Next:

Frontiers in Aerospace, Defense, Undersea Technologies, and Remote Sensing

UMASS

University of Massachusetts

Scanning the surface of Mars

Physicist Noureddine Melikechi, dean of UMass Lowell's Kennedy College of Sciences, is a member of the science team for SuperCam, a remote-sensing instrument aboard the Mars rover Perseverance, launched by NASA in July 2020. Perseverance will use SuperCam's powerful laser to reveal the chemical composition of Mars' surface, vaporizing bits of distant landscape and analyzing the resulting flash of light with a spectrograph for chemical signatures. SuperCam will use artificial intelligence to select targets. Scientists are particularly interested in the presence of minerals like clays that form near liquid water.

Melikechi was also on the team behind the laser-induced breakdown spectroscopy (LIBS) instrument on the rover Curiosity, which landed on Mars in 2012 and is still operating there today. Melikechi's research group has also used LIBS technology to detect cancer biomarkers from a single drop of blood and is evaluating its ability to detect the COVID-19 virus in blood, saliva, and urine samples.

The Internet. Global Positioning Systems. Drones. Much of the most world-changing, ubiquitous technology to emerge over the past 50 years has sprung from research sponsored by the Department of Defense and NASA in partnership with academic institutions like UMass.

DoD's need for research innovation to maintain security and strategic advantage is constant and wide-ranging—which is why it is the largest sponsor of basic and applied science research in the nation. The department spent $64.5 billion on R&D in FY 2020, dwarfing the expenditures of the National Institutes of Health (which averages $41.7B per year), the Department of Health and Human Services ($38B) and the National Science Foundation ($6.3B). Together, DoD and NASA—the government's other driver of technological innovation—dispense roughly half of the total federal R&D budget.

The UMass system has been a productive partner for both DoD and NASA for many years. Among our standout collaborations are UMass Lowell's Harnessing Emerging Research Opportunities to Empower Soldiers program and Northstar campus, UMass Dartmouth's longstanding collaboration with Naval Undersea Warfare Center Division Newport, and the state-of-the-art VA outpatient clinic opening in 2021 on the UMass Medical School campus. For the system, these partnerships enable:

- The prospect of contributing to very real and pressing issues of national defense—from securing intellectual property from cyberattack to improving the protection and maneuverability of the nation's soldiers.
- The chance to push the envelope in many fields with innovative solutions to DoD's and NASA's unique needs.
- The ability to harvest dual-use applications of immense benefit to civilians from defense-sponsored research, the source of medical breakthroughs from ultrasounds and EpiPens to penicillin and prosthetics.
- The opportunity to contribute commercialization potential and workforce to the Commonwealth's defense industries, which support more than 103,000 jobs and a total annual payroll of $10.1 billion.

Technology development related to defense, aerospace, the undersea domain, and remote sensing is more vital than ever. Bolstering cybersecurity is a national imperative made all the more urgent by the far-reaching SolarWind hack in December 2020. The launch of the Space Force, the success of Space X, and the explosion of interest in small satellites have redoubled the need for technological advances in space. Remote sensing is a critical technology with applications ranging from documentation of a warming planet to defense imperatives, as are ocean modeling and undersea vehicle and drone autonomy. The U.S. Army Combat Capabilities Development Command Soldier Center and soon-to-open Soldier Squad Performance Research Institute facility in Natick, Mass.—both of which have close partnerships with UMass Lowell—will drive new innovation in human performance sensing and augmentation in the state.

UMass is uniquely positioned—in terms of expertise, established partnerships, and even proximity—to meet the needs of NASA, the Armed Forces, and society as a whole in these research areas, and has an exciting vision for where these technologies can take us in the future.

BIG IDEAS

UMass Amherst is a pioneer in reinforcement learning, a fundamental concept in artificial intelligence and autonomous systems. The machine-learning technique, built around rewards and punishments, was developed in the 1980s by computer engineers Andrew Barto, former co-director of UMass Amherst's Autonomous Learning Lab, and Richard Sutton, who was a doctoral student at the time. Today, reinforcement learning is widely used in automated cyber defense.

Predicting the monsoon

Monsoons bring 50 to 90 percent of the rainfall that sustains Indian agriculture—and, increasingly, catastrophic floods that destroy crops and displace millions. UMass Dartmouth oceanographer Amit Tandon has led two consecutive Navy–funded initiatives that are using moored and drifting sensors, autonomous undersea vehicles, research vessels, and high-resolution computer modeling to understand the air-sea interactions that shape monsoons in the Indian Ocean. More than 20 research institutions from India, Sri-Lanka, and the US have collaborated on these projects, which are providing knowledge needed for better, earlier monsoon predictions and safety of ships and naval assets at sea.

Today's strengths

Across its five campuses, UMass has hundreds of research initiatives that develop or apply advanced technologies for remote sensing, undersea and aerospace exploration and operations, and defense. Among them, we have particular strength in these five areas.

Cybersecurity

The US is under constant cyberattack; threats range from email phishing scams to direct takeover of defense systems. Consequently, maintaining dominance in defensive and offensive cyber capabilities is a top priority for the Department of Defense. Ongoing cyber-operations require cutting-edge research and workforce development—two UMass strengths.

Three of our campuses have developed research centers committed to cybersecurity innovation: the **Center for Terrorism and Security Studies, Center for Internet Security and Forensics Education and Research,** and **New England Cybersecurity Operation and Research Center** at UMass Lowell; the **Cybersecurity Center** at UMass Dartmouth; and UMass Amherst's **Cybersecurity Institute**, which conducts more than $5 million in federally sponsored research each year. Scientists affiliated with these groups collaborate with premier cybersecurity federal R&D centers—MITRE Corp., the Archimedes Center for Medical Device Security at the University of Michigan, MIT's Lincoln Laboratory—and draw upon the system's longstanding strengths in AI and public policy to develop next-generation systems and strategies for protecting American interests and residents online.

