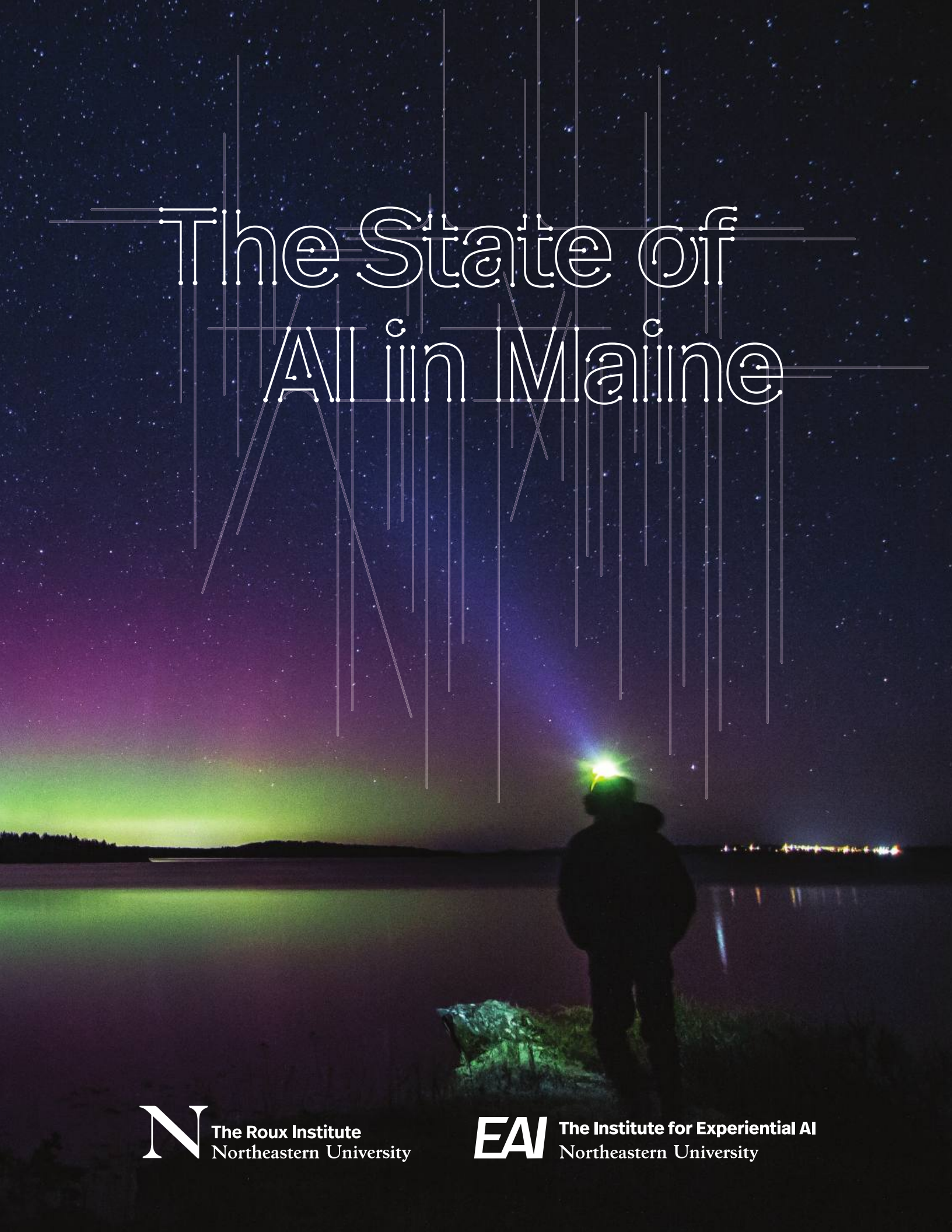

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50 Interviews
5 Industries

Aionetics
Bangor Savings Bank
Bigelow Laboratory
Bath Iron Works
Colby College
Diligent Robotics
Dynamic Grid
E2Tech
Educate Maine
FMI
Forager
FullscopeRMS
Gulf of Maine Research Institute
Hancock Lumber
HighByte
IDEXX
Innospark Ventures
The Institute for Experiential AI at Northeastern University
J.D. Irving, Limited
The Jackson Laboratory
Maine Department of Administrative and Financial Services
Maine EPSCoR
MaineHealth
Maine Technology Institute
MDI Biological Laboratory
MedRhythms
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Norway Savings Bank
Omnic Data
Prospector
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COVER PHOTO: ANDY GAGNE
The northern lights from Islesboro in Penobscot Bay

Methods and Reporting

Findings were drawn from 50 interviews conducted between July and December 2022. Interviewees were selected based on research by the reporting team and referrals from The State of AI in Maine Advisory Committee and many others. This report is a companion piece to The State of AI in Maine event, scheduled for Jan. 27, 2023. The report and event were created in parallel, with guidance from The State of Maine Advisory Committee and jointly funded by the Institute for Experiential AI and the Roux Institute at Northeastern University.

Creative/Editorial Director and Lead Writer
Anna Fiorentino

Manager
Olivia Saucier

Contributing Writers
Tyler Lynch
Olivia Saucier
Chandler Smith

Designer
Jessica Grant

Photographers
Andy Gagne
Nicole Wolf
Anna Fiorentino
Jaymee Minner

Contact
For questions or further inquiries please contact StateofAI@northeastern.edu.

FOREWORD

Usama Fayyad, executive director of the Institute for Experiential AI at Northeastern University

As with any transformative technology, artificial intelligence (AI) opens doors, but often without enough emphasis on the biggest challenges and frequently with a lot of hype to add to the confusion. Our job at the Institute of Experiential AI (EAI) at Northeastern University is to focus on the right opportunities and how to advance towards them practically and correctly. One of the big misunderstandings about today's pragmatic AI is its very heavy dependence on data–data that is needed to train machine learning (ML) and data science algorithms. Global networks of trade, commerce, and innovation increasingly depend on large data sets to model market-competitive solutions, yet biases and inaccuracies in those data sets create numerous risks in the form of biased or incomplete/false predictions and adverse societal impact. The more this dependence on data increases, the more challenging to resolve those (sometimes unintended) biases and inaccuracies.

With each wondrous application of AI we find this same dual nature: large language models smart enough to write academic papers may help companies classify documents or develop code, but they raise difficult questions about authorship, plagiarism, and factuality. And while headline-grabbing examples of text-based image generators like Dall-E or Lensa AI may be fascinating, many forget about the huge dependence of these methods on the availability of a lot of data, both structured and unstructured, that enable these algorithms.

An important part of the journey in AI is understanding how to prepare ourselves to make advances and which tools to leverage. AI represents a powerful evolution of computer technology that has profound economic and social consequences. In hospitals, laboratories, factories, and businesses around the world, AI is already being used to diagnose illnesses, model protein structures, automate assembly lines, and predict stock prices. With a global footprint, AI's reach extends to every industry and academic discipline. What remains to be seen is how the AI revolution will play out at the local level.

Our questions in this report are pragmatic: WHAT advances in AI matter to the state of Maine, and what differentiates the state in its rapidly evolving novel uses of the technology? The first step of this endeavor is to take stock, understand, and form a baseline for what the state of AI in Maine is.

Maine represents a fascinating example of how AI is helping to transform an old economy into a new one. With its budding tech market far from the commercial maturity of New York or California, the state stands to benefit from the best practices laid out by others while capitalizing on its own advantages. It's a vision that harmonizes well with Maine's own economic development plan, which focuses on promoting innovation over the next decade. This report details some of the challenges and opportunities that are sure to emerge along the way: the heritage industries countering AI's more destabilizing traits; the rural character searching for use cases beyond the tech markets; and the burgeoning innovation hubs pointing to a new era for Maine.

Some of the themes that emerged from the research for this report are indeed very encouraging. The ethos of many of the ongoing efforts and applications of AI in the state have a bias towards doing things the right way–a balance between what is "good" against what is economically compelling. This is consistent with Mainers and their concern for the environment, for nature, and for social justice. In the areas of responsible or trustworthy AI, these principles can form an advantage for Maine over other states where economics and efficiency take a higher precedence. Whether it is out of concern for sustainability and environmental responsibility, preservation of the woods or marine environment, caring for an aging population, or facing the challenges of sustaining rural communities, all these areas can form a basis for taking AI to new directions that other states–and possibly even countries–can follow.

I have been blessed and privileged to have had the first-hand experience of working with our partners in Maine. The team at Bangor Savings Bank has repeatedly reminded me they care about customer experience and well-being first and foremost. MaineHealth is focused on patient care as providers strive to use predictive AI models to prevent potentially bad clinical outcomes, and The Jackson Laboratory is investing in understanding cancer progression in humans–an area outside their core business–to build more effective mapping from mouse models to humans. Working with the actuarial team at Maine's Sun

Life affiliate, Northeastern's EAI and Roux Institute helped introduce AI innovation and experiential educational training to build the right talent for AI and data science–a big industry pain point globally. Providing these learning experiences to employees and students who enrolled in the custom AI course demonstrated that lifelong learning is a core tenant in employee retention and upskilling.

Lastly, on a personal note, the significant human contribution to the operation of an AI system is near and dear to our hearts. It is how we define Experiential AI at the Institute for Experiential AI at Northeastern University. We strongly believe this is the right way to approach AI advances and the way to advance the field meaningfully and effectively. The human-centric ethos of AI work in Maine is consistent with our EAI definition, always emphasizing the role of the human in the loop in a working AI system.

It is the hope of the Institute for Experiential AI and the Roux Institute at Northeastern University that this report starts a conversation about the role AI will play in shaping Maine's future. It is the culmination of many months of vigorous research involving dozens of companies, stakeholders, and thought leaders. But as much as we've endeavored to provide an overview of one state's AI ecosystem, a report like this can never be considered complete. More questions need to be asked as this exciting technology continues to evolve. We will continue in our effort to understand, track, and encourage the development and adoption of AI as a core component of Maine's future prosperity. But before anything else, we must understand where we are in this new landscape. We hope this report provides a good baseline for that and we look forward to helping Maine in its future AI journey.

Michael Pollastri, senior vice provost and academic lead at the Roux Institute at Northeastern University

The Roux Institute at Northeastern University was founded in 2020 with the goal of catalyzing the growth of the tech and life science economy in Maine and across northern New England. We do this through a combination of learning programs in computer science, data science, data analytics, bioinformatics, and biotechnology, and research programs focusing on computational medicine, data-intensive engineering, and human-data interaction, activities that support the entrepreneurial ecosystem in the state.

The report emphasizes the promise that AI can bring to the entire Maine economy and will be directive for us at the Roux as we come up with new approaches for workforce development and prioritize areas for innovative, data-driven research that align with the needs of the state's burgeoning tech economy.

While applications of AI have proliferated across the nation, given the centrality of healthcare, education, and natural resources to Mainers, it is perhaps not surprising that these fields are furthest along in applications of AI in the state. The pandemic has accelerated the development of an innovation economy in the state, and AI has been increasingly infused into Maine's woods and waters, businesses, hospitals, and institutions of higher education.

There is much to be done. It's essential that we ensure that AI applications are introduced to the state in a responsible and ethical manner, and in one that does not create or exacerbate socioeconomic challenges and disparities. This growth should be supported by a strong workforce of data and computer scientists, at all levels, particularly those who are equipped with skills within each sector and who also understand the value and nuances of trustworthy AI. And pipelines to opportunities to join this workforce must be created and reinforced to make them accessible to Mainers from across the state, and to attract new talent into the region.

Maine's higher education institutions–at the Davis Institute of AI at Colby College, here at the Roux Institute and the Institute for Experiential AI, in the University of Maine system, and others–must continue to join forces to drive this workforce growth and focus on opportunities in the Maine economy in a way that only Maine-based institutions can do.

We all have an opportunity to work together to bring technology to both new and legacy industries in Maine, so that we support, not supplant, the things that make Maine a special place. And the ways in which we do this here in Maine can be a signal to other areas of the nation–specifically those not currently identified as "high-tech regions"–that wish to deploy AI in their own specific contexts.

For all these reasons, this is an exciting time in Maine, and there is much to be done together for the benefit of all.

Height of Land in Rangeley
PHOTO: ANNA FIORENTINO

INTRODUCTION

Maine leaders had already been bracing for climate change, an aging workforce, and global economic headwinds, when the state experienced unprecedented growth during the pandemic. Rich natural resources and diversifying industry made The Pine Tree State one of the country's most desirable places to live, with the Census Bureau reporting the largest population increase–of nearly 10,000 people between April 2020 and July 2021–in two decades.

Forestry, fishing, logging, tourism, and hospitality have almost always driven Maine's economy, but whether a budding tech sector can keep pace with new demands remains to be seen. What's clear is that the state is changing. Experts are exploring how automation can augment an economy largely dependent on heritage industries, many of which still utilize old-fashioned methods. Exploiting advantages in a complex, evolving landscape will depend on the degree to which Mainers can react to dynamic changes in the economy, the climate, and the population–all of which may be better understood through data.

This report aims to establish an understanding of how artificial intelligence (AI) is being used throughout Maine's key economic pillars of healthcare and life sciences, manufacturing, natural resources, education, and financial and insurance services. Our findings from 50 interviews with academic, state, and business leaders show the innovation, challenges, and opportunities taking place in the fields of AI and data science in Maine.

A proliferation of big data–large, fast or complex information that is difficult or impossible to process using traditional methods–has enabled the development of AI capabilities over the last decade, particularly in the past two years. And in the most rural and the most forested state in the country, there is no shortage of data. Forward-thinking business leaders and scientists at Maine's Carnegie classified research institutions–the University of Maine in Orono and the Roux Institute at Northeastern University in Portland–and others are working quickly to find the most effective and ethical ways to harness unstructured data from advanced video, satellite, and healthcare imaging techniques to grow and protect the state.

AI is defined by Stanford University as "that activity devoted to making machines intelligent" with intelligence being "that quality that enables an entity to function appropriately and with foresight in its environment." The umbrella term encompasses subfields of machine learning (ML), which enables machines to learn from experience, natural language processing (NLP), and computer vision, where computers gain high-level understanding from digital images or videos. It employs the use of algorithms to make decisions, predict outcomes, and extract insights from vast sums of information where human capacity falls short. Maine's leaders adhere to varying definitions of AI, some equating it to any tool that mimics human capabilities and others insisting learning must be present in an AI algorithm. The goal of this report is to describe the AI taking place across the state of Maine.

Wolfe's Neck Woods State Park
PHOTO: ANNA FIORENTINO

While each sector tells a story about its use of AI, progress is often subject to cultural inertia and fears of job displacement. Automation existed in Maine long before AI. The state's early AI adoption, particularly in healthcare, education, and natural resources, volunteers a potential case study in how a rural tourist economy can compete on a global scale. With an unprecedented use of environmental AI now mapping forests and monitoring fishing boats, for example, there's an opportunity for others in remote areas of the country to learn from the state of AI in Maine.

The Changing Workforce

In 2019, Governor Janet Mills unveiled a 10-year Economic Development Strategy for Maine–the first in several decades to identify future opportunities and challenges. She set out to attract 75,000 workers to Maine by 2030 and to grow annual wages by 10 percent, however, at the time, without increased migration to the state, the labor force faced long-term decline. With the oldest median age in the country of 45, and the state's monetary value of products and services lower than the national average, Maine was at a crossroads. "Our economy can't stay the same; doing nothing will result in dramatic economic, wage, and job loss," concludes the authors of the Economic Development Strategy. Today, three years later, AI has the potential to drive economic growth by allowing companies to compete in an increasingly data-defined marketplace.

With COVID-19 came the rise of remote work, spurring investment in cloud-based platforms and conferencing tools, and drawing young professionals to Maine's quality of life.Boomerangs and newcomers are diversifying workforce demographics, even while many work remotely for out-of-state employers.

"When I was manager at WEX in the 1980s, we had employees who wanted to live in Maine and were willing to take a haircut on salary in order to get here. During this pandemic, the Maine salary differential has gone away because everybody can work from home," says Matthew Hoffner, entrepreneur-in-residence at Maine Technology Institute (MTI), a state organization in Brunswick that distributes legislative funds and invests in technology companies.

Today, Hoffner and others believe AI will disrupt the economy, allowing new industries to emerge and creating more technology jobs. The Maine Jobs and Recovery plan appropriates nearly $1 billion for career programs, community investments, and business development plans to prepare the state for a prosperous future. While the pandemic helped jumpstart AI in Maine, new challenges are arising. How, for example, do employers fill thousands of vacant computing positions, while only 60 percent of public high schools offer a foundational computer science course?

Maine businesses stand at different points along the AI journey. Some rely on internal or external data science teams to build complex ML models. Others are growing analytics capabilities to understand customer data. Many experiment with burgeoning access to off-the-shelf products that automate specific tasks. These companies are using what Preetha Sekharan, head of digital strategy at Unum, calls a "blended model" of off-the-shelf tools, vendors, and internal resources that may be integrated into an existing system. Even those with dedicated data teams are customizing these open-source algorithms based on their data. So while most every AI solution, even if it's off-the-shelf, is a unique application, these tools are becoming easier to access. Companies can benefit from

robust open-source AI, but they must also assess risk associated with using publicly available models, especially those trained on data from the web.

According to Maine's Economic Development Strategy, "AI will change the way we work." With the power to automate, business leaders are beginning to offload mundane tasks onto machines, freeing up employees to use their trained skills for tasks better suited to human control. "Human intervention creates great opportunities to gather valuable data to be used in machine learning to further train algorithms and refine them," says Usama Fayyad, executive director of the Institute for Experiential AI at Northeastern University.

Trained professionals across almost any functional discipline are strategizing about how to introduce ML models into their decision-making process. However, sources interviewed for this report were firm and nearly unanimous in their belief that humans will remain core to that process, whether it's to audit, review, or make decisions. Some industries, like banking and healthcare, place trust at the center of the provider-customer relationship, underscoring the importance of human oversight. "The machine could have put it all together [with] 99 percent confidence that this is the right action to take, but there needs to be a person looking at that and saying, 'I agree or I disagree,'" says David Messinger, director and associate actuary at FullscopeRMS in Portland.

The Road to Adoption

AI and automation are difficult to uncouple. The past few decades of job loss can be attributed in part to a collapse in the state's manufacturing sector from automation and advanced robotics. It's up to economists to decide whether to blame global trade realignments, but fears of automation, which lags behind other sectors in Maine, continue to prevail.

The state's factories are sensitive to interruptions and legacy industries still depend on manual labor. Many say they don't see the advantage of AI or may not understand that it requires a full digital transformation. To achieve adoption companies need to invest in better data management practices and update technology systems, which can be costly, especially when changes over time negatively impact a model's accuracy and performance, known as data drift. Successful AI requires critical inspections of cloud computing, data processing, and workflow integrations.

Another barrier to successful AI deployment is bad data. When a "black box" algorithm isn't transparent, humans can unknowingly create bias and ethical dilemmas with serious consequences. This is particularly problematic in the healthcare sector, where AI-assisted diagnostic tools can draw erroneous, potentially life-threatening conclusions if they're not trained on diverse populations or data sets. Successful applications must unveil their innerworkings and achieve buy-in from all stakeholders–patients, workers, and developers.

All this makes AI a difficult pill to swallow for some Mainers. It's inarguably a good thing that so many are sensitive to concerns around fairness, ethics, transparency, and legality. As Christine McCann, assistant vice president of Norway Savings Bank, explains, "We're very mindful about what we let in our house." But because AI stands to impact virtually everyone in the state, risk assessments should evaluate far more than return on investment.

By late 2022, at least 17 U.S. states had introduced general AI bills or resolutions, with Maine still navigating how to create

Tumbledown Mountain in Township 6 PHOTO: ANNA FIORENTINO

a task force to study and catalog the use of AI in state government. Around that time, the U.S. also announced a Blueprint for a Bill of AI Rights to help guide, develop, and deploy AI responsibly and ethically. Some experts have stressed the need to approach AI regulation on a global level, and while certain European countries have made regulatory headway, the country still has a long way to go—particularly rural areas. In Maine, according to the 2020 Census, 9 percent of households don't even own a computer and 15 percent go without access to broadband internet. But progress is being made. The Maine Connectivity Authority, established in 2021 with funds from the American Rescue Plan, has set out to address the disparity by bringing affordable high-speed broadband to all Maine homes, which will attract newcomers to remote areas and islands. "We will eventually be able to tap into worldwide technology," says Hoffner.

The state is already benefiting from a growing coalition of AI researchers and academics at the University of Maine AI Initiative and Colby College's Davis Institute for AI in Waterville. Public and private partnerships are critical for advancing new technology responsibly and equitably, and as sponsors of this report, Northeastern University's Roux Institute and Institute of Experiential AI hope to be a convening voice that connects practitioners, researchers, and educators working in AI.

Healthcare & Life Sciences

In Maine today, AI is running behind the scenes at our clinics. It's in wet labs and will be roving hospital halls to deliver medications. These predictive tools are recognizing images to detect cancer and finding links between genetics and addiction. They are alerting cardiologists about when to intervene to prevent a heart attack, and inspiring new brain therapeutics that sync music beats to a patient's stride. Maine's use of AI to improve healthcare and life sciences has significantly lagged behind urban centers like Boston and San Francisco, but today, with better access to data from a growing number of AI healthcare practitioners, that's beginning to change.

Rai Winslow

Dan Nigrin

When the pandemic hit, Maine leapt furthest ahead in its journey toward AI healthcare and life sciences. As one of the country's top places to live in 2021, the state benefited from the shared medical domain and data science expertise of world-class healthcare and technology leaders, including Rai Winslow, who founded and for 15 years directed the Institute for Computational Medicine at Johns Hopkins University. He'd been among the first to prove that machine learning (ML) is vital to the future of medicine. By 2020, he was being named director of life science and medical research at a new Portland-based innovation hub, Northeastern University's Roux Institute. "The algorithm will become a valued member of the healthcare team," says Winslow, now a core member of Northeastern University's Institute for Experiential AI and professor of bioengineering at the Roux.

A year later, Dan Nigrin, a pediatric endocrinologist who'd led technology at the world's top pediatric hospital, Boston Children's Hospital, and former assistant professor in pediatrics at Harvard Medical School, also moved to Maine to become chief information officer at MaineHealth. A biotech company delivering peripheral neuropathy drugs and therapies via AI, called Neuright, formed out of the University of Maine, joining a new proliferation of AI startups out of innovation accelerators, including the Founder Residency at the Roux Institute, one at MaineHealth, Dirigo Labs in Waterville, Maine Technology Institute (MTI), Maine Center for Entrepreneurs in Portland, and others. In Maine, the AI in healthcare landscape was growing, with IDEXX still paving the way after 13 years of AI in veterinary diagnostics (see IDEXX on page 18). A former vice president of Westbrook's IDEXX even became chief executive officer of a Portland-based digital health startup using AI to help us understand body movement, Kinotek.

But as the population increased and the pandemic rolled on, access to care also became more scarce. When Maine's healthcare system started to become overwhelmed, Paul Chausse, vice president of revenue cycle at MaineHealth, introduced a novel AI tool to streamline operations, free up staff for more important tasks, and reduce turnover at Portland's Maine Medical Center. He tailored a health data management AI software program, called Olive, to automate the system's cash posting processes. And, in the largest state in New England, an off-the-shelf AI cloud-based eye camera technology was introduced by MaineHealth physician Brian Nolan to specialists in hard-to-reach areas of the state so they could screen images on-site for vision threats within seconds to potentially prevent blindness.

When burnout hit clinical staff, Maine's top integrated healthcare systems piloted natural language processing (NLP) tools to passively listen to conversation between doctors and their patients and generate the necessary documentation after each visit, freeing up time for prevention, diagnosis, and treatment. "That level of documentation is something that doctors were introduced to by the electronic health record, and it is contributing to the burnout of these clinicians," says Nigrin, about MaineHealth's NLP program, called Nuance DAX. The voice-enabled solution transcribes a patient's conversation with their doctor and interprets and annotates concepts to generate documentation. "I wish I had this when I was still practicing," adds Nigrin. Similarly, Brewer-headquartered Northern Light Health's Chart Assist is enlisting AI to help providers improve documentation and capture missing diagnoses.

Today, Maine's premiere life sciences research institutes in Bar Harbor, The Jackson Laboratory (JAX) and Mount Desert Island Biological Laboratory

(MDI Biological Laboratory), are using AI to speed up drug discovery, and building data science teams that draw from Maine's growing number of graduate programs at UMaine and the Roux Institute. Experts are forming collaborations in AI spanning industry and higher education. But despite these early applications, the rapid adoption of AI in life sciences and healthcare in Maine, like everywhere, presents a unique set of ethical and regulatory challenges that may be hard to overcome when a patient's life is at stake.

Clearing Hurdles

The elephant in the room for healthcare startups introducing AI is the lack of a clear path to regulatory oversight, including approval by the Food and Drug Administration (FDA). That's because ML models aren't always transparent about how they draw conclusions from data sets, disguising bias and leading to ethical concerns, in what's referred to as a "black box." Approval is at a standstill, but in Maine that hasn't stopped experimentation with novel uses.

"We are setting the foundation to enable our algorithms to get better over time to drive insights into a patient's diagnosis and understand how we may best use music as treatment for their conditions," says MedRhythms co-founder and chief executive officer Brian Harris. Portland-based MedRhythms is pioneering next-generation neurotherapeutics designed to improve walking, mobility, and related functional outcomes through a patented technology platform. They combine sensors, software, and music with advanced neuroscience to target neural circuitry. "AI is a transformational technology that drives algorithms, treatments, and diagnostics to improve over time," says Harris.

Most regulatory frameworks for medical technologies used to treat, manage, or diagnose disease are designed to measure safety and efficacy. The question is, how do you know that a changing algorithm won't introduce new questions about that safety or efficacy after approval? To address this, the FDA initially considered a Pre-Certification Pilot to streamline approval by allowing

reviewed changes to software-based devices after they're greenlighted. Ultimately, though, the agency acknowledged the program's shortcomings. "The rapidly evolving technologies in the modern medical device landscape could benefit from a new regulatory paradigm, which would require legislative change," states a recent FDA report.

The FDA has, however, authorized a growing number of devices, including software, with ML across different fields of medicine on a case-by-case basis. "It is an ever-changing environment, but we are really optimistic that progress will continue to be made to help patients," says Harris.

The default position is that AI should merely support decisions made by a caregiver and patient, keeping the human in the loop. "In a healthcare setting, many of these AI tools could have life-threatening implications. Ensuring fairness and transparency is critical," says Nigrin. Even patients need to understand how AI is helping them and their providers. "We need to enable patients to understand the strengths and weaknesses of the predictions we make," adds Winslow.

Progress at many healthcare startups has been stifled by a lack of regulatory guidelines to eliminate biases, which can be introduced by those building the algorithms. Despite a standstill in FDA approval from a lack of transparency for many AI tools, researchers find themselves against the current. As they see more automated techniques, some have provided incremental improvements, but ML as a whole on its own, in its basic form, may not always be interpretable.

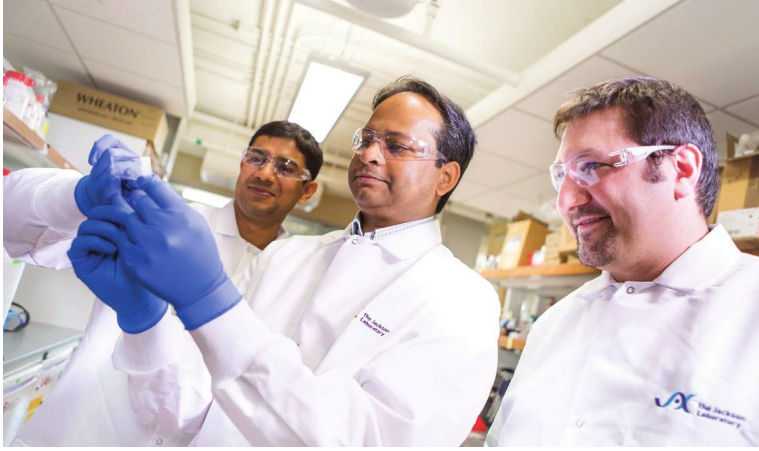
Health startup Kinotek has managed to avoid some regulatory hurdles by using AI as a measuring tool rather than for therapy, with new motion capture technology and data visualization tools assisting medical and fitness professions. The company is using AI to extract trends in photos taken to understand limb movement. Kinotek founder and chief strategy officer, Justin Hafner, who spun the digital health platform out of his UMaine kinesiology research, was part of the inaugural Roux Institute Founder Residency and raised $2 million last year. Other researchers at IDEXX, JAX, and MDI Biological Laboratory have avoided regulatory setbacks since they are using AI in applications with animals rather than humans.

Big Health Data

Patient data is accumulating from wearables, imaging techniques, medical records, and bedside monitors, becoming easier to access and shedding light on the underpinnings of disease. In Maine, the ability to monitor health activity with real-time sensors is opening up doors for AI to advance basic science more rapidly.

At JAX, a video camera aimed at mice in a preclinical lab continuously collects endless hours of footage. This research led by associate professor Vivek Kumar uses a neural network–a type of ML algorithm loosely modeled after biological neurons–to automate footage to help make connections between genetics and the subtle movement of mice. By looking at how these animals groom themselves, walk and pose, or sleep, and their size, scientists can start to draw conclusions about how inherited mutations may cause addiction, Alzheimer's, cancer, and other diseases. These techniques open new avenues in behavioral research.

With so many videos and photos, medicine is considered one of the best cases for AI, particularly in radiology where large labeled data sets and models can be cross checked against outcomes. In fact, there are more AI tools for radiology than for any other specialty. Inside UMaine's Computational Modeling,



Vivek Kumar and the JAX team

Analysis of Imagery and Numerical Experiments (CompuMAINE) lab, founder and UMaine professor of biomedical engineering Andre Khalil and his Ph.D. student Kendra Batchelder are testing a method of analyzing dense tissue in mammogram images to estimate breast cancer risk. Their patented AI technology identifies regions in dense breast tissue that are unorganized and therefore more likely to host a tumor, but appear identical to normal tissue on a scan to humans.

"We take a mammogram and we cut it up into thousands of overlapping sub images, which are each run through the algorithm to categorize based on their structural organization," says Khalil. Through technology transfer at UMaine, Khalil and Batchelder are among the first to infer that cancer isn't only uncontrolled, chaotic, and disorganized on a cellular level, like we've long known, but also in the images of tissue seen on a mammogram. Their work is ultimately helping to predict a patient's risk for developing breast cancer.

Across medical and life science disciplines in Maine, data scientists are benefiting from working directly with healthcare providers to build or find an optimal AI model for sorting and labeling data and the best data set to avoid biases and faulty decision making. In some cases, these optimal models rely on the largest and the most diverse data set available. Universal biobanks, data libraries, and genome-wide association studies are growing by the day to include different patient populations, tumor subtypes, comorbidities, age groups, and ethnicities.

But according to Winslow, in other cases, scientific research requires a more focused data set to teach a specific model that isn't as generalizable to multiple populations, be it background, ethnicity, tumor phenotype, and even geography. The problem is that data is rarely captured locally.

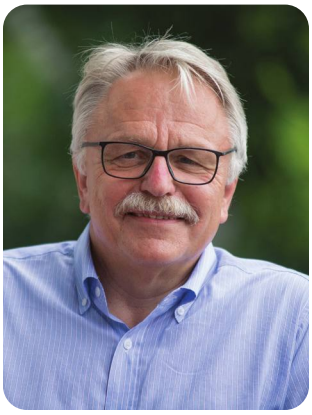
"One of the big opportunities and challenges in medicine is to begin capturing physiological data routinely and saving it for every patient. It will tell you about the state of that patient," says Winslow. "What could be more actionable than that kind of data?"

The benefits of local data collection in healthcare AI are playing out inside the intensive care unit (ICU) of Maine's largest hospital. Data is continuously streamed to a HIPAA-protected data warehouse–the first AI data storage ever permitted by MaineHealth–to learn on ML intervals over time to ultimately prevent heart attack, for example (see HE(ART) on page 16).

"I think there's greater value in learning about specific populations and then pulling out the predictive algorithm that has been learned for a person with those demographics and those characteristics and those comorbidities," says Winslow.

Another local database in Maine by Northern Light Health is analyzing a patient's individual and community risk scores for disease, based on details like demographics, background, and healthcare records. Among other applications, Northern Light Health is now using AI and ML to link health outcomes to the way that Mainers live, learn, work, and play. This Social Determinants of Health Screening and Data improvement process, in partnership with Pfizer and a Boston-area nonprofit called the Institute for Healthcare Improvement, addresses long-standing poverty and homelessness in Maine, which was only exacerbated by the pandemic.

Making observations at Mount Desert Island Biological Laboratory



Hermann Haller

"For the individual, the AI provides the calculated risk score, based on the top five features that feed into that score for a person and the specific clinical guidance recommendations that a care manager can take action on," says April Giard, senior vice president and chief digital and innovation officer of Northern Light Health. They're looking at everything from food and housing instability to transportation, social functioning, and interpersonal safety barriers in an effort to distribute food and refer patients to community services.

Thinking Outside the Lab

AI is changing the way research institutions are accelerating basic science toward drug discovery. While it traditionally takes at least 10 years and many phases to evaluate efficacy and safety from a lab bench to the bedside of patients, experts agree AI is already beginning to revolutionize and significantly speed up that process. Maine laboratories and clinics are no exception to the rule.

At JAX, for example, big data AI analysis is forming a circular research feedback loop that may allow scientists to arrive at clinical trials faster–just as safely and effectively. A researcher can continuously adapt their experiments, based on how the user responds to AI input, retraining and improving models over time, according to Vivek Kumar, associate professor at JAX.

"Drug development for psychiatric conditions remains challenging with many pharmaceutical companies stepping out of this space. There are many reasons for the lack of innovation, including the need for better preclinical animal models," says Kumar, who uses computer vision (computers gaining high-level understanding from digital images or videos) and ML to develop the next generation of preclinical assays in the laboratory mouse for new neurotherapeutics.

Meanwhile, Hermann Haller, president and professor of MDI Biological Laboratory, has teamed up with Samuel Beck, associate professor of the Boston University School of Medicine Dermatology/Center for Aging Research and Skincare, to make preclinical discoveries in an attempt to reverse aging. Using a supercomputer, he compared animal models with humans to link degeneration with specific areas of the genome, similarly discovering that AI can create a more direct–and cheaper–route to early breakthroughs.

"When you age your genes become more unstable and you produce proteins that are altered and inflammatory," says Haller. "We needed supercomputers to analyze that. Without AI, it's too complex; there's just too many data points."

MDI Biological Laboratory is also using AI to test thousands of novel compounds in zebrafish and other animals and in organoids derived from stem cells to develop new disease models and diagnostic tools for personalized medicine. This combination of experimental science and advanced data analysis and modeling, which is generating big data, is opening doors for scientists at MDI Biological Laboratory to discover new therapeutic strategies for patients.

"AI is a huge opportunity for Maine because we are generating data from excellent research institutions. To translate this data you need AI, especially in a state like Maine where people are not centrally located," says Haller. "It will allow us to form new coalitions that are far stronger than ever before."

On behalf of MTI, a state organization that distributes legislative funds to and invests in technology companies, entrepreneur-in-residence Matthew Hoffner has seen the feedback loop as advisor to life sciences company RockStep Solutions. The Portland-based tech startup is developing in vivo research management software that uses AI to clean, organize, and label data collected in labs so it can be analyzed faster, allowing scientists to be more productive.

"With the data being analyzed faster, licensing and the permitting through the FDA can be accelerated. What used to be a seven to 10 year window to try and get a drug approved can be significantly reduced," says Hoffner, who sits on the board of seven technology companies for MTI. Of them, Kinotek, which uses a predictive neuromuscular analysis system, is the only other company using AI, but, he says, many are strategizing about how to implement predictive tools.

Hoffner has sat front and center to Maine's technology evolution, after serving beginning in the 1980s for 15 years as one of the original managers of Portland-based WEX, now a global leader in financial technology solutions. He later founded and became president and chief executive officer of the online jobs board, JobsInME.com, before the URL was sold and used by all 50 states. Hoffner expects AI to catapult life sciences research, along with other Maine industries, in the next few years. He says Maine's businesses, 90 percent of which have under 10 employees, are already starting to benefit from growing access to inexpensive off-the-shelf AI through third parties like Amazon Web Services and Microsoft Azure.

"As easy as Amazon made it for you to put your entire cloud application on the server, the company is now making it just as easy to take advantage of all the AI tools they've developed," says Hoffner. "Small businesses in Maine can now buy a chatbot or an ML tool for pennies without needing AI configuration architecture."

MaineHealth's HE(ART) is another effective example of how research is being accelerated–this time in the clinic. The Roux Institute partnership, led by Winslow, thoracic surgeon Robert Kramer, and physician-scientist Douglas Sawyer, chief of cardiovascular services, aims to extend lives in Maine Medical Center's Cardiothoracic ICU. As part of Northeastern University's new Impact Engine model, they're utilizing a chosen application to solve a global problem out in the field, rather than in the lab, paving the way for HE(ART) to lead the greater scientific community to discoveries about growing real-time AI in ICUs across the globe.

Today, by leveraging the right data sets, keeping the provider in the loop, and clearing necessary regulatory hurdles, Maine's computational medicine experts believe AI will lead to breakthroughs. The right data science and domain expertise can deliver the right models to transform the way that patients receive care. Predictive tools are already paving the way for doctors to take a more personalized approach to treatment, assessing risk, and preventing genetic disease. And in Maine, AI in medicine will be listed as a priority growth area in the first-ever AI section of the Maine Innovation Economy Action Plan, due out in mid-2023.

"AI is widely used in the medical domain to monitor patients, develop pharmaceutical products, perform remote robotic surgeries, and perform other tasks," according to a draft of the report.

CASE STUDY 01

HE(ART) at MaineHealth

Beeps and waveforms from bedside monitors in Maine Medical Center's Cardiothoracic Intensive Care Unit (CTICU) capture the moments between life and death. These machines unlock critical information about a condition, yet, in virtually every hospital in the country, the data is gone forever when it leaves the screen. Until now. Last October, national leader in computational medicine and native Mainer Rai Winslow teamed up with MaineHealth to begin collecting and storing data, measuring everything from continuous blood pressure to the heart's electrical signals. The new MaineHealth initiative, in partnership with the Roux Institute, aims to deliver invaluable insight into extending life and improving care for heart surgery patients in Maine. All you need is the right algorithm.

"Our goal is to understand how to use these data to make forward predictions in general, not just in the cardiothoracic ICU, but to take and develop an approach that we can apply to many different kinds of problems in critical care units," says Winslow, director of life science and medicine research at the Roux Institute and a core faculty member at the Institute for Experiential AI, both at Northeastern University.

The AI pilot project called the Healthcare Enabled by AI in Real Time Impact Engine, or HE(ART), runs algorithms on patients rotating in and out of 12 CTICU beds at Maine's largest hospital, now one of only a few hospitals in the world implementing an early alert system to save lives. As Winslow, founder and former director of the seminal Institute for Computational Medicine at Johns Hopkins University, likes to say, the algorithm will become a valued member of the healthcare team.

This novel machine learning (ML) tool will train on a combination of ICU monitor real-time physiological waveform and mobile wearable data, vital signs, and a patient's electronic health records to help warn the medical team that they need to intervene to prevent a heart attack, for example.

"A patient can go from a very low risk to a very high risk in what is essentially the blink of an eye when the natural control mechanisms that help the body cope are pushed to their absolute limit, but we still don't understand biologically how that happens in detail," says Winslow, who was doing similar groundbreaking work to predict a patient's decline at Johns Hopkins. "What that says is you really need computers and machines to be watching these risk scores. It's not something that busy caregivers are going to notice."

The supervised learning algorithm will map out constantly changing variables from the monitors that generate output to recognize data patterns indicating whether a patient will have a life-threatening cardiac event and how much time they have before the event takes place. Maybe most importantly, he says, the technology also tests the reliability of its predictions using up-to-date labeled training data.

Suddenly, the cardiologist is allotted warning time to treat the patient before it's too late. This is particularly important given that approximately 20 percent of cardiac surgical patients develop complications, and of those patients, 20 percent don't survive, according to research.

"Our goal in HE(ART) is to reduce the rate of these complications and of patient mortality in the ICU," says Winslow.

The heart health data is continuously streaming from each Maine Med CTICU patient to a HIPAA-protected data warehouse–the first AI-supporting data storage ever permitted by MaineHealth–that continues to learn on intervals over time.

"This project, like other AI taking place at MaineHealth, is about asking, 'how can we use technology to assist providers to make sure that their patients are getting the very best care possible?'" says Dan Nigrin, a pediatric endocrinologist and chief information officer at MaineHealth, who led technology at Boston Children's Hospital and was assistant professor in pediatrics at Harvard Medical School before moving to Maine a year ago. Both Nigrin and Winslow emphasize the importance of leaving medical decisions up to the provider, not the machine.

HE(ART) doubles as one of the first five projects in Northeastern University's new Impact Engine program, aimed at working directly with an application to solve a global problem out in the field, rather than starting from scratch in a lab like most university research. Results will help the greater scientific community make discoveries to grow real-time AI in ICUs across the world.

PHOTO COURTESY OF MAINEHEALTH

PHOTO: JAYMEE MINNER

CASE STUDY 02

IDEXX Diagnostics

Jeff Dixon of Westbrook-based IDEXX Laboratories believes that pets deserve the best access to healthcare, just like their owners. But dogs and cats can't tell their owners when they're feeling sick. Veterinarians need top-notch diagnostics, and according to Dixon, senior vice president and chief software engineering officer, AI-powered diagnostics provide the best method for detecting disease in animals.

Applied, highly tuned algorithms in tools and services supplied by IDEXX alert veterinarians in minutes whether an animal is facing kidney disease. Rather than waiting to interpret samples in-house or at the lab, the state-of-the-art urinalysis software screens photos of samples for conditions that often go unnoticed. This is important given that one in ten seemingly healthy dogs are actually experiencing clinical problems, according to Dixon. It's made IDEXX an AI leader nationally and in Maine, which is becoming a hub for animal health.

Their SediVue DX program, used globally by veterinary clinics, looks for abnormalities like bacteria and crystals in urine samples, leaving the vet to make the call on treatment. The diagnostic equipment in the clinics of IDEXX's many veterinary partners connects a live data stream that continues to inform the algorithm.

"We have tens of millions of sample images that we can train models on and provide accurate data sets for," says Dixon. "Our AI software collects and labels them, giving the vet the data he or she needs to make a decision about an animal's welfare." Another tool by IDEXX uses automation to help vets stage and diagnose chronic kidney disease eight times faster than the standard of care by incorporating results and other pet health data.

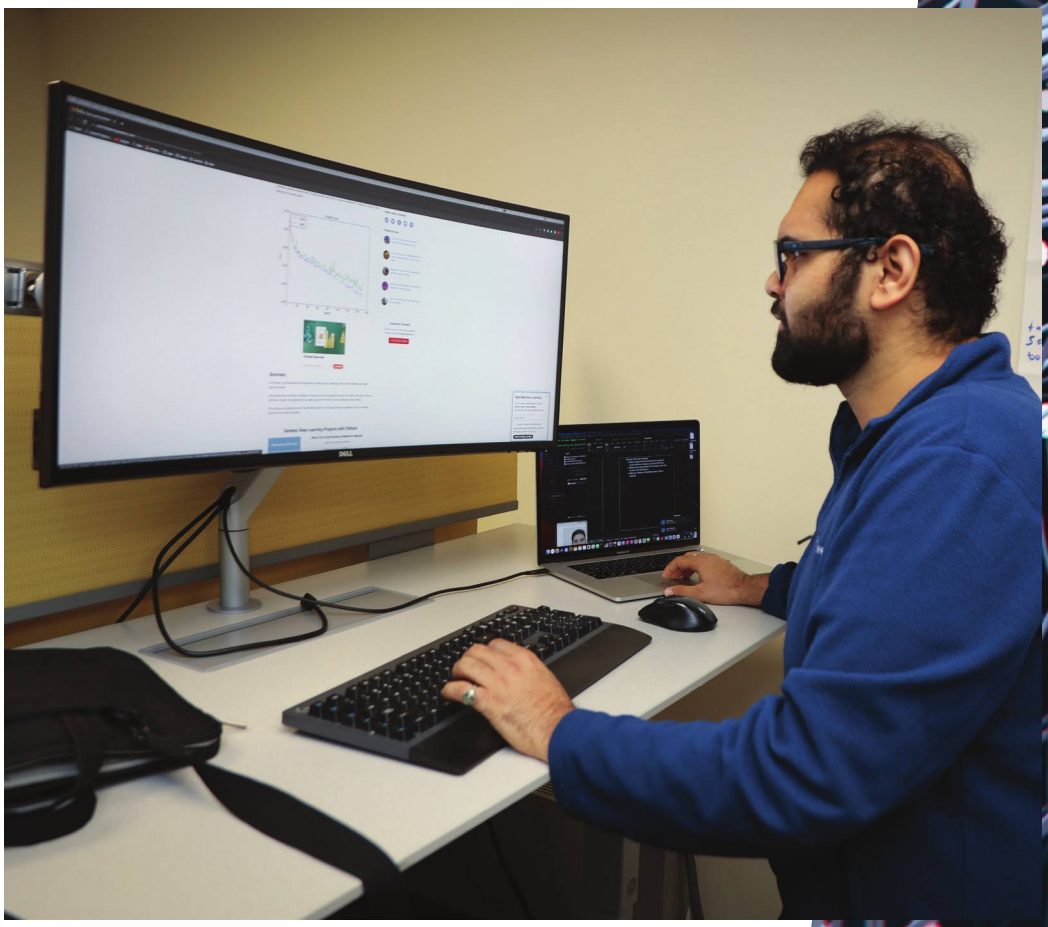
While playing a critical role in-house to diagnose and prevent disease in animals, the AI also helps bridge the gap created by a national shortage of veterinarians. The company had the foresight to take the diagnostics route to AI in the first place 13 years ago when machine learning (ML) technologies were developing faster in the imaging space. Thanks to disease-focused big data, the pet sector is now leveraging actionable insights from next-generation imaging technologies, like an open-source AI/ML library by Google

called TensorFlow that trains deep neural networks, and another IDEXX AI software program that detects parasites.

So why have AI technologies advanced faster in animals than humans? Because pet healthcare is not limited by the same governance structures that stifle innovation in human healthcare. While patient data is already vital to healthcare, AI advances for humans are often stalled by federal privacy laws, like the Health Insurance Portability and Accountability Act, and still a lack of clear AI regulations by the Food and Drug Administration, for example.

The unstructured nature of veterinary practice data also paves the way for accurate diagnosis and effective treatment, giving our pets longer, fuller lives. And with veterinarians adding approximately seven million live images to its cloud each week, IDEXX's growing team of 25 data scientists has plenty of visual data sets to work with.

"The key to success is the right curated data set," says Dixon. "We had the foresight to collect and curate data and that gave us the raw materials to become a leader in this space."



Amit Priyansh Pare on the job at IDEXX PHOTO: JAYMEE MINNER

TECH SPOTLIGHT:

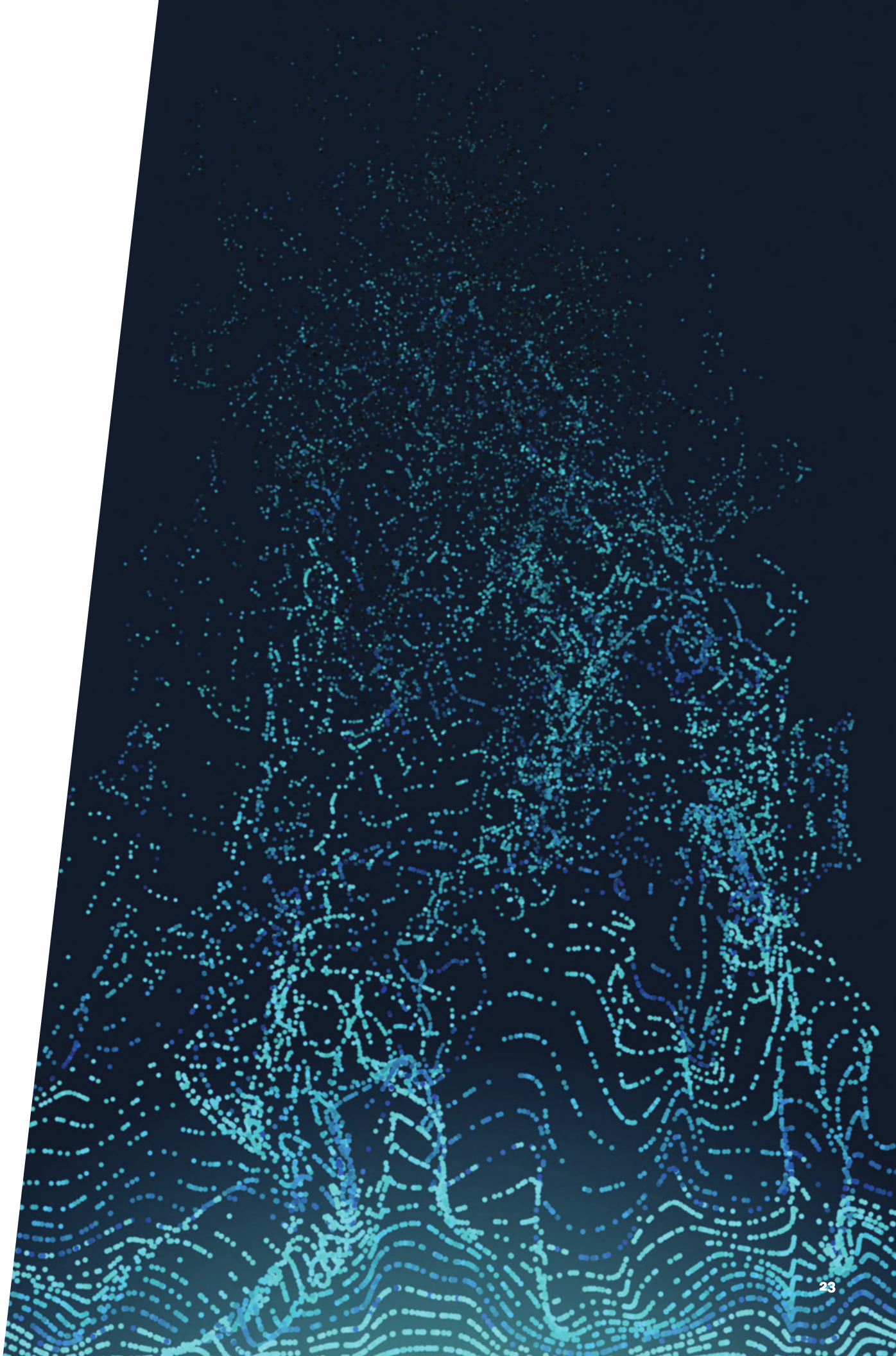
Moxi

In the halls of one Maine hospital, a robot named Moxi will soon be delivering medications and supplies, freeing up nurses to spend more time with patients. As Maine's healthcare system grapples with a nursing shortage, Moxi will be using AI to support the state's frontline workers.

