direction.

Much of the latest golf ball chemistry is designed to make balls that are more controllable or fly farther—or both. Softer balls typically give golfers better control, while harder balls travel faster. About 1.2 billion golf balls are produced every year and there are more than 80 different types of balls of varying construction materials and designs.



Drag coefficient Cd for a sphere as a function of Reynolds number Re, as obtained from laboratory experiments. The dark line is for a sphere with a smooth surface, while the lighter line is for the case of a rough surface (e.g. with small dimples). There is a range of fluid velocities where a rough-surfaced golf ball experiences less drag than a smooth ball. The numbers along the line indicate several flow regimes and associated changes in the drag coefficient: *(air is treated as a fluid)*

•2: attached flow (Stokes flow) and steady separated flow,

•3: separated unsteady flow, having a laminar flow boundary layer upstream of the separation, and producing a vortex street,

•4: separated unsteady flow with a laminar boundary layer at the upstream side, before flow separation, with downstream of the sphere a chaotic turbulent wake,

•5: post-critical separated flow, with a turbulent boundary layer.

First, the dimples on the surface of a golf ball cause the boundary layer (outside) on the upstream side of the ball to transition from laminar to turbulent air flow. The turbulent boundary layer is able to remain attached to the surface of the ball much longer than a laminar boundary and so creates a narrower low-pressure wake and less pressure drag. The reduction in pressure drag causes the ball to travel further.

Second, backspin generates lift by deforming the airflow around the ball in a similar manner to an airplane wing. This is called the Magnus effect.

Mag•nus ef•fect
/'magnəs ə,fekt/
Noun Physics
noun: **Magnus effect**

1. the force exerted on a rapidly spinning cylinder or sphere moving through air or another fluid in a direction at an angle to the axis of spin. This force is responsible for the swerving of balls when hit or thrown with spin.

Backspin happens in almost every shot due to the golf club's loft (i.e., angle between the club face and a vertical plane). A back-spinning ball experiences an upward lift force which makes it fly higher and longer in the air than a ball without spin. But this backspin usually causes the ball to not roll as far once on the grass. Your engineering decision making comes into play as you decide, "Do I want more height or more roll?".

Your decision will require the science of aerodynamics and the physics of ground friction, affected by wet grass v/s dry.

To keep the best aerodynamics, the golf ball needs to be clean, including all dimples. This is why golfers should wash their golf balls whenever permissible by the rules of golf.

1 Piece Golf Balls:
This is the most basic of golf ball construction and the cheapest as well. These type of balls are aimed at beginners, driving ranges and mini golf courses. Rarely would a one piece ball be used for anyone interested in improving their game on a real golf course. A one piece balls is usually made from a piece of Surlyn that has a mold with dimples. They have a clunky feel and spin very little.

2 Piece Golf Balls:
A two piece golf ball has a solid core usually made from rubber or something similar like Polybutadiene (a synthetic rubber) and is surrounded by an exterior cover made of Surlyn or urethane.

This type of ball is good for beginners due to the fact that they would roll father and generate more distance than all other ball types (including a three, four and five piece ball which are geared to more advanced golfers looking for more spin and control vs distance).

3 Piece Golf Balls:
A three piece golf ball is comprised of a solid liquid or rubber core surrounded by a secondary layer of enhanced rubber and covered by a durable Surlyn, Balata or Urethene material. Golfers who are seeking out greater feel and control typically would start with a three piece ball.

4 Piece Golf Balls:
A four piece ball has a solid rubber center, an inner cover layer, the middle cover (which is the extra layer of a three piece ball) and then the outer cover which is usually made of Urethane and provides much of the feel. The extra layer helps in adding power during high compression as well as spin. These balls are not as forgiving as the lesser layered balls.

5 Piece Golf Balls:
Five piece balls are the latest in high performance balls. Tour pro's and low handicappers would seek out these balls as they have the most spin and performance benefits of all ball types. Each of the layers helps react to different types of shots and swing speeds.

Year after year, both clubs and golf balls will continue to see innovation and some change, compelling the golfer to pull out the credit card and hope for that magic formula that will make them better than ever. Golf tech career fields will continue to offer interesting paths for your consideration.

A few of the golf industry career opportunities include, mechanical engineer, industrial engineering, mechanical design, computer science, physics, statistics, mathematics, creative technologies, marketing, sales, customer service, and materials construction. I'm sure one of these will get your interest.