In 2019, UMass Lowell launched the Commonwealth's first public university **Cyber Range**—an isolated computer network for cyber defense training and security research. The university is also establishing a **Sensitive Compartmented Information Facility** for government-sponsored research involving top-secret information.

The US government has recognized UMass as a leader in this field. Both UMass Dartmouth and UMass Lowell are National Security Agency and Department of Homeland Defense–designated **National Centers of Academic Excellence in Cybersecurity Research**, and UMass Dartmouth and UMass Amherst have active federal partnerships to fill the cybersecurity talent pipeline.

UMass Amherst was the first public university in New England to receive National Science Foundation funding ($4.2 million) to launch a **CyberCorps Scholarship for Service** program, which provides students financial aid in exchange for years of service in government cybersecurity positions. UMass Dartmouth's **Cybersecurity Center**, meanwhile, is collaborating with the 102nd Intelligence Wing of the Air National Guard and has developed agreements that enable National Guard personnel to transfer credits earned as part of Air Force training toward a four-year degree in computer science or computer engineering.

Cybersecurity and child safety

Millions of images of child sexual abuse circulate online each year—more than law enforcement officers could possibly scrutinize manually. The UMass Amherst Rescue Lab, led by Cybersecurity Institute Director Brian Levine, has created machine-learning-enabled computer methods that scan faces in large sets of photos and videos to help investigators identify victims and perpetrators. Thousands of children have been rescued from abuse with the help of Rescue Lab's free tools, in every US state and more than 40 countries.

UMass Lowell researchers collaborate with scientists at the US Army's DEVCOM-Soldier Center to develop technologies that increase the safety and endurance of American troops.

Human-performance augmentation and sensing

From sensors that track troop health to exoskeletons that rebuild strength, technologies for monitoring and extending the capabilities of the human body have transformational potential for defense and beyond. UMass has pioneered augmentation technologies for military and healthcare use—a combined strength that is perhaps unmatched in the US and ideal for developing dual-use applications to serve the citizens of the Commonwealth.

UMass Lowell and DoD are advancing the state of this art together. The **Harnessing Emerging Research Opportunities to Empower Soldiers** (HEROES) program is a unique collaborative research and development center run in partnership with the U.S. Army Combat Capabilities Development Command Soldier Center (DEVCOM-SC), which has granted UMass Lowell scientists more than $26 million to create survival- and endurance-enhancing technologies for troops. Tech developed at HEROES includes a handheld electronic "tongue" for detecting food and water contamination in the field, wearable conformable photovoltaic devices for portable power, and multifunctional uniforms and body armor embedded with communications systems.

HEROES and DEVCOM-SC work closely with UMass Lowell's **New England Robotics Validation and Experimentation (NERVE) Center**, a national leader in performance evaluation of human-augmenting robotics. (The center develops national standards for exoskeleton testing for the National Institute of Standards and Technology). NERVE is currently testing wearable, robotic exoskeletons from HEROES/DEVCOM Soldier Center that could help soldiers haul heavy loads.

UMass Amherst's **Human Robot Systems Lab** and **Mechatronics and Robotics Research Laboratory** (MRRL) are tackling exoskeletons from a healthcare perspective, both investigating how robotichip exoskeletons can help people with gait difficulties to walk. MRRL has developed powered lower-leg prosthetics that, unlike standard prosthetics, provide thrust the way an intact limb does, making walking easier for people who use artificial limbs.

Commercialization of these technologies is also a system strength: UMass Lowell's and UMass Medical School's jointly operated **Massachusetts Medical Device Development Center** helps start-up companies in the Commonwealth develop a wide range of medical devices and bring them to market, including biosensors for cancer diagnosis, injectable cushioning gels for osteoarthritis, and injectable adhesives for repair of fractured bone.

Tracking climate change from space

Since 1998, NASA's Earth Science Missions have used satellite-based remote sensing for monitoring environmental change on Earth. UMass Boston remote-sensing experts Crystal Schaaf and Zhong Ping Lee—pioneers in global-light-reflectance and ocean-color sensing, respectively—have been key contributors to these missions. Lee developed ocean color analysis tools for NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite, set to launch in 2023, and Schaaf is a member of the scientific instrumentation teams on NASA's Terra, Aqua, Suomi NPP, and Landsat satellites, as well as providing ground-based data to the Lidar team on the International Space Station.

Aerospace and undersea sensing and communications

UMass has system-wide strength in sensing, modeling, communications, and antenna innovation that crosses domains—from space to air to undersea.

In the space domain, UMass excels in instrumentation and modeling. UMass Boston's **Schaaf and Lee Labs** are world leaders in the use of satellite-based remote sensing to monitor the Earth's environment and are major contributors to NASA's ongoing Earth Science missions. UMass Lowell's **Center for Space Science and Technology** is developing high-speed communications instruments for breadbox-sized satellites. In spring 2021, one of these "CubeSats" will be launched by Lowell undergraduates to enable transmission of research data 10 to 20 times faster than existing systems. The university's **Space Science Lab**, meanwhile, was awarded a three-year contract by the Air Force Research Laboratory to support a SpaceX-launched satellite mission to discover the source of "killer electrons" that can damage astronauts and orbiting satellites.

The system also has considerable strength in ground- and drone-based sensing and communications. UMass Amherst hosts the National Science Foundation's **Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere**, which is pioneering the use of dense networks of low-cost, high-resolution radar systems to monitor weather, drone traffic, and airborne threats at low altitudes that literally fall under most existing radar coverage.

UMass Air, a collaborative effort between UMass Amherst's **Transportation Center** and UMass Dartmouth's **Electrical & Computer Engineering Department**, is researching unmanned aerial systems at Westover Metropolitan Airport—a commercial property contiguous with Westover Air Reserve Base—including the use of drones for roadway and environmental monitoring. UMass Boston's **Stone Living Laboratory** is also deploying drone-based environmental sensors, as well as terrestrial Lidar, to gather data informing coastal resilience strategies in Boston Harbor.

The dense undersea environment makes situational awareness, sensing, and communications particularly challenging for the Navy. The Office of Naval Research has awarded the **Marine and Undersea Technology program**—which grew out of UMass Dartmouth's relationship with the Naval Undersea Warfare Center Division Newport—more than $8.8M for research related to underwater sensing and autonomous vehicle development. Researchers in UMass Dartmouth's **School for Marine Science & Technology** are developing cutting-edge technology for undersea wake detection, acoustic transducers and arrays in maritime sensors, and modeling upper-ocean processes that impact weather prediction, underwater communication, and submarine operation.

UMass Lowell is at the forefront of developing and validating key technologies needed for advance imaging. With more than $10 million of funding from NASA, the UMass Lowell **Center for Space Science and Technology** has developed new high-contrast imaging technology, as well as hyperspectral imagers from UV to near IR, and in collaboration with UMass Boston, Lidar technology for remote sensing of forest structures.

Multi-domain awareness and operation

Situational awareness and coordinated operation across the land, maritime, air, space, and cyberspace domains are top strategic imperatives for DoD today. For maximum overmatch—that is, the ability to outmaneuver and overpower adversaries—the Air Force, Army, Navy, and Space Force must be able to gather and share data and coordinate operations in real time. UMass is working on both sensing and communications over the entire electromagnetic spectrum, on devices from major radar infrastructure to band-aid-sized body sensors developed by UMass Amherst chemical engineer James Watkins to monitor soldier stress.

To build the foundation for dominant multi-domain operations, DoD launched the **Internet of Battlefield Things DoD Army Research Laboratory Collaborative Research Alliance** in 2017, with $25 million for its first five years. The four-institution consortium, which includes a team of computer network and machine learning experts from UMass Amherst, is tasked with developing the scientific principles, models, and methods needed to coordinate the wide array of networked battlefield devices—including smart armor, radios, weapons, and unmanned vehicles—

UMass scientists are developing drone-based sensors for a variety of uses, including contaminant detection, environmental monitoring, and infrastructure maintenance.

that will characterize the battlefield of the future. Scientists from UMass Amherst's **Institute for Applied Life Sciences** will also contribute research efforts related to wearable sensors and mobile health sensing.

Development of multi-domain operations driven by connected devices touches on many other areas of strength across UMass, including UMass Amherst's recognized expertise in human and asset monitoring to assess survivability, lethality, and effectiveness of soldiers and squads; excellence in acoustics, underwater sensors and sensor fusion, and underwater vehicle autonomy at UMass Dartmouth; and modeling algorithms and data fusion expertise at UMass Lowell's HEROES initiative.

The system also has significant strength in antenna technology across the electromagnetic spectrum, through research groups like UMass Amherst's **Antennas and Propagation Lab, Quantum Radio Frequency Group,** and **Remote Hyperspectral Observers Group**, as well as UMass Boston's **Engineering Department**. UMass Boston applied electromagnetics researcher KC Kerby-Patel won a DARPA Young Faculty Award for her work on miniaturization technologies for communication and sensing antennas, which aligns with the miniaturization emphasis of the Internet of Battlefield Things initiative.

High-performance materials and sensors for challenging environments

UMass Lowell's **HEROES** initiative, in collaboration with DEVCOM Solider Center, is a leader in the development of advanced materials that protect soldiers from harsh and dangerous environments.

Fabrics developed at HEROES help soldiers function in extreme environments, providing protection that enables enhanced performance and sustainment. HEROES is exploring multifunctional Army uniforms,

UMass Lowell mechanical engineers are developing advanced modeling tools to improve combat helmets.

for example, that can provide a combination of fire-retardant, antimicrobial, and insect-repelling characteristics, while—vitally—remaining comfortable and nontoxic. Multi-functionality is a guiding principle here; clothing that serves more than one purpose can reduce the equipment load that soldiers must carry in the field.

Other materials from HEROES include garments that harvest electrical power from light, transparent armor, thermoresponsive fabrics that adapt to external temperature, self-healing materials, ice-repelling surfaces, and self-cleaning fabrics that slough water, oil, and solvents thanks to micro- and nanoscale structures built into their fibers.

UMass Amherst's world-leading expertise in polymer science and engineering and UMass Dartmouth's expertise in textiles and composites contribute to these remarkable advances. UMass Dartmouth bioengineers Yong Kim and Armand Lewis and mechanical engineer Vijaya Chalivendra, for example, developed textile liners for helmets and body armor whose fibers act as millions of springs, absorbing the energy of blunt impacts. Fiber work at UMass Lowell includes imbedded optical fibers that can sense potentially problematic construction flaws in helmets, bridges, and aircraft wings.

Making advanced materials requires advanced manufacturing, and UMass is a longstanding leader in that field, with research in and industrial-scale facilities for additive, roll-to-roll, nano-, and biomanufacturing spanning its campuses. The system is a partner in eight of the nation's fifteen Manufacturing USA Institutes, including **Advanced Functional Fabrics of America,** the **Institute for Advanced Composites Manufacturing Innovation,** and the **Flexible Hybrid Electronics Manufacturing Innovation Institute**.

Today UMass teams are exploring the use of additive manufacturing to create complex structures that can't be made in other ways, from more effective armaments for long-range precision weapons to printed medicines for enhanced dose control. UMass Amherst mechanical engineer Jae-Hwang Lee conducted foundational research with the Army Research Laboratory to understand the molecular processes of cold-spray metal "printing"—now being considered by DoD for field repairs of metal parts.

HEROES is also focused on creating environmental sensors to protect soldiers from hazards in battle zones. UMass Lowell engineer Pradeep Kurup, for example, invented the food-and-water-testing electronic tongue and an electronic nose that can sniff out traces of explosives at concentrations less than one part per trillion. His colleague Xuejun Lu has developed infrared devices that can be integrated into drones and used for long-distance chemical and contaminant sensing.

Tomorrow's frontiers

Our strengths position UMass to make important contributions to these critical research frontiers:

Next frontier 1:

Real-time autonomous cyber operations

As computing speeds increase and the number of networked devices and systems skyrocket, the scope and pace of cyber threat are exploding—for the military, industry, and private citizens. With the speed of cyber operations now measured in nanoseconds, the only way to detect, analyze, and defend against cyber threats as they happen is to create autonomous systems that can remove human agents from the loop.

Over the next five to ten years, creating and evolving AI-enabled, self-guided systems will be one of the most urgent objective for US cybersecurity, enabling domestic and international threat sharing and response at rates unattainable by human experts.

UMass is already tackling the automation imperative from the angles of security, IT operations, and software development, integrating both social science and public policy.

Automated software engineering pipelines that can deliver new functionality quickly while preserving essential properties like reliability and security are a key research avenue for UMass, enabling rapid evolution in the face of adversaries actively trying to dismantle AI systems for profit or warfare.

Next frontier 2:

Human-machine-team-system integration

Systems that combine the power of people and machines—from clothing laced with electronics to full-body wearable robotics—provide valuable boosts to human monitoring, strength, and endurance. But if these systems don't integrate well with their users—if they cause physiological or psychological stress or inadvertently encourage misuse—their utility can be offset by the problems they create.

Seamless human-machine integration is an important frontier in the human augmentation realm. UMass Lowell's **NERVE Center** is doing important work in evaluating human-centered mechatronics while in use by people. It is testing, for example, soldiers' physical and mental responses to wearing bomb suits, which must be sturdy but avoid being too heavy, clumsy, oppressive, or stifling. These kinds of data will continue to drive design improvements, but there is more to be done. Next steps include long-term human monitoring for actionable performance prediction and the development of active sensing for predictive augmentation that anticipates the user's needs.

Over the next ten years we will extend human language technologies and shared situational awareness across multi-human-robot teams—increasing the safety, capabilities, and effectiveness of our soldiers and creating powerful yet human-friendly tech that will eventually lead to advances for civilians as well.

Next frontier 3:

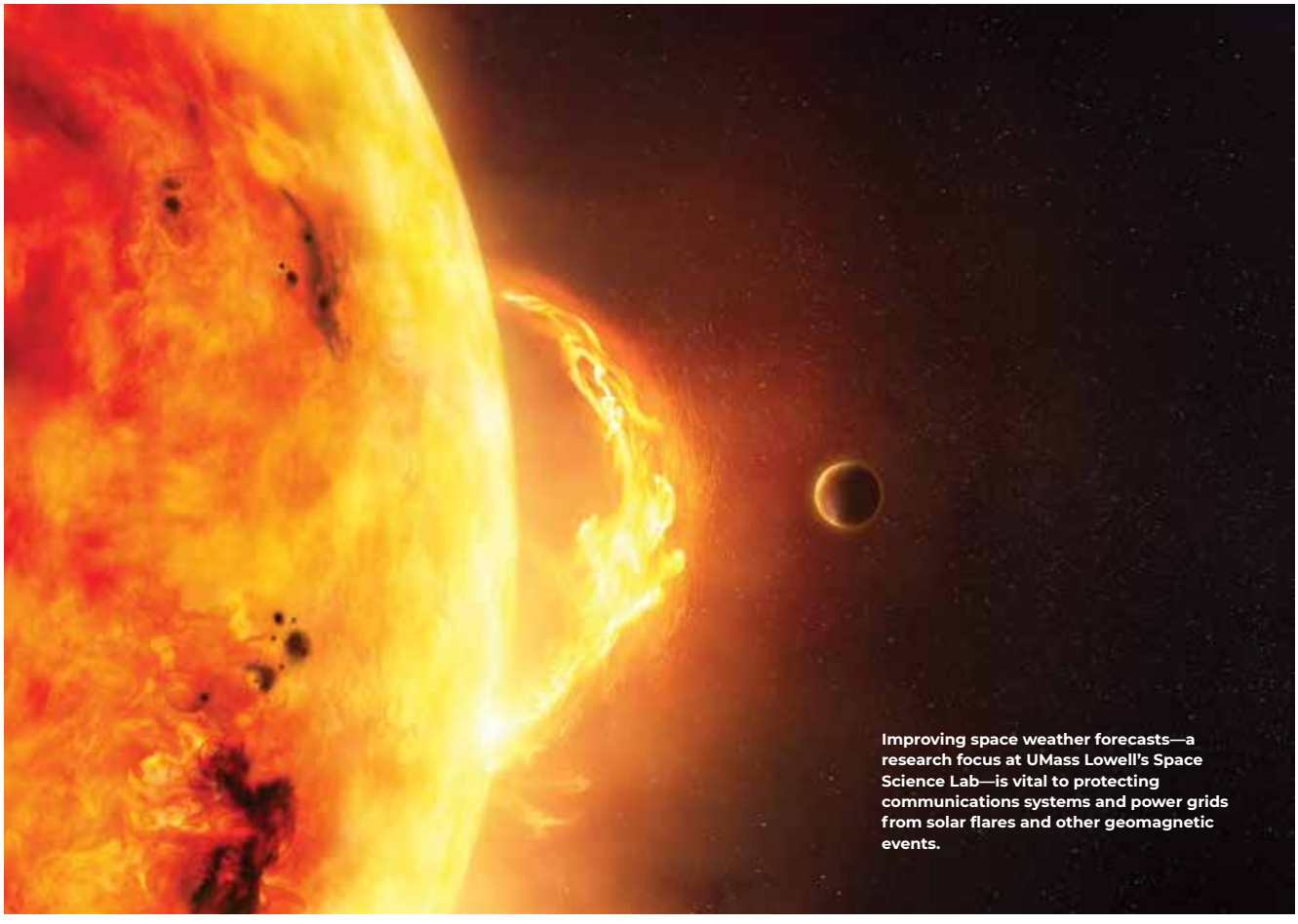
Pervasive awareness and monitoring

Over the coming decade, UMass engineers will continue to develop and evolve sensing technologies that can provide soldiers and command with a holistic view of the battlefield and the adversary's actions within it. In this way, we will contribute to DoD's goal of multi-domain operational dominance, which must rely upon increasingly pervasive awareness and monitoring within the zone of operations.