This socially intelligent cobot, or collaborative robot, will be roving Brunswick's Mid Coast Hospital, continuously learning new tasks from its environment and interactions with hospital staff. The patented AI technology by Texas-based Diligent Robotics relies on auditory input, motion sensors, haptic feedback, and image recognition to navigate dynamic environments, always keeping the provider in the loop.

"Nurses spend up to 30 percent of their time gathering supplies. That's a lot of time away from patients," says Andrea Tomaz, who invented Moxi and runs Diligent Robotics with Chief Technology Officer Vivian Chu. "We envision a future where robots work in harmony with humans to improve care for all, supporting our valued nurses and hospital staff."

If, for example, the robot is assigned a new task, like grasping a gauze pad, it will request directions from a hospital personnel before recording key information about the object like weight, color, and sound. Mid Coast Hospital is one of a handful of locations where Moxi has been implemented. Others include Cedars Sinai in California and Mary Washington Hospital in Virginia.



Natural Resources

Maine earned its nickname "The Pine Tree State" when it was established in 1820 and remains the most forested state in the country, driving the timber industry and drawing millions of tourists each year to camp and hike. Visitors arrive in droves to watch fishing boats glide along Maine's rocky coastline–the fourth longest in the country, according to the National Oceanic and Atmospheric Administration. More recently, as work went remote, many made Vacationland their home. Now, an unprecedented use of predictive tools in Maine–from a growing number of data scientists and institutes–presents an opportunity for others in rural America to learn from the state of AI in Maine.

As Maine's heritage industries face unrivaled challenges, from climate change to the energy crisis, leaders are turning to innovative solutions. In the most rural state in the country, they are searching for ways to apply these powerful tools in the pulp woods, potato fields, low bush blueberry barrens, and lobster boats.

In early 2022, nearly $1 billion for the Maine Jobs and Recovery Plan included federal funds to fortify and grow Maine's economy in the wake of the pandemic. The plan addresses the long-term threats from a shift in competitiveness from "supply and demand, supply chain disruptions, and new technologies that impact the growing, processing, and use of natural resources" according to Maine Technology Institute (MTI). From these funds, MTI allocated millions to help create new technologies, new markets, and innovative solutions for Maine's seafood industry and forests.

"Maine has all of the needed natural ingredients to grow and prosper over the next ten years and beyond. In a world that is seeking renewable resources to replace petroleum-based products, Maine has an abundance of forests and the technology to convert them into environmentally responsible alternatives," reads Maine's 10 year Economic Strategy.

For the first time ever, an AI section is also now being drafted into the Maine Innovation Economy Action Plan, set for release in mid 2023. The document aligns AI in Maine with global priorities, including environmental protection–pollution prediction systems and wildlife monitoring techniques–and precision agriculture, including drone-based crop monitoring methodologies. The preliminary report doesn't fail to recognize that "developing algorithms to solve complex problems is not always an easy task" and "must address ethical issues and bias."

Waters

With the Gulf of Maine warming faster than 99 percent of the world's oceans, Maine's federal waters are more regulated than ever. The use of data and algorithms is shaping how ocean research impacts people. Predictions are being made about native marine species migrating north and invasive fish that are arriving. Given the sheer volume of data required to study the ocean, experts call AI the natural next step to monitor and protect Maine's cherished marine habitats and ensure stable livelihoods for fishermen. With this in mind, the state recently delegated $1.2 million to help strengthen Maine's lobster industry with data imaging and communications tools.

In Portland, at the Gulf of Maine Research Institute (GMRI), research associate Miguel Barajas is improving the accuracy of groundfish stock estimations, year over year. In a recent study, Barajas adapted an advanced machine learning (ML) technique, called boosted regression trees, that eliminates irrelevant variables and compensates for missing data to make better predictions about the number of fish living on the ocean floor.

"In the last couple years, there has been a lot of new off-the-shelf software packages that are using ML approaches, and so now someone like me who comes from a statistical background can try out these novel techniques," says Barajas. "It allowed us flexibility to work with a bunch of variables in a way that we couldn't using a traditional type of model."

His algorithm, adapted from off-the-shelf software, has potential to help the government correct miscalculated stock assessments that impact fishery management decisions and now put Maine at risk of overfishing, ultimately creating long-term harm to marine environments.

Also on Portland's waterfront, New England Marine Monitoring is exploring the use of AI tools like image recognition and data visualization to accurately expedite analysis of hours of video footage monitoring fishing vessels in federal waters–rather than relying on human observers (see New England Marine Monitoring on page 30).

As water warms, the Gulf of Maine is also facing increased threats of "red tide" or algae blooms–recent outbreaks forced shellfish farmers to temporarily cease operations. In response, Nick Record,

senior research scientist at Bigelow Laboratory for Ocean Sciences in East Boothbay, has created a new deep learning AI tool that trains over time to alert aquaculture farmers about potential toxic blooms. He says Maine's shellfish industry plays an important role in cleaning the water and regrowing wild fish populations, with the booming aquaculture industry lending itself well to AI methods.

Record's model, which collects data about ocean dynamics like temperature and salinity to make predictions with 80 to 90 percent accuracy, has been adopted by sea farmers, including Bangs Island Mussels. "It's much better than the tools that have been in place. Forecast users are able to use ML to help guide their decision making," says Record, who helped launch Bigelow's AI-focused Tandy Center for Ocean Forecasting in the summer of 2021.

His prediction methods, which he worked on with Izzi Grasso while she was a student at Southern Maine Community College and Bigelow Labs forecasting researcher Johnathan Evanilla, have also been adopted by Maine's Department of Marine Resources. Until now they could only make rough predictions from water samples about spikes in toxic algae blooms. His team is also using ML algorithms to improve models of right whale distributions so that decisions by the National Oceanic and Atmospheric Administration can more accurately reflect how whales are moving and responding to their changing environment.

PHOTO: MAURA NIEMISTO OF BIGELOW LABORATORY

Calanus finmarchicus, a food source for right whales in the Gulf of Maine and vulnerable to climate change

Record has avoided AI pitfalls such as bias and lack of transparency by working early on in AI development directly with the fishing community and staying ahead of changing regulations in the U.S. and other countries (where his work is also being implemented). "One of the

Crescent Beach State Park in Cape Elizabeth
PHOTO: ANNA FIORENTINO

challenges with AI is that the algorithms that you produce can sometimes be really well intentioned, but have unintended consequences," says Record. "Just like resume sorting or predictive policing, these data justice issues could apply in predicting the environment or the ocean."

A Portland-based environmentally focused company called Running Tide is using AI–advanced computer vision algorithms and deep neural networks–to revive marine environments by restoring kelp and algae, which are similarly essential to healthy marine habitats. "The idea is to restore ecosystems by planting these shellfish in places where populations have been depleted due to pollution and rising water temperatures," explains Franklin Heng, computer vision engineer at Running Tide. He's running algorithms on images of kelp and algae to retrieve essential genetic information that can guide selection toward optimal crops.

To understand the impact of warming temperatures on our oceans, Maine researchers are also looking up to the skies. Bird population and migration patterns can be a strong indicator of marine ecosystem health. At UMaine's Maine Software Agents/AI Laboratory (MaineSAIL), off-the-shelf ML approaches to computer vision are enabling researchers Roy Turner and Cynthia Loftin to automate the process of counting seabirds on Maine's offshore islands from government plane and local drone imagery. Using ML can drastically speed up the process, which is currently done manually and can take up to 28 hours for each of Maine's 3000-plus islands.

"If you notice the bird species are not doing well that's probably because something is going on in the environment. So people use bird populations as a proxy for marine coastal health," says Turner. "We hope to get better images and we think this methodology will be a good tool for identifying most of the birds and where there might be problematic areas."

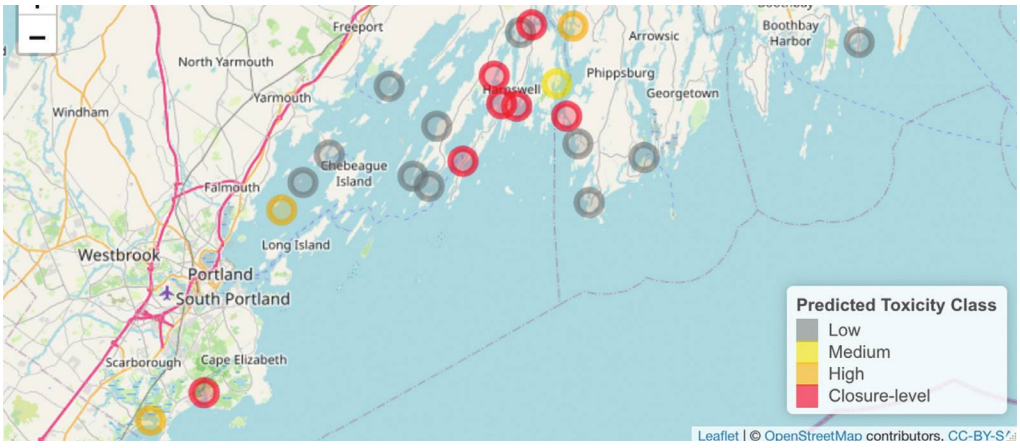
Woods

Essential to Maine's economy and paramount to its future, Maine's forest and lumber industry illustrates the transformative power of environmental applications in AI. The state's sprawling woodlands hold the power to help address climate change and preserve and conserve Maine's 33,000 wildlife and 1,500 plant species.

Robust AI is running in UMaine's Wireless Sensor Networks (WiSe-Net), a laboratory designing a solar-powered field-based sensor network. The system utilizes ML to optimize energy efficiency, monitor soil moisture, and selectively communicate

3D-generated model from buoy algae
COURTESY OF RUNNING TIDE

AI is helping prevent another infestation of spruce budworm.



Shellfish toxicity forecasting mapping by Bigelow Laboratory and the Maine Department of Environmental Protection

data from hard-to-reach areas of the forests. “Before this technology, you had to buy a bulky sensor for several hundred thousand dollars and send people out regularly to get the data and change the battery,” says Ali Abedi, associate vice president for research and director of the Center for Undergraduate Research. “This credit card-sized sensor can last a long time with no maintenance.”

WiSe-Net’s efficient sensors collect and measure soil moisture–the primary driver of tree growth–and run on an algorithm that susses out whether that data set is reliable. They gauge the device’s battery life and wireless network connection, and account for the upcoming weather forecast, before remotely transmitting only the data that is reliable. While these sensors are currently designed to measure soil moisture, Abedi, who has plans to expand this work, says the technology holds the potential to measure other vital factors of climate research, like snow depth and temperature.

In Maine’s woods, an infestation of a toxic invasive species called browntail moth caterpillar was a timely subject for the inaugural Davis AI Datathon, run by Colby College’s new Davis Institute for Artificial Intelligence. Student teams worked with the municipality of Waterville to manipulate data using an AI data platform called Dataiku in an attempt to prevent infestation. Meanwhile, AI simultaneously helped prevent an outbreak of a moth larva, called budworm, through satellite tree species mapping at UMaine (see Forest Mapping on page 32).

Another professor at UMaine, Mohamad Musavi, director of the Stormwater Management Research Teams and associate dean of the College of Engineering at UMaine, was one of the first in Maine to bring AI methods to the timber industry in the 1980s–optimizing workflow and quality assurance in Maine’s paper mills. Musavi’s novel ML technique predicts the quality of the paper based on the raw timber materials entering a machine, allowing operators to improve quality and cut cost. “Previously, testing paper quality was a slow, limited process that could result in extensive delays and unnecessary costs,” says Musavi.

Today, AI continues to transform the way the lumber industry is run throughout the U.S. and Canada. Forest products manufacturer J.D. Irving, which owns more than a million acres of Maine’s timberland and

Allagash Wilderness Waterway PHOTO: ANNA FIORENTINO

operates two sawmills in the state, has incorporated advanced computer vision algorithms into the manufacturing line. "In Ashland, our mill was built in 2014 with the latest technology," says Josh Philbrook, sawmill manager in Ashland. "Since then, we've continued to modernize and update our systems to be able to identify species through the use of AI." The new technology identifies tree species in real time, without making contact with the tree or using any consumables, making the sawmills more efficient (see Forest Mapping on page 32).

"The adoption of AI technology to identify lumber species is one of the most exciting improvements I've seen since I've been with J.D. Irving," says Ashley Ballanger, an engineer and continuous improvement specialist. "We have another upgrade planned that will use AI to improve detection of defects in our lumber. It's an exciting time to be part of this industry."

Hancock Lumber, owner of timberland, sawmills, lumber yards, and manufacturing facilities in Casco, has similarly discovered other advanced AI software tools to improve processes.

The state's unique and quickly changing natural landscape is under a global microscope, as natural resources industries rise to the challenge of finding advanced ways to monitor fish, address the state's lack of petroleum energy production, and preserve our forests. It is a collective workforce that's evolving, adapting to these new technologies with a growing willingness to embrace change, and setting the stage for Maine to become a global leader in environmental AI for years to come.

Energy

Over the past two decades, Maine has seen a 50 percent drop in power production. Burdened by a heavily dispersed population and no petroleum, natural gas, or coal production, Maine's energy industry is primed for disruption. In 1996, the supply was cut by 30 percent after the state's only nuclear power plant closed. Now, with a shift toward renewable resources, leaders are finding new ways to optimize energy production, with 79 percent of in-state electricity net generation now in wind, water, forest, and solar energy. While the energy industry is in its initial phase of implementation, Maine companies believe dynamic ML solutions have an enormous potential to improve the way Maine distributes and consumes energy. Several efforts are already underway to utilize AI and maximize these environmentally responsible energy alternatives.

Introspective Systems/Dynamic Grid, an ML software company based out of Portland, uses patented system architectures and ML algorithms embedded

in custom hardware devices to coordinate the distribution of electricity on the power grid. With real-time, continuous learning algorithms on the distribution grid edge, the software coordinates the use of power by heat pumps, air-conditioners, energy storage, or other controllable electrical loads. “Equipment like heat pumps and air conditioners use ML algorithms to make decisions about when it is the most cost-effective to use or provide power, resulting in a more energy efficient, cost-effective utility and consumer systems,” says founder and chief executive officer Kay Aikin. Additionally, while the product is further refined and deployed at scale, Dynamic Grid is planning to roll out roughly $50 million in plant manufacturing energy storage and hardware in southern Maine that will employ nearly 200 workers.

A lack of energy storage is causing limitations to widespread adoption of renewable energy sources across the U.S. While Tesla and SunPower are working to increase storage capacity, in-state solar energy company ReVision Energy is using AI to optimize storage systems. The company is implementing algorithms at Hyatt Place Hotel in the heart of Portland’s Old Port to predict usage trends so a human in the loop can decide when to distribute energy.

“The amount of energy used by the hotel differs depending on the hour, day, or season. The system gets smarter over time to distribute based on usage,” says Fortunat Mueller, president and co-founder of ReVision Energy in South Portland. “That is one place where I think AI actually adds value in the near term.”

And there are others in Maine’s energy industry who acknowledge the potential of ML too. “We are well aware that the value of machine learning could be enormous,” says Lance Ahearn, founder of Alonetics, an energy management platform headquartered in Lincolnville. “Just think about every device in every home. Eventually they’ll be connected.”

ReVision Energy uses AI to optimize energy storage at the Hyatt Place Hotel in Portland. PHOTO: REVISION ENERGY

CASE STUDY 03
New England Marine Monitoring

The last time you purchased haddock from the grocery store you may have walked away with a filet of pollock. That's because studies have shown that at least 20 percent of fish species sold today are tagged incorrectly. But a Portland-based company called New England Marine Monitoring (NEMM) is looking to end the mislabeling via AI.

