DELAWARE SCIENCE, TECHNOLOGY AND ECONOMIC DEVELOPMENT PLAN

2024

The purpose of this document is to provide a current perspective on science and technology (S&T) based economic development in Delaware with the purpose of catalyzing collaborative partnerships among the academic, private and public sectors to improve the State's competitive position and provide social and economic benefit.

Science and Technology in Delaware

State leadership acknowledges the importance of collaborative R&D partnerships to strengthen the innovation economy in Delaware and to advance the state's reputation as an "innovation hub" in the technologies and industries discussed herein. The State recognