The Trend in ENGINEERING

UNIVERSITY OF WASHINGTON COLLEGE OF ENGINEERING NEWSLETTER / **AUTUMN 2024**

Animal tooth enamel provides a blueprint for advancing resilient materials

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FROM THE **DEAN**

What does it mean to "be boundless"? To me, being boundless is about believing in possibilities. It's about optimism, determination and connection. It's the drive to break down barriers, develop innovative solutions and create a better world.

"Engineering Excellence for the Public Good," the College of Engineering's five-year strategic plan, exemplifies being boundless. Engineering education must prepare students to create significant societal impact, shaping a healthier and better world.

This year marks the midpoint of our strategic plan. Launched in 2021, it set an ambitious vision for our college. With years one and two of implementation complete, we now embark on our pivotal third year. We invite you to learn about our progress so far and where we're headed next: **engr.uw.edu/plan**.

Over the last year we've seen significant federal funding in AI and semiconductor research, which we've shared with you in past issues of the Trend. In this issue, you'll read about two more major investments: In July, the National Science Foundation awarded the UW $50 million to lead a national research security center. In August, the Biden Administration's "Cancer Moonshot" initiative through ARPA-H awarded $21 million for a project to help surgeons remove tumors more quickly and accurately. Both multi-institutional endeavors are being led by UW College of Engineering faculty. Federal investment like this is critical — it drives innovation, fuels economic growth and advances technology, and it positions us to truly create positive public impact.

In addition to celebrating the midway point of our strategic plan, this academic year marks another notable milestone: the close of the Interdisciplinary Engineering Building fundraising campaign and the opening of the new building. Thank you to everyone who has contributed and supported this project. We hope you will visit when the building opens in 2025!

Nancy Allbritton, M.D., Ph.D.
Frank & Julie Jungers Dean of Engineering

ALUMNI HONORS

TIME'S 100 MOST INFLUENTIAL PEOPLE IN HEALTH

Civil and environmental engineering alumna Jenna Forsyth, who received her master's degree in 2012, was named to the 2024 TIME100 Health list, which recognizes 100 individuals who have made significant contributions to global health. Forsyth's work studying lead exposure in vulnerable populations has led to governmental regulations in South Asia and an immediate decline in lead exposure and poisoning in Bangladesh, where her research was centered.

TECH LEADER AND MRS. UNIVERSE AMERICA

Electrical and computer engineering alumna Arpita Ghosh Dacy, who received her bachelor's degree in 2010, was crowned Mrs. Universe America 2023–24 in December 2023. She received this honor after spending almost a decade developing products built on artificial intelligence, data science, and machine learning. "I have no modeling or pageantry background. I come from engineering, a tech background," says Dacy, a senior technical program manager at Amazon on the Alexa Kids Experience team. After being introduced to beauty pageants just three years ago, Dacy will next compete for the worldwide title in Incheon, South Korea, in October.

COLLEGE NEWS

New chair of Industrial & Systems Engineering

This autumn, Professor Juming Tang was named chair in the Department of Industrial & Systems Engineering (ISE). Tang recently joined the UW with joint faculty appointments in ISE and the Department of Mechanical Engineering. His record of innovative research, collaborative leadership and service positions him well to lead the ISE department's future growth. Prior to joining the UW, Tang was a Regents Professor and Distinguished Chair of Food Engineering in the Department of Biological Systems Engineering in the College of Agricultural, Human and Natural Resource Sciences at Washington State University (WSU). From 2016 to 2020, he served as chair of the Department of Biological Systems Engineering at WSU. He has conducted pioneering research in food safety and processing engineering, supported by the Department of Defense, Department of Energy, Department of Agricultural National Institute of Food and Agriculture, as well as private companies.

Interim Associate Dean for Inclusive Excellence

To provide strategic leadership in the College's Office of Inclusive Excellence (OIE), Robin Neal Clayton began serving as interim Associate Dean for Inclusive Excellence this past summer. In this role, Clayton oversees OIE programs and initiatives and the College's efforts to advance and sustain inclusive environments for faculty, staff and students. The interim position builds on Clayton's leadership and advocacy experience related to diversity, equity and inclusion, as well as her contributions to advancing the College's strategic goals around inclusive excellence. Clayton joined the College in October 2020 as the Director of Engineering Excellence and previously held several roles on campus including Director of the Educational Opportunity Program in the Office of Minority Affairs & Diversity.

Accelerating impact

With a focus on technology innovation, the UW's Global Innovation Exchange (GIX) blends engineering and business.

This year we welcome GIX — the UW's engineering and business institute for emerging technology leaders — to the UW engineering community. Launched in 2017 with support from Microsoft, GIX is now jointly integrated in the College of Engineering and Foster School of Business.

"This is where students learn the skills to innovate and develop technology solutions," says GIX Executive Director and CEO Sean Carr. "At the same time, we teach them how to understand users' needs and bring ideas to market. Rarely does all this happen in one program, which makes GIX programs incredibly exciting learning environments."

Located in the Steve Ballmer Building in Bellevue, Washington, GIX equips students to design technologies, develop prototypes and create business solutions. Its labs, makerspace and studios make innovation practical and immersive. The institute houses the Master of Science in Technology Innovation, an 18-month program taught by UW faculty and business and tech experts.

"GIX is at the forefront of advanced degree education," says College of Engineering Dean Nancy Allbritton. "Employers increasingly seek multifaceted talent, innovative thinkers who are as fluent in technological development and design as they are skilled in business analytics and marketing. GIX is tailored to train this new generation of cross-functional professionals."

Learn more at **gix.uw.edu**

Photo courtesy of GIX

Engineering by NATURE

Researchers across the College of Engineering are drawing inspiration from nature to drive cutting-edge innovations. Here we highlight a few recent projects where researchers take their cues from birds, dandelions, stingrays, butterflies, falling leaves and more.

Stingray-inspired underwater propulsion

By studying the unique swimming abilities of stingrays and other batoids, researchers hope to unlock the secrets of efficient undulatory propulsion — ultimately informing a new generation of quiet, sustainable underwater vehicles powered by wavelike motions.

"Stingrays are fast, efficient and maneuverable swimmers that propel themselves by undulating their pectoral fins," explains John Michael Racy, a mechanical engineering undergraduate researcher. "We want to understand the structural dynamics they use to achieve this elegant mode of propulsion."

The research team is taking an approach that combines biological studies of batoid anatomy with physics-based modeling and experimental testing. The goal is to translate the rays' unique structural and dynamic characteristics into practical engineering designs.

Racy notes the diversity in body shapes, skeletal structures and swimming modes among batoid species, which can provide insights for bio-inspired robotic designs adapted to different scenarios. Current underwater vehicle designs use complicated systems to create motion, but batoids are able to achieve similar motion more simply by recycling ocean wave energy through a network of specialized musculoskeletal elements.

In particular, the team thinks that batoids have developed special fins that move on their own. These fins have different stiffness in different parts, which helps them make waves when they move. Experimental and finite element models have demonstrated this effect, suggesting that this approach could simplify actuation and control for robotic undulatory propulsion.

Ed Habtour, an assistant professor of aeronautics and astronautics, emphasizes the project's interdisciplinary nature, combining biology, dynamics and engineering: "By uncovering the core mechanisms behind batoids' extraordinary swimming talents, [the team's] insights could catalyze transformation in underwater vehicle design."

Exploring the world through butterfly eyes

Most people notice the beauty of butterfly wings. But for Gary Bernard, an electrical and computer engineering affiliate professor and alumnus (BSEE '59, MSEE '60, Ph.D. '64), butterfly eyes are what he finds most captivating. Investigating their vision has, in fact, become his life's work.

"How does a small butterfly eye behave so beautifully and do such amazing things?" asks Bernard, who has held positions at MIT, Yale and The Boeing Company. "The technological fallout from our work has been absolutely amazing."

It all started in 1966, when Bernard made a notable scientific discovery after placing a butterfly under a microscope. Through the lens, he saw a green reflection from the butterfly eye, which quickly disappeared. The next time he looked, it mysteriously changed to red. Now known as butterfly eyeshine, this phenomenon is caused by a reflector behind the retina. Since it is most often found in nocturnal animals, it's still a mystery why eyeshine occurs in butterflies — which are active only during the day.

The discovery of butterfly eyeshine set Bernard on the research path he still follows to this day, investigating how light can be used as an optical probe to learn about butterfly vision. Since then, he and his colleagues have also discovered that some species of butterflies have high visual acuity due to the ability to see polarized light. The research has had notable impact, including advancing machine vision and real-time monitoring of manufacturing processes.

Insert: Affiliate professor and alumnus Gary Bernard studies depolarized butterfly eyeshine photos. Photo by Ryan Hoover

The nature of falling

Taking inspiration from dandelion seeds and leaves, Vikram Iyer, an assistant professor in the Paul G. Allen School of Computer Science & Engineering, has two projects that advance the dissemination of sensing devices and miniature wireless robots.

For the first project, Iyer's team developed a tiny sensor-carrying device that is modeled after how dandelions use the wind to distribute their seeds. This device can travel up to 100 meters in a moderate breeze, which provides a way to quickly distribute hundreds of tiny wireless sensors that could monitor conditions across large plots of land, from forests to farms.

"The way dandelion seed structures work is that they have a central point and these little bristles sticking out to slow down their fall. We took a 2D projection of that to create the base design for our structures," explains Iyer. "We added a ring structure to make it more stiff and take up more area to help slow it down."

Iyer's lab also took inspiration from a geometric pattern found in leaves, which informs the Miura-ori origami fold, to develop small robotic devices called "microfliers." They snap into a folded origami position during their descent, which allows researchers to control where they land.

"In its unfolded flat state, our origami structure tumbles chaotically in the wind, similar to an elm leaf," says Iyer. "But switching to the folded state changes the airflow around it and enables a stable descent, similarly to how a maple leaf falls."

Insert: A microflier. Photo by Mark Stone

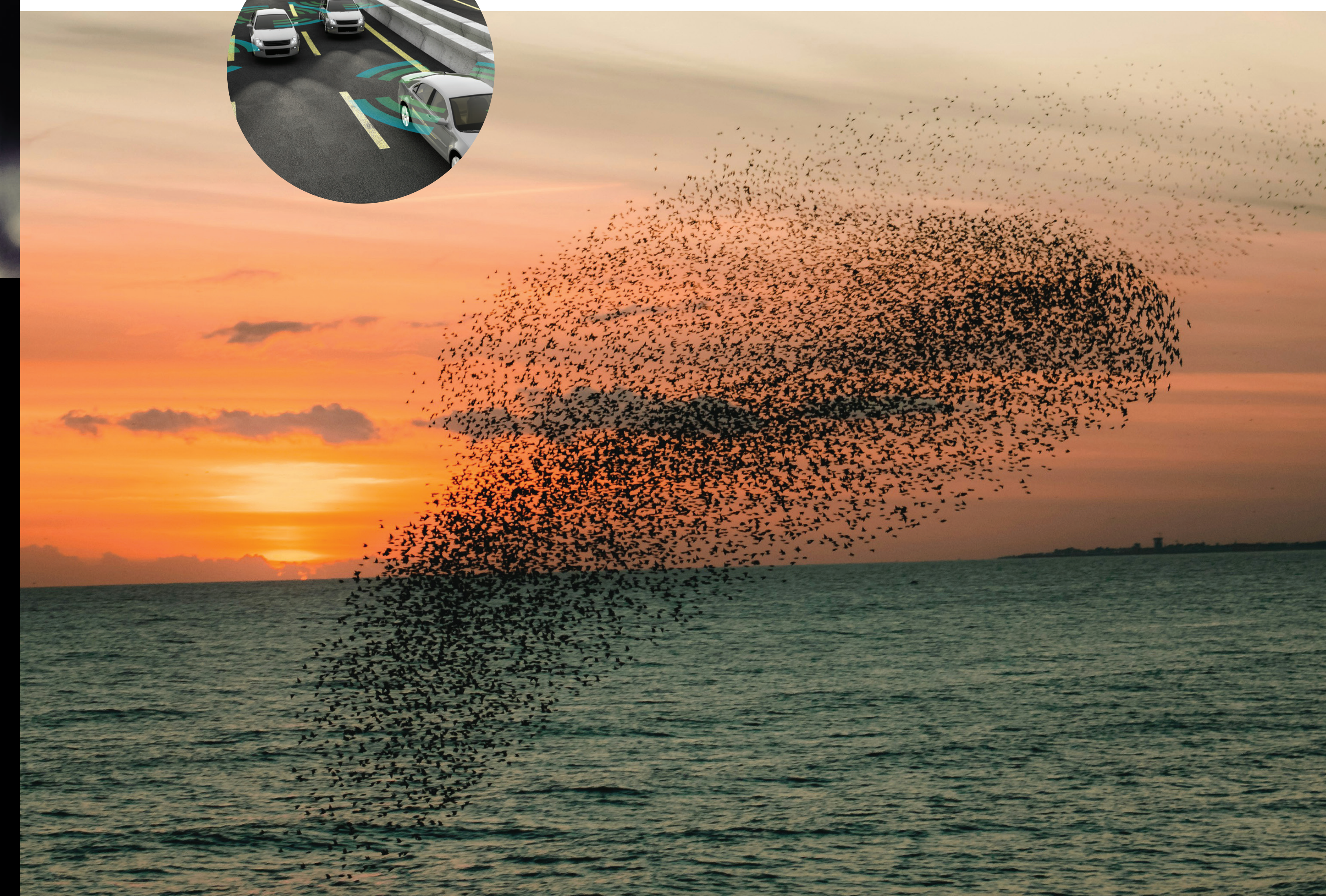
To improve self-driving vehicles, look to birds

When the light turns green in an intersection, there's a delay between when the driver in the first car advances and when the driver in the eighth car advances. Even autonomous vehicles aren't able to start moving at the same time. More vehicles would be able to cross the intersection at the same light if they all "knew" the light was turning green, started together and continued moving together.

Traffic is one area studied by Santosh Devasia, a professor of mechanical engineering, who recently improved a mathematical model describing how birds flock together while suppressing unwanted noise. This algorithm could be applied to build robots that work together better — such as a fleet of self-driving cars, or robots working in a large group to carry an item without damaging it.

In swarms of birds, information propagates without distortion. For example, to avoid predators, a flock of starlings can perform parallel sharp turns. Devasia's model takes into account that each bird adjusts its actions based on observations from its neighbors as well as its own previous actions, a concept he calls delayed self-reinforcement. His improved model shows that delayed self-reinforcement can reduce distortion during information propagation, even in noisy environments. This model could be used to improve cohesion in engineered networks, such as autonomous drone formations and in traffic.

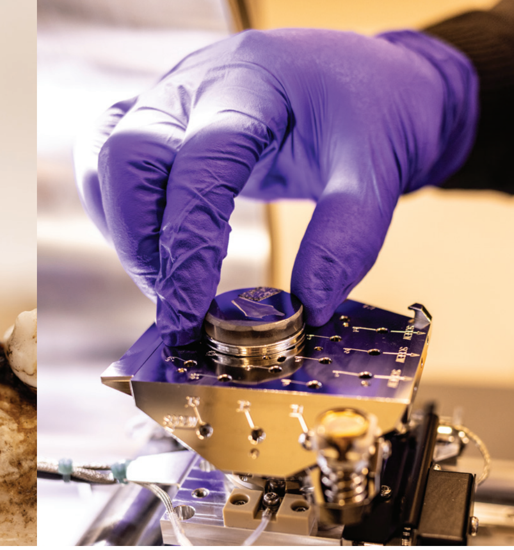
"Our method removes the high-frequency noise," Devasia says. "You don't want to follow the noise; you want to follow the motion."



BITING into fracture-resistant materials

By Brooke Fisher

Photos: Dennis Wise



Animal enamel provides a blueprint for advancing resilient materials.

When it comes to developing next-generation engineering materials that are fracture resistant, a team of UW researchers is all smiles about the prospect of utilizing insight gleaned from the hardest tissue in all mammals: tooth enamel.

“I started researching teeth when I broke a tooth on a sandwich,” says Dwayne Arola, a professor of materials science and engineering (MSE). “My dentist said teeth have a way to resist fracture. They are a mixture of mineral and hard tissue, so I got interested in why that occurred.”

The researchers are exploring exactly how enamel, which is the outer layer of a tooth, works to keep teeth functioning throughout a lifespan. Their goal is to ultimately inform the development of synthetic materials — for a variety of uses, such as structures — that are designed to manage cracks and not easily succumb to strong forces.

The success of the project is largely due to investigating enamel from animals, rather than humans. Since animal enamel is less dense and not typically fluoridated except for zoo animals, the team discovered it is easier to view the underlying microstructure. To access animal teeth specimens, Arola, together with MSE Ph.D. student Jack Grimm and postdoctoral researcher Cameron Renteria, is collaborating with the Burke Museum of Natural History & Culture. Other partners include Ohio State University and Idaho National Labs.

“Teeth rely on enamel, which is arguably one of the most damage-tolerant materials in all of nature,” says Arola. “We are using reverse engineering to interpret what nature has done.”

Cracks become confused

Composed primarily of the mineral hydroxyapatite, enamel has a natural tendency to be brittle. Cracking is therefore not only common, but expected.

“Why would Mother Nature put this material in this region when it’s subject to so many cycles of contact?” asks Arola. “The most fascinating thing about enamel is that you can see cracks in the tissue, but they don’t often enable fracture of the tooth.”

To investigate what prevents cracks from propagating, the researchers began by monitoring cracks microscopically. They found that cracks grow inward and are eventually arrested before reaching dentin, the layer directly underneath the enamel. They attribute this to decussation, the pattern inherent in the microstructure of the enamel.

“The crack is confused and blocked by the woven pattern of the enamel rods,” Arola explains. “The woven patterns are important — they are the secret behind this. The crack is trying to follow the path of least resistance, but that keeps changing so it starts undergoing bifurcation or forking.”

Exploring enamel patterns

Since the microstructure of enamel varies among species, the researchers were eager to learn which animals possess the most fracture-resistant enamel. To do so, they correlated the decussation patterns to the functionality of the tooth — in this case, the strength of an animal’s bite, called the bite force quotient.

Jeffrey Bradley, mammalogy collection manager at the Burke Museum, holds part of an African wild dog skull.

“We think there are predation requirements — what the animals with high bite forces are eating, along with how they acquire food, requires a higher fracture toughness,” explains Renteria, who received his Ph.D. in 2023 from MSE. “We believe that’s what causes different patterns in the decussation.”

Since molars are subjected to higher bite forces, the researchers obtained molar specimens for various animals including lion, wild African dog, gray wolf, black bear and snow leopard. Using high-resolution 3D imaging technology called X-ray microcomputed tomography, they could clearly see — for the very first time across these species — unique patterns in the enamel microstructure, particularly the angles and orientation of enamel rods. Distinct designs in enamel from animals with the highest bite force quotient, namely lions, wild African dogs and wolves, also became more evident.

“The enamel rods cross each other at a steeper angle, which does a better job of constraining cracks — it takes the crack more energy to keep moving,” explains Grimm. “A wild African dog might be biting into bone, while other animals are eating softer foods, so its enamel is designed more for crack growth resistance.”

Modeling Mother Nature’s materials

The researchers are currently working to define the exact composition of the patterns in the enamel of animals with the highest bite force quotient. The ultimate goal is to model the various microstructure patterns in synthetic materials to meet certain performance demands, from fracture toughness to wear resistance. Materials that don’t easily break when subject to strong forces could have a variety of uses, from armor for tanks to ballistics to structural materials for aerospace applications.

“Imagine seeing a crack on the outer surface of an airplane and being told it will stop, the materials will not allow it to penetrate any further,” Arola says. “We don’t have engineering materials like that yet — that would be the holy grail.”

Above left to right: Postdoctoral researcher Cameron Renteria with a lion skull; A close-up of lion teeth; A sectioned lion tooth sample on the stage of a scanning electron microscope.

The Burke Museum: A tooth ‘bank’ and research partner

Located on the UW campus, the Burke Museum of Natural History & Culture cares for and shares natural and cultural collections with a focus on dinosaurs, fossils, Northwest Native art, plant and animal collections and more. Except for rare items, the museum loans specimens to researchers nationwide. With storage cabinets full of teeth from a wide variety of mammals, the Burke “is like a bank for us,” says Arola.

“The whole collection is here for research,” explains Jeffrey Bradley, mammalogy collection manager at the Burke. “Most people who use the collection are asking biological questions, so this [engineering collaboration] is unique.”

Safeguarding American research

By Leah Pistorius

The UW is leading a national effort to strengthen U.S. research security thanks to a five-year, $50 million investment from the National Science Foundation (NSF). The initiative, known as the Safeguarding the Entire Community of the U.S. Research Ecosystem (SECURE) Center, aims to empower the research community to address issues of security and integrity.

Texas A&M University has received an additional $17 million over five years to establish the SECURE Analytics program, bringing the total investment in the SECURE initiative to $67 million. This funding will help the research community make informed decisions that protect the value of their work.

“Community-centered solutions are essential not only to the design of enhanced research security capabilities, but also to their adoption and use,” says Mark Haselkorn, professor of human centered design and engineering and director of the SECURE Center. “Through SECURE, we will work to ensure the community of researchers and research administrators feel ownership of these enhancements and assure that they meet their needs and work in their environments.”

The SECURE Center will establish a national infrastructure, partnering with academic institutions, nonprofits, and businesses to develop tools and information that safeguard U.S. research. Five regional centers will also be established: SECURE Northeast led by Northeastern University, SECURE Southeast led by Emory University, SECURE Midwest led by the University of Missouri, SECURE Southwest led by the University of Texas San Antonio and Texas A&M University, and SECURE West led by the UW.

Additionally the University of Michigan, Mississippi State University, and Stanford University’s Hoover Institution will lead efforts in specialized areas like high-risk research and geopolitical analysis, while other partners at the College of Charleston and MindCette will focus on equitable access and balancing collaboration with protection.

This investment follows the 2022 CHIPS and Science Act, which authorized $280 billion to bolster U.S. research and manufacturing. The NSF, a key partner in this initiative, funds approximately $10 billion of U.S. research annually.

Insert (above): Mark Haselkorn

WHY FEDERAL FUNDING MATTERS

Federal investment is the engine behind Washington’s tech boom — from Boeing’s expansion after World War II to today’s advancements in AI, semiconductors, health care and quantum computing. Here’s why it’s critical:

Financial support: Federal funding provides the resources for large-scale and long-term research projects that universities often can’t fund on their own.

High risk, high rewards: It supports ambitious, groundbreaking research projects that carry significant risk but could potentially revolutionize entire fields — endeavors often too uncertain for other types of investment.

Innovation and discovery: It leads to discoveries that advance technology and benefit society.

Infrastructure and equipment: It supports cutting-edge equipment, technology and facilities essential for high-quality research.

Talent development: Federal funding helps train the next generation of engineers, scientists and researchers through grants, scholarships and assistantships.

