VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS

STRATEGIC RESEARCH FRAMEWORK

The UNIVERSITY *of* OKLAHOMA

VICE PRESIDENT FOR RESEARCH AND PARTNERSHIPS

CONVERGENCE

A vision for transdisciplinary research and creative activity with lasting social impact at the University of Oklahoma.

INTRODUCTION

We live in a time when global social megatrends present the planet with wicked problems that are broad, challenging, and complex. Ten billion people; rising inequality; pandemics and health disparities; doubling, and even tripling, energy demand; changes in weather patterns and impacts of climate change; world-wide need for access to clean water; geopolitical shifts and international conflict; asymmetric threats and unconventional sources of insecurity and disinformation. We face many challenges to sustain and improve our planet's quality of life, today and for decades to come.

Nonetheless, we live in an era of tremendous promise and abundance. Today more than ever, the rapid and global pace of innovation and the democratization of technology are bringing opportunity and a higher quality of life to many around the world. While much work remains to eliminate inequities and further democratize access to technology, the future is promising, and research universities such as the University of Oklahoma have a strong role to play in making this future a reality.

The answers to these global challenges require an ambitious research and development approach that converges big science and engineering ideas with a comprehensive understanding of underlying human, social, business, and policy dynamics. True solutions, with positive social impact, require working across and beyond traditional academic boundaries that often separate humanists, artists, designers, business leaders, and social scientists from natural scientists, engineers, and technologists.

Leading universities around the U.S. and the world are disrupting themselves and making a strong, strategic push to be at the forefront of this convergence of fields of knowledge and research. State and federal research agencies, as well as philanthropies, are developing

GRAND CHALLENGES

programs that increasingly focus research funding into big idea programs that leverage the power of convergence.

As a flagship public institution that is keenly focused on societal impact through research and creative activity, OU is uniquely positioned to bring disparate academic disciplines, from the core STEM fields to the humanities and fine arts, together to foster creative, comprehensive solutions to global challenges. In our vision for research and creative activity, researchers move beyond and across traditional academic boundaries, collaborating across disciplines and globally with other universities, policymakers, economists, and business leaders to create solutions for a better world. Our goal is to transcend academic disciplines and bring all of OU's institutional strengths together to tackle global challenges and accelerate the delivery of practical solutions that impact society in direct and tangible ways.

This ambitious vision is encapsulated in, and consistent with, the university's recently published Lead On, University Strategic Plan. This plan, which was approved by the OU Board of Regents in July 2020, lays out the university's raison d'être – "We Change Lives," as well as a series of pillars with associated

CONVERGENCE
Our Vision of Impact

Researchers at the University of Oklahoma will create new knowledge and drive convergent solutions that impact global grand challenges.

At OU, researchers, artists, and designers will move beyond traditional boundaries, collaborating across disciplines and with policy makers and business leaders to create solutions for a better world.

strategies and tactics that define precisely how we are going to realize our vision for the future.

Pillar 5 of OU's Lead On Strategic Plan is titled "Enrich and Positively Impact Oklahoma, the Nation, and the World Through Research and Creative Activity" and lays out the university's ambition to change people's lives through discovery, innovation, and creative works. The pillar defines four strategic areas of research focused on grand challenges in aerospace, defense, and global security; environment, energy, and sustainability; the future of health; and society and community transformation. These so-called strategic research verticals represent a way to encapsulate some of the most wicked grand challenges we face as a planet in the 21st century.

In order to explore where OU's strengths and faculty interest can converge with maximum impact around these strategic research verticals, we convened a team of faculty across campus to participate in a series of strategic planning discussions over several months. The team members were nominated by their deans and the Faculty Senate Executive Committee, and included faculty from all three OU campuses. The teams for each strategic research vertical are listed at the end of this document. The effort was coordinated by members of the strategic planning firm Thinkenomics. The teams solicited input from and shared their progress with faculty across campus in a series of online town hall meetings, and this document represents the results of those intensive efforts.

The document lays out in great detail a full strategic plan for the future of these four "vertical areas" at OU. The plan outlines the mission and vision for each area, along with the sub-areas where we plan to focus our effort in order to have maximum impact (we call these the strategic research sub-verticals). The plan also lays out the detailed goals and objectives for each area (i.e., how are we going to succeed), which, for consistency with the Lead On plan, we label as strategies and tactics.

Naturally, there exist tremendous synergies and complementary areas across these strategic themes. Nothing in the world we live in exists in a silo, and our comprehensive strategy strives to identify and exploit those synergies in order to build a plan that is truly transformative and transdisciplinary.

STRATEGIC THEMES
DRIVING SOLUTIONS TO GLOBAL CHALLENGES

STRATEGIC RESEARCH VERTICALS

AEROSPACE, DEFENSE, AND GLOBAL SECURITY

Oklahoma Aerospace and Defense Innovation Institute (OADII)

Gene Kirkland, Executive Director

ENVIRONMENT, ENERGY, AND SUSTAINABILITY

Institute for Resilient Environmental and Energy Systems (IREES)

Tim Filley, Director

THE FUTURE OF HEALTH

Integrative Life Sciences Institute (ILSI)

Director to be appointed in FY23

SOCIETY AND COMMUNITY TRANSFORMATION

Institute for Community and Society Transformation (ICAST)

Shane Connelly, Director

CROSS CUTTING FOUNDATIONS

- **Data Institute for Societal Challenges (DISC)**
  David Ebert, Director
- **Center of Optimal Materials for Emerging Technologies (COMET)**
  Venky Venkatesan, Director
- **Institute for Public Policy Research and Analysis (IPPRA)**
  Hank Jenkins-Smith, Co-Director | Carol Silva, Co-Director
- **Advanced Radar Research Center (ARRC)**
  Robert Palmer, Executive Director

As a top-tier research university, it is also critically important that the academic disciplines and research infrastructure that provide the basis upon which to create and translate new knowledge into solutions to society's challenges be as strong as possible. Without that strong foundation in fundamental and applied research, our transdisciplinary work to impact society's grand challenges through the strategic research verticals will not succeed. Therefore, in addition to these pillars, we are also starting to engage with colleges across campus to think about what enabling, cross-cutting academic research capabilities need to be strengthened at OU in order to provide the strongest possible integrated system of research and creative activity.

Accomplishing these ambitious goals requires continued faculty growth and an ability to recruit top faculty, student, and staff talent into the university in critical areas of strategic focus. To this end, this research verticals strategic plan is closely coordinated with the Provost's and deans' hiring initiatives. Pillar 1 of the Lead On plan lays out the foundation for success in meeting the university's ambitious goal of becoming a "Top-Tier Public Research University" and discusses how new strategic faculty hires and increased doctoral student and staffing levels will be key areas of focus for the next years. Through close coordination and cooperation between the offices of Provost, the deans, and the Vice President for Research and Partnerships, we will ensure success in the implementation of our strategic plans.

Our vision for the future of OU is ambitious. As the flagship university in the state, we will continue to grow as a regional, national, and global force that positively impacts society through education, community service and engagement, and research and creative activity. When we succeed in moving beyond traditional boundaries, collaborating across disciplines and with policymakers and business leaders to create new knowledge and drive convergent solutions that impact global grand challenges, we will no doubt succeed in our ambition to leave the world a better place. Everything else will follow.

Tomás Díaz de la Rubia
Vice President for Research and Partnerships
University of Oklahoma

EXCELLENCE SERVICE INNOVATION
INCLUSIVENESS DIVERSITY
COLLABORATION RESPECT

STRATEGIC RESEARCH VERTICALS

COLLECTIVE VALUES

CURIOSITY CREATIVITY TRUST
HUMILITY TRANSPARENCY
TEAMWORK INTEGRITY

AEROSPACE, DEFENSE, AND GLOBAL SECURITY

STRATEGIC PLAN

AEROSPACE, DEFENSE, AND GLOBAL SECURITY

WHERE WE'RE GOING TO HAVE AN IMPACT

A strategic investment in aerospace, defense, and global security will unite the resources of the University of Oklahoma as a major research university, with the unique network of industry and government partners to advance security, liberty, and prosperity for our state, nation, and world. We are poised to grow to national prominence in four crucial areas: Radar Innovations, Sustainment and Modernization, Advanced Technologies, and International Security policy.

OU's Advanced Radar Research Center is the largest university-based radar center in the nation. Next-generation radio frequency sensing and communication systems address a range of national security issues like spectrum superiority

to extreme weather associated with climate change. Oklahoma is home to several military installations, including the headquarters for the Air Force Sustainment Center. Through new partnerships, we would provide sustainment and modernization support through expertise in embedded software systems and advanced manufacturing technologies. Building on expertise in OU's Center for Autonomous Sensing and Sampling, and the Center for Quantum Research and Technology, we address two areas of critical importance to the U.S. Department of Defense, unmanned systems and applications stemming from quantum science. Global security challenges require actionable policy recommendations. By leveraging existing OU strengths in cybersecurity policy, climate science, and contextual analysis of emerging technologies, we will address global security challenges including climate change and emerging technologies like artificial intelligence and quantum.

Ensuring National and Global Security through Radar Innovations

Ensuring national and global security into the future requires continuous innovation for an advanced arsenal of defense infrastructure. Sensing systems are a vital component of all Department of Defense platforms including

aircraft, ships, tanks, satellites, missiles, and more. Radar is an indispensable sensor because of its long-range, day/night, and all-weather capability. As a result, projections show that by 2027 the size of the global military radar market will exceed $20 billion. However, global challenges in the area of sensing for the U.S. and its allies are growing, including the increased technical sophistication of our near-peer adversaries, spectrum competition regarding 5G and 6G communications, and an aging DOD workforce.

Through strategic investments over the last two decades, OU has created the nationally-recognized Advanced Radar Research Center. The ARRC has developed an exemplary reputation for innovations in radar. By leveraging and growing the ARRC's infrastructure, personnel, established sponsors, and private-sector contacts, we intend to become the nation's academic leader in defense-related radar. By realizing this bold vision, we will provide a major contribution to the national defense, which directly impacts many societal challenges. Workforce development is another vital impact, and we intend for OU's students to be leaders in the defense industry for decades to come. Likewise, our developments will continue to be an important part of OU's weather community through radar's use for observing extreme weather events.

After more than 50 years of partnership with NOAA, we have built a vibrant weather monitoring and prediction ecosystem in Norman that includes government, academic, and private-sector leaders. The ARRC grew from this ecosystem and has developed the capability to design, fabricate, and field the most advanced weather radars in the world. These radars are largely based on bleeding-edge technologies that are gaining the attention of the DOD, which is the primary reason the ARRC's research and development has grown exponentially over the last several years in the DOD space, including current sponsors such as the Navy, Air Force, Army, and DARPA.

Now is the perfect time for OU to leverage these advancements to become the academic leader in defense-related radar.

Supporting the Defense Sustainment and Modernization Enterprise

Sustaining DOD platforms is key to maintaining the readiness and operational capability of the U.S. military. Of the phases in the DOD acquisition process, the sustainment phase is the most costly and lengthiest, often spanning several decades. Through evaluation and utilization of new technologies, we will develop innovative approaches to drive down the cost of sustainment and provide innovative enhancements to the functionality of legacy systems.

We are developing and strengthening partnerships with both commercial and government entities within the sustainment community in Oklahoma. We maintain a formal educational partnership agreement with the Oklahoma City Air Logistics Complex and interact routinely with the complex and the Air Force Sustainment Center headquarters at Tinker Air Force Base. Through collaborative partnerships, we have identified two of the sustainment community's most critical areas of need, advanced manufacturing and embedded software systems, and have aligned our strategic hiring and infrastructure development plans to expand

our capabilities and capacities in these areas. Our partnership model delivers impacts at the national, state, and university levels. By creating more efficient and cost-effective methods for sustainment and modernization, our military can retain the technical superiority required to deter potential adversaries.

The aerospace and defense sector is currently the second-largest contributor to the state economy. Applied research and development in this sector also produces a highly skilled workforce for Oklahoma and increases the portfolio of DOD-funded research at the university. Our proximity to and alignment with the military sustainment community in Oklahoma gives us a competitive advantage. Our long-standing partnerships at the local level, coupled with strong executive leadership and a strategic vision at OU, provide us with unprecedented opportunities. OU is committed to continued growth and investment in support of state and national needs and priorities in the realm of DOD sustainment.

Addressing Emerging Security Challenges through Advanced Technologies

The White House Office of Science and Technology Policy has identified quantum technology, artificial intelligence, and advanced manufacturing as "Industries of the Future," which will define future focus areas and funding directions for the DOD and other federal entities. These advanced technologies are vital to address current and emerging national and global security challenges. The resulting game-changing technologies will provide unique advantages and enable an agile response to ever-growing threats.

We will build on and integrate work at existing centers at OU, such as the Center for Quantum Research and Technology, the Data Institute for Societal Challenges, and the Center for Autonomous Sensing and Sampling, to establish OU as a national player in these areas. Innovative convergence research that will define new fields of exploration will extend this solid foundation. To further enhance our capabilities, we will continue to develop partnerships with industry and national laboratories. To achieve our goals, we will make strategic hires at the interface of these critical areas and develop state-of-the-art research facilities.

Our convergent approach to advanced technologies will lead to novel, deployable defense and security capabilities. Such advances will enhance global and national security through innovations in telecommunications, navigation systems, and sensing capabilities. Additionally, through our early alignment with the Industries of the Future, we will become a key player in these critical national and economic security areas. This will attract investment and new businesses to Oklahoma and will position OU as a key player in developing the workforce of the future.

OU is likewise well-positioned to define new directions for emerging technologies. The existence of centers with expertise in quantum science, artificial intelligence, and advanced manufacturing affiliated with a single institute will provide a unique environment to forge novel research directions at the interface between existing and emerging technologies.

For example, the convergence of radar and quantum science, or artificial intelligence and quantum science, will lead to new and enhanced defense capabilities necessary to tackle global security grand challenges.

Developing Innovative and Agile International Security Policy Solutions

Global security challenges demand coherent strategies coupled with actionable policy recommendations. The U.S. and the world are confronting urgent challenges, including the re-emergence of near-peer geopolitical competition among great powers, disruptive emerging technologies, climate change, and pandemic disease. These circumstances require innovative international security policy thinking that is firmly grounded in sound research, yet able to anticipate and respond to rapidly evolving threats and opportunities. This thinking underpins the revitalization of a stable rules-based international order and renewal of American global leadership.

We generate world-class international security policy research by pairing the university's areas of excellence in technological research and development with expertise in international security policy. We create knowledge that crosses disciplinary boundaries to ensure that technological systems are ready for effective deployment in a rapidly evolving policy and geopolitical landscape. We also ensure that policymakers are equipped to anticipate and respond to future disruptive advances, transforming threats into opportunities.

We fulfill the promise of OU's motto – for the benefit of the citizen and the state. We do so by building an array of government, industry, and civil society partnerships. Our work ensures that American national security strategy and policy remain innovative and agile, outpacing peer competitors and providing essential global leadership. We also advise state and local governments, assisting them in serving their indispensable role in securing the homeland. We connect Oklahoma companies to national policy discussions, helping them identify and win business opportunities in the defense and security sector. Finally, we provide transformative educational opportunities to Oklahoma students, preparing them for careers as leaders in national and international security.

We bring together talent and resources from across the university and a unique network of industry and government partners to do what cannot be done elsewhere. From work on spectrum allocation policy at the DOD's 5G testbed at Tinker AFB, to research on cybersecurity policy for government and industry partners in cyber-governance labs, to studies of emerging technologies in a human context, we provide holistic solutions to complex problems. Together, we are poised to develop 21st century policy solutions responsive to the needs and concerns of the American heartland.

ENVIRONMENT, ENERGY, AND SUSTAINABILITY

STRATEGIC PLAN

ENVIRONMENT, ENERGY, AND SUSTAINABILITY

WHERE WE'RE GOING TO HAVE AN IMPACT

We will integrate and expand on OU's expertise in weather, water, environment, energy technology, climate change, infrastructure, policy, business, entrepreneurship, and community engagement to develop novel solutions that help drive the transformation of the U.S. energy sector while reducing greenhouse gas emissions and enabling a net-zero carbon economy by 2050. Our solutions will increase community resilience and sustainability. To address this grand challenge, we focus on complex interactions among the hydrosphere, atmosphere, geosphere, and biosphere in the critical zone, the thin layer from the shallow subsurface to the lower atmosphere. It has harbored life since its inception, is critical for human welfare, and is threatened by anthropogenic change. Our transdisciplinary research framework focuses on three key research areas: Observing and Predicting Earth Systems, Transforming Energy and Infrastructure Systems, and Co-generating Community Resilience and Environmental Justice.

Observing and Predicting Earth Systems

The Global Risks Report 2020 of the World Economic Forum identified extreme weather, climate action failure, natural disasters, biodiversity loss, and human-made environmental disasters as the top five global risks. All fall into the environmental category, and the report notes that “it is the first time in the survey’s history that one category has occupied all five of the top spots.” The report further highlights the interconnected nature of these risks and calls for a multi-stakeholder mitigation approach. Recognizing these findings and the critical role of weather, climate, water, and ecosystem predictions for many sectors of our society, the U.S. Office of Science and Technology Policy identified “Earth System Predictability” as a top budget priority.

OU has existing strengths in weather, climate, water, and ecosystem science, but these strengths are fragmented by siloed academic departments housed in different colleges. To facilitate a compelling research agenda focused

on Earth system predictions, we propose to invest in a transdisciplinary culture and organization that provides institutional support to teams of scholars who embrace the complexity of the Earth system and seek convergent solutions linking the biosphere, geosphere, hydrosphere, and atmosphere in the critical zone of life. We envision a framework that integrates multiscale modeling, observations, and data science to advance predictions of weather, water, climate, and ecosystems. We will expand our partnerships with federal agencies, including NOAA, NASA, DOE, DOI, and the USDA to collaborate on increasingly ambitious, high-impact projects.

Anthropogenic climate change is driving rapid shifts in weather and water hazards as well as declines in biodiversity and ecosystem services. These impacts threaten the resiliency of Great Plains communities, like those in Oklahoma, that are central to energy production and the transition to a net-zero carbon economy. OU is emerging as a regional and national leader at the interface of weather, water, climate, and ecosystems. Targeted investments focused on Earth system observation and prediction will propel OU to become a national leader in forecasting future environments and working with impacted communities in the state, nation, and internationally to co-generate strategies that increase resilience.

Weather and climate research are critical for OU's research landscape and Oklahoma's economy; nearly 50% of OU's research expenditures currently are in this sector. The partnership with NOAA in the National Weather Center, NASA's GeoCarb mission, the USGS South Central Climate Science Adaptation Center, and OU's significant investments in the Advanced Radar Research Center and Data Science Institute for Societal Change are important assets which attract private companies to OU's research campus. OU is well positioned for the leap to become a global leader in Earth system observation and prediction, capitalizing on its existing expertise in weather, climate, water, ecosystem, and data science. Further, research in these areas is of high societal relevance. The southern Plains are severely impacted by climate and weather hazards. These challenges call for innovations that enable Oklahoma's economy and communities to become resilient to rapid environmental changes.

Transforming Energy and Infrastructure Systems

Society faces an existential threat from a changing climate linked to anthropogenic carbon dioxide emissions. In addition, population and economic growth are projected to cause a 50% increase in energy use over the next 30 years, further straining aging infrastructure components including the built environment. Decarbonizing solutions that lead to a net-zero energy economy are necessary to mitigate future risks by reducing carbon footprints while providing an equitable supply of energy for the world.

Our research approach focuses on transforming energy and infrastructure systems to become more sustainable in ways that meet the needs of a growing population, enhance resilience, and limit environmental and human impacts. We will find practical solutions to obtain equitable carbon negative solutions, capitalizing on electricity, heat, and hydrogen as the energy carriers of the future. We will infuse smart infrastructure

technology into the design and operation of the built environment to optimize performance and minimize cost. We will take a systems-based approach that treats interconnected systems as a whole, apply a 'design for life' concept to infrastructure policy, and engage stakeholders to seek socially acceptable, economically viable, and technologically innovative solutions while preserving ecosystems.

Achieving our aim of transforming energy and infrastructure systems utilizing a diverse energy portfolio and smart technologies will have profound environmental and societal impact. OU's energy and infrastructure expertise and Oklahoma's considerable wind, biomass, and natural gas resources uniquely position OU to lead a transition to a net-negative, restorative carbon economy in the state, region, and nation. This initiative will grow OU's research enterprise and elevate the university's academic standing. The modernization and diversification of energy sources is critical for revitalizing the state's economy by attracting new investments, building new enterprises, and increasing employment opportunities.

OU's research focus on energy and infrastructure has stemmed from Oklahoma's rich, diverse energy resources and the need for infrastructure resilience to natural hazards across the state. OU is home to federally-funded centers such as the Oklahoma Established Program to Stimulate Competitive Research Center on socially sustainable solutions for water, carbon, and infrastructure resilience in Oklahoma sponsored by the National Science Foundation, and the Southern Plains Transportation Center. OU also has a history of collaborative partnerships between science, technology, engineering, and mathematics fields and applied social scientists at the Institute for Public Policy Research and Analysis (formerly called the National Institute for Risk and Resilience) and Center for Applied Social Research, which makes us an ideal location for transdisciplinary convergence research. We are experienced in engaging stakeholders to create solutions that are socially acceptable, economically viable, and technologically innovative. Our track record of embedding research findings in all educational activities to create next-generation thought leaders is an additional asset.

Co-generating Community Resilience and Environmental Justice

Mitigating the risks posed by extreme weather, climate action failure, natural disasters, biodiversity loss, and human-made environmental disasters requires innovative scientific solutions built upon world-class observatories, systems modeling capabilities, and transformative infrastructure development. However, without a robust social science and humanities focus on human behavior, human institutions, and belief systems, it will be impossible to transform at-risk communities to not only effectively use available resources to respond to and recover from adverse situations, but to grow and thrive in the future. Patterns of environmental injustice have made communities of color and indigenous peoples disproportionately vulnerable to environmental harm and excluded from the benefits of new energy technologies. At the same time, these communities have often not had equitable participation in decisions that affect their lives and lands. We will work to offer solutions that enhance

resilience, create new economic opportunities, and guard against creating new unjust outcomes.

Using social science and humanities-driven data collection, modeling, and theoretical frameworks, we will provide the knowledge necessary to support and build resilient communities. We approach this work with the understanding that many communities already hold knowledge systems that are crucial to a more environmentally just and resilient future. Respectful and reciprocal community partnerships are necessary for all research in these domains, as historic patterns of exploitation have eroded trust among many communities of color and indigenous peoples. Our approach begins from these understandings about the real-world impact and will enable a co-production of knowledge between citizens and researchers as we build a future with new economic opportunities and work to rectify a legacy of environmental injustice.

We will connect our strategic research areas of focus with community-supported and informed social science and humanities scholarship to further community resilience and improve environmental justice outcomes. With meaningful commitments to community-based methods and reciprocal partnerships, OU researchers can provide benefits to our stakeholder communities by offering research that targets stakeholder-defined problems and offering stakeholder-informed solutions that help counter the impacts of extreme weather, climate action failure, natural disasters, biodiversity loss, poor infrastructure, and human-made environmental disasters.

OU is uniquely positioned to succeed in these endeavors due to our strengths in engineering, business, weather, water, climate, and ecosystem science, complemented by strengths in Native American studies, public policy, humanities, and social science. Oklahoma, with its unique All-Black towns and in the heart of Native America, provides opportunities to elevate unheard voices and leaders within Oklahoma's minority communities. We will promote governance and economic systems that recognize and rectify unjust energy commodity chains and enact community knowledge systems to create sustainable futures for all peoples.

THE FUTURE OF HEALTH

STRATEGIC PLAN

THE FUTURE OF HEALTH

WHERE WE'RE GOING TO HAVE AN IMPACT

Global challenges that affect human health and well-being are rooted in a complex and ever-evolving web of sociodemographic and biospheric systems. These challenges are broad and pervasive in Oklahoma, as evidenced by the state's unenviable position at or near the bottom of the national rankings in most health indicators. Oklahoma scores poorly in overall health, health care system performance, and population health disparities. Building on existing strengths across its three campuses, OU is poised to be at the forefront of transdisciplinary convergent research endeavors that will drive fundamental discoveries related to: clarifying mechanisms and cellular processes to develop new therapies and technologies to combat and eradicate deadly diseases, such as diabetes and cancer, that intersect with clinical and translational research at OU Health; monitoring, predicting, and responding to pathogenic threats, including drug-resistant bacteria, rapidly evolving viral pathogens, environmental risk factors, and the geographical expansion of vector-borne and zoonotic diseases; and addressing growing health-related disparities by partnering OU expertise with industry and Oklahoma's diverse communities.

Eliminating Health Disparities

The U.S. exhibits striking disparities across groups and regions in health outcomes including chronic conditions, disease states, and life expectancy. These disparities are shaped by structural processes of inequality, discrimination, and an economic system that limits access to needed resources in the built, natural, and social environment. The lack of resources, as well as experiences of adversity, lead to biological processes that impact all levels of organismal functioning including gene expression, neurological structure and function, the microbiome, and metabolic processes. Reduced access to resources and increased adversity also shape health behaviors, which combine with biological processes to perpetuate and exacerbate demographic and socioeconomic disparities that negatively impact health outcomes. These poor and disparate health

outcomes are an urgent societal challenge, with billions of dollars in economic costs for the U.S. each year as well as immeasurable costs for humanity.

Addressing the grand challenge of health disparities requires a dynamic and innovative approach essential to provide resources and build individual and systemic resilience in partnership with affected communities. Large-scale, transdisciplinary and multi-method data collection and analysis is needed to identify existing patterns and the societal and biological mechanisms that drive health disparities. Micro-processes shaping health outcomes can be unpacked by leveraging laboratory-based cellular and animal research. Together, these efforts will converge to identify and implement interventions to reduce health disparities and improve health outcomes for all.

Uncovering and addressing mechanisms driving poor outcomes, particularly for marginalized populations, will lay the foundation for important policy and public health initiatives to increase opportunity and reduce the impacts of adversity. Providing improved resources and opportunities will support the adoption of positive health behaviors and facilitate healthy development across the human lifespan. Together, these interventions will shore up the health of all people and reduce increased risk of morbidity and premature mortality for marginalized populations.

OU's disciplinary strengths in social and natural sciences and engineering, combined with expertise in disease state prevention and treatment, provide a strong foundation for this strategic investment. Vibrant existing community partnerships with urban, rural, and tribal communities offer unique opportunities to connect converging disciplinary expertise to communities and frontline staff to ensure the feasibility of efforts to intervene on health disparities. As promising interventions are identified, OU experts in public policy and business are poised to

partner with translational scientists at OU Health to design, advocate for, implement, and scale up promising new strategies. Oklahoma is a state with persistent poor health rankings, and some of its communities are living examples of worse outcomes for minoritized and impoverished groups. We will harness the expertise across our university, from the humanities and social sciences to the biological and health sciences and other STEM areas, to better determine and address the health needs of these populations. As disciplines from across OU converge to address these grand and persistent challenges, we all win as we support the health of all Oklahomans and provide a model for the nation.

Molecules to Medicine: discoveries transforming therapeutics and diagnostics

The molecular identification, characterization, and manipulation of cellular pathways that lead to disease is a global grand challenge in the life sciences. Additionally, the development of advanced technologies for the accurate detection and diagnosis of chronic diseases is critical, especially in Oklahoma, as it has one of the nation's highest cancer mortality rates and ranks in the top five states for diabetes and obesity. Furthermore, Oklahoma's Native American population has a higher risk of developing diabetes and is almost twice as likely as non-Hispanic whites to die from diabetes. Research in molecular and cell sciences, technology development, and technology transfer will enable

OU to translate fundamental discoveries into new leads for drug development, new and improved diagnostic capabilities, and ultimately disease treatment.

We will leverage OU expertise in: the development of basic natural and physical sciences, data science, and engineering; the Office of Technology Commercialization and strengths in product management through the business college; and partnerships across the university's campuses. Fundamental disease-oriented research on the Norman campus significantly complements clinical research trials and patient care provided at the Stephenson Cancer Center and Harold Hamm Diabetes Center. Other areas of cross-campus research strengths include neuroscience, infectious diseases, antibiotic resistance, the gut microbiome, and natural medicines. These areas also support a strategic focus on fundamental research that will pave the way to improved health outcomes. An important component of this approach is the determination of how social, economic, and environmental factors affect drug efficacy at the molecular level and, in turn, impact pathophysiology and patient responses.

It is well known that early detection and treatment of cancer, diabetes, and many other diseases decreases the mortality rate by allowing earlier therapeutic intervention. The translation of fundamental research to products and services that may be deployed in the marketplace is well supported by the applied research and capabilities of OU's top-25 business college, including the Center for the Business of Healthcare and the Tom Love Innovation Hub. For example, understanding fundamental mechanisms whereby nutritional interventions impact our gut microbiome has a direct clinical translation for preventing and treating diabetes and obesity risk, as well as cancer therapeutics. Our goal is to develop disease-focused research at OU into a nationally recognized powerhouse in both the basic science and the translation of that science into products and services that will improve the lives of people in Oklahoma and beyond.

OU-Norman researchers are uniquely positioned to focus on the rational development of new drugs and technologies that improve the human condition, particularly in areas of emphasis that align with the OU Health Sciences and OU-Tulsa campuses, such as cancer and diabetes. Our research strengths are focused on understanding the molecular basis of disease to identify druggable cellular targets, develop drug leads, and advance technology for disease diagnosis and treatment. Our vision is to join forces with our entrepreneurial colleagues to leverage new insights into diabetes, cancer, and infectious diseases along with the tools to invent and launch revolutionary new diagnostics and treatments for these diseases.

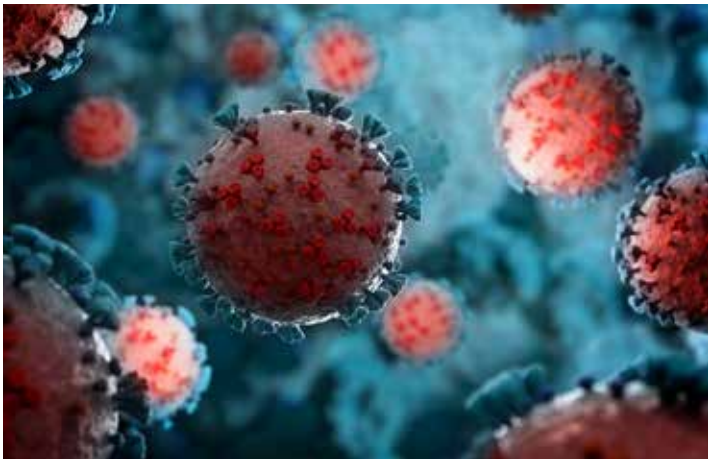
Predicting, Preventing, and Responding to Emergent Pathogenic Threats

Human population growth, urbanization, societal behaviors, and climate change are accelerating the emergence and migration of pathogenic threats. Such drug-resistant and rapidly evolving pathogens and expanding vector-borne and zoonotic diseases will have significant impacts on planetary health in the coming decades. Understanding and addressing these grand challenges requires innovation at microscopic to global scales in systems ranging from molecules

to the biosphere. The COVID-19 pandemic has demonstrated how the lack of timely and accurate information prevents effective response to an emerging disease and the impact this can have on vulnerable human populations in both rural and urban areas. There is a need to extend our knowledge of the pathogens that pose the greatest threats, mechanisms that produce them, locations where they will emerge, specific triggers that lead to outbreaks, dynamics of spread, patterns of human vulnerability, and resulting health risks. Convergence research is needed to prevent future pandemics and to ensure a more effective response when new pathogens emerge.

OU will accelerate the development of methods to predict, prevent, and respond to emerging health threats to provide benefits that have broad global impact. A major barrier to addressing such threats lies in the need to clarify the dynamic and ever-evolving interactions between environmental, socioeconomic, and epidemiological factors through convergence across disciplines. To better understand emerging pathogens, we will engage in bold, coordinated, transdisciplinary efforts. This endeavor requires diverse expertise ranging from biologists who study the characteristics and evolution of viruses and microorganisms, ecologists who study the habitat associations of vector and host species, climatologists and geographers who study how environments will change in the future, social scientists who study human behavioral responses and identify populations at greatest risk, and data scientists who apply cutting-edge data analytics to understand complex interconnections.

Specific outcomes will include predictive models that direct disease surveillance toward high-risk locations and times, new informatics tools that can track rapid changes in transmission risk during a disease outbreak, and robust diagnostics and treatments that are quickly adapted and applied in response to novel pathogenic threats. Through transdisciplinary research, OU is well positioned to develop new datasets and models that will significantly advance our capabilities for predicting environmental risk factors associated with disease emergence and spread, providing critical data for pandemic interventions, and advancing our understanding of microbial resistance and the development of novel therapeutic compounds.



OU has foundational expertise for convergence and applied research on pathogens, including integrative studies of infectious diseases and zoonoses, pathogen invasion and persistence, ecosystem and community resilience, social sciences and human health disparities, and environmental monitoring systems with disease applications. By combining strong expertise in climate research with strengths in evolutionary biology, microbiology, geography, ecology, and social science, we have built a foundation that uniquely positions OU to become a leader in addressing emerging pathogenic challenges that face Oklahoma, the nation, and the world.

SOCIETY AND COMMUNITY TRANSFORMATION

STRATEGIC PLAN

SOCIETY AND COMMUNITY TRANSFORMATION

WHERE WE'RE GOING TO HAVE AN IMPACT

OU has an opportunity to capitalize upon its expertise and build on existing strengths to promote societal well-being by focusing on three key research areas: Technology, Society, and Human Flourishing; Native Nations, Sovereignty, and Partnerships; and Equity and Opportunity. Existing and emerging research at OU will enhance knowledge about the beneficial and harmful impacts of technology on society, including artificial intelligence and the impact of technological adaptation, and on human behavior across health, education, and work-family life.

OU's institutional resources and collections, faculty capabilities, and geographic location in the state provide an unmatched opportunity for community-engaged, collaborative partnerships that place the sovereignty of Native nations and the cultural continuance of Native peoples at the center of academic research and forms a key area for OU's growth and national distinction. Oklahoma has a population that suffers from many significant challenges, including very poor outcomes in education and health and high levels of incarceration, especially among women. OU is uniquely positioned to conduct meaningful transdisciplinary research to address issues related to equity and opportunity at the state and national levels by expanding existing expertise in early childhood, carceral studies, and health disparities across all three OU campuses.

Enhancing Knowledge at the Intersections of Technology and Society

Technology profoundly influences the human experience, offering potential to advance the flourishing of individuals and communities. Medical technologies and information systems extend health care to people lacking access. Learning technologies support both remote and face-to-face education. E-commerce and business analytics inform the way we work today and in the future. Communication technologies bring new levels and types of social and cultural connections. Artificial intelligence and machine learning technologies are influencing work, public policy, and everyday life. These technologies also introduce challenges such as cybersecurity threats, workforce changes,

family strains, digital disinformation campaigns, and inauthentic behavior enabled by digital media. The use of biased algorithms can foster discriminatory practices and decisions. The study of the interconnections between technology and society is a robust field embracing work from many disciplines, ranging from historical technology studies, to social scientific analyses of emerging technologies, to explorations of human-centered design.

Research on technology and society focuses on data and computing, ethics and virtue, information systems and analytics, workplace innovation and well-being, leadership, and health and technology. OU is an R1 research institution, providing the highest level of research activity among the nation's universities. As such, we are positioned to deploy our unique strengths in these fields. We have a strong foundation for new research that will extend and enhance our knowledge of technology in its human context. Our capacities and strengths in this area are grounded in a number of internationally known interdisciplinary research centers and institutes, as well as departments and graduate programs. Our world-class faculty members bring diverse interests and methodological capabilities that already contribute to funded research projects in these areas.

By leveraging transdisciplinary research related to society and community transformation, from the humanities and creative arts to the social sciences and core STEM fields, we can effectively address emerging needs in the public/private sector at state, national, and global levels. We will study the capabilities and risks of artificial intelligence technologies and identify cybersecurity vulnerabilities. We will better understand the impacts of health care information systems and medical technology on public health. We will explore the ethics of technology uses and social media communication, technology adoption, and legal implications along with technology impacts on the U.S. workforce, U.S. intelligence gathering, and technology-related public policies.

Research on emerging technologies offers numerous opportunities for OU. Furthermore, our location in Oklahoma uniquely positions us to study the impacts of technology on multiple populations, including Native nations, and to address state challenges such as poverty and social inequities.

Advancing Equity and Opportunity

Societies that flourish are those that provide safe, stable, and nurturing environments for children and families. However, individuals and communities flounder when there is unequal access to opportunities and supportive environments. These inequalities are reflected in vast disparities in education and health outcomes and in disproportionate and excessive incarceration. Emerging transdisciplinary research shows promise of discovering actionable solutions to help all caregivers of young children provide nurturing environments, improve education and health outcomes at the individual and community level, and prevent involvement in the criminal justice system.

Oklahoma has a population that suffers from many significant challenges. Oklahoma ranks last

or near the bottom in several educational and health indicators, and first in female incarceration. Most of these indicators show disparities by race, ethnicity, and social class and cluster in segments of the Oklahoma population that further amplify inequity. Women, children, and families bear a large burden of these challenges that carry the potential for intergenerational cycles of social disadvantage with high costs to society if not addressed.

While these challenges and the disparities are complex, the solution lies in holistic transdisciplinary research. A recent landmark study found that high-quality early childhood programming improves children's educational outcomes as well as longer-term outcomes, such as adult employment, health, and lower incarceration rates. Preventing adversities in early childhood is also associated with better health and longevity. While this growing body of research is compelling, little is known about the underlying mechanisms producing these results, how to equalize opportunity for the most disadvantaged, and how to disrupt the interconnections between early childhood experiences, educational problems, involvement with the criminal justice system, and health and well-being throughout life. These topics are significant not just for Oklahoma, but for other states, the nation, and international contexts.

Convergence research positions OU to make real progress in improving the prospects for many of Oklahoma's citizens and communities and applying this scholarship beyond Oklahoma. The transdisciplinary, partnership approach proposed here will also attract graduate students and faculty who want to conduct meaningful scholarship with positive benefits to society. Few top academic institutions have this targeted comprehensive focus on improving the lives of and addressing inequities for women, children, and families through research-based solutions, transdisciplinary emphasis, and innovative graduate training. OU could become the place that grows top new faculty, inviting the best to stay at OU and launching others to fill top positions at other institutions.

By virtue of its location in the midst of communities with high levels of need, OU can fill a void and emerge as a leader in these research areas and bridge theoretical and practical interconnections among them. We will build on strong existing relationships among researchers and Oklahoma communities and state and tribal agency leadership to ensure our research is relevant and put into practice.

Partnering with Native Nations to Strengthen Cultural Continuance and Sovereignty

A recent resurgence of tribal institutions and dynamic new leadership is addressing global challenges for Native nations. Oklahoma is home to 39 culturally distinctive Native nations and nearly 500,000 American Indians, representing approximately 16% of the total state population. Native nations are key actors in Oklahoma's culture, economy, and governance structures. Building roads and bridges, funding schools, operating health care clinics and hospitals, providing social services and child welfare programming, shepherding environmental and natural resource management and research, and preserving and revitalizing languages and cultural practices, Oklahoma tribes are, more

now than at any time in U.S. history, creating greater opportunities for everyone in the state. Unfortunately, tribal communities have often lacked true partners from research institutions, and models for effective collaboration are in short supply. Our work in this area seeks to advance the science and scholarship of tribal engagement, establishing the standard for national and international work to advance the causes of Native peoples.

OU's institutional resources and collections, faculty capabilities, diverse student body, and geographic location in the midst of unique and diverse tribal nations provide an unmatched opportunity for community-engaged, collaborative partnerships that center the sovereignty of Native nations and the cultural continuance of Native peoples. Our grand challenge is to seek out and address the needs of tribal communities where tribes set the priorities and shape research, scholarship, and creative activity to advance the well-being of tribal citizens and communities, while also providing unique opportunities for university faculty, staff, and students.

A legacy of historical trauma and loss, combined with persistent ongoing neglect by U.S. institutions, has often generated significant disparities for Native people. Despite these challenges, tribal communities across the country have articulated innovative models of tribal governance and unique approaches to addressing global challenges. Authentic engagement by the university with tribal institutions, which privileges Native voices and perspectives, can point the way to transformations in Native communities throughout the world.

There is, quite simply, no other institution in the country with the tribal partnerships and historical commitments to do this work. OU serves unrivaled numbers of Native students for a research-intensive institution, with significant Native faculty leadership in almost every college, including every campus. Numerous tribal partnerships have now been in place for decades, giving rise to significant work in the arts and humanities as well as the social and natural sciences, while our professional programs have been foundational for the tribal workforce in the state. These dynamics make OU uniquely positioned to advance this work.

CROSS-CUTTING ENABLING CORE CAPABILITIES

DATA INSTITUTE FOR SOCIETAL CHALLENGES

STRATEGIC PLAN

DATA INSTITUTE FOR SOCIETAL CHALLENGES

WHERE WE'RE GOING TO HAVE AN IMPACT

Data science is becoming increasingly critical to current and future discovery and innovation in the state of Oklahoma, the nation, and the world. The University of Oklahoma is redefining the landscape as a leading center of excellence in data science research and data-driven solutions. With the introduction of the Data Institute for Societal Challenges (DISC), OU is swiftly advancing the forefront of discovery through its investment in highly skilled researchers, top-tier research facilities, and partnerships that bridge the academic, private, industrial, and governmental sectors. DISC is setting a new benchmark for cutting-edge advances in artificial intelligence, machine learning, and real-world applications driven by advancements in data-enabled research. OU's extensive research investment in these technologies will profoundly impact society, from breakthroughs in the development of robust and predictive software and guidance systems used by the U.S. Air Force, Army, and Department of Homeland Security, to advances in precision medicine that aid in the early detection and more effective treatment of disease, to the development of more accurate, timely, physics-informed weather and severe storm predictions and forecasts, all of which protect millions of lives. The development of ecologically sustainable communities and energy grids, as well as transformed modern supply chains around the world, are not just goals, they are achievable through the data science research endeavors at OU.

The DISC team is focused, driven, and fully committed to tackling the greatest data science challenges facing society today and tomorrow to develop real-world solutions and innovation at the local and global scale. Through the development and growth of convergent research teams, DISC will achieve these goals and lead the way in foundational data science and data-enabled research for aerospace, defense, and global security; community and societal transformation; the future of health; and the environment, energy, and sustainability. Societal challenges recognized, solutions realized – DISC is defining what it means to be a leader in data science research.

Human-Guided Artificial Intelligence and Machine Learning

Artificial intelligence (AI) and machine learning (ML) are unlocking the next generation of advances in science, engineering, and other disciplines. AI and ML are currently used in a variety of capacities, such as developing pricing models for utilities and assisting with drug and protein discovery. However, AI and ML systems function in ways that are not always well understood and are still in their infancy.

The goal of developing robust, trustable, explainable, and fair AI and ML is to help users understand how these systems produce results, remove biases in how these systems work, and promote the further use and adoption of AI and ML. Developing interactive, human-guided techniques that harness user expertise and knowledge has the potential to improve the robustness and performance of pure automated AI/ML techniques and to increase understandability and trust in the results.

AI and ML will have a lasting impact on the community, the nation, and the world. For example, the near-term impacts include the development of the next generation of AI and ML systems to help public health officials respond to infectious diseases, predict the development and trajectories of large-scale weather events, and generate patient-specific treatment strategies. AI and ML have the potential to unlock new insights for low-carbon power grids and carbon-neutral energy production.

OU is currently using and developing innovative AI and ML convergent research that brings together expertise from science, engineering, and social science, as well as computer and data science. Specifically, OU is home to one of five NSF Artificial Intelligence Institutes that will create trustworthy AI methods for environmental scientists while revolutionizing our understanding of atmospheric phenomena. DISC is leading an NSF Planning Grant to create a roadmap for ensuring sustainable agricultural production and communities using AI and ML. DISC will build on OU's strength in integrating AI/ML specialists with social scientists, cognitive psychologists, political scientists, biologists, and engineers to create cross-disciplinary AI/ML solutions for advancing theories to solve societal challenges.

Human-Computer Teaming

Human-computer teaming, a critical problem space for data-enabled research, is the efficient and effective integration of humans and complex machines. Effectively blending human and machine capabilities while accounting for the unique strengths and limitations of both will enable us to address complex problems, such as introducing autonomous vehicles to roadways, disaster recovery, and medical diagnostics.

Over the last 25 years, discoveries in cognitive neuroscience and technological advancements in machine learning have led to new insights into the underlying capacities needed to support effective human-computer teams and overcome the limited contextual knowledge, cognitive inflexibility, and opaqueness of AI and ML. Transforming intelligent machines from tools to teammates requires cognitive and computational models of beliefs, desires, intentionality, and capabilities. Our approach draws on the expertise of cognitive psychologists, device designers, human factors

engineers, decision-making and risk-perception researchers, user experience researchers, and computer scientists. Each supplies unique insights into how humans work in team science and process design.

Many aspects of society can benefit from improvements in human-computer teaming. OU researchers are well-positioned to address these challenges, given the existing strengths and collaborations of AI and ML specialists and social scientists, cognitive and social psychologists, computer scientists, human factors engineers, and medical researchers, scientists, and engineers.

Predictive Analytics

Predictive analytics, the practice of analyzing and mining data and historical trends to make a prediction or find a solution, is empowering research, policies, and decisions that affect our daily lives. Predictive analytics is needed to solve some of the world's most pressing problems.

OU researchers have expertise in creating tools and systems capable of extracting, assimilating, and analyzing data for accurate, timely, reliable forecasts and predictions with quantifiable uncertainty. Predictive analytics are already impacting our daily lives by transforming drug discovery, vaccine production, and enabling effective, personalized treatments and new pathways for the future of health. Futhermore, predictive analytics have led to earlier and more precise forecasts for the impact of various events. However, research is needed to identify and correct for some potential pitfalls of predictive analytics. Our goal is to develop analytics in such a way that we can be constantly correcting for unintended consequences or adverse implications.

OU centers and labs are conducting research at the forefront of predictive analytics, including industrial, health, atmospheric science, and business applications. One such center is the Energy Institute in the Price College of Business, which uses predictive analytics to assess the impact of risk on energy markets. Additionally, OU has multidisciplinary research teams developing predictive analytics to detect and deter the spread of medical misinformation. These teams bring science-based and social principles together with statistical and computational theories to develop new impactful and robust predictive analytics for many domains.

Collaborative, Data-Driven, Discovery, and Decision-Making Environment; Visual Analytics

The data revolution has led to a rapid increase in the rate at which systems generate and store data. Computers are better equipped and designed to process, store, and utilize large volumes of data than humans are. Combining human expertise with computational methods through interactive environments and visual analytics systems improves data-driven decision-making.

Recent advances in AI and deep learning have made it feasible to combine highly accurate and efficient ML outputs with human expertise to generate actionable insights for decision-making in domains such as cyber and aerospace security, disaster response, agriculture and community sustainability, and medical preparedness. Further, developing novel visual analytics systems that combine state-of-the-art AI and interactive techniques will be foundational to providing near

real-time decision-making environments in which users can rapidly identify complex patterns and actionable insights from massive amounts of data.

The design, development, and deployment of human-computer decision-support systems is an enabling technology for discovering new relationships and is relevant to all of OU's strategic pillars. Innovative human-computer collaborative environments can expedite and improve situational awareness and decision-making related to public health crises, natural disasters, global security, environmental sustainability, and community outreach. One such project led by OU researchers has been the development of machine learning models to help doctors predict preeclampsia in pregnant women.

OU is well-positioned to provide innovative solutions for data-driven decision-making and visual analytics by leveraging the skills and expertise of leading interdisciplinary researchers in centers such as DISC, the Cognitive Science Research Center, and the Center for Cyber-Physical-Social Systems.

Scalable, High-Performance Software and Hardware Architectures

Cutting-edge AI and ML algorithms are computationally intensive and must process large quantities of data to perform well. The slow training and performance of AI and ML algorithms are attributable to large volumes of data necessary for learning and their increasing computational complexity. This challenge limits their wider use in real-time applications (e.g., self-driving cars). Interdisciplinary teams researching solutions to global grand challenges need scalable and elastic solutions powered by emerging computing architectures, cloud-based storage, and the processing of globally distributed data.

Neuromorphic computing, probabilistic computing, and quantum computing, all have the potential to transform our ability to create real-time, trustable AI and ML solutions. These new hardware architectures also require updated software architectures and pipelines for reliable, efficient execution that can scale to the ever-growing sea of data generated by evolving sensing technologies and platforms. The development of these new hardware and software architectures enables advances in AI and ML research. Specifically, these technologies would enable AI and ML systems to be used in situations where scalable, secure, and real-time processing is needed, such as pandemic response, object detection for cyber and aerospace defense, and route efficiency optimization.

At OU, we have research teams developing and applying these new approaches to power data-enabled science as they work to solve problems such as early detection and response to emerging infectious diseases; sub-surface carbon sequestration to create net-zero carbon energy and sustainable environmental solutions; improved maintenance and life-extension of critical defense aircrafts; improved medical treatments and strategies to reduce health disparity; digital preservation of cultural artifacts and understanding of ancient peoples and societies; and social justice and reduced disparity among communities. The ongoing, synergistic AI and ML research at OU seeks to solve today's challenges using tomorrow's technologies.

CENTER OF OPTIMAL MATERIALS FOR EMERGING TECHNOLOGIES

STRATEGIC PLAN

CENTER OF OPTIMAL MATERIALS FOR EMERGING TECHNOLOGIES

WHERE WE'RE GOING TO HAVE AN IMPACT

Advanced materials are the basis for several emerging technologies of importance to Oklahoma, the nation, and the world. The Center of Optimal Materials for Emerging Technologies, or COMET, addresses this vital need and aims to make the University of Oklahoma a world leader in research and development of next generation advanced materials of importance to several technologies and industry sectors.

As a state, Oklahoma has developed a strong foundation on energy-related technologies, mainly through the fuel industry which is realigning itself with newer energy technologies of the next generation. Oklahoma is home to more than 1,000 companies in the aerospace sector as well as the Oklahoma City Air Logistics Complex, Tinker Air Force Base, which is one of the largest units in the Air Force Material Command. These entities use a variety of advanced technologies that are based on strategic materials COMET will focus on technologies of importance to these industries and in addition focus on areas that are aligned well with the four strategic research verticals underlying OU's research strategy.

COMET will enable OU researchers to obtain high value-added instruments housed in a shared facility enabling a strong collaborative environment. COMET will empower innovators to conduct disruptive transdisciplinary research in materials science and technology to revolutionize the economy and quality of life locally, nationally, and globally. Our goal is to become the worldwide resource and solutions provider for materials science and technology.

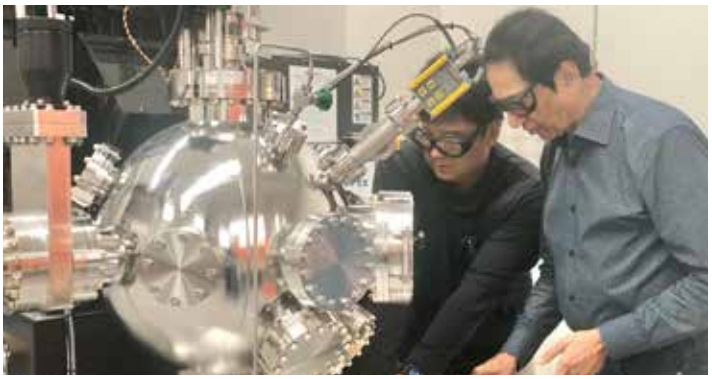
Advanced Materials to Address Next Generation Electronics

The semiconductor electronics industry is at an inflection point. The area of maximal profitability for semiconductor companies is now in advanced packaging with this sector of the semiconductor industry registering a 40% compound annual growth rate. Advanced packaging addresses the industry's goal to maximize the number of circuits per unit volume, not primarily by

shrinking transistor size, but instead by stacking circuits in the vertical dimension. Another important aspect of advanced packaging is heterogeneous integration where different materials are combined with silicon circuitry to enable additional functionalities. OU has materials capabilities in two distinct areas of importance to the heterogeneous integration effort. First, state-of-the-art optical emitters and detectors can be made from compound semiconductors but not from silicon. Hence, on-chip LEDs or lasers become possible when compound semiconductors are integrated onto a silicon chip. Second, novel oxide materials exhibit functional properties such as ferroelectricity, ferromagnetism, and electro-optic behavior. Integration of oxide materials with silicon circuitry will empower silicon chips to address new application areas.

Materials for the Mid-IR

The optical materials market in 2019 was estimated to be over $22 trillion and is expected to increase significantly – and soon. Optical materials include highly transparent media that are used as windows and lenses, highly reflective substances exploited to redirect and manipulate light, and highly absorptive materials that emit and sense light. The ability to produce manmade materials with atomic precision has enabled new technology that enriches our daily life. These technologies include tablets, smartphones,



ultra-high-resolution TVs, solar cells, fiber optic communication, lightning, and wearable devices. The University of Oklahoma has a historic strength in infrared optoelectronics spanning from the end of the visible spectrum into longer wavelengths invisible to the naked eye. This area is traditionally funded by the U.S. Department of Defense and is also finding niches in civilian life in the form of chemical sensors for pollution monitoring, gas sensing, temperature sensors and other applications. More recently, infrared emitters and detectors are being incorporated in cars to support safe fully autonomous driving. The latter will demand inexpensive detectors with high sensitivity at room temperature, which will require the development of new materials and devices.