As for your "golf budget"? That "decision" may be in the hands of your significant other !

Another approach to golf, as you know is to just "grip it and rip it".

Georgia State Ranks ***No. 2*** For Innovation, Remains Top Public University for Undergraduate Teaching In 2022 U.S. News & World Report Survey

Georgia State University is ranked the No. 2 most innovative university in the country and No. 2 for best undergraduate teaching in the 2022 edition of U.S. News & World Report's Best Colleges. Georgia State improved its position in the categories, having ranked No. 3 for both innovation and undergraduate teaching in the 2021 survey. It's the fourth year in a row the university has been ranked by the magazine in the top three among national universities for its "unusually strong commitment to undergraduate teaching." Georgia State is the top-ranked public university in the category.

The innovation and undergraduate teaching rankings are based on a survey of presidents, provosts and admissions deans at colleges and universities across the country.

"We continue to improve our position among higher education institutions across the nation because we are focused on what matters to our students: success in the classroom and after graduation," said Georgia State President M. Brian Blake. "Our place at the top of U.S. News' rankings for innovation and undergraduate teaching recognizes our continued commitment to serving students and providing them with the tools and technologies they need to succeed."

Georgia State also once again ranked highly in the Social Mobility and Academic Programs to Look For categories. The Top Performers on Social Mobility rankings are based on how well a school advances equity among low-income families and families with stronger financial backgrounds. Georgia State ranked 11th in the category on the 2022 survey.
In the Academic Programs to Look For category, Georgia State ranked sixth for its first-year experience. The indicator measures how well a university builds into its curriculum first-year seminars or other academic programs that regularly bring small groups of students together with faculty or staff.

For the third year in a row, the university ranked fifth in the Learning Communities category. College and university presidents, chief academic officers, deans of students and deans of admissions rank these programs, which offer students opportunities to take two or more linked course as a group.

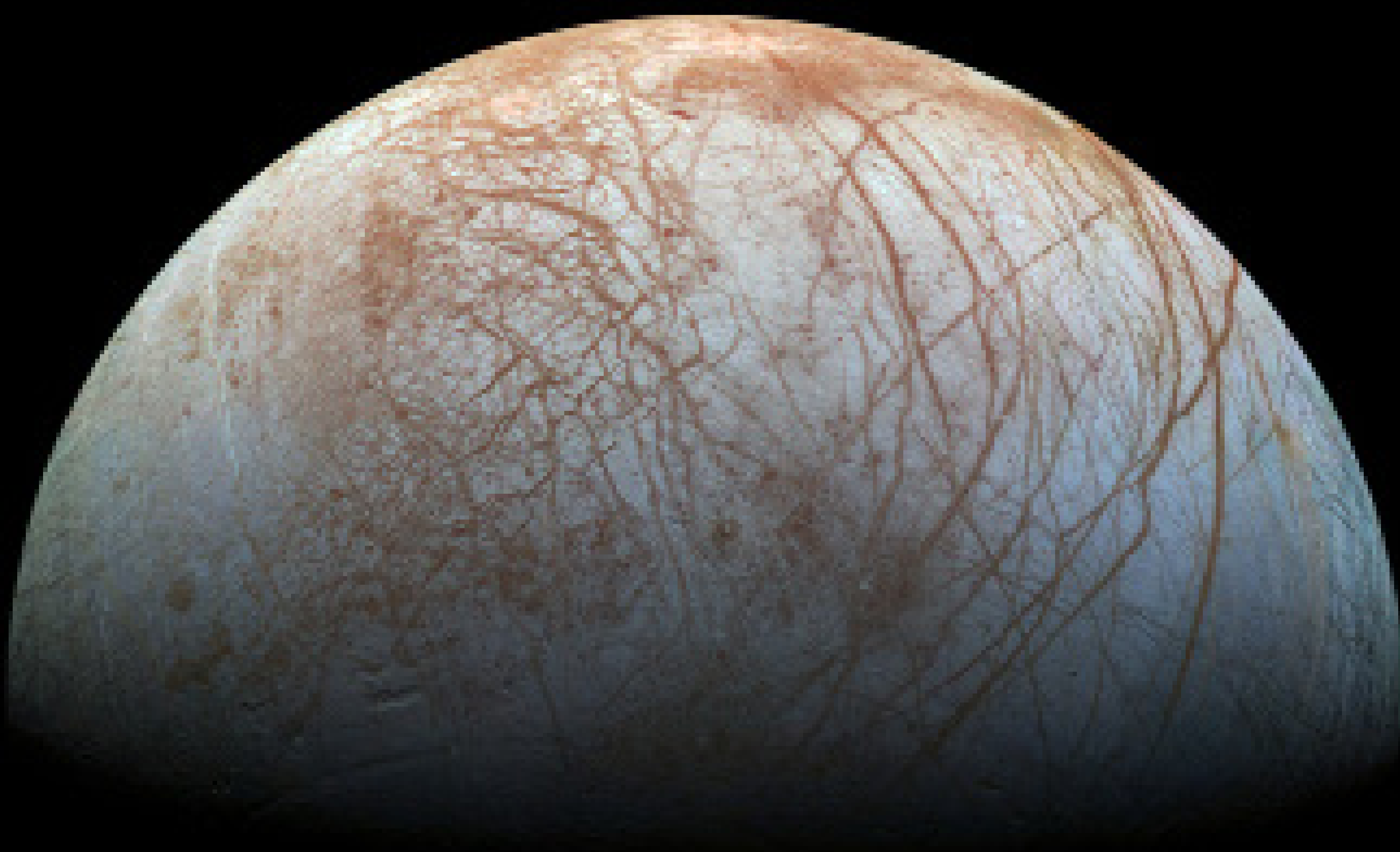
Georgia State also remains among the most diverse campuses in the nation, according to U.S. News' diversity index, which gives only 12 institutions a higher score.