Satellite and drone-based remote sensing is one important aspect of this approach. As the number of satellites collecting high-resolution imaging data grows, the need for faster

Self-healing hazard suits

Chemical-biological protective clothing like the Army's Joint Protective Aircrew Ensemble is impervious to viruses, bacteria, and harmful chemicals like nerve gas. It seals soldiers off from contaminated environments—unless it is punctured as they navigate rough surroundings. UMass Lowell mechanical engineer Chris Hansen and his team, in collaboration with Triton Systems, Inc. and researchers at DEVCOM-SC, developed a self-healing coating that enables these garments to repair themselves, much as scratched skin scabs over. When torn, micro-capsules in the coating release fluid that seals the breach, protecting the soldier securely again.



Improving space weather forecasts—a research focus at UMass Lowell's Space Science Lab—is vital to protecting communications systems and power grids from solar flares and other geomagnetic events.

space-to-ground and inter-satellite data transfer will also increase. This unmet need for commercial as well as defense applications will be an important area of innovation going forward.

We must also strive for dominance in the electromagnetic spectrum—an increasingly contested and vital battle space—which will require cutting-edge sensing, communications, and electronic warfare capabilities.

Swarms are also coming: coordinated groups of small satellites, unmanned aerial vehicles, or undersea autonomous vehicles working cooperatively and across platforms for purposes including, but not limited to, intelligence, surveillance, and reconnaissance. The emergence of relatively inexpensive small satellite technology—an area of emphasis at both NASA and DoD—has launched a "space race" in satellite swarms: SpaceX has launched 955 of a planned 12,000 satellites in its Starlink constellation; Amazon has FCC approval for its own constellation of 3,236 satellites. Swarms present a number of technological challenges, including issues of control, data processing, and sensor fusion. UMass Dartmouth's **School for Marine Science & Technology** is already tackling many of these challenges in its work on undersea autonomous vehicles, and researchers at UMass Lowell are developing drone-based mesh networks that can be deployed for mobile coverage in GPS- or internet-denied areas.

Next frontier 4: Exploration in challenging environments

Space, complex terrestrial and coastal ecosystems, and the world of undersea exploration are all forbidding environments for research. Yet they hold profound implications for the way we live. Using advanced sensing technologies to explore these realms is a vital frontier for applied scientists in fields from electrical engineering to climate science.

One key research thrust: improving space weather predictions. Space weather events like geomagnetic storms can irradiate astronauts and airline travelers, knock out communications and navigation satellites, and damage power grids. (A March 1989 solar event collapsed the Hydro-Québec power grid, leaving 6 million people without power for hours; scientists warn that a repeat of a 1859 solar superstorm could cause worldwide blackouts and communications collapse today.)

Prior warning would allow NASA, airlines, and utilities to prepare, but space weather forecasts are unreliable today. UMass Lowell has been working on this problem for years, and has

built and deployed ionosphere-sensing space weather instruments on NASA's IMAGE satellite, the Air Force's DSX spacecraft, and 100 ground locations worldwide. Over the next ten years, researchers will continue to push toward a comprehensive monitoring program that uses ground instruments, unmanned aerial vehicles, satellites, and advanced diagnostics tools to provide actionable space weather predictions.

Other priorities for the coming decade include advancing analysis of hyperspectral imaging for space exploration and terrestrial mapping—work currently underway in UMass Amherst's **Remote Hyperspectral Observers Group**—and ocean modeling projects like those recently launched at UMass Boston's **Stone Living Lab** and UMass Amherst's **Northeast Center for Coastal Resilience** to investigate strategies for urban coastal resilience as the climate changes.

Autonomous exploration is particularly important in challenging environments, and UMass will continue advancing in that area as well, building on, for example, unmanned underwater vehicle cooperation and coordination work at UMass Dartmouth and drone-based explosives sensing in development at UMass Lowell.

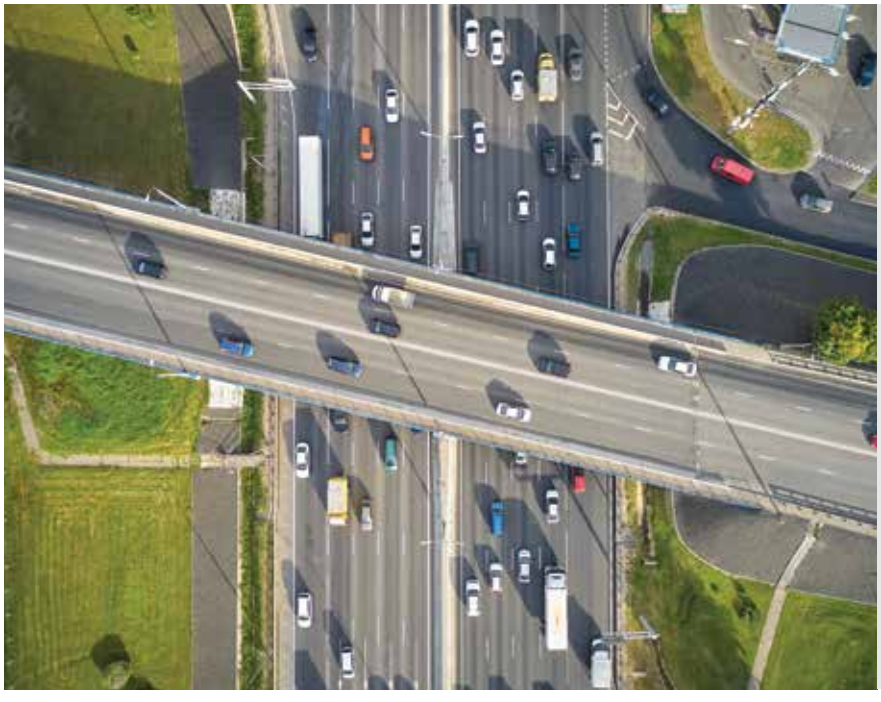
Next frontier 5:
Adaptable next-gen materials and manufacturing