Filet Finder, patented by NEMM founder Mark Hager, uses AI to automatically identify fish based on their unique tissue structure. Hager and his team are developing a smartphone app that, through image recognition software, analyzes tens of thousands of photos to zero in on the species we buy from behind the fish counter. While this potential game-changer is still in the early stages, NEMM is working on a federal Small Business Innovation Research grant with research and development partners like Portland's Bristol Seafoods and Wegmans Food Markets to collect images of fish.

Filet Finder is just one of many AI applications that NEMM, a leader in the emerging marine field of electronic monitoring (EM), is angling to implement across New England. Also at the heart of the company's boundless AI potential is a new method of using video footage to monitor fishing vessels in federal waters. Naturally, EM is gaining ground to replace the human observers traditionally used to monitor fishing vessels on board. As a pioneer in the burgeoning method of digitally monitoring the location, movement, and behavior of fishermen, NEMM employees spend countless hours watching video footage to collect the data needed to manage the fishery off the Gulf of Maine, which runs from the southern provinces of Canada down to Cape Cod. It didn't take long to prove that augmenting with AI tools like image recognition and data visualization can save major time and money–and are just as accurate as a human.

It's really no surprise that Maine is a leader in both EM and marine AI, considering the Gulf of Maine, which is warming faster than 99 percent of the world's oceans, according to the Gulf of Maine Research Institute, is one of the most regulated bodies of water in the world.

"There's a huge data lag issue with all of the stock assessments and that's really dangerous when you have a region under extreme pressure, like the Gulf of Maine," says Anthony Lucia, NEMM operations manager and former fish observer for the federal government. "That's where I think the timeliness of getting this data, using EM and AI, can help us adapt to climate change."

Since NEMM rolled out EM in 2019, AI and machine learning (ML) pilot projects have tracked everything from water temperature to catch size to ensure compliance. But like so many industries today, a lack of federal standards and regulations has created a roadblock to fully implementing AI in EM beyond research.

For one of those pilot projects, called Kept Catch, NEMM partnered with the Roux Institute at Northeastern University to automatically collect data from video about the catch that fishermen bring back to the dock. Roux Institute graduate students and faculty are helping strengthen that data by manipulating outputs generated by the algorithms.

"Having a human count hundreds of baskets of fish going into a fish hold or thousands of fish going into a cutting machine is just not efficient. But by training an algorithm to do the same task we may be able to create a detailed picture of what a vessel catches," says Lucia.

Another NEMM program now in operation, called The New England Groundfish Audit, replaces federal monitoring with EM and experiments with AI to identify species of discards so they're consistent with federal standards.

"You could have a lot of valuable data that can take eons to count for a person, but if you can train an AI to count pixels and bucket size you can start to figure out trends and growth that we would never otherwise know," says Lucia "Those are the doors that AI can open."

So whether identifying a fish species in the grocery store or keeping tabs on fishermen, there's real potential for AI-assisted EM to save time and help review large data sets. They even saw a 20-to-54 percent reduction in video review time with just as accurate results, on a previous project with the National Fish and Wildlife Foundation.

"We compared AI assisted versus human review and have seen a time reduction without any significant loss in data quality," says Lucia.

As an early adopter of EM and marine AI, Hager has set up shop on a Commercial Street wharf in Portland. NEMM, a spin out from the Gulf of Maine Research Institute and graduate of the Roux Institute Founder Residency, was bought last year by Vesper Company and continues to partner with Northeastern University data science co-ops.

Nandita Gurwara, a Roux co-op at Portland-based startup New England Marine Monitoring

PHOTO: NICOLE WOLF

UMaine's Ali Abedi shows students his AI-based forest monitors PHOTO COURTESY OF UMAINE

CASE STUDY 04

Forest Mapping

In the 1970s, Maine's extensive natural forests fell victim to the largest infestation ever recorded of one particular native insect species, wiping out between 20 and 25 million cords of spruce. The most forested state in the country experienced massive environmental devastation. It took two decades and hundreds of millions of dollars to fully recover.

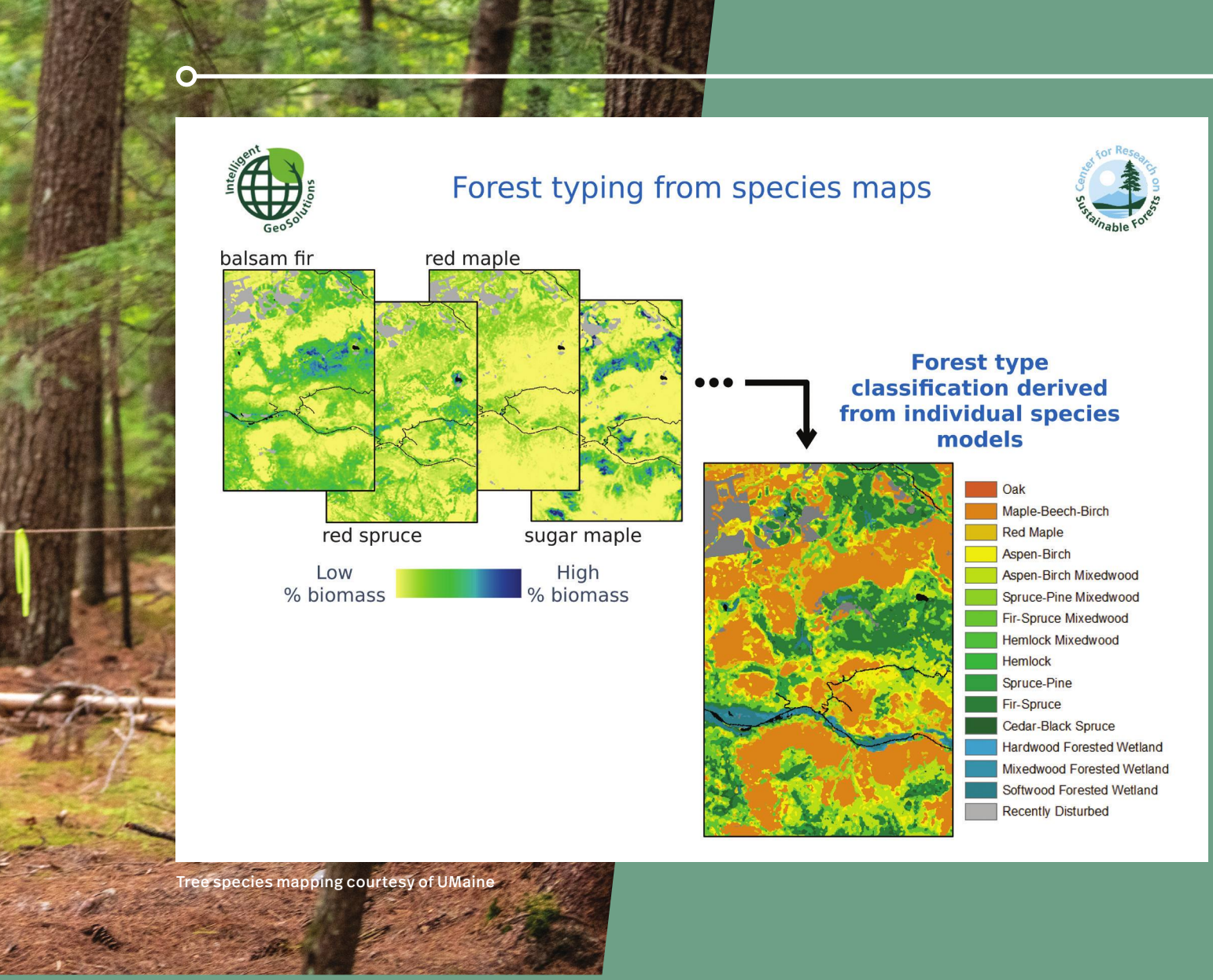
Today, what many may not know is that moth larva, called budworm, has returned, but this time Maine scientists are ready. Through their novel AI geospatial prediction method, University of Maine researchers began working with the state to identify vulnerable areas of spruce and balsam fir trees across millions of acres to try to prevent another serious outbreak.

"If you know where your spruce is, you can prepare, and if you do detect unhealthy trees, you can target the potential beginning of the spruce budworm outbreak with a native insecticide," says University of Maine professor and Irving Chair of Forest Ecosystem Management Aaron Weiskittel, who also directs the Center for Research on Sustainable Forests.

After budworm larvae recently began eroding eastern Canadian forests, the state acted quickly to protect Maine's forest products industry, which represents 4 percent of the state's gross domestic product. Weiskittel and his team got to work on what became the most precise, accurate, and scalable multi-objective AI/machine learning (ML) technique for forest mapping yet. Meanwhile, to date, over 20 million acres in Canada's eastern forests have been devastated by budworm.

"There's been small areas that have shown the presence of budworm, but our map allows people to identify and closely monitor the most vulnerable areas so that if defoliation shows up we know that we need to treat that area," he says.

The algorithm, known as a multi-objective support vector regression, relies on image recognition and



Tree species mapping courtesy of UMaine

classification to automatically label, clean, and seamlessly integrate satellite images of trees throughout the 89 percent of the state that is forested. To make clear predictions about the shape, location, and changes of species under diverse conditions like snow, high canopy cover, and clouds, the team harmonized algorithmic techniques to eliminate uncertainty and reduce bias, processing time, and manual reliance.

The breakthrough mapping technique developed by UMaine researcher Kasey Legaard is now being utilized to create the National Oceanic and Atmospheric Administration's first-ever high-resolution map of Maine forests and has led to the creation of an increasingly popular online decision-support app called the Maine Forest Ecosystem Status and Trends. It's also being used by a major landowner and leader in forestry products, J.D. Irving, to inform forest management decisions and optimize processing and recovery inside their Ashland sawmill.

"In the future we will further improve our results by continuing to modernize and update our systems using the latest AI technology," says Josh Philbrook, mill manager at J.D. Irving. The model may even be able to provide important continuous real-time data about Maine's millions of remote forested acres that are privately managed and difficult to access.

"We have a very high mix of species in Maine. Some have higher financial value; some have higher conservation value, so just having this information on a large scale will allow more informed and better management decisions across landowners," says Weiskittel.

While most of the data is now collected about every five years, he hopes to eventually begin using real-time sensors developed by Ali Abedi, UMaine associate vice president for research and director of the Center for Undergraduate Research, to obtain instant access to tree species and other remote sensing data.

Education

Working hard at the Roux Institute at Northeastern University

For more than a century, Mainers worked hard canning goods at historic brick factories along the coast. The state's sizable Franco-American population and others relied on labor-intensive industrialized jobs in fishing, logging, shipbuilding, and farming. Today, the transformation of one remaining original factory building, B&M Baked Beans in Portland, marks a new era in Maine. Academia is the cornerstone.

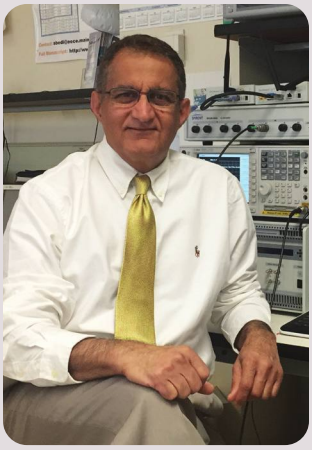
The 40,000-square-foot former cannery, which last fall was designated a historic landmark, will become part of a more expansive 13-acre technology hub for the Roux Institute at Northeastern University. The Roux first opened in a nearby temporary space on Portland's waterfront in 2020 with philanthropic support from tech entrepreneur David Roux and his wife Barbara, and, subsequently, the Harold Alfond Foundation. The institute set out to train data scientists and students pursuing tech-forward roles to carry the state into a future where AI is assisting humans in growth and productivity. "We're going to make a massive investment in advanced education and research activities, focused at the most technically advanced edge of the technology sphere–which is AI and machine learning," Roux, who grew up in Lewiston, announced the day the institute was announced in 2020.

By 2021, Colby College in Waterville had opened the first interdisciplinary institute for AI at a liberal arts college, the Davis Institute for Artificial Intelligence, and global AI leader Amanda Stent moved to Maine to become inaugural director. "After working in industry I was convinced that while we need a lot more AI engineers and Ph.D. students, what we really need, even more than that, is AI product managers, designers, user experience experts, sales people, and journalists," says Stent. "We need people who are informed users of AI who know how to decide when and how to use it and the risks and the potential rewards."

As the world turned to big data for answers, Bowdoin College in Brunswick was selected in 2022 by Google and the National Humanities Center to develop academic courses that tackle the ethical issues raised by AI technologies. In Lewiston, Bates College is hard at work supporting research in neuroscience, cognitive science, and AI to create a publicly accessible video database on its largest grant ever. Together, these schools and others are beginning to change the way the state conducts business, addressing the high demand for data scientists.

"Outside of Maine, nobody talks about the tech industry in Maine," says Stent, noting that the state's well-established influential tech companies are increasingly using AI, ML, and NLP. "There should be more attention on the growing AI industry in Maine."

Northeastern University President Joseph Aoun (left) walks in Portland's Old Port with Barbara and David Roux (right).



Mohamad Musavi

A Brief History

Back in the bean factory's heyday, in the 1980s, many had never even heard of artificial intelligence. One of the first introductions to AI in Maine was taking place inside the classroom of Mohamad Musavi. "I created and taught a robotics course and developed a robotics lab with financial support from Maine industry," says Musavi, associate dean at UMaine's College of Engineering and director of the Stormwater Management Research Team. His graduate student's widely publicized robot became the first in the nation to play chess against a human–an autonomous machine built from a high-precision 3D robot, an image processing system, and AI-based chess-playing software.

Musavi began using AI to solve Maine's industrial and scientific problems at the South Portland branch of Fairchild (now ON) Semiconductor, founded, along with Intel Corporation, by the late Robert Noyce, inventor of the integrated circuit. (Noyce's ex wife, the late Betty Noyce, became one of Maine's biggest investors ever, giving millions of philanthropic funds back to manufacturing towns, dairy farms, and many other areas to help boost the economy in the 1990s. Her Libra Foundation is still driving economic growth today.)

As for Musavi, today, his research has landed in over 90 journal articles and conference publications and in applications used to classify human and mouse chromosomes, predict product quality in the pulp and paper industry at the former S.D. Warren and other mills, in NASA satellite imagery, and to extract watershed areas from digital terrain elevation data. "There was no need to use feature extraction to reduce the number of elements for image classifications and rule-based processes anymore," says Musavi. "Adaptive machine learning techniques could now do it for you."

UMaine

Over the past ten years, UMaine has committed to meeting the educational and research needs of the community through AI and deep learning. AI technologies by faculty and students have led to groundbreaking discoveries and collaborations with the state, J.D. Irving–the largest landowner in Maine–and many others (see Transportation on page 45).

Automation research is now taking place in more than a dozen labs. Since 1995, in the Maine Software Agents and Artificial Intelligence Laboratory (MaineSAIL), Roy Turner has been exploring applications including intelligent control of autonomous underwater vehicles for the Office of Naval Research, while Ali Abedi, associate vice president for research and director of the Center for Undergraduate Research, is employing cyber physical systems to address climate change with a wireless sensor network in WiSe-Net Lab (see Forest Mapping on page 32). On the learning and teaching side, Penny Rheingans, professor of computer science and director of the School of Computing and Information Science, is increasing retention and success of computing students on a National Science Foundation grant through 2028.

Students and faculty have patented more than 200 inventions in areas of materials science, composites, and advanced manufacturing. The Advanced Structures and Composites Center is home to the world's largest 3D printer, which generated the largest 3D-printed boat for the Department of Defense, and more recently, a bio-based 3D-printed house that could address Maine's lack of affordable housing, which hit a high during the pandemic (see Factory of the Future on page 58). Labs are crossing disciplines, forming collaborations, and carrying AI into the real world (see NASA's James Webb Telescope on page 42).

"UMaine has a long history of innovating in diverse areas of AI. We have led research initiatives to advance the theoretical understanding of AI and machine learning while also developing innovative technologies utilizing AI," reads a draft of the first-ever AI section of the Maine Innovation Economy Action Plan, set for release in mid 2023.

K-12

Jason Judd, executive director of Educate Maine in Portland, says Maine educators and policy makers are working diligently to provide additional funding to bring AI into K-12 schools. One of those initiatives, announced in late 2021, was spearheaded by the Emergency Education Relief Fund by Governor Janet Mills to provide every Maine public school with a free mobile computer science lab to offer real-word training in robotics, programming, augmented and virtual reality, coding, and hardware.

"We're trying to get K-12 students to understand what computer science is, what the pathways are, and how it connects to sectors where you don't have to major in computer science, but you can actually major in another content area with a strong technology foundation," says Judd, on behalf of the nonprofit focused on increasing educational attainment and enabling all students to succeed in postsecondary education and in the workplace.