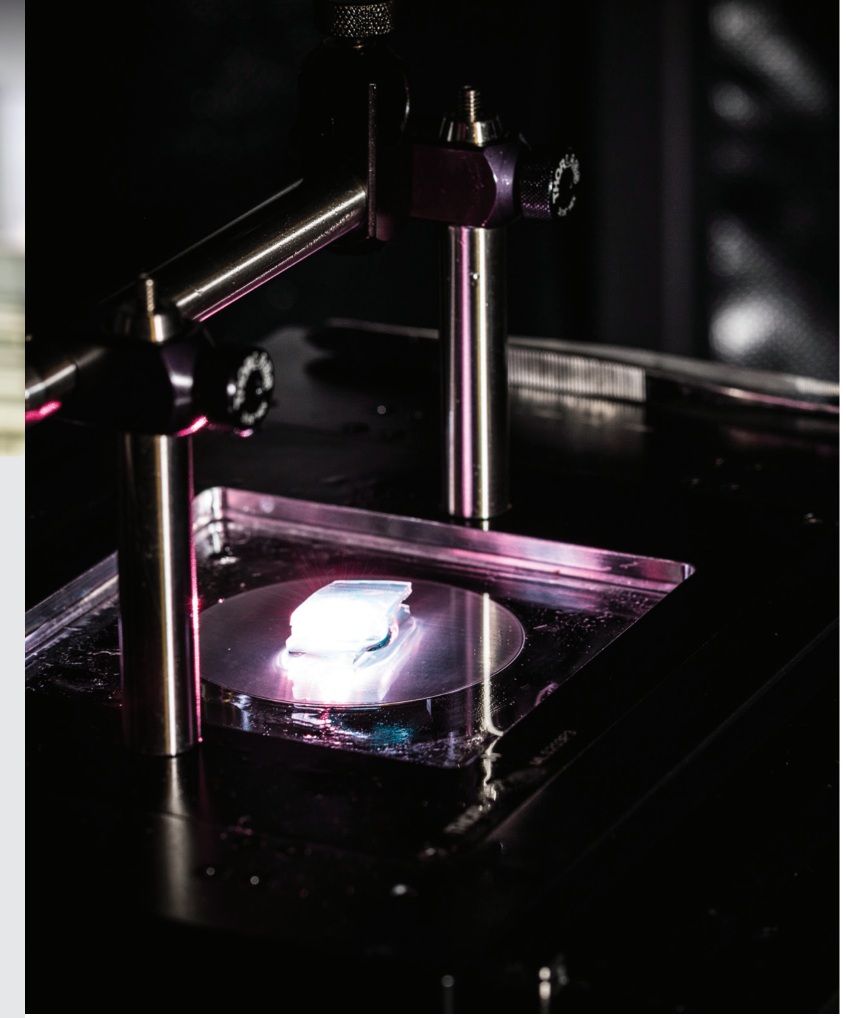
Collaborative opportunities: It encourages partnerships between universities, industries and government agencies, promoting multidisciplinary research and shared expertise.

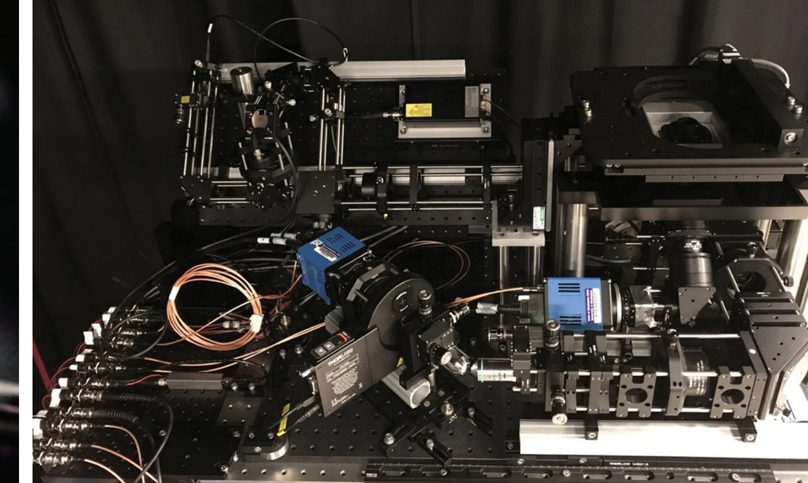
Economic impact: Federally funded research can spark new technologies and industries, driving economic growth and jobs.

Global competitiveness: Sustained investment ensures the U.S. remains a leader in technological and scientific advancements.

Addressing national challenges: It targets national priorities such as health, security, energy and environmental challenges, directing research efforts toward solutions.

Peer-reviewed validation: Securing federal grants involves rigorous peer review, ensuring only high-quality, impactful research receives support, maintaining high scientific standards.





Better cancer surgery outcomes

By Lyra Fontaine

Nearly 2 million cancer cases are diagnosed annually in the U.S., with surgical removal often being the first line of treatment for solid tumors. Accurately identifying the surgical margin — the edge of healthy tissue around the tumor — remains challenging for surgeons. If cancer is left at the margin, patients may face worse long-term outcomes and may require additional costly and risky treatments, including more surgeries.

A new multi-university project, led by Jonathan Liu, a mechanical engineering professor, aims to help surgeons remove cancer tumors more completely and quickly in a single procedure. The project has secured up to $21.1 million in funding through the Biden Administration’s “Cancer Moonshot” initiative, which has allocated $150 million to researchers nationwide. The funding, provided by the Advanced Research Projects Agency for Health (ARPA-H), focuses on improving tumor-removal surgery success rates.

Liu’s team, in collaboration with Alpenglow Biosciences Inc., Harvard Medical School, UW Medicine, and Vanderbilt University Medical Center, is developing an intraoperative “flatbed scanner” that can image the margin surfaces of surgical specimens within 15 minutes of removal. Located in the operating room, the device will help surgeons confirm complete tumor removal and identify areas needing further resection.

Preliminary studies have shown that the open-top light-sheet microscopy technology developed in Liu’s lab can rapidly image fresh tissue surfaces, providing a 3D view of the margin. This approach could lead to more complete tumor removal and better patient outcomes, reducing the need for manual tissue preparation and lowering costs.

The funding will allow Liu’s team to refine the technology, ensuring it can image large specimens at the cellular scale within a short time frame, making it practical for surgical use.

“Developing these technologies, which include imaging hardware and AI analysis methods, and validating them well in the clinic requires a large team of investigators, which is difficult to fund with other funding mechanisms,” Liu says. “ARPA-H provides the vision, resources and funding to make this type of research possible.”

The microscopy technologies developed in Jonathan Liu’s lab can rapidly image tissue samples in 3D. A new project will build on these technologies to guide tumor-resection procedures. Photos by Mark Stone. Insert: Jonathan Liu

AI headphones isolate one voice with a glance

By Stefan Milne

Noise-canceling headphones have gotten very good at creating an auditory blank slate. But allowing certain sounds from a wearer's environment through the erasure still challenges researchers.

A UW team has developed an artificial intelligence system that lets a user wearing headphones look at a person speaking for three to five seconds to "enroll" them. The system, called "Target Speech Hearing," then cancels all other sounds in the environment and plays just the enrolled speaker's voice in real time.