Materials for Quantum Applications

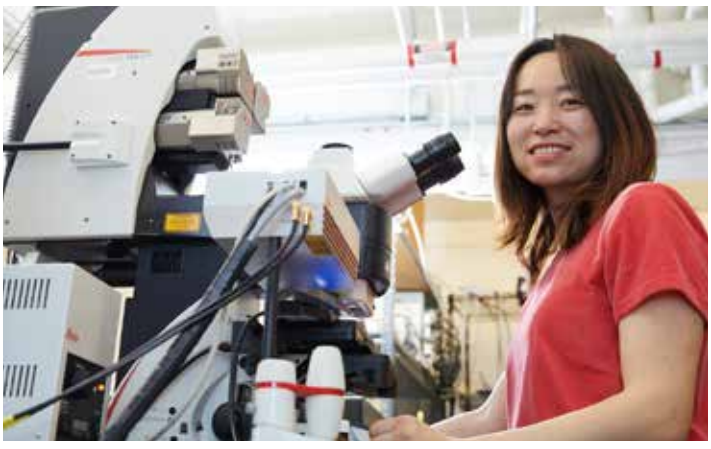
Quantum technology is an emerging area of applied physics that promises to utilize some of the lesser-known properties of quantum mechanics for far-reaching improvements in computational capability, cybersecurity, and sensing of physical phenomenon. The faculty affiliated with OU's Center for Quantum Research and Technology (CQRT) include experts in quantum applications for sensing, metrology, and communications. The CQRT also studies and develops the quantum materials and other physical platforms needed to carry out these applications. Quantum technology is the next generation electronics with promise of higher computational capability and enhanced precision in several measurement and sensing

methodologies. Quantum optical communication promises ultimate cyber security in information transfer.

Advanced Materials to Address Energy and Environmental Challenges

The University of Oklahoma will leverage existing strengths in academia and across the state to both meet growing global energy demand while enhancing environmental quality. The design and study of catalytically active materials is essential to addressing many of these challenges. Important areas such as the generation of carbon dioxide-free hydrogen, carbon dioxide conversion, waste plastics conversion and upcycling, water purification, and the production of sustainable fuels and chemicals from renewable resources will all rely on advancements in catalysis.

OU's expertise in the design and study of heterogeneous catalysts will be essential to approaching these challenges. Advancements in heterogeneous catalysis, electrocatalysis, photocatalysis, plasmonically active catalysts, as well as the incorporation of catalyst surfaces with plasmas and other dynamic and non-equilibrium environments will be necessary to realize these advancements. Advanced materials characterization, along with the ability to study materials in the presence of reaction conditions will be essential in the coming years. The study of catalysts, or materials that modify



energetic barriers leading to chemical reactions, also provides the fundamental basis to better understand important areas such as hydrogen transportation in pipelines, and storage of hydrogen and carbon dioxide in reservoirs.

In addition, novel polymeric membrane materials will be critical for developing energy efficient processes to remove salt and other impurities for water decontamination. Polymeric membrane materials are also necessary for low energy industrial separations replacing distillation. Advanced synthesis and characterization techniques are necessary to create these new materials.

Developing novel materials for energy conversion and storage is critical to achieving a sustainable and environment-friendly modern society. COMET will enhance OU's cutting-edge research activities in leading the influx of energy conversion and storage deployment nationally and globally by extending the university capabilities in rational design, synthesis, characterization, and performance evaluations of advanced energy materials.

Photovoltaics has a critical role to play in the global energy transition. Despite growth of solar cell technology, the sustainability and carbon footprint of manufacturing on such a scale is a critical discussion. Within this context, solar cells with conversions efficiency of more than 30% and lifetimes of 50 years are considered necessary to provide a sustainable footprint for photovoltaics implementation at scale. Current commercial solar cell technology is dominated by silicon – solar cells that operate at power conversion efficiencies of approximately 21% and therefore would not meet sustainability criteria if implemented at the proposed terawatt scale.

As such, new high efficiency, high stability systems that are cost effective are required. Within the context of high efficiency advanced

concept solar cell and materials, OU has a core group of researchers across physics, chemistry and engineering that have developed impactful programs across the state under the umbrella of the Oklahoma Photovoltaics Research Institute. Specific emphasis in photovoltaics at OU is related to new materials that show promise for both terrestrial and in space power applications, and single junction solar cells with the potential to reach efficiencies of greater than 60%.

With the emergence of battery use for large scale applications, such as transportation, not only are advanced batteries necessary, but the re-use of spent batteries and recycling of battery materials will emerge as an important growing field. Evaluation of the modification of materials after various treatments will be essential for progressing this important field.

Approaches to modify polymers and create advanced recycling will be essential to eliminate plastics waste. This requires advancements in separation and mechanical recycling, as well as the development of advanced research where polymeric materials are transformed, or upcycled, using catalysts. Also of interest is using renewable feedstocks and creating biodegradable polymers. OUs expertise in all areas of polymer science will be critical to achieving more environmentally friendly approaches to the 700 billion pound per year worldwide plastics industry.

Advanced Materials for the Future of Human Health

Advances in biomedical technologies in the diagnosis and treatment of chronic and infectious diseases have already produced considerable improvement in the natural lifespan. Materials created to serve human health are tailored to function as a part of the body to improve the quality of life. This research covers the physical and chemical interactions between complex biological systems and synthetic or modified natural materials.

Depending on the application, materials are designed to be hard or soft. Hard materials, e.g. metals, ceramics and highly-filled polymers, are intended to replace hard tissues, such as implants for skeleton and dental applications. Soft materials research, because of its compatible properties with the tissues, cover broader applications. Synthetic polymers, modifications on naturally resourced materials, and their combinations are utilized to match the requirements of the human body. New technologies for improving mechanical and surface properties to address the requirements in human health and discoveries of new properties to diagnose and treat diseases are part of these research efforts at OU.

OU's research involving soft materials includes the renewably sourced soft materials, like surfactants, colloids, and bio-inspired nanoparticles, to reduce dependence on fossil fuels. Specifically, OU researchers are looking to improve energy-intensive cleaning processes to allow lower temperatures to be used; which is approximately 10% of all energy used in people homes. A critical part of the fundamental science underlying this effort in soft materials is understanding liquid-solid interfaces in both natural and engineered environmental systems. OU researchers are integrating new characterization tools and additive manufacturing protocols to achieve soft materials.

ADVANCED RADAR RESEARCH CENTER

STRATEGIC PLAN

ADVANCED RADAR RESEARCH CENTER

WHERE WE ARE NOW AND HOW WE GOT HERE

Radar is the most important tool for observing, understanding, and predicting hazardous weather. With the goal of mitigating the negative impacts of severe weather on society, the University of Oklahoma (OU) and the National Oceanic and Atmospheric Administration (NOAA) established a partnership in Norman over 50 years ago. This close collaboration resulted in the creation of the OU School of Meteorology and the NOAA National Severe Storms Laboratory (NSSL). It is now firmly established that Norman is the world's center for severe weather R&D, particularly in advancements in weather radar science and technology.

In 2005, OU established the Advanced Radar Research Center (ARRC), which has become the largest academic research center in the nation focused on the development and application of innovative radar technologies. In partnership with NSSL, the ARRC has demonstrated that phased array radar (PAR) technology holds tremendous potential for advancing our observation capabilities of high-impact weather. In addition to weather applications, the ARRC's all-digital PAR technology has garnered the attention of the Department of Defense (DoD) resulting in significant growth in that sector. Initially leveraging this energy and excitement in radar, OU started an ambitious research initiative into defense applications more broadly. After many years of rapid growth, the ARRC's R&D portfolio is now almost evenly split between weather-focused projects and those from the DoD with growing annual expenditures well over $14M. Current core competencies include:

- Fully digital phased array radars
- Severe weather/hydrometeorology/hydrology
- Satellite Remote sensing
- Signal processing/AI/ML
- Passive and bistatic radar
- Radar imaging
- Spectrum sharing and frequency agility
- Applied electromagnetics/antennas
- Automotive radar
- Biomedical sensors
- UAS/cUAS
- Microwave/mmW components/packaging

The ARRC has 20 faculty members who are also affiliated with the Schools of Meteorology, Electrical & Computer Engineering, and Civil Engineering & Environmental Science. Several of these faculty members are Fellows of international societies. There are currently four textbooks in print from these respected scientists and engineers with others in the planning stages. Some early career faculty members have received prestigious DoD Young Investigator awards, which highlights the ARRC's growth in that space, as well as awards from the American Meteorological Society and NASA. Students are the ARRC's most-important source of pride with several receiving highly competitive national fellowships from the National Science Foundation, NASA, and the DoD. Now with well over 120 alumni, the ARRC is quickly becoming known to industry as "the place to go" for a well-trained workforce. At a major defense contractor in the Dallas area, several graduates affectionately call themselves "ARRC South," which shows the pride in what has been accomplished in the ARRC. With significant encouragement from industry, the ARRC recently started the Strategic Partner Consortium (SPARC), which is growing rapidly and currently has membership from major industry leaders.

From the beginning, the ARRC has focused on developing and fielding robust, reliable, and innovative radar systems for science and societally relevant applications. The idea of fielding end-to-end radar solutions makes the ARRC unique in comparison to other academic research centers around the country. This type of development would not have been possible without both the intellectual leadership of its faculty and the professional engineering team, which now boasts over 25 members including full-time electrical, mechanical, and software engineers. In addition, the ARRC has established a project management office, which has raised the ARRC's professionalism to the next level. While building a foundation of intellectual strength in its engineers and faculty, the ARRC has been privileged to have the continued support of the OU administration, which has resulted in multiple high-tech buildings including the Radar Innovations Laboratory (RIL), the RIL Annex, and two new facilities that are focused on secure R&D.

At present, the ARRC finds itself at an exciting inflection point in its development. Several important questions, which could have a profound impact on the ARRC's future direction in technology, hiring strategies, organizational structure, culture, and even its existence in its current form, must be considered.