The goal is that in the near future, every middle and high school student in Maine, regardless of geography and background, will have access to an AI foundation through a core curriculum computer science course. But the reality is that the percentage of students taking computer science falls at around 60 percent, with a sharp increase over the last few years. (Nationally, over the last decade, the number of high schools offering computer science courses has jumped from 35 to 50 percent, but inequities remain between rural and urban schools.) There's still a long way to go, particularly in rural parts of the state.

"Maine schools are learning how to teach the foundational aspects of computer science, which then allows both students and educators to be much more exploratory," says Judd, adding that schools are encouraging students to enter career paths in software, hardware, and other areas feeding directly into the subfields of AI.

Female high school students across the state are more and more interested in data science and STEM fields, but equity is also still an issue in Maine. "Many affluent students opt into computer science courses, while our underserved and female students don't," says Judd. "To achieve gender parity, many are advocating to make computer science courses a graduation requirement."

Educate Maine, along with a variety of other nonprofits and colleges, is also working to train educators without data science knowledge on how to develop lesson plans, so they can help meet the needs of Maine's growing innovation economy.

"There is great work happening in different parts of the state, and much of that is led by industry with nearby employers saying, 'Hey, we've got lots of jobs. If you can demonstrate skills that relate to machine learning, AI, etc, we'll hire you,'" explains Judd. "Employers are sending that message to schools, locally."

Colby College
PHOTO: JAYMEE MINNER

Colby College

To Colby College's new Davis Center for AI, director Amanda Stent brought life-long achievements in natural language processing, including more than 30 patents. She is also aware of Maine's needs for government bodies to ensure that AI is responsible and trustworthy, as a member of the National Academies Committee aimed at setting guidelines for Responsible Computing Research. "There is a need for more regulation of AI. I have written to our senators about it," says Stent. "I would love to see Maine take a lead in having external groups that really think about the application of AI in heathcare and education."

Across Colby, an undergraduate college, Stent says there is a growing student interest in AI classes, with about 15 percent enrollment in related classes. "I don't believe that AI should be done independently," says Stent. "AI involves deep collaborations with subject matter and domain experts to define the problem and to define the techniques that will be used to solve the problem and to define the solutions."

PHOTO: JAYMEE MINNER

Amanda Stent

Colby's growing list of AI classes range from computational chemistry to economic forecasting to a popular course about AI and God. The school is also hosting an international artist in residence, Oscar Santillán, who will teach students about the AI he uses in and as the subject of his own art.

Across the state, Stent can see that Mainers are sitting on years of untapped environmental data that researchers are just beginning to analyze to make predictions. "The state is experiencing unprecedented climate changes that can be predicted through new AI techniques," she says. Among many partnerships at Colby, students and faculty are working with global ocean health institute Bigelow Labs and with the municipality of Waterville to prevent toxic browntail moth caterpillar outbreak. Colby is also home to some of the earliest research on the James Webb Telescope (see NASA's James Webb Telescope on page 42), which is using AI to explore the connection between galaxy structure and the growth of supermassive black holes with support from students at Colby College and UMaine. And it's thanks to the Davis family and trustee of its charitable foundation Andrew Davis, Colby graduate and AI visionary, that the institute is now setting a precedent for how undergraduate students can shape Maine's future through AI.

Catherine Mitchell, senior research scientist at Bigelow Laboratory, teaches advanced coding, data processing, and AI.
COURTESY OF BIGELOW LABS

The new campus for the Roux Institute at Northeastern University will sit in and around the former B&M Baked Beans factory in Portland.

RENDERING COURTESY OF TSOI KOBUS DESIGN AND STIMSON LANDSCAPE ARCHITECTS

The Roux Institute and the Institute for Experiential AI at Northeastern University

At the center of Maine's many new AI-focused initiatives is the Roux Institute, which opened in a temporary space on Portland's waterfront in 2020. In a few years, the Roux will move into its permanent Boston campus inside the former B&M Baked Beans factory and a new state-of-the-art building surrounded by waterfront parks, furthering human-centered digital innovation that equitably benefits the state. The Roux Institute was founded in the first place to stimulate the regional economy by growing talent and cutting-edge technology capabilities in Maine and northern New England, eliminating the boundaries between industry and academia.

With an international presence, the Institute for Experiential AI (EAI), directed by global data leader Usama Fayyad, will continue to share a space with its partner institute, the Roux, while also residing in Boston at Northeastern University's main campus. Ensuring fairness and responsible AI, EAI scientists offer algorithmic audit services and employ an ethics review board for businesses in Maine and across the globe. In this emerging area, EAI develops relevant and targeted training curricula for students and learners.

"Human and machine intelligence can find solutions to real-world problems that are better than solutions devised by people or machines on their own," says

Fayyad. "Machines should be processing large amounts of data and performing repetitive and mundane tasks. It's up to humans to do the reasoning and understanding, and to adapt to uncertainty and unusual situations."

As the state enters this new era of big data, the Roux is filling Maine's gap in graduate education and research capabilities, not just in AI, but in computer and data sciences, digital engineering, and advanced life sciences and medicine (see HE(ART) on page 16).

The school conducts interdisciplinary STEM research to solve challenges that affect Portland, the state, and communities globally. Partnerships with Maine's undergraduate schools allow more students to stay in state to pursue advanced data science degrees, and students are arriving in Maine from all over the country and the world to pursue degrees, extending the innovation corridor from Boston to the northeastern tip of the country.

"In order for AI to be leveraged throughout Maine organizations, both existing and new employees need to bring more data literacy to the conversation," says Dan Koloski, professor of the practice and head of learning programs at the Roux.

Beyond building and deploying algorithms and a data pipeline, he says executives need to understand the questions they want to ask, how data can provide answers, and the analytical outputs that impact their decisions. Leaning on Northeastern's long-standing model of experiential learning, Roux students and co-ops are out in the field conducting research, equipping companies with data science skills, and launching innovative startup companies. Already, student data science teams have helped Maine schools predict the success of post high school students. They've helped the Governor's Office of Policy Innovation and the Future make home heating fuel policy recommendations.

The Roux's Venture Creation and Acceleration Program, which includes a Founder Residency, supports entrepreneurial ventures. And adding to Maine's growing roster of startup accelerator programs at MaineHealth, Dirigo Labs, Maine Technology Institute, and Maine Center for Entrepreneurs, they are funneling new AI startups into Maine from all over the world (see Omnic on page 44).

"The Roux Institute Venture Creation and Acceleration programs are key drivers of the growth of AI-powered startups in Maine," says Chris Wolfel, head of entrepreneurship and venture creation. "To date, we have engaged 35 companies, many of which are using AI to solve pressing problems, while creating jobs in Maine and attracting investment capital from around the world."

By fundamentally changing how people interact with data to address difficult societal challenges in Maine, leaders hope the Roux will become a model for other urban centers to compete in the global innovation economy. "Maine is not alone. Ability and ambition is very broadly distributed across our state and across the country, but opportunity is not," Roux has said in the past. "Opportunity today is very highly concentrated in only a few large urban areas. What do those super cities have in common? Every single one of them has at least one great research university. They have a cluster of highly innovative corporations and they have a bustling high-wage job market."

CASE STUDY 05
NASA's James Webb Telescope

The James Webb Space Telescope (JWST) is the biggest and most powerful space telescope ever made–and it's just getting started. In July 2022, NASA unveiled the first operational image from JWST: a tiny sliver of night sky covering thousands of super-distant galaxies. That first deep field shot by Hubble Space Telescope's $10 billion successor illuminated light from galaxies as far as 13 billion light years away, giving stargazers a glimpse into the universe when it was just a few hundred million years old. It's the highest-resolution image of the early universe ever taken.

Orbiting nearly a million miles from Earth, JWST is jam-packed with cutting-edge spectrographs, long exposure cameras, and sensors to observe the universe with astonishing fidelity. The telescope acts like a giant bucket, gathering the faintest light across the universe at extraordinarily high resolutions. That astronomical data is gold to the Cosmic Evolution Early Release Science Survey (CEERS), one of the first 13 research teams selected by NASA to view JWST images.

Some of JWST's earliest findings began with a NASA proposal by Dale Kocevski, founding member of the CEERS team, and his wife Elizabeth McGrath, both associate undergraduate professors in the Physics and Astronomy Department at Colby College in Waterville.

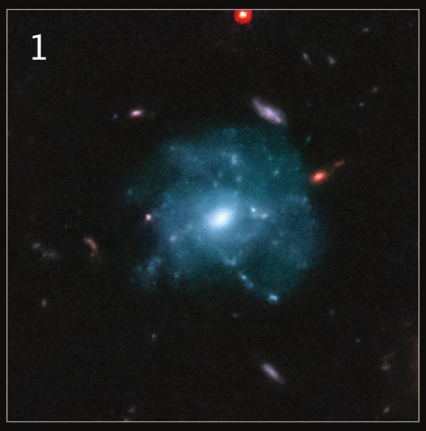
PHOTO: JAYMEE MINNER

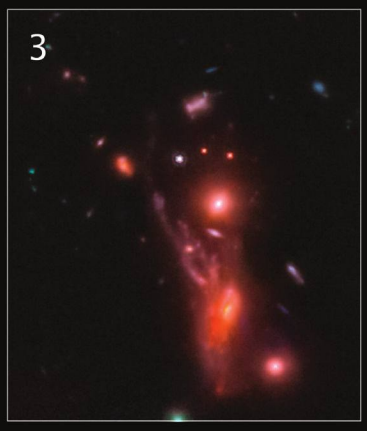
Dale Kocevski

"We made this argument that we could effectively use the telescope in survey mode," says Kocevski.

While other investigators proposed point and shoot telescopes, used up until now to image a single shot kept on record for over a century, CEERS set out to capture many large detailed images of the night sky. The astronomers' mosaic approach now also allows NASA to test its instruments for accuracy and function.

Kocevski and his team have already used JWST to make discoveries that weren't possible with Hubble, like identifying a candidate for the most distant galaxy ever discovered, which existed roughly 350 million years after the Big Bang. "When you get a lot of good data it usually





PHOTOS FROM JAMES WEBB SPACE TELESCOPE COURTESY OF DALE KOCEVSKI

leads to more data because there's follow-up observations," says Kocevski, whose collaboration just earned more NASA funding to verify if the 350 million-year-old galaxy is indeed the most distant.

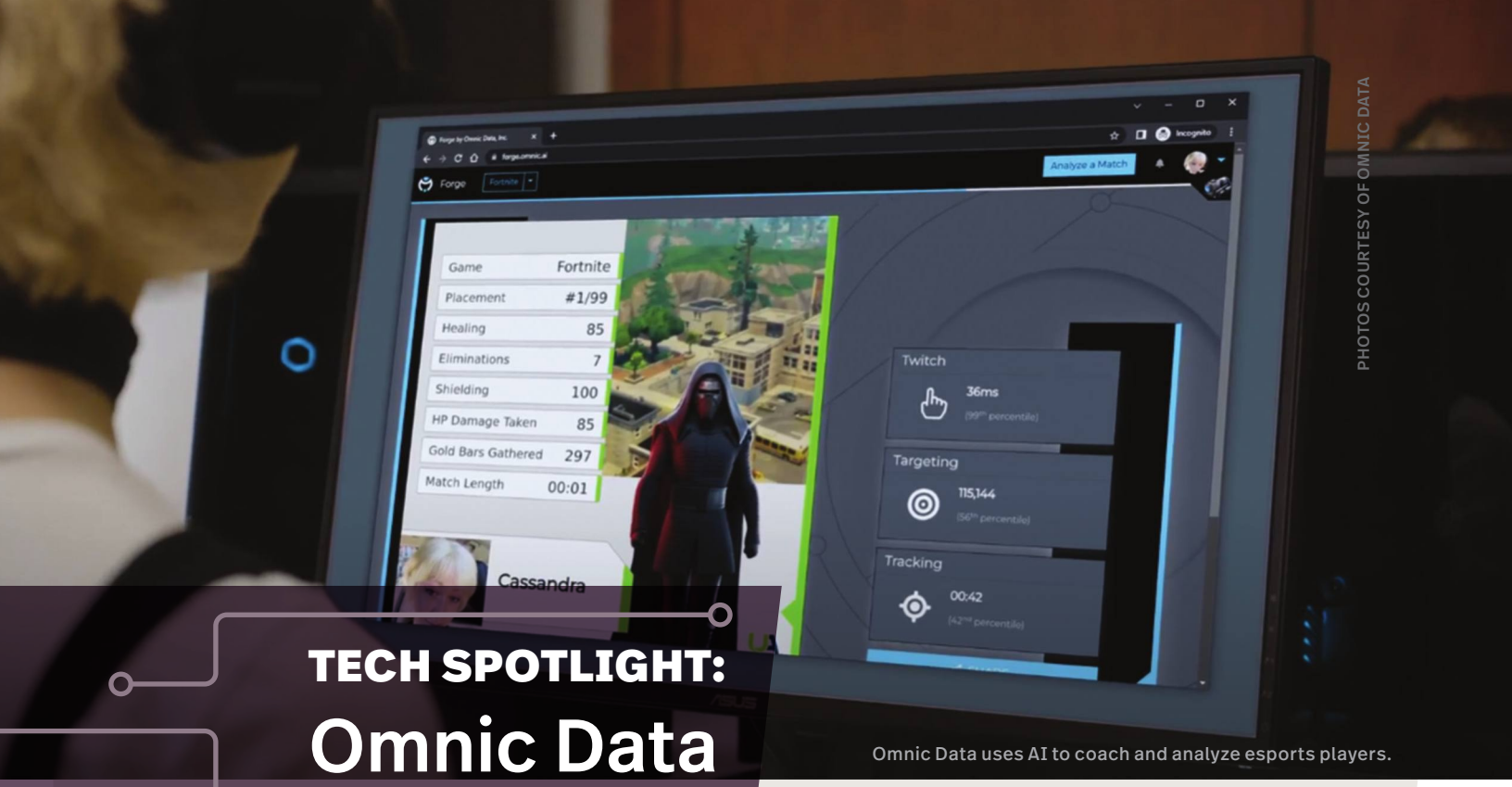
"If you want to find an Earth-like planet around another star, you would need to know the brightness of a few billion stars in the sky, measure that brightness, and then compare them over short timescales to see what's changing," says Kocevski. "There's no way individual astronomers could do this. You need AI algorithms."

Through AI, astronomers can test a predominant theory–that interactions between converging galaxies cause supermassive black holes to grow–to look for galaxies with growing supermassive black holes. They believe that at the center of every galaxy are these enormously dense objects that attract massive amounts of dust and gas and form growing disks that emit enough energy to regulate nearby star formation.

The interaction between a supermassive black hole and the increasing mass around it creates a feedback loop that influences the evolution of the entire galaxy. What baffles Kocevski is why only about 10 percent of supermassive black holes appear to be actively growing while the galaxies around them are always growing and creating new stars. "Somehow the black hole knows something about how the galaxy grows and vice versa," explains Kocevski, who is studying their shape and how they interact with other galaxies.

Getting the data is easy. Visually sorting and analyzing potentially billions of galaxies is the hard part. A single survey may include half a million galaxies, and classifying just 10,000 of them can take as long as a year. But, Kocevski says, with the right initial data set you can use convolutional neural networks to rapidly speed up the classification process.

"You train a machine learning algorithm to know which galaxies are discs, which galaxies are spiral galaxies, which galaxies are spheroidal, which galaxies are interacting and merging. And then you can run it on the other 500,000 galaxies," he says.



PHOTOS COURTESY OF OMNIC DATA

Omnic Data uses AI to coach and analyze esports players.

TECH SPOTLIGHT: Omnic Data

No different than professional athletes, esports players review game and training footage to improve performance. Brunswick-based Omnic Data, which was part of the inaugural 2021 Roux Institute's Techstars Accelerator class, is running algorithms on esports data to deliver coaching insights and analysis. Since 2019, its machine learning (ML) platform has been improving the virtual skills not only of professional esports teams and coaches, but also of amateur players.

"There is no other esports coaching product that is able to provide these kinds of personalized AI-driven insights to players," says Shaun Meredith, chief executive officer and co-founder.

The platform–Omnic Forge–uses a mixed-architecture ML engine to extract performance data to make recommendations to esports athletes and teams. By running a stream of game play through image classification and object detection, the ML engine can analyze performance and gaming behavior. A classifier network then examines the outputs from the players, taking into account patterns and determining the strengths and weaknesses of individual athletes and teams. And with hundreds of millions of esports fans across the globe, that puts the company ahead of the game.