The university's J. Mack Robinson College of Business is 49th this year, up from 53rd, in the magazine's ranking of undergraduate business programs. Its Risk Management & Insurance program remained at fourth in the rankings. Robinson's Computer Information Systems program ranked 8th.

The business school and program rankings are based on a survey of deans and senior faculty at institutions across the country.

Georgia State University

SpaceX lands NASA launch contract for mission to Jupiter's moon Europa



With all the latest news about "tourist in space" and the recent launches by Blue Origin and Virgin Galactic, some have called it the billionaires space race. It's fascinating to consider someday spending your vacation on an orbiting hotel, but probably not in the lifetime of most residents of Earth.

Interestingly, the leader of private space pursuits, SpaceX, was awarded a $178 million launch services contract for NASA's first mission focusing on Jupiter's moon Europa and to explore whether it may be suitable for life. The Europa Clipper mission is scheduled for October 2024 on a Falcon Heavy rocket owned by Space Exploration Technologies Corp, and would depart from NASA's Kennedy Space Center in Florida.

The contract is supportive of NASA's latest vote of confidence in the Hawthorne, California-based company, which has carried several cargo payloads and astronauts to the International Space Station for NASA in recent years.

This past April, SpaceX was awarded a $2.9 billion contract to build the lunar lander spacecraft for the planned Artemis program that would carry NASA astronauts back to the moon for the first time since 1972. The partly reusable 23-story Falcon Heavy, currently the most powerful operational space launch vehicle in the world, flew its first commercial payload into orbit in 2019.

The continued focus on exploration of our solar system by SpaceX, rather then orbiting hotels means jobs; tons of jobs over the next decade in a vast variety of STEM related career paths to prepare and execute journey's to the moon and beyond. Since these career opportunities are outside of the private companies of the rich, our chances of landing our dream job are greatly enhanced.

The probe is to conduct a detailed survey of the ice-covered Jovian satellite, which is a bit smaller than Earth's moon and is a leading candidate in the search for life elsewhere in the solar system.

A bend in Europa's magnetic field observed by NASA's Galileo spacecraft in 1997 appeared to have been caused by a geyser gushing through the moon's frozen crust from a vast subsurface ocean, researchers concluded in 2018. Those findings supported other evidence of Europa plumes. Among the Clipper mission's objectives are to produce high-resolution images of Europa's surface, determine its composition, look for signs of geologic activity, measure the thickness of its icy shell and determine the depth and salinity of its ocean.

Europa [yur-ROH-pah] is a unique moon of Jupiter that has fascinated scientists for hundreds of years. Its surface is among the brightest in the solar system, a consequence of sunlight reflecting off a relatively young icy crust. Its face is also among the smoothest, lacking the heavily cratered appearance characteristic of Callisto and Ganymede. Lines and cracks wrap the exterior as if a child had scribbled around it. Europa may be internally active, and its crust may have, or had in the past, liquid water which can harbor life.

Europa is named after the beautiful Phoenician princess who, according to Greek mythology, Zeus saw gathering flowers and immediately fell in love with. Zeus transformed himself into a white bull and carried Europa away to the island of Crete. He then revealed his true identity and Europa became the first queen of Crete. By Zeus, she mothered Trojan war contemporaries Minos, Rhadamanthus, and Sarpedon. Zeus later re-created the shape of the white bull in the stars which is now known as the constellation Taurus.

The fascination with Europa began centuries ago in 1610 when Galileo Galilei discovered four Jovian satellites: Io, Callisto, Ganymede, and Europa. But only recently have we begun to learn more about the sphere. About forty years ago, modern astronomer Gerard Kuiper and others showed that Europa's crust was composed of water and ice. In the 1970s, space exploration of Jupiter's satellite system began with the Pioneer and Voyager fly-by missions which verified Kuiper's analysis of Europa and discovered other characteristics.

In 1995, the Galileo spacecraft began gathering more detailed images and measurements within the system, providing the information needed to piece together Europa's past, present, and future.

Facts about Europa

- Europa is estimated to be about 4.5 billion years old, about the same age of Jupiter.

- On average, Europa's distance from the sun is about 485 million miles (or 780 million kilometers).

- Europa is Jupiter's sixth satellite. Its orbital distance from Jupiter is 414,000 miles (670,900 km). It takes Europa three and a half Earth-days to orbit Jupiter. Europa is tidally locked, so the same side faces Jupiter at all times.

- Europa is 1,900 miles (3,100 km) in diameter, making it smaller than Earth's moon, but larger than Pluto. It is the smallest of the Galilean moons.

~~IM~~POSSIBLE

ORNL's superb materials expertise, data and AI tools propel progress

By Dawn Levy / ORNL

At the Department of Energy's Oak Ridge National Laboratory, scientists use artificial intelligence, or AI, to accelerate the discovery and development of materials for energy and information technologies. "AI gives scientists the ability to extract insights from an ever-expanding volume of data," said David Womble, ORNL's AI program director. "New AI tools, together with world-class computing capabilities, are critical to maintaining scientific leadership."