Creating and evolving lightweight, adaptable, multifunctional materials to protect, power, and connect soldiers in challenging environments will continue to be an essential area of research in the coming decade and beyond.

We must harness high-powered computing to develop those materials faster and more cheaply than ever before. Several UMass research groups have launched projects related to the Materials Genome Initiative, a federal program involving both DoD and NASA that is driving the development of a national computing infrastructure for materials science that will slash both time and costs.

One example: With a $400,000 Designing Materials to Revolutionize and Engineer our Future (DMREF) grant (the NSF's arm of the Materials Genome Initiative), renowned UMass Amherst data science pioneer Andrew McCallum is using data-mining and machine-learning techniques to create an AI-enabled materials "cookbook" that scientists can use to pull tested materials-synthesis methods from the scientific literature. The tool will also predict optimal or new recipes for materials. An interdisciplinary team led by UMass Amherst industrial engineer Stephen Nonneman is using its $1.75 million DMREF grant to create flexible, protein-based nano-scale electrical wires for soft, stretchable electronics in wearable devices and soft robotics.

Another focus for defense over the next five to ten years will be agility in manufacturing—the creation of manufacturing systems that are adaptable (to change in demand or unforeseen crises like the COVID-19 pandemic), able to produce precision products at high speeds, and totally US-controlled. Deployable additive manufacturing systems would allow defense teams in the field to a produce needed tools and parts on demand.



Drone's-eye view

UMass Amherst and UMass Dartmouth researchers from the UMass Air team have received funding from the Massachusetts Department of Transportation to investigate how drones can help address the Commonwealth's transportation needs. The group, which works out of a facility at Westover Air Force Base, will assess the use of drones to monitor pavement condition, track vehicle speed, and support emergency services, and evaluate cybersecurity threats to the state's surface transportation.

Building the advanced technology workforce

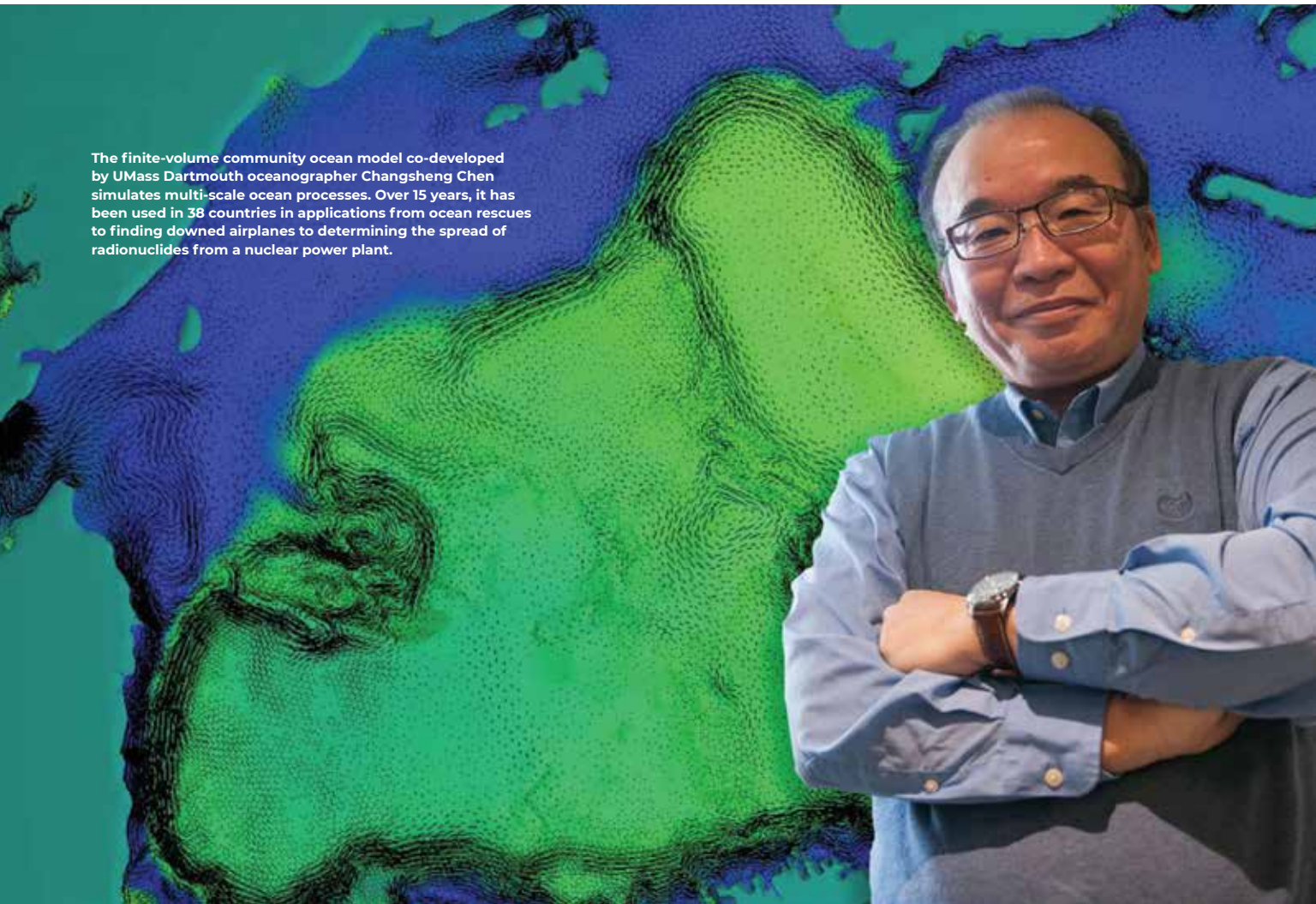
The aerospace, defense, and maritime industries are significant contributors to our global, national, and state economies.