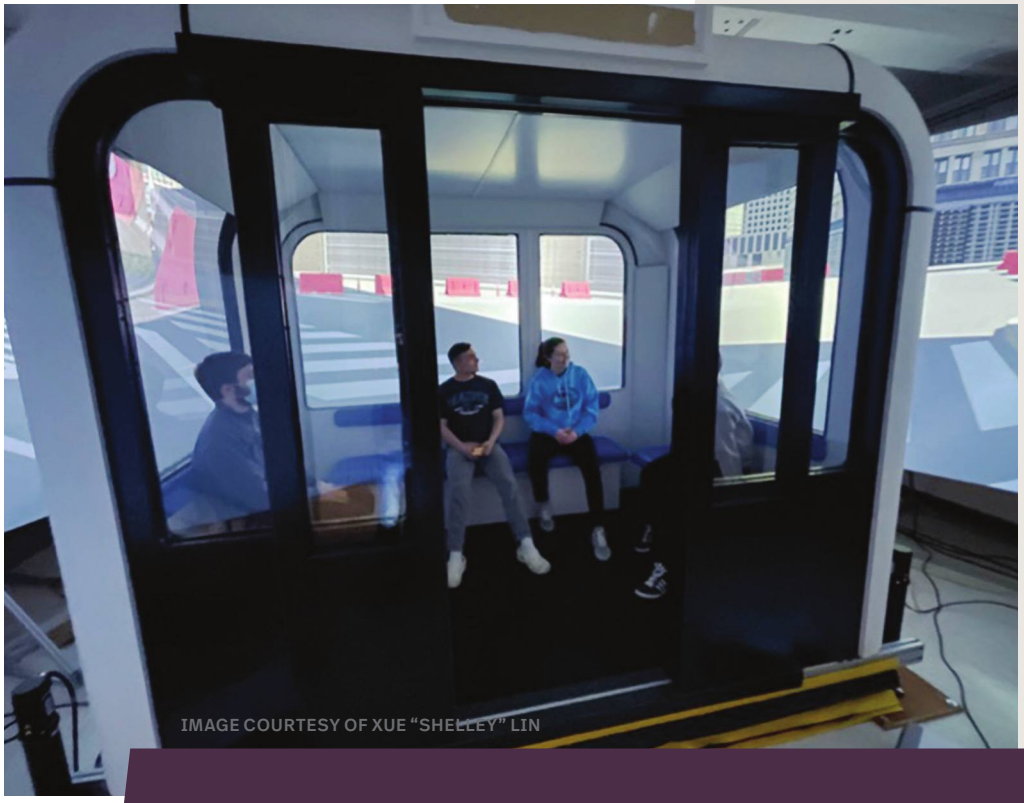


IMAGE COURTESY OF XUE "SHELLEY" LIN

A simulator aids in the development of a new smartphone app for trip planning for those with disabilities.

TECH SPOTLIGHT:

Transportation

In one of many AI collaborations taking place across academia in Maine, researchers from the University of Maine, Colby College, and Northeastern University's Institute for Experiential AI recently finished third in the U.S. Department of Transportation's national Inclusive Design Challenge. Their emerging smartphone app, the Autonomous Vehicle Assistant, assists with trip planning, traveling to pick-up locations, and boarding vehicles. The goal of the challenge was to develop assistive technologies that help those with disabilities access autonomous transportation.

"We applied our techniques on efficient deep learning to help people with sensory disabilities," says Xue "Shelley" Lin, one of the researchers who serves as assistant professor and core member of EAI at Northeastern University. "My students and I designed a real-time computer vision interface enhanced by audio descriptions to detect a user-driven set of navigational hazards."

The team of professors also included Stacy Doore, of Colby College, and Nicholas Giudice and Richard Corey, of UMaine. Their team, The Autonomous Vehicle Research Group, was originally selected as one of 10 semifinalists in the U.S. Department of Transportation Inclusive Design Challenge in 2021 to develop their work, before going on to place third.

Insurance & Financial Services

Banks possess such a wealth of customer information that McKinsey referred to data as the "fundamental raw material" of the banking industry. While financial industry leaders in Maine are generally interested in exploring how AI could add value to their businesses, they are also exercising caution. Trust is central to a bank's relationship with customers, so executives are sensitive to concerns about regulatory oversight, fairness, and transparency. "The opportunities are abundant, so we have put rules in place to ensure we invest in AI only in the ways that bring more value to our customers while creating business efficiencies," says Amber-Heffner Cosby, senior vice president and director of business intelligence at Bangor Savings Bank.

"The data itself is so powerful," she says, "but we've got to do it in the right way and not do harm." Caution about AI is not unique to Maine. In a recent global survey of IT executives in the banking industry, most reported that the complexity and risks of AI projects outweighed the benefits to the customer experience.

Removing the Mundane

Leading consultants have encouraged banks to become "AI First" institutions so that they can successfully compete and retain customers. Otherwise, they risk becoming overtaken by competition, especially from tech giants entering the financial space. Faced with this pressure but also navigating the AI-powered digital era with caution, banks have sought low-risk ways to optimize their internal processes, such as automating repetitive tasks.

At Norway Savings Bank, the business intelligence team has adopted Robotic Process Automation (RPA) as a natural first step in their AI journey. These rules-based tools–which emulate human actions interacting with digital systems–may be especially well-suited for self-proclaimed "conservative" financial institutions. Norway Savings differentiates between "true AI" and RPA tools that follow a precise script built by the team, where there is no learning involved or algorithms using historical data for decision making. "It's going to do exactly what I've told it in the script that I've built," explains Christine McCann, assistant vice president of Norway Savings Bank. "It's not going to do anything more or anything less."


520.0
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440.0
400.0
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320.0
280.0
240.0
200.0
2M
1M

Norway Savings uses a vendor RPA tool to perform redundant tasks such as updating many records at a time. "If you were to watch it run, you would actually see the [cursor] moving across the page and the keyboard entering the data. It looks just like there's an invisible person sitting there doing that file maintenance," explains McCann. Employees have welcomed the technology because it removes monotonous work and frees up their time, a theme we've seen echoed across other industries in this report. McMann sees it as a way to let employees use their brain power. "We really aren't taking work away from them. We're freeing them up to focus on the things we want a trained mind to be able to focus on."

FullscopeRMS, a Sun Life affiliate with many employees working in and around Portland, is a leader in turn-key insurance solutions. When it comes to disability insurance, the company is similarly interested in using AI to offload mundane and simple tasks, allowing employees to operate in what David Messinger, director and associate actuary, calls "ambiguous spaces." There are myriad opportunities to use AI for extracting information from documents or speeding up the claims approval process. "Freeing up and automating away the unambiguous tasks that highly trained professionals are doing" is the best opportunity for AI in the insurance industry, he says. "Too many highly-trained professionals spend too long doing things that are unambiguous."

FullscopeRMS, like Norway Savings Bank, is interested in exploring ways to automate redundant tasks to a point, but Messinger says a bot will never fully replace a claims analyst. From a regulatory standpoint, any decision could theoretically be called up in front of a court or public official. "Saying, 'well, the machine told me to' is simply not good enough," he says.

Similarly, Norway Savings is not willing to adopt an AI tool that lacks transparency. "We're very mindful about what we let in our house, so to speak," explains McCann.

Even at AI-centered startups, human analysts continue to play a critical role. Waterville-based Prospector, which is in startup accelerator Dirigo Labs' inaugural class, relies on NLP to extract tabular data from the lengthy financial disclosure documents that mining companies are obligated to release. Their platform serves as a research tool for anyone interested in investing in the mining industry. According to Jonathan Godbout, Prospector's chief operations officer, the company uses machine learning (ML) and natural language processing (NLP) to augment the manual work of an analyst. Allowing employees to focus on reviewing rather than extracting means Prospector, which is interested in moving into other verticals beyond mining, can perform content analysis at a previously unimaginable scale, having already analyzed two million public disclosure documents.

But even with NLP, there are still clear challenges with text extraction from unstructured documents. As Godbout explains, the industry has not matured to a point where "we can just take the hands off the wheel" and trust a model to synthesize all relevant information without having an analyst review it.

Human Review

Leading financial companies in Maine are embracing AI to support loan or claims processing, but they differ in how they address actual decision making. For example, the analytics team at Portland-based benefits and insurance provider Unum built an AI model that has the potential to reduce the approval time for claims. When the company saw an increase in claims during the COVID-19 pandemic and staff had to work overtime, the model made a substantial

difference, explains Preetha Sekharan, vice president of digital strategy and transformations at Unum. Sekharan's team zeroed in on high-transaction, high-volume, high-velocity claims (See Four Tips for Successful AI Deployment on page 50).

Within the same category of automating and streamlining redundant internal tasks, both banking and insurance require extensive documents to be received and logged so that customer-facing decisions–whether for loans or claims approvals–can be made. AI can do much of the busywork of compiling, consolidating, and indexing documents. Norway Savings is in the process of implementing an orchestration system for loan origination that receives and files information accordingly. The system can automatically spot risks or trigger a request for a credit check or home appraisal. The tool will aid in the administrative process of gathering and sorting documents, but as vice president for business intelligence Vicky Libby notes, it will not be used for automatic decision making.

Decision Making

Globally, banks routinely use AI to qualify applicants for loans using systematized, rule-based models, which factor in credit scores and other publicly available information. Portland-based payments company WEX is one of these financial technology or "fintech" companies leveraging AI for credit, fraud, and key decisions across WEX, according to Ryan Taylor, senior vice president of enterprise data and analytics.

More recently, fintech companies have been developing complex algorithms that factor in a broader range of unstructured data about a person, including social network activity. How invasive these models might become has been a source of concern, but regulators have not been sitting idle. Because federal law requires that applicants who are denied credit be told why, a compliant AI-based credit decision making model must have a certain level of transparency and be able to provide an explanation. The Consumer Financial Protection Bureau released a memo in early 2022 to remind lending institutions of an applicant's "right to a specific explanation if their application for credit was denied." Lenders cannot blame noncompliance on the fact that their technology "is too complicated, too opaque in its decision-making, or too new," the agency noted. For this reason, financial institutions like WEX implement explainable AI and formal model governance processes that enable transparency in decisions, explains Taylor.

Advocates for using AI for credit decisions point out that lending has historically been rife with discrimination and that AI algorithms can be specifically designed to be more equitable.

CASE STUDY 06

Four Tips for Successful AI Deployment

PHOTO: ANNA FIORENTINO

1: Start with a targeted use case or proof of concept (POC) to build excitement.

When selecting an initial AI use case, data teams might choose the low-hanging fruit–the easiest project that provides the greatest reward. A logical place to start might be in high-data areas of the company such as the marketing team, which may already have a good representation of customer data and be relatively more sophisticated in its use of analytics.

Preetha Sekharan, Unum's head of digital strategy, and her team piloted off-the-shelf technology to intelligently transcribe documents during the insurance quoting process. "Generating excitement around that POC and the POC results was the first step that was needed," she explains. "Then we were able to obtain funding to start working on scale."

Still, the barriers to AI adoption may be more cultural than technical. "The technical barriers have dropped dramatically," explains Ryan Taylor, senior vice president of enterprise data and analytics at WEX. "For those that have the capital to spend on it, AI can be built into solutions in a variety of accessible ways." When thinking about scaling, advocates of AI must appeal to individuals and teams who may not recognize how they can directly benefit. According to Taylor, an effective approach for winning the hearts and minds of the business teams is to understand the critical problems and help demonstrate how data and AI can help address those problems.

2: Involve all stakeholders in the 'test and learn' process.

To gain broad employee acceptance of a new AI tool, users must be involved from day one. "We had to engineer how we did this project to make sure people were comfortable with it," says Sekharan. Unum asked analysts to spend three months studying the output of the AI tool and this allowed them to observe, firsthand, that the tool produced high-quality results.

There is a clear challenge here to overcome what David Messinger, director and associate actuary at FullscopeRMS, calls the "not my day job problem." How do you involve employees in innovation around AI while allowing time for them to accomplish their day-to-day tasks?

"It's incredibly important that the stakeholders are not just a point of contact, but are really integrated through the whole arc of the project," he says. "That's a huge time commitment on a speculative project that is, in reality, not their day job. But nothing that I've seen has been more crucial to success."

The Business Intelligence team at Bangor Savings Bank worked with the Institute for Experiential AI and the Roux Institute at Northeastern University to build a machine learning model that helps the bank's frontline staff understand which, if any, financial products a customer is likely to be interested in. They then can use that knowledge to more confidently start a conversation with the goal of becoming a trusted advisor. During the model development, Bangor Savings Bank's analytics, engineering, and business teams met frequently with the Roux team to provide guidance around the model's inputs and features. They also conducted focus groups with frontline staff to understand the context in which the tool would be used and get feedback from users on which features would be most helpful.

Involving stakeholders in the model build also means it is more likely the model will be integrated into the current infrastructure, as opposed to operating in a silo. However brilliant an AI solution, if designed to operate outside an organization's primary systems and interface, chances are it will not be used.

3: Nurture computational subject matter experts.

"The word 'computational' is now in front of every subject," explains Venkat Srinivasan, founder and managing director of Innospark Venture Capital. In the future, he explains, "there will be no special purpose AI modelers–data scientists as we call them today. Every subject matter expert will also be a data scientist." Today, however, that may be easier said than done.

According to Messinger, finding talent with that optimal mix of domain and data skills remains a missing piece: "You need people who understand data science very closely. But they also really need to understand the business problems and the regulatory environment we're operating in." The proliferation of out-of-the-box AI tools means that subject matter experts, whether in insurance, finance, or other areas, can leverage their knowledge to deliver more valuable data outcomes compared to a data scientist without industry experience.

4: Lay the groundwork.

"The investment in the groundwork is still well behind," Messinger notes. "For many insurance companies, just saying, 'We've digitized all our policy contracts into PDFs feels like a victory."

Indeed, technology systems at insurance and financial institutions are built for stability. They perform core operations well but also require extensive maintenance. New systems must often be built with "legacy capability" in mind, and data might be siloed across multiple business units.

Consolidating data between previously siloed teams into cross-organizational data systems is one common approach to achieving AI readiness. These centralized management systems form a "data backbone," providing access to data in a timely, secure, and role-appropriate way.

Manufacturing & Supply Chain

AI has made inroads into many sectors of the economy, but its use in manufacturing is still relatively limited in Maine and beyond. High-precision robotics, laser cutters, and gantry mills may seem cutting-edge, but they're actually hard-coded. Most machines still rely on traditional programming known as Industry 3.0–automation that operates on logic processors and is configured and programmed by humans prior to starting operations.

The next phase in the industrial revolution, known as Industry 4.0, will be about interconnectivity, machine learning (ML), and real-time data. Industry 4.0 factories offer the competitive edge with higher production capacities, shorter lead times, reduced downtime, and material efficiencies. With the right data governance, manufacturers will be able to anticipate breakdowns beforehand by modeling predictive maintenance schedules. The question is, how does the industry transition from human labor to human-assisted AI to create more dynamic interconnected factories?

"While we are firmly in the age of Industry 3.0, the shift to Industry 4.0 where smart factories leverage AI to optimize processes across the plant, improve quality, and grease their supply chain has not yet been realized by most manufacturing companies," says Nathan Post, research associate professor at the Roux Institute at Northeastern University.

This is true here in Maine where high-tech industries from aerospace composites to stadium seating to orthopedic implants are leveraging automation in their manufacturing processes.

Part of the problem in and out of the state, explains Post, is that businesses building everything from vehicles to wind turbines still can't collect and leverage data at scale to optimize manufacturing and supply chains.

In the manufacturing of high-end components, many plants still use antiquated paper records in their quality control systems. Digitizing these records is laborious and the benefits may not be immediately seen. Similarly, separate automated processes may produce data, but collecting and integrating them into a central repository so they can be leveraged by AI can be challenging. Transitioning to digital records requires updating and recertifying systems that have worked for decades and also retraining the workforce. And AI for quality control and process improvements can require significant investments in data management systems just to get access to the required information.

These advances are predicated on a complete digital transformation on the factory floor and its supply chains. It requires a mix of cameras, sensors, high-performance computing, advanced

PHOTO COURTESY OF UMAINE

Amber Parker at University of Maine Advanced Manufacturing Center

robotics, augmented reality, autonomous machinery, data harvesting, and software systems to model a digital thread from material procurement to product distribution. "One of the primary challenges for adaptation of industry 4.0 practices is data availability and quality," says Post.

In Maine, manufacturing has been on a steady decline, now representing less than 9 percent of the workforce, despite manufacturing gross domestic product increasing steadily since 2000 from global trade and automation. While many leaders in Maine sectors ranging from paper to food processing express interest in using AI and in some cases have implemented third-party data solutions, most appear to be adopting a "wait and see" strategy. The state's legacy industries are still heavily reliant on manual labor, while the aging population has led to a skills gap and workforce struggles with technical skill shortages and, in some cases, distrust in automation and certain technologies. In other cases, the reverse is true. "We have also heard that it can be easier to find people who want to work on robotic machines than to do manual skilled labor like welding," Post explains.

Leveraging Good Data

Industrial data is abundant, but factories often lack the means to leverage it. "Even when data is collected and available, expertise to leverage this data and AI to turn it into actionable insights is lacking in many industries," says Post. "If AI is implemented blindly without human intelligence and situational awareness of a particular industry need, it often will not provide very useful results."

That sentiment is shared by many including Torey Penrod-Cambra, co-founder and chief communications officer at HighByte, a Portland-based startup that provides data integration and modeling software to manufacturers: "We think of manufacturing as an advanced industry, but in terms of its data use for advanced analytics, it's actually far behind other verticals like finance or healthcare."

HighByte clients include dozens of large multinational corporations, but even for giants in pharmaceutical, automotive, and food and beverage manufacturing, AI is a step behind. "Go into manufacturing environments that you would expect to be sophisticated based on the brand name and you'll see things are still being done on clipboards and whiteboards," says Penrod-Cambra. "Many manufacturers are still trying to scale automation. AI case studies are growing, but documented [return on investment] is not yet common."

Acquiring data is one of the first steps in the digital transformation and that's not such an easy task in an industry still heavily reliant on manual labor and physical controls. Companies like HighByte supply advanced data preparation for AI, however these offerings are generally only practical for large companies with multi-plant global facilities. Smaller competitors can't always afford sweeping data architecture overhauls or are not convinced they need them. That includes small lumber mills, many of which are outcompeted by large mills like J.D. Irving and Hancock Lumber, where AI-assisted computer vision systems can analyze and sort timber boards before leaving the mill. Irving even uses an ML system to gather data from harvested trees and predict which trees are the best quality.

The technological gap is apparent to small lumber producers. John Belding, director of the Advanced Manufacturing Center (AMC) at UMaine, has worked with many of them in the state that are looking to use AI without breaking the bank. One solution involves automating the process of removing bark from a tree, or debarking, which, when done manually, results in 20 to 30 percent excess wood loss. "The laser scans the wood, the AI finds the optimal placement solution, and then the robot places the wood to be debarked," says Belding.

Why Change?

Despite small advances, Belding, who works with companies throughout Maine to introduce new technologies and upskill their workforces, agrees Maine factories are lagging behind others when it comes to technology. Slow AI adoption can have as much to do with culture and skills training as it does data: "A lot of it is traditional, 'doing it the way we've always done it,'" he says. "But [it's also about] the resources and the training and the employees that are willing to adopt these newer technologies."

Smaller producers may consider a piecemeal approach to AI that allows them to get their foot in the door without disrupting processes that have traditionally worked fine. "It is very appealing for them to be able to pick and choose what they want," adds Belding, explaining it's also in line with the AMC's mission to help operators of small factories in Maine scale their operations.

Jaime Schorr, chief procurement officer for the Maine Department of Administrative and Financial Services, is also in a position to see how factories across Maine are dealing with torrents of data. She sees one of two complaints. "One, there isn't data, or two, there's too much data," she says.

Schorr explains data shortages are generally a matter of companies collecting the wrong information or not adequately analyzing the information they have. The far more pervasive problem of too much data, she says, usually has more to do with bandwidth. That may imply a skills shortage, where engineers or analysts do not know what to do with the data they have, and that shortage is not limited to the production side. Distributors and supply chain managers deal with enormously complex logistics networks that, given the abundance of data, would be well served by predictive or decision-making algorithms. But, as Schorr says, "We're just trying to implement some of the smaller pieces to work towards the bigger pieces that will assist in moving from manual procurement processing to the more intelligent procurement."

Leveraging AI to optimize supply chains will require an increase in data sharing between companies and while this could be advantageous to the industry, some individual organizations often prefer not to share data. Both the intrinsic value of data and potential to impact sales are seen as risks to oversharing.

"This lack of data shared in real time makes supply chain optimization difficult outside of vertically integrated companies," Post explains.

Preparing for Industry 4.0

Small factories may not be less advanced, and large factories aren't always better equipped to leverage big data. One of the largest employers in Maine, General Dynamics Bath Iron Works (BIW)– a subsidiary of the fifth-largest defense contractor in the world–relies heavily on skilled manual trades labor to build a ship. Many parts are manufactured in isolation, underscoring the challenge of developing an Industry 4.0-style model of interconnectivity, automation, ML, and real-time data on the factory floor. BIW's AI initiatives are limited to looking for patterns in enterprise data to help reduce errors that impact how the parts become the ship. The shipbuilder deployed a hierarchical data structure to represent manufacturing activities that assist in back-scheduling fabrication and procurement processes.

"We're probably going to develop AI at a very slow pace compared to the rest of the industry," said Christopher Ouellette, director of strategic planning at Bath Iron Works, adding that future capabilities depend on a redesign of the manufacturing process. In the short term, opportunities for AI lie in pre-production and small-part manufacturing.

Like the large number of aerospace and defense contractors, some Maine manufacturers deal with lower production volumes. Fiber Materials Inc. (FMI), a Biddeford-based producer of high-temperature carbon-carbon composites for rocket exit cones, produces fewer than a thousand parts in a single year. There just isn't enough data to develop a quality

assurance or robotic process automation (RPA) system. With only a single customer, FMI sees little need to disrupt processes with black box technologies, even with the promised efficiency gains.

"We do have fairly regimented processes that need to maintain a certain temperature profile in order to get the characteristics that the customer likes for the material," says Steve Macaluso, technology development manager at FMI. "But it's not that complex. A simple Programmable Logic Controller and a simple program can do it."

At the UMaine Advanced Structures and Composite Center–now also known as the Factory of the Future–researchers are collecting terabytes worth of manufacturing data and examining ways to connect different parts and process parameters. The University of Maine is the largest educational investor in advanced manufacturing technologies in the region. It is home to the largest 3D printer in the world and the U.S. Congress recently appropriated $35 million to expand its operations, including a substantial investment in AI to help connect data from the manufacturing environment to the quality of the end product.

The investment disparity between research and practice is not unique to Maine, but the state's prevailing economic challenges follow similar patterns in manufacturing. Educational and industry leaders stress the need for greater student recruitment, workforce diversity initiatives, and training programs in additive manufacturing to resolve the technical skills gap. Data challenges can be expected to grow with the transition to Industry 4.0, representing a first-order objective for factories looking to make the switch to smarter, more efficient production environments. For now, a lack of trained data scientists who are also familiar with manufacturing and supply chains and the generally high salaries that data scientists can command in the tech sector only further slows integration of Industry 4.0 practices, but the transition is happening.

The jump ahead to Industry 4.0 is particularly challenging for factories, which are sensitive to disruption. In Maine, very few manufacturers have adequate budgets to digitally transform all of their operations. However, researchers at the University of Maine are arriving at Industry 4.0 through research and development.

"As a new generation of manufacturing engineers are trained to think more like data scientists and industry recognizes value in implementing data best practices throughout their operations, new opportunities are emerging," says Post. "Because manufacturing involves physical systems it isn't going to be as agile as the digital tech sector in adapting new technology quickly, but it will get there over time."

PHOTO COURTESY OF UMAINE

A bio-based 3D-printed house, produced by UMaine

PHOTOS COURTESY OF UMAINE

CASE STUDY 07

Factory of the Future

In Orono, the Advanced Structures and Composites Center (ASCC) is helping define the future of manufacturing under a new name–the Factory of the Future.

Through a $35 million federal grant, this new space will be built on more than 20 years of work in the materials science and manufacturing space. It will continue to drive research and innovation in the green manufacturing space through a combination of AI, sustainable materials, advanced robotics, and large-scale additive manufacturing.

"The Factory of the Future is a way to scale up from the desktop or benchtop to a factory environment, where you're producing parts at a much larger throughput and much larger scale," says Habib Dagher, ASCC founding executive director and Bath Iron Works professor of structural engineering.

Today, inside sits the largest 3D printer in the world, capable of cranking out parts as long as 60 feet and more advanced fabrication methods at UMaine than ever before. In 2019, over the course of 72 hours it created the largest 3D-printed object in history–a 5,000-pound patrol boat for the Department of Defense. Last fall, UMaine's supermachine also printed a bio-based house that could address the affordable housing issues in Maine.

The center is already utilizing forest-derived, bio-based materials that are natural to a state like Maine. Wood-based additives are recyclable and can be developed to rival certain metals in strength. Such an ambitious goal requires a revolutionary enhancement of the manufacturing environment, one that visualizes and represents processes from end to end.

The neighboring Advanced Manufacturing Center (AMC) is breaking down barriers between industry and academia, allowing local manufacturers to make use of new fabrication technologies and methods. Together, these centers are responsible for some of the most cutting-edge use of AI-assisted manufacturing in Maine. Traditional 3D printing uses non-biodegradable plastics to build parts layer by layer. The additive process is generally less wasteful than subtractive forms of manufacturing like milling or cutting, but it produces toxic fumes and depends on fossil fuels for its materials.

As an Industry 4.0 environment, the Factory of the Future is also equipped with an array of sensors that produce many terabytes worth of data for ML algorithms to use. The successful processing of all that data is critical to ensuring the core promises of Industry 4.0, such as flexible automation, error detection, and breakdown prevention.

"What we're looking at is a digital manufacturing environment,'' explains Dagher. "As you manufacture, you're keeping track of all the manufacturing processes through a digital thread. You're sensing what's going on [and creating] a feedback loop with the sensors, which will allow you to utilize AI in order to drive decisions on the manufacturing floor."

Whether the process is additive, subtractive, mechanical, or robotic, AI can provide the corrective mechanisms needed to reduce waste, limit downtime, and strengthen products, unifying and completing that digital thread.

"The ultimate goal here is to be able to improve the quality of the manufacturing parts and eventually be able to produce certified parts," says Dagher. Eventually, these AI systems will be able to identify subtle relationships between manufacturing conditions and quality of parts that are invisible to the human eye.

But the manufacturing environment is still heavily dependent on human oversight. Humans learn from machines and machines learn from humans, creating a feedback loop to account for inconsistencies in the data that AI, in its current state, has trouble modeling. This deficiency is behind some of the biggest controversies in ML.

If the ASCC is considered the research arm of UMaine's manufacturing interests, then the AMC is their business arm. The AMC works with Maine businesses to create Industry 4.0-style solutions to address pressing manufacturing challenges. Some projects involve automation and a growing number use AI. Manufacturers see particular value in computer vision systems that can dynamically analyze parts for quality control. A number of lumber producers in Maine have already adopted vision-based AI systems to identify timber boards at their mills, and the AMC is using those techniques to help factories boost their own quality control efforts.

"I have a laundry list of companies that are interested in this technology but don't have a good place to start," says John Belding, director of the AMC. "And so, we're starting to do some small implementation projects to help companies realize what the technology is and how to put it into place."

Belding says AI is also helping Maine factories procure materials and optimize their supply chains. In Computer Numerical Control metal machining, for example, price pressures often lead manufacturers to procure the smallest castings possible when producing small metal parts. The trouble comes when they try to machine the final part out of the casting. As Belding explains, "It doesn't clean up completely because there is such a tight tolerance between the final part and the part that was put in there." An AI-assisted 3D scanner, however, can be used to determine the right size and position of the castings so that the end product is well within specified design parameters.

For the vast majority of manufacturers, AI adoption is still in its early stages. Whether the reason is cultural, practical, or financial, many consider disruption unnecessary. Some Maine businesses are reluctant to embrace new technologies, particularly those associated with automation. "I think Maine is lagging behind quite a bit on the manufacturing side as far as adopting new technologies," says Belding.

Fears of job displacement are not unfounded in a state like Maine, where between 1979 and 2010 nearly 30,000 manufacturing jobs disappeared. An impression has taken root that traditional methods are good enough, but that may be a risky long-term view for both factories and workers. As Belding explains, providing companies and employees with the resources and training to make the digital transition, as the University of Maine is doing, offers the best of both worlds: a realistic embrace of competitive technologies and a skilled workforce that's fit for the future. "It's not a short game," he adds. "It's a long game."

AFTERWORD

Amanda Stent, director of the Davis Institute for artificial intelligence at Colby College

The Maine state seal captures the essence of the state: a love of nature (represented by a pine tree and moose) carefully cultivated by and for humanity (represented by a farmer and seaman) with the state motto underneath: Dirigo, Latin for lead, direct or guide. Today, Maine leads in several important ways, including scientific assessment and management of climate change, respectful ways to productively manage an aging population, and infrastructure modernization.

This report highlights another way in which Maine could soon be leading: through the careful and cost-effective development and application of AI to serve the interests of humanity and the lived environment. Our institutions of higher education across the state, from Orono to Waterville to Portland, are conducting leading-edge research in the use of ML techniques to model the natural environment and develop more sustainable human environments, and training the next generation in the use, benefits, and risks of AI. World-renowned research labs, including Mount Desert Island Biological Laboratory, The Jackson Laboratory and Bigelow Laboratory for Ocean Science, are developing novel uses of AI and ML, in deliberate and continuous collaboration with stakeholders from fisheries to hospitals. And companies are developing novel applications of AI that make a real difference in terms of our valuable natural resources (Prospector, New England Marine Monitoring) and our communities (Unum and IDEXX Laboratories).

Here's my closing argument for The State of AI in Maine: if you are considering a career in AI, consider Maine; and if you live in Maine, consider how you can influence the deployment of AI.

Over the past six months, we have again seen the cyclical nature of high-tech employment. However, recent reporting ("As Silicon Valley Retrenches, a Tech Talent Shift Accelerates," *New York Times*, Dec. 29, 2022) has confirmed that tech–AI included–is now pervasive across every industry. As the case studies in this report illustrate, you don't have to move to Austin or San Jose to have a career in AI. In fact, the AI you do in Maine may matter more because the ways we are shaping the development of AI in Maine are critical to the cultivation of our environment and because you can have a disproportionately large impact.

We all know that AI is pervasive in our lives and homes, from "smart" doorbells to "smart" electricity meters, and from smartphones to AI-driven social media. What we don't see so easily is the ways AI is directing society. AI is used to assign shift workers, to monitor and assess students and teachers, to select and evaluate employees, to help judges make decisions in criminal and civil cases and politicians decide what issues matter, to monitor patients in hospitals and residents in care homes, and to determine what qualifies as free speech online. In addition to the stunning natural environment, one of the things I appreciate about Maine is that Mainers focus on what matters. Mainers value hard work in balance with family and community life. Mainers care for each other in ways that encourage independence and sustainability. We can also lead in the careful and deliberate choice of when and how to use AI. With our government, we can establish AI policies and practices that respect and sustain our land, the rich history of our indigenous peoples, our cultural heritage, and the lived experiences of Mainers of every age and demographic. As more of us become AI innovators, let's all become informed and critical AI consumers. Let's Dirigo.

Allagash Wilderness Waterway
PHOTO: ANNA FIORENTINO

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The State of AI in Maine Advisory Committee

Miguel Barajas, research associate at Gulf of Maine Research Institute

Madeleine Braun, chief of presidential initiatives at The Jackson Laboratory

Brian Bousquet-Smith, head of engineering at MedRhythms

George Casey, chair of Vistage Group

Lucas Ives, AI/ML at Apple

Jason Judd, executive director at Educate Maine

John Karp, program manager at Maine Manufacturing Extension Partnership

Dan Nigrin, chief information officer at MaineHealth

Penny Rheingans, professor and director of the School of Computing and Information Sciences at University of Maine

Anthony Ronzio, deputy director of the Governor's Office of Policy Innovation and the Future

Amanda Stent, director of the Davis Institute for AI at Colby College

Ryan Taylor, senior vice president of data and analytics at WEX

The Institute for Experiential AI at Northeastern University

The Institute for Experiential AI (EAI) at Northeastern University conducts foundational and applied research. EAI operates an AI Solutions Hub focused on developing practical, responsible AI solutions to solve real-world problems and shaping the next generation of AI talent. The institute's human-centric approach to AI is helping organizations leverage data that amplifies the impact of ML, mitigates bias, and yields more responsible AI solutions, forming the basis for experiential learning at the university and partner companies. Serving as a credible source of expertise and insights into the state of AI, the institute has over 90 faculty members spanning disciplines. It bridges the gap between industry and academia, connecting industry stakeholders to experts. In return, academic stakeholders can apply their work to real-world situations and make a lasting impact on business and society.

The Roux Institute at Northeastern University

Northeastern University's Roux Institute was founded by David and Barbara Roux to stimulate the regional economy through the cultivation of talent and cutting-edge technology capabilities within Maine and northern New England. It is providing economic impact and erasing the boundaries between the real world and academia through learning programs and research initiatives that meet the needs of employers, integrating classroom learning with professional experience, and supporting the launch of innovative startup companies. The institute is preparing workforce talent for today's innovation economy, focusing on STEM fields, and conducting interdisciplinary research to solve challenges that affect Portland, the state of Maine, and communities globally. The institute aims to fundamentally change how people interact with data and address difficult societal challenges, becoming a model for other urban centers to ensure and sustain their competitiveness in the global innovation economy.