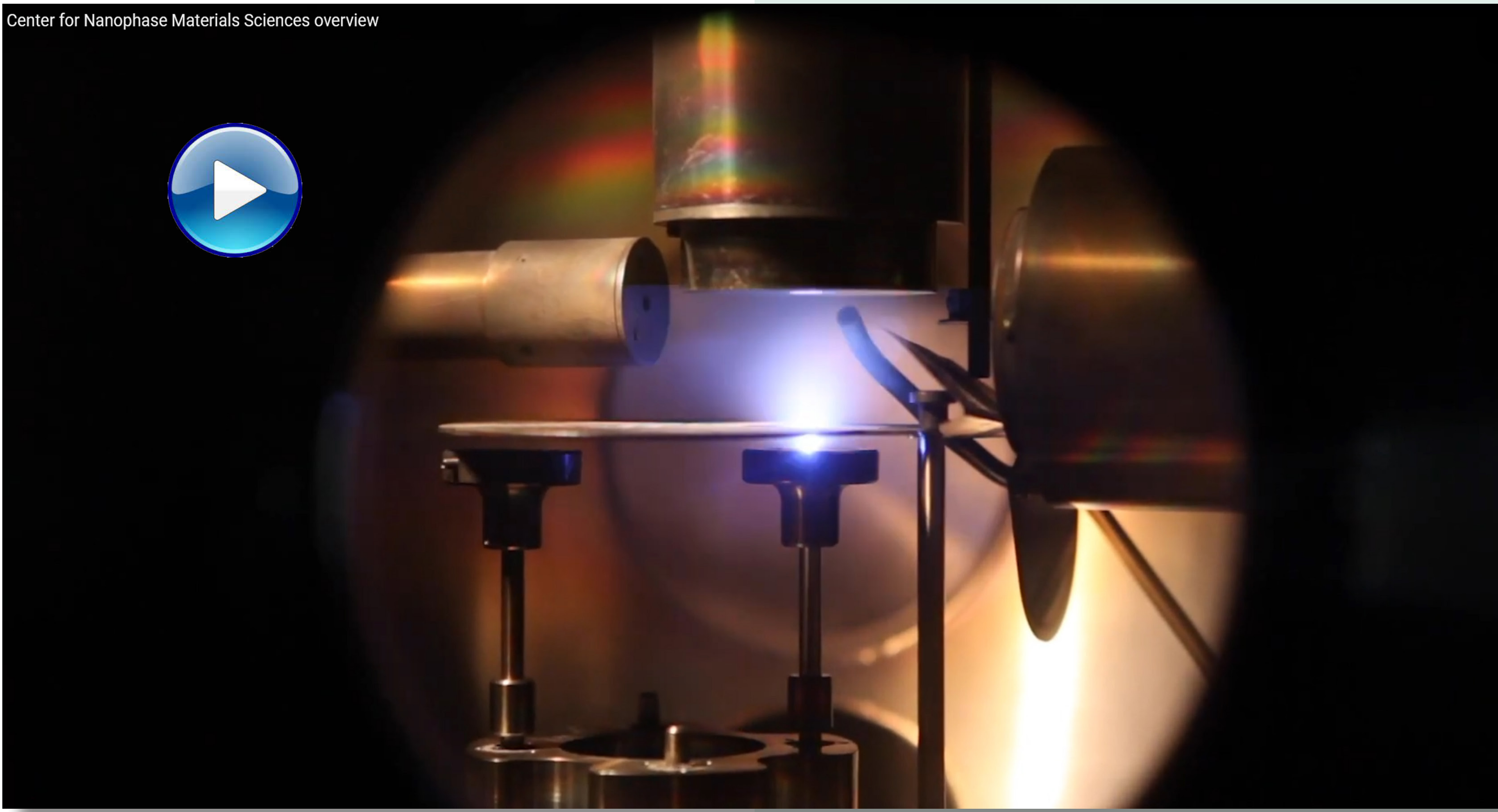
AI uses computers to mine mountains of data for scientific and engineering insights. Starting with high-quality data matters. Well-characterized materials create a strong knowledge foundation for the design of new materials that launch technologies and expand economies. ORNL has a history of materials development dating back to World War II and a rich archive of data generated on world-class instruments by expert researchers.

Increasingly, researchers generate high-resolution materials data at a volume, variety and velocity they never before have had to tackle.

"Ten years ago, a Ph.D. student working on steels might analyze five precipitates a day," said electron microscopist Chad Parish of ORNL. Such precipitates could embrittle an alloy and cause it to fail. "Now we've developed a technique that lets us do a thousand precipitates in five hours. We're drowning in data. AI may hold the key to making the best use of it all."

Two types of AI help make sense of big data. Machine learning runs algorithms on high-performance computers to find correlations within large data sets and determine how well they match expectations. In doing so, it reveals features that traditional data analyses may miss because they are subtle, infrequent, complex or unexpected. A step further, deep learning models the workings of the human brain (e.g., applying logic and expertise) to distinguish features in data sets that improve discovery, learning and decision making.

“We can now design machines to do the work that once required a human expert, except much faster and on a larger scale,” said ORNL materials scientist Stephen Jesse.



Harnessing machines

ORNL researchers have stood at the forefront of efforts to harness machines to propel progress in materials science. Starting in 1992, Bobby Sumpter worked on foundational theory and chemical/materials science aspects of machine learning. Markus Eisenbach joined him in creating the machine learning basis for integrating imaging instruments and high-performance computers. They ran theory-based models on supercomputers and validated the results against experimental findings.

In 2001, when the Materials Research Society issued a conference proceeding on AI methods in materials science, ORNL researchers were well represented, advancing methods to analyze, compress and visualize multidimensional data.

Image credit: Oak Ridge National Laboratory, U.S. Dept. of Energy; photographer Genevieve Martin, photo collage Allison Gray.

At ORNL's Center for Nanophase Materials Sciences, Sergei Kalinin, a founding member of the American Physical Society topical group on data science, works with colleagues to pioneer automated analysis of growing data from high-resolution microscopy experiments.