"We tend to think of AI now as web-based chatbots that answer questions," says Shyam Gollakota, a professor in the Paul G. Allen School of Computer Science & Engineering. "But in this project, we develop AI to modify the auditory perception of anyone wearing headphones, given their preferences. With our devices you can now hear a single speaker clearly even if you are in a noisy environment with lots of other people talking."

To use the system, a person wearing off-the-shelf headphones fitted with microphones taps a button while directing their head at someone talking. When the sound waves reach microphones on the headset, a signal is sent to an on-board embedded computer, where the team's machine learning software learns the desired speaker's vocal patterns. The system latches onto that speaker's voice, even as the pair moves around. The team is currently working to expand the system to earbuds and hearing aids.

With microphones on both sides, the headset relays sound waves from a speaker's voice to an on-board embedded computer.

Restoring hand function for some with spinal injury

By Chris Talbott

After half a decade of tirelessly working to reverse the effects of a 2005 spinal cord injury following a shallow-diving incident, Jon Schlueter remembers finally lowering his expectations.

Fifteen years later, Schlueter has a renewed outlook on recovery after participating in a UW School of Medicine study of an electrical-stimulation device that shows great promise for patients with loss of function and other side effects of spinal cord injury. Having regained the use of his right hand and arm, the 49-year-old Seattle resident now plays the guitar for hours each week and continues to improve.

The international clinical trial used a device that provides electrical current to the spinal cord through electrodes on the skin. The patches are designed to numb the contact point to allow for five times more current to be delivered compared to standard treatments. A research team led by Chet Moritz, a professor of electrical and computer engineering and of rehabilitation medicine, found that 72% of participants significantly improved strength and function after two months.

"We've seen people that have no functional use of their hands at all go from not being able to pick up an object or manipulate an object all the way to being able to play an electric guitar or use a paint brush on canvas," said Moritz. "We've also seen some people who had no movement of their fingers at all start moving them for the first time in more than a year since their injury."

Patches cover the electrodes delivering pulses to the patient's area of injured spine.

Q&A: The climate change toll on roads — two UW professors weigh in

We mostly take roads for granted until something bad happens — a heatwave leads to a street buckling or an atmospheric river makes a neighborhood creek spill over its banks and flood our route to work.

As climate change brings about rising sea levels and more extreme weather, these issues with our roads are likely to be exacerbated. Two UW researchers are investigating how to mitigate the effects of climate change on common road pavements, such as asphalt and concrete. Stephen Muench, professor of civil and environmental engineering, and Nara Almeida, assistant teaching professor in the School of Engineering & Technology at UW Tacoma, share their insights.

By Sarah McQuate

How do extreme temperatures affect roads?

Nara Almeida (NA): Cold temperatures can make pavements that are meant to be flexible, such as asphalt, more likely to crack. Also, during freeze-thaw cycles, water inside the pavement expands when it freezes and contracts when it thaws. This phenomenon can accelerate deterioration, which leads to large cracks in rigid pavements, such as concrete, and potholes in flexible pavements, such as asphalt.

Stephen Muench (SM): Another temperature issue that we notice here in Seattle is what happens during increasingly common heat waves — say, three consecutive days of over 100 F weather. Infrastructure actually expands during hot weather, which can cause the edges of concrete pavement slabs to butt up and push on one another until the joint gives out and pops up to relieve stress.

How does your research addresses these issues?

NA: I am interested in using what is called "pervious concrete" as the surface layer of pavement. These pavements absorb rainwater and recharge water tables, and also help filter contaminants in stormwater runoff. Pervious concrete could be helpful in the Seattle and Tacoma region, where preserving aquatic wildlife, particularly salmon populations, is a major issue.

SM: The industry buzzword for addressing climate change is "resilience." It is not practical to design a pavement to be resistant to everything. At some point, you have to admit that if a flood or other event is strong enough, you have to absorb damage and then recover. I want to know how to triage a system, and then recover quickly with what will surely be limited resources.

We just started a project that addresses how flooding impacts the resiliency of pavement systems. Our current work in the National Cooperative Highway Research Program will provide guidance to state departments of transportation on how to quantify the effects of flooding and improve resilience.

Read more research news at **engr.uw.edu/news**

BLAZING A TRAIL WITH WILDFIRE RESEARCH

By Brooke Fisher

Photos: Dennis Wise

An increase in wildfires across the nation, especially along the West Coast, has lit a fire under many UW engineering researchers. And they're responding in a number of ways — from developing cutting-edge safety technology to uncovering the long-term hazards of post-wildfire sediment transport.

Improved escape route planning

During wildfire season, while working to contain and extinguish fires in rugged wilderness areas, firefighters are often in precarious situations — especially when the direction a wildfire is traveling suddenly shifts. To provide escape route suggestions, a team of aeronautics and astronautics (A&A) researchers is developing real-time drone-based technology.

"The idea is that as the drone is flying around, it can map out where the fire is," says A&A Assistant Professor Karen Leung. "This can be used for decision support, to help those behind the line managing the operation. Safety is critical, so they can't make a mistake."

Currently, helicopters are used to monitor wildfires, but drones equipped with sensors could present a more efficient, cost-effective option. They can provide real-time data faster and have fewer restrictions on flying and launching. The project builds on Leung's expertise enabling autonomous systems to operate safely around humans — from delivery robots that navigate sidewalks to driverless cars that share the road with motorists

"This can also extend to drone applications, where the autonomy provides support for the human, but the human is ultimately making the final decision," Leung explains.

The researchers are designing an integrative system that features a fire map produced in real-time with thermal data gathered by drone, with terrain and elevation maps overlaid to indicate steep cliffs or rivers. They're also developing a path planning system that will recommend safe travel routes. Since wildfires can move quickly and unexpectedly change direction, the team will incorporate these variables.

Understanding post-wildfire sediment hazards

Although home to scorched trees and barren soil, the upper slopes of the North Cascades, which were ravaged by the Bolt Creek fire in 2022, are fertile ground for research. To improve predictive models for hazards that occur several years following a wildfire — particularly risks associated with sediment traveling down the mountainside — a team of civil and environmental engineering (CEE) researchers is gathering data.