The space economy alone has grown by 70 percent worldwide since 2010, reaching $423.8 billion globally and $27 billion in the US. Massachusetts—the eighth largest defense-contracting state in the US.—received $13.7 billion in DoD and DHS grants and contracts in 2019, generating $26.5 million of economic activity in the state. More than 20 percent of that funding was for projects related to search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing, sectors of strength for UMass.

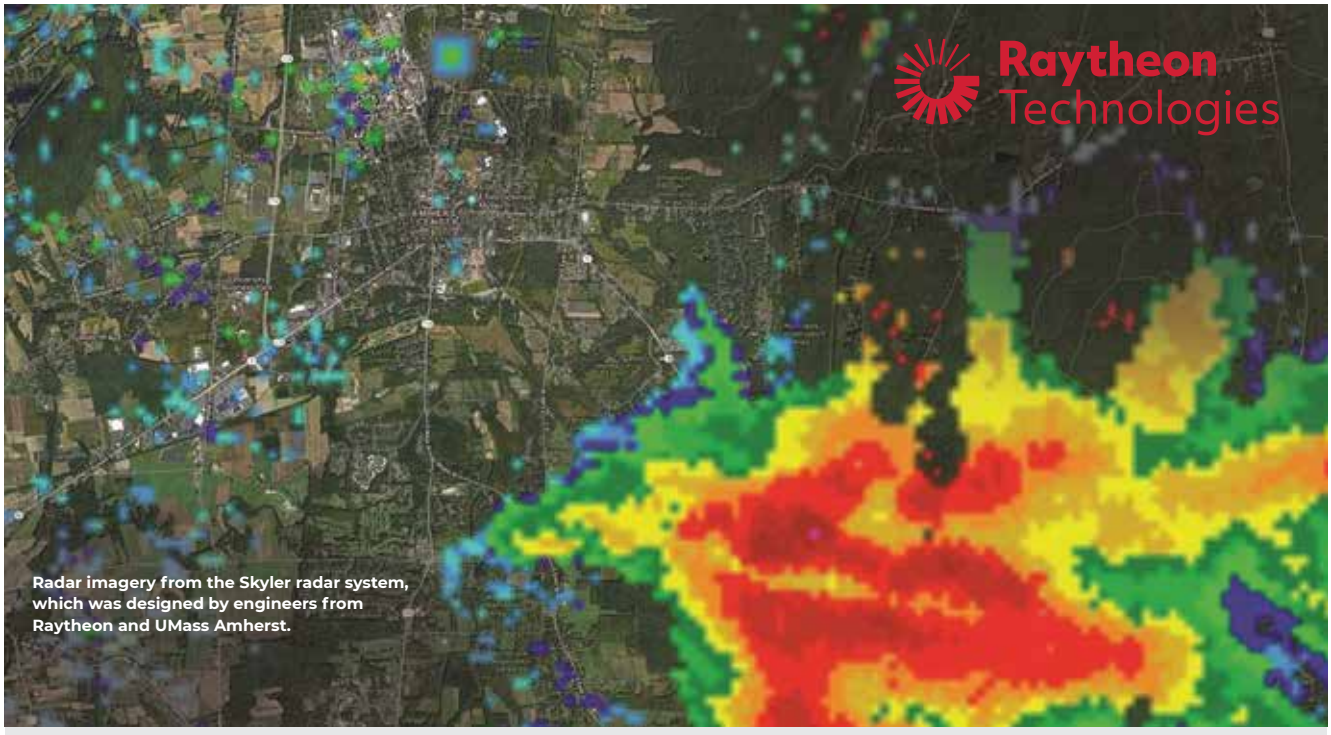
Today, more than 775,000 people in the Commonwealth work in fields related to aerospace, defense, and undersea technologies. Over the next ten years, demand for talent in these field is projected to grow by more than 5 percent, outstripping Massachusetts and US projections for employment growth overall. Between now and 2030, more than 75,000 related jobs are expected to open in the Commonwealth. These will be desirable positions; according to a recent UMass Dartmouth **Public Policy Center** report, jobs in the marine technology sector, for example, pay more than twice the average wage for Massachusetts workers.

In some sectors, the workforce need will be urgent. For example, highly skilled professionals in cybersecurity is a critical requirement of the DoD. The Center for Cyber Safety and Education forecasts a workforce gap of 1.8 million worldwide and 265,000 in North America by 2022 in this domain alone. The proliferation of small satellite technology also suggests a growing need for workforce with related training.

Where will workers qualified to fill these positions come from? In the Commonwealth, the majority will be graduates of the University of Massachusetts. In 2019, UMass awarded 17 percent of all related degrees conferred in the state, making the system the top producer of degree-holders in our region.



The finite-volume community ocean model co-developed by UMass Dartmouth oceanographer Changsheng Chen simulates multi-scale ocean processes. Over 15 years, it has been used in 38 countries in applications from ocean rescues to finding downed airplanes to determining the spread of radionuclides from a nuclear power plant.



Radar imagery from the Skyler radar system, which was designed by engineers from Raytheon and UMass Amherst.