"We turned to machine learning methods because traditional approaches were not practical or sufficient," Kalinin said.

Around 2008, ORNL researchers began publishing papers advancing machine learning and deep learning in processing big data from microscopy and tying experimental results to theoretical models.

This effort grew over the subsequent decade to include AI advances such as:

- Complex scanning probe microscope imaging and spectroscopy methods to reveal nanoscale properties in greater detail
- Complete capture of big data streams from microscope detectors
- Workflows for on-the-fly analytics of scanning transmission electron microscopy data
- Automated conversion of microscopy data into libraries of structures and defects

- Algorithms for learning physical laws from observational data

- Assistance to tune microscopes, choose regions of interest in samples and control atom-by-atom assembly

"We are still just scratching the surface with the use of deep learning for quantitative structural analysis of microscopy data," ORNL's Albina Borisevich said. "If we can transition from isolated problems to a more general approach, it can completely revolutionize the field."

For example, ORNL researchers Wei-Ren Chen and Changwoo Do at the Spallation Neutron Source use machine learning to assist in small-angle neutron scattering characterization of a wide range of material structures. The machine learning methods may help them suggest models for data analysis.

ORNL researchers such as Suhas Somnath also have investigated ways to share data widely. He scales codes to run on distributed computing architectures and develops data infrastructure solutions.

"Continual advancements in automation, computational power, and resolution and speed of detectors in instruments now result in ever larger, numerous, more diverse and complex data sets from both simulations and experiments," said Somnath. "DataFed and the CADES Data Gateway will imminently facilitate collaborative collection, curation, annotation and sharing of data."

The Summit supercomputer at the Oak Ridge Leadership Computing Facility is ideally suited for training and deployment of AI algorithms on large data sets owing to its 27,648 state-of-art graphics processing units, high-speed file system and large memory. A recent materials microscopy application demonstrated AI scaled to use all of Summit while running at 93% efficiency.

Quality in, quality out

"The major focus in AI tends to be on data analytics, but we should emphasize that the data itself is important," said ORNL materials scientist Dongwon Shin, who runs thermodynamic models on supercomputers to design high-performance alloys.

He said the ORNL advantage is akin to "grandma knowledge." You may follow a cookie recipe to the letter, but your grandmother — with her in-depth knowledge of ingredient interactions, etc. — will out-bake you every time. Likewise, ORNL researchers who have worked on materials for decades have world-class data sets with detailed pedigrees.

Shin realized that most machine learning tools were developed by and for programming experts, not the domain scientists. His team developed an open-source toolkit called ASCENDS that lets scientists with little knowledge of programming or data science apply data analytics as easily as using Excel. ASCENDS analyzes correlations between input features and target properties to facilitate the generation and validation of hypotheses and training of machine learning models that predict materials behavior.

Visualizing material success

Visualizing big data is an additional challenge. Materials scientists often use software that comes with the instruments they buy. “Much of the vendor software presents the data collected by instruments in a bad way,” said ORNL’s Philip Edmondson, who investigates materials for nuclear fission and fusion applications.

The scientific community is clamoring for open-source software to help turn big data into something the human mind can interpret. Edmondson and Parish have recommended best practices for improving data visualization.

Materials for advanced nuclear reactors are irradiated in ORNL’s High Flux Isotope Reactor. Then scientists characterize the specimens in detail, and machine learning methods analyze the measurements to determine how irradiation changes the microstructures and properties that are likely to affect the lifetimes of fission or fusion energy systems. “With nuclear materials, there might be millions of dollars and five or more years of investment behind getting one three-millimeter sample into the electron microscope,” Parish explained. “You want to make sure that you’re gleaning all of the scientific insight you can from that sample.”

“We’re investing a lot of money and time into collecting good data,” Edmondson said. “Let’s understand it.”

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"Real World" Classroom STEM Activity

This is easily an in class experiment and data collection exercise with direct STEM career applications for any K-12 age group.

Purchase or borrow 5 different brands of golf balls, both old and new.

Using a table top or other piece of furniture of your choice or design, create a measurement stand using a tape measure (material tape measure used in fabric alterations is best) attached from the hard surface floor to the top of the furniture.

A much larger measurement tool can be made of cardboard with large inch labels drawn on for better viewing and notation.

The golf balls will be dropped from the same height adjacent to the measurement tool.

- Note type of golf ball dropped.