WHERE WE'RE GOING TO HAVE AN IMPACT

Building on a solid technical and scientific foundation, synergy with OU's Lead On strategic plan, and strong encouragement of the R&D community at large, the ARRC is excited to blaze a trail of innovation in radar technology and science. Challenging applications across the defense, science, and commercial sectors are abundant for radar and more broadly defined use of the radio spectrum. Challenges do exist for the ARRC as it moves forward. Examples include innovation-driven questions such as improving the technological limits of radio frequencies (RF) electronics to the ultimate spatiotemporal resolution needs for understanding and better predicting severe storms and precipitation. Other logistical challenges also need to be tackled, from workforce development and supply chain issues to security concerns in a university environment. Nevertheless, the ARRC is well positioned and committed to defining the future use of the electromagnetic spectrum for the betterment of the state, the nation, and the world.

The core R&D competencies listed above will continue to be areas of strength and investment for the ARRC. As one example of particular importance, now is the ideal time to leverage the ARRC's fully digital PAR technology for larger-aperture systems, which will provide unprecedented temporal and spatial resolution. Based on federal government interest, nascent opportunities will be pursued for nationally impactful projects over the next few years in both the defense and science fields. If awarded, these projects will transform the ARRC into a national powerhouse in innovative radars on a scale comparable to established national laboratories. These opportunities are over 10x larger than other projects currently in the ARRC.

With further expansion in mind, the ARRC will leverage its experience in end-to-end radar solutions, its expanding network of leaders in the community, and its deep understanding of defense and science needs, to develop a visionary technology roadmap, which will guide the future direction and investments of the ARRC. As an integral part of the execution of this strategic plan (Strategy 1, Tactic 1.1), the technology roadmap will result from a thoughtful assessment of the potential for national impact in both defense and science. Although it would be premature to choose areas for future investment before the formal assessment process is complete, the following are just a few exciting examples that should be considered.

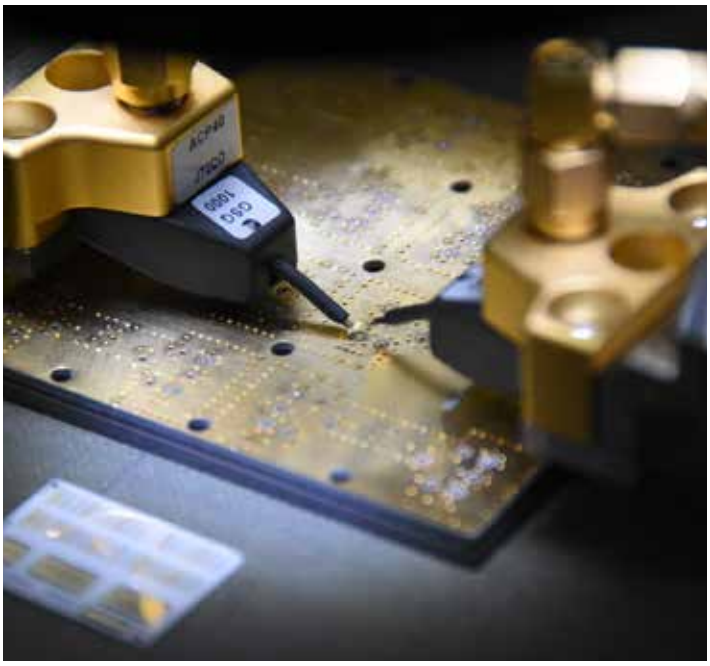
Reaching for the Sky - Airborne and Spaceborne

The ARRC was established with the goal of becoming the recognized leader in ground-based weather radar. With expansion into the defense sector, the focus has mostly remained on sophisticated ground-based systems. Burgeoning programs in the ARRC have started in airborne radars, but the ARRC has yet to focus its significant intellectual and engineering resources in this area. Airborne radar and other sensors require stringent considerations on Size, Weight, and Power (SWaP), but provide tremendous opportunities in atmospheric science (e.g., open-ocean hurricanes, cloud microphysics and

dynamics, remote sensing), defense (e.g., foliage-penetration for detection/monitoring, synthetic aperture radar), and civilian aviation (e.g., navigation, airspace management). With the move of OU's School of Aviation to the ARRC's original home college, the time may be right for the ARRC to expand into airborne radars/sensors. After success in airborne radars, the next logical step would lead to higher altitudes in the stratosphere and even space. The stratosphere has been identified as the next frontier for engineering, mission concepts, and science. These systems would provide global reach of the ARRC's innovations. Nationally recognized scientific work in remote sensing is already underway in the ARRC (e.g., precipitation monitoring), but its engineering strength has yet to target the rapidly growing field of spaceborne systems and applications. New partnerships with major national laboratories will be integral to the ARRC's success in this area.

Chips for Radar Applications

Over the course of OU's push in radar in the last 20 years, many faculty members have been recruited to the program. Clear national dominance exists in the ARRC is areas such as antennas, phased array radars, and signal processing. One area that has had little investment is integrated circuit (IC) design, especially for frequencies of interest for radar. This lack of investment has mostly been because of the prioritization of other areas of radar, which has brought the ARRC to the forefront of the field, but also the broad availability of commercial ICs for radar and communications applications. Largely caused by the COVID-19 pandemic, supply chain challenges, including US reliance on foreign suppliers, have gained national attention. With the ARRC's focus on phased array radars, which rely on thousands of individual RF transceivers and amplifiers, a potential area of national influence could be in the design of the chips that drive these systems.



Again, partnerships will be key if the ARRC moves into this area, not only with industry but with key academic departments at OU. In addition to the design of next-generation RF transceivers that include important capabilities for phased array radar (e.g., high bandwidth, low noise), high-power amplifiers are key to increasing the sensitivity of radars while reducing power consumption and increasing efficiency. Gallium Nitride (GaN) semiconductors used to implement high-power amplifiers are commercially available and are used in almost all ARRC radars. Advancements in GaN-on-diamond technology hold promise for addressing cooling challenges for high-power applications, with even more recent work in Gallium Oxide (Ga2O3) semiconductors. With the importance of integrated circuit technology for radar, this potential area of ARRC expansion should be considered.

Broadening the Spectrum

The radio spectrum is a limited and precious resource. The choice of radar frequency dictates scattering and propagation characteristics, which drives the type of science and applications that can be conducted. Radar frequency also sets

limits on detection performance for long-range targets, making it a fundamentally important choice for military operations. Currently, the ARRC has focused on frequencies between 2-12 GHz with more recent work at frequencies up to 100 GHz. This history is defined by the ARRC's origins in weather radar. As the ARRC expands into new application spaces within defense and atmospheric science, it may be time to begin exploring frequencies outside its experience wheelhouse. Examples include work at much lower frequencies, such as HF (3-30 MHz), which is advantageous for over-the-horizon (OTH) radar. These systems rely on reflections from the ionosphere to allow detection/monitoring of targets at much farther distances than would normally be possible. On the other end of the spectrum, the ARRC has just started looking at the potential for applications in the 90-300 GHz sub-terahertz (sub-THz) band. Examples include material characterization and ultra-high-speed, short-range communications.

Resolution is arguably the most important specification of a radar. In the range dimension, resolution is controlled by the bandwidth that the system can generate, receive, and process. Weather radar applications require relatively low bandwidths, with a typical requirement of tens of MHz. This fact has limited much of the ARRC's previous radar developments. Defense applications require much higher bandwidth, especially for imaging and target recognition use cases. As the ARRC is developing its technology roadmap, it will be important to consider the seemingly unlimited need for higher-bandwidth systems in the defense space. Higher frequencies with larger bandwidths may also prove important for scientific applications, such as studies of turbulence and microphysical processes. For all these reasons, expanding capabilities through a broader use of the radio spectrum must be investigated as the ARRC moves into the future.

Harnessing the Potential of Artificial Intelligence

Interest in radar and communications applications of artificial intelligence and machine learning (AI/ML) has risen dramatically in recent years, but the benefits of applying AI/ML to radar are still mostly unrealized. AI/ML can be used to extract the information content in radar observations and advance its applications such as improving radar resource management, spectrum dominance, detection and tracking in cluttered and high-interference environments, classification of targets or physical events (e.g., tornadoes), scene characterization, multi-sensor fusion, and other important functions. Achieving these benefits, however, requires synergistic expertise not only in AI/ML methods, but also in the relevant application domains, radar system design and analysis, modeling/phenomenology, and high-performance computing. Therefore, many research institutions lack the full range of integrated expertise needed to create models that produce realizable and physically meaningful solutions. Through working together, the ARRC already has significant breadth and depth of expertise within these areas, such that modest strategic investment would position the ARRC as a world leader on this important and growing research topic. Furthermore, the ARRC has the system-level prototyping and field-testing expertise needed to take AI/ML algorithms from concept or simulation study to field-demonstrated technology.

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Thank you to the members of the strategic theme working groups for their help developing our areas of focus.

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Glossary

AGS	College of Atmospheric and Geographic Sciences
CAS	Dodge Family College of Arts and Sciences
CIS	College of International Studies
CoB	Price College of Business
CQRT	Center for Quantum Research & Technology
GCoE	Gallogy College of Engineering
MCEE	Mewborne College of Earth and Energy
OU HSC	OU Health Sciences Center
OVPRP	Office of the Vice President for Research and Partnerships

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