Shared success

University-industry partnerships are powerful forces for advancing applied science.

Over a 40-year period, UMass Amherst helped build Raytheon's industry-leading radar program—and vice versa. In 1980, the university and Raytheon launched the Advanced Studies Program, through which annual cohorts of Raytheon employees spend a year on campus, earning master's degrees in microwave engineering from the university's electrical and computer engineering department. Today 400+ UMass Amherst alumni work at Raytheon, and the university's microwave engineering program is among the best in the country. Raytheon also partners in the department's research, and recently loaned the Microwave Remote Sensing Laboratory a prototype of the company's next-generation Skyler radar unit—which UMass Amherst researchers helped design—to use in the lab's storm-tracking research.

Raytheon engineers work closely with UMass faculty on both internal and government-funded research projects at the Raytheon-UMass Lowell Research Institute (RURI), an on-campus research partnership that develops additive manufacturing for defense electronics. Raytheon is a key member of the university's academic-industry Printed Electronics Research Collaborative, which has been successful in training future engineers for work in the defense, manufacturing, and aerospace sectors.

Massachusetts employment data in occupations related to defense/space/naval technologies

778.7k
Current MA employment in 250 related fields in 2020

5.3%
Projected growth in MA employment over next ten years (2020–2030)

75.4k
Projected estimated MA annual job openings (2020–2030)

UMass degree completions in fields related to defense/space/naval technologies

7,224
UMass degree completions in 114 related fields in 2018–2019

#1
UMass rank in degree completions among MA institutions

17%
UMass percent of all degree completions in related fields (2018–2019)

The University of Massachusetts' longstanding partnerships with the Army, Navy, Air Force, and NASA are spawning innovations with tremendous potential for human impact. These range from cybersecurity techniques that can ward off US adversaries and sexual abusers to ocean-process models that increase the safety of naval vessels and millions of people in India facing life-threatening monsoons.

As the University of Massachusetts looks to the next decade, we stand ready to join the Department of Defense and NASA in creating the technologies that will shape the future of defense, space exploration, rehabilitation, climate science, and more. We are confident that the mutual investments that we have made in collaborative research to date will continue to yield dividends in discovery, workforce development, job creation, and economic prosperity for the Commonwealth.

Government partnerships amplify the work of our faculty, staff, and students, taking it from the lab bench to the public realm, the battlefield, even the far reaches of space. Moreover, we know that these investments produce a plethora of technologies, materials, and data that benefit civilians in their everyday lives. The University of Massachusetts is proud to serve as a vital backbone for these advances, and looks forward to ongoing collaboration at the frontiers of applied science.

Seeing past star-shine

Imaging planets around even the nearest stars, says UMass Lowell's Center for Space Science and Technology director Supriya Chakrabarti, is like taking a picture from San Francisco of an insect flying near a shining lighthouse on Cape Cod. But with a $5.6 million grant from NASA, the center has developed a high-contrast imaging system with a space telescope and software tools capable of imaging very faint objects next to extremely bright ones. High-contrast imaging has applications beyond the search for exoplanets; turned toward earth, it could see dim object objects of interest on the ground that are obscured by bright lights.

Dig deeper

Aerospace, defense, undersea technologies, and remote sensing research is happening in labs and centers across the University of Massachusetts. Visit the links below to find out more about some of the work going on across the state and the researchers conducting it.

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Cybersecurity Center (Dartmouth)
www.umassd.edu/cybersecurity-center

Cyber Range (Lowell)
www.uml.edu/sciences/computer-science/cyber-range

Cybersecurity Institute (Amherst)
infosec.cs.umass.edu

Human-performance augmentation and sensing
Harnessing Emerging Research Opportunities to Empower Soldiers (Lowell)
www.uml.edu/research/HEROES

New England Robotics Validation and Experimentation Center (Lowell)
www.uml.edu/research/NERVE

Mechatronics and Robotics Research Lab (Amherst)
blogs.umass.edu/mrrl

Human Robot Systems Lab (Amherst)
www.hrs-lab.org

Massachusetts Medical Device Development Center (Lowell and Worcester)
www.uml.edu/research/m2d2

IALS Center for Personalized Health Monitoring (Amherst)
www.umass.edu/cphm

Aerospace and undersea sensing and communications
Lowell Center for Space Science and Technology (Lowell)
www.uml.edu/research/locsst

SSL Space Science Laboratory (Lowell)
ulcar.uml.edu

Schaaf Lab (Boston)
www.umb.edu/spectralmass

Optical Oceanography Laboratory (Boston)
www.umb.edu/spectralmass

Stone Living Laboratory (Boston)
stonelivinglab.org

Antennas and Propagation Lab (Amherst)
www.ecs.umass.edu/ece/labs/antlab/APLab

UMass Air (Amherst, Dartmouth)
www.umasstransportationcenter.org/umtc/UMassAir1.asp

Engineering Research Center for Collaborative Sensing of the Atmosphere
www.casa.umass.edu

Microwave Remote Sensing Laboratory
mirsl.ecs.umass.edu

Multi-domain awareness and operation
Antennas and Propagation Lab (Amherst)
ece.umass.edu/antennas-and-propagation-lab

Center for Collaborative Adaptive Sensing of the Atmosphere (Amherst)
www.casa.umass.edu

Microwave Remote Sensing Laboratory (Amherst)
mirsl.ecs.umass.edu

Applied Research Corporation (Lowell 501c3)
umlarc.org

Lowell Research Institute (Lowell)
www.uml.edu/research-institute

High-performance materials and sensors for challenging environments
Harnessing Emerging Research Opportunities to Empower Soldiers (Lowell)
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Polymer Science and Engineering Department (Amherst)
www.pse.umass.edu

Advanced Digital Design and Fabrication (Amherst)
mass.edu/ials/addfab

University of Massachusetts

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