- Note rebound height on measurement tool as close as possible in inches or centimeters if you wish.

Repeat 3 times for each golf ball and average the results for each golf ball.

Using an Excel spreadsheet, create a chart for each golf ball brand.

Compare the bounce measurement results for each brand and discuss how they differ, how this might affect ball performance.

A similar activity could be used for the **"roll"** factors using an AstroTurf type artificial grass material.

For consistent ball roll, a small ramp of some kind can be designed. A much larger measurement tool will have to be designed as well.

- A science experiment
(the systematic accumulation of knowledge)

- An engineering project

- Group collaboration

- Creativity

- Data collection

- Computer science / use

- Software use / Excel (or other)

- General mathematics

"How my academic training helped me become a better Scientist in industry."

by **Minal Mehta**
Research Scientist, AstraZeneca, Gaithersburg, Maryland

I was ecstatic when I first found out that I got an industry job offer in a major pharmaceutical company, a few months before I was defending my PhD dissertation.

The role was a great fit-- it was a lab-based scientist position, and the work I was doing was very similar to what I had pursued during my PhD and what I honestly enjoyed.

It all felt like a dream come true, as my career goal at the time was to get an industry research position, with a meaningful opportunity to have a wider impact through my work by helping to deliver medicines to patients faster through evidence-based scientific research. It was certainly not an easy journey landing this role-- I had heard from colleagues and friends how difficult it is to break out of the ivory tower without industry experience.

Towards the last six to nine months of my PhD career, I was frantically preparing to finish my dissertation, manuscript, complete the last big experiments, and on top of it to find a position relevant to my knowledge base, interests and skill set. I applied to over 80 job positions, only to be fraught by the emails I would get saying,

"Thank you for applying, but we will not be moving forward with your candidacy."

I did countless phone interviews, long in-person interviews for many jobs, and fortunately towards the last two months of PhD, I found a role that was a good fit, and received a job offer within one week of my interview. It was certainly a very stressful time but nonetheless the hard-work certainly paid off.

One of my primary concerns was whether I had the skills that allowed me to function and thrive outside of academia. I felt like I was pigeon-holed into a very specialized niche within my field that breaking out of it would seem difficult.

Through personal reflection and preparation, I discovered that I did have the knowledge, experience and skills that are useful for the industry roles I wanted.

One of the key skills we learn as PhD scientists is how to communicate our science well to others. This is paramount to success in every function across industries. Knowing how to organize your thoughts well, present them in a clear and concise manner, and telling a compelling story of your data and results is crucial for success.

In graduate school, we have to convince our advisors and thesis committees that our research and ideas are sound and promising, and are worth pursuing. This task is no different than when sales representatives have to convince their customers that their company's product is worth buying, or when lawyers have to procure clients for their services by marketing their legal skills.

Similarly, as an industry scientist in a discovery research group, I have to routinely deliver compelling presentations with strong scientific evidence to convince my colleagues and managers that the drug target is worth pursuing, allowing the timeline of the product development cycle to move forward, with the ultimate goal to reach to patients in need faster.

My PhD academic training helped me become well-prepared to shoulder this responsibility and improve on it every day.

As I continue to practice communicating my science with others, I became better at building professional relationships with my colleagues, peers, managers, upper management, and cross-functional teams, and larger networks. I also learned so much from them and their functions and feel very satisfied to meaningfully contribute to the organization as a whole.

Another key skill that is an incredibly valuable asset of a PhD scientist is their problem-solving mindset that drives them to solve complex problems with a sense of urgency and persistence. We become relentless in pursuing the research questions without fearing failure. In fact, we actually thrive in it, because we are not afraid to take risks and keep moving forward. This essentially drives the discovery research and innovation programs forward, because without someone actually doing the work to figure out if novel drug target are worth working on, these programs will stop and nothing will get delivered.

I routinely have to deliver on this as part of one of my performance goals. The best part is it is it all feels like solving puzzles. Every day is a different day, with different challenges and problems to solve. Figuring out what resources needs to be allocated to what projects, and how to design experiments strategically to answer the right research questions, are the skills we all learn in our academic training.