"It's inevitable that there is increased sediment yield, but when? If we know when, then we can prepare for it," says CEE Professor Erkan Istanbulluoglu.

The Bolt Creek fire burned more than 14,600 acres along a stretch of Highway 2 near Skykomish, Washington. The steep slopes above the Skykomish and Beckler rivers make it an ideal site to investigate the mechanics behind sediment transport, and the role it plays in flooding.

"Flooding is not only a rainfall problem, but a sediment problem. Typically, when assessing flood hazards, sediment isn't considered as a factor," explains Istanbulluoglu. "If we have megafires, a huge amount of sediment in the streams could cause a lot of flooding."

Since most early warning models for post-fire debris flow were developed using data from drier climates, the researchers aim to improve models for areas with higher precipitation.

In severe burn situations, soil may not fully recover the ability to absorb water for several months to a year, due to the formation of an organic water-repellent coating. This, together with decaying tree roots that no longer have the strength to hold soil in place, can cause increased sediment transport on steep slopes. While the risk typically peaks within several years, the precise timing is still unknown.

To survey the hilltops surrounding the Bolt Creek fire, the researchers collaborated with the Natural Hazards Reconnaissance Facility, known as RAPID. Data collected from drone-based lidar and aerial imagery will be used to build high-resolution elevation and terrain models, which will be compared to historical models to observe changes in topography. Using modeling software called Landlab, developed by Istanbulluoglu's research group, real-life scenarios will also be simulated.

Top: Real-time data on the drone flight controller. Bottom: Launching a drone.

Advancing wildfire research

Since the RAPID Center launched six years ago, post-wildfire deployments have not only surfaced, but have spread quickly — not unlike wildfire.

"When we started the facility, wildfire was not mentioned a single time in the [funding] proposal and now it's about 30% of what we do," says RAPID Director and CEE Professor Joe Wartman.

This new class of extreme events, which includes wildfires and also landslides, is triggered by warming temperatures, says Wartman. In response, the facility — which is based at the UW — has incorporated them into its mission to respond to natural disasters such as hurricanes, earthquakes, tsunamis and more. The first center of its kind in the world, RAPID has transformed the natural hazards reconnaissance field by offering mission planning and deployment support for extreme event reconnaissance organizations, universities, government agencies and international organizations.

To meet the demand for post-wildfire resources, the center continues to advance its offerings, from growing its collection of more than 100 unique state-of-the-art pieces of equipment to enhancing data processing and archiving protocols to ensure that data sets may be reused and shared.

"Understanding the cascading effects are a big part of wildfire research," explains Wartman. "Things like ash can enter the groundwater system and permanently destroy water resources. In rural areas, the water can become fully contaminated and people can no longer use the wells."

Testing an in-home MOBILITY SYSTEM

By Lyra Fontaine | *Photos: Jorge Azpeitia and Matt Hagen*

Engineering students are pushing the boundaries of mobility design through innovative capstone projects.

In collaboration with Seattle-area fitness trainer Mary Meyer and architect Stan Chiu, mechanical engineering (ME) students developed prototypes for a unique in-home mobility system that could help people with limited mobility.

This hands-on project gave students the chance to work closely with clients and collaborate across teams to design, fabricate and test prototypes aimed at enhancing mobility for people with limited physical abilities.

"The goal is to create a holistic physical environment that is beautiful, affirming and adaptable to individuals' needs as they change over time," says Meyer, a lifelong athlete who was diagnosed with severe spinal multiple sclerosis (MS) at age 45. "This includes a mobility system that would inspire individuals to stay active and mobile while being supportive."

Unlike traditional mobility systems, which often focus on wheelchair use, Meyer envisions an adaptable home environment that empowers individuals to choose the level of support they need.

"I'm challenged enough outside, and now I'm coming inside and want to relax, feel safe and feel good about who I am and where I am," she says.

Meyer and Chiu first partnered with human centered design and engineering researchers to shape the concept, and then ME students took on the challenge of developing prototypes. Known as the Adaptable House Project, the system was the focus of four 2023–24 capstone projects, two of which are highlighted here.

An adjustable harness system

One capstone team designed a harness-based support system attached to an overhead frame to provide multiple levels of support for people with mobility-based disabilities. To increase users' independence and confidence, the goal was to make the system safe, durable, aesthetically pleasing and comfortable for long periods of wear.

"Mary wanted to emphasize empowering the user, so we worked to make the harness and chair feel positive and not debilitating," says team member Monica Santiago (BSME '24).

The team brainstormed harness and chair ideas with Meyer, Chiu and their faculty mentor Eli Patten, ME capstone director and assistant teaching professor. For their prototype, they used a non-stretchable cotton blend material with nylon webbing, padding on the shoulders, 3D-printed plastic to provide back and abdominal support and Velcro to secure the harness. The chair they selected for the full support mode was a hammock chair fitted with a footrest and a foam back rest. Testing showed that the frame and harness can support up to 300 pounds for all system modes and can be worn comfortably for more than four hours.

Left: Students Monica Santiago and Tori Landrum demo a harness-based support system they helped design. Right: Student John Shim demonstrates a prototype for a lift control system.

> "Injuries and aging happen to all of us. A mobility system like this could extend all of our possibilities."
>
> \- STAN CHIU, ARCHITECT

"We emphasized the user experience by working to understand Mary's needs and considering colors, fabric feel and more," says Tori Landrum (BSME '24), who tested the comfort of the harness by wearing it for a day, including to class. "We applied ME fundamentals to things we've never done before, such as testing fabric and Velcro using a tensile testing machine."

Lift control using mechatronics

The capstone team responsible for the overhead mobility system's lifting control demonstrated how to implement adaptable body weight and fall protection systems to aid and empower individuals with mobility impairments.

"If the user is wearing the harness, the prototype we built can adjust their body weight by taking some weight off them," says John Shim (BSME '24). "Such a dynamical system will provide optimal mobility support tailored toward each individual."

In addition to body weight support, the lift control system has two other modes: fall protection and float. Fall protection catches a falling user by automatically activating when the user exceeds a specified velocity threshold. In float mode, users are suspended in the air, allowing caretakers to move them around the room with a gentle push or pull.