This is tremendously valuable in the industry context as well. I have the ability to find the answers to complex questions, to find novel and creative solutions, to generate new valuable data, improve on processes that may have become outdated, or require new fresh perspectives. I am able to critically reason research ideas, by applying my own knowledge and experience. At the same time, I am able to leverage my team's expertise, and efforts, and build on working together to bring the solutions forward.

In concluding, I hope that through the snippets of my experiences that I shared above, I was able to show you that you too are able to take leaps forward into applying to those dream industry jobs that you always wanted and be successful in your scientific careers outside of academia.

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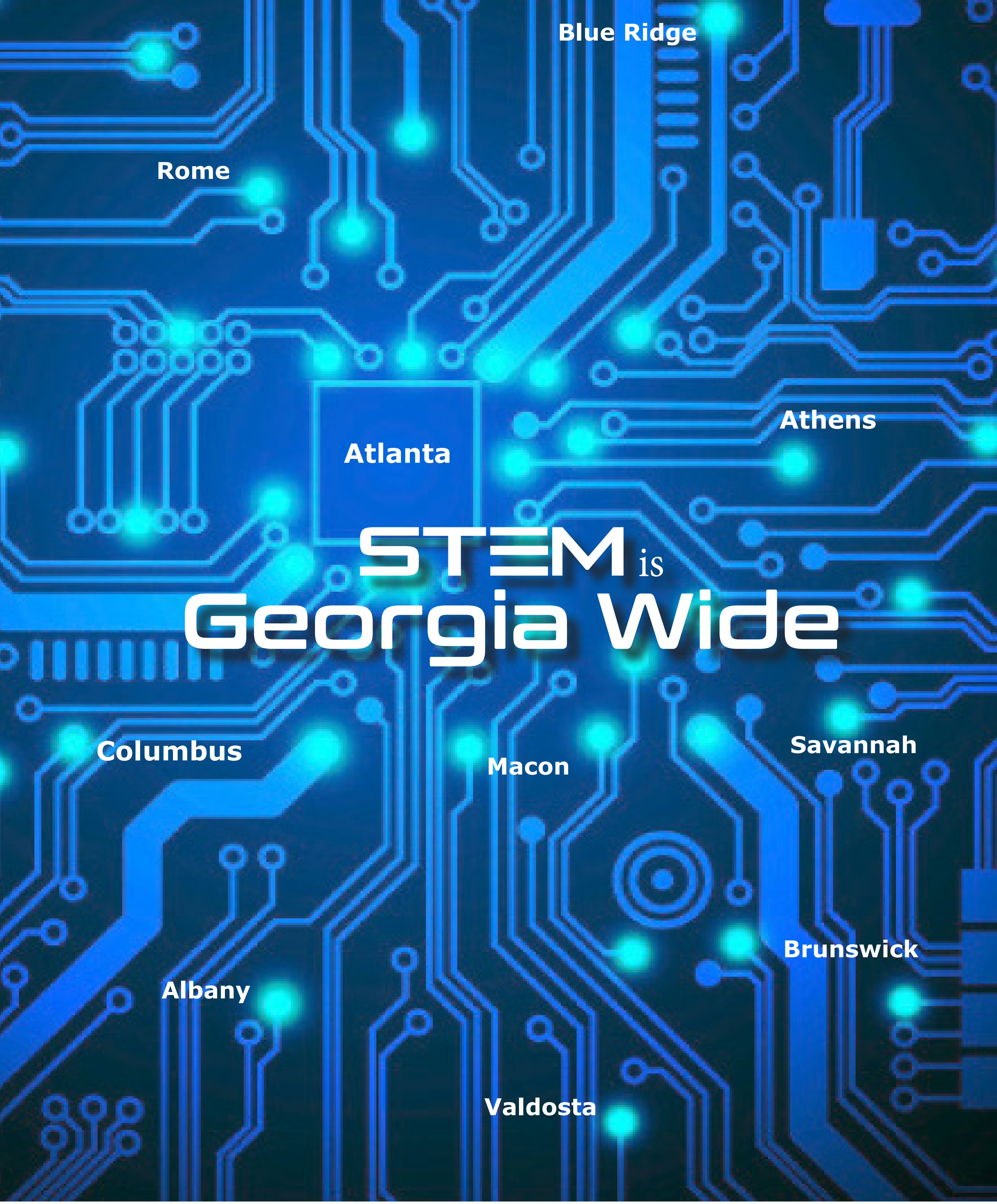

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