After discussions with Meyer and Chiu to understand the project needs, the team members built a prototype consisting of a motor that provides rotational energy and a pulley that redirects the rotational power to lift the user. The design was successfully tested by Shim and teammates Everett Hirano, Keita Yamamoto and Maya Larson.

"This project was a perfect fit because I wanted to get involved in the medical industry and help others using technology," Shim says. "The skills we learned, such as modeling dynamic systems, professionally presenting our experimental results and collaborating with others, will be invaluable as I pursue a career."

Tori Landrum adjusts a prototype of the harness, which is shown in detail below.

Expanding possibilities

With testing showing that the mobility system is feasible, the students provided ideas for improvement so that future capstone teams can build upon their work.

"Injuries and aging happen to all of us," says Chiu. "A mobility system like this could extend all of our possibilities."

Similarly, Meyer is guided by questions such as "Can we make life a little easier for people? Why don't we have houses that we can grow old in?"

"Working with the students is really encouraging," Meyer says. "I love that it's such a real-life experience. Seeing it all come together has been exceptional."

A foundation of community support

We celebrate the close of a successful donor fundraising campaign for the IEB.

When the new Interdisciplinary Engineering Building (IEB) opens next spring, it will be built on a foundation that extends beyond the physical footprint. Support from numerous alumni, individuals, corporations and organizations throughout the region and across the nation played a critical role in bringing the vision for a new student-focused learning facility to fruition.

The strong outpouring of donor support — which totaled $46 million — made up 45% of the total project funding for the IEB, which will advance engineering education by providing an academic home for all undergraduate engineering students. This funding, combined with $50 million from the state and $6 million from the UW, collectively financed the $102 million project.

"We are thrilled to have met our fundraising goal and are grateful for gifts from donors, as well as the state and the UW's investment," says Nancy Allbritton, Frank & Julie Jungers Dean of Engineering. "The success of the project truly relied on both public and private support."

The building itself will serve as a tribute to many people and corporations that made significant contributions to the facility. In addition to a donor recognition wall, spaces throughout the building will be named after families and businesses.

The 75,000 square-foot, state-of-the-art learning facility is designed to maximize innovation and collaboration. It will feature a makerspace, space for clubs and student groups, lab space, an engineering academic center, an AI teaching institute and dedicated space for industry capstone projects. The IEB is scheduled for substantial completion in December 2024, and classes are anticipated to be held in the five-story building starting next spring.

A lasting legacy

A TRANSFORMATIVE GIFT FROM THE LIAO FAMILY SUPPORTS THE NEW INTERDISCIPLINARY ENGINEERING BUILDING.

For engineering students, the lobby of the IEB will be a hub of educational activity, offering a comfortable spot to study and a central gathering place. And for the Liao family, it will serve as a lasting legacy and testament to the transformational power of education.

The lobby of the new building will be named after the Liao family, who provided a significant gift in support of the IEB. In particular, the gift honors the legacy of late civil and environmental engineering alumnus Paul Liao, who credited much of his success to educational opportunities and the support of his family. After Paul's passing in 2018, his wife Mei-Yei and daughters Darlene and Dahlia, both UW graduates, stepped forward to honor him as well as the couple's son, Darwin, who passed in 2013.

In his early years in Taiwan, where he was raised on a farm, Paul walked an hour to attend school. The first in his family to receive a college degree, Paul worked as a civil engineer in Taiwan before attending the UW to earn his doctorate, which he completed in 1972. During his graduate studies, Paul worked at a local consulting company, gaining international recognition for his research on methods of water treatment for fisheries, which led to advancements in global seafood production.

This work led to a career at KCM, a Seattle-based engineering company that merged with Tetra-Tech in 1995. Paul served as chairman, CEO and CFO of the company, which became one of the largest engineering firms in the country, and was responsible for important projects in the Puget Sound area. His contributions helped to shape aquaculture and fisheries work in the Pacific Northwest and around the world.

Prior to the family's recent philanthropic gift, they established a Regental Fellowship in the UW Civil and Environmental Engineering Department, which supports exchange with the National Cheng Kung University in Taiwan.

The Liao family. Photo credit: Wing Luke Museum

MAJOR MILESTONES

A glance at major milestones that contributed to the success of the soon-to-open IEB.

2017–2019: The state initiates the project with $4.6 million in pre-design and design funding.

Spring 2020: The UW Board of Regents approves moving forward with the design phase of the IEB. Fundraising begins.

Summer 2020: A college-wide building planning committee is formed, to ensure that the interests of all engineering departments are represented.

Spring 2021: The state approves $45.4 million in the capital budget to fund construction. The UW selects a contractor, Hensel Phelps, as well as a project architect, KieranTimberlake.

Autumn 2021: To ensure inclusive design, architects and leaders incorporate student feedback.

Autumn 2022: The UW breaks ground on the new $102 million IEB.

Summer 2023: Construction is officially underway, and the concrete foundation is poured.

Summer 2024: The fundraising campaign comes to a close after reaching the goal of $46 million.

COLLEGE OF ENGINEERING
UNIVERSITY *of* WASHINGTON

371 Loew Hall, Box 352180
Seattle, Washington 98195-2180

Nancy Allbritton, M.D., Ph.D.
Frank & Julie Jungers Dean of Engineering

David Iyall
Associate Dean of Advancement

Heather Hoeksema
Executive Director, Strategy & External Relations

Chelsea Yates
Director of Content

Brooke Fisher
Assistant Director of Content

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Launching cultural connections in science and engineering

A lofty goal isn't the only thing that members of the UW Chapter of the American Indian Science and Engineering Society (AISES UW) have in common. In addition to launching rockets, they also have a shared cultural connection. Open to undergraduate and graduate students from indigenous cultures, the club's mission is to increase representation of tribal cultures within the STEM field while promoting traditional native values. For the fourth year in a row, the students competed in NASA's First Nations Launch this past spring. They won the Team Spirit award, Team Safety award and took third place in the Mars Challenge, which entails designing, developing and launching a rocket. Way to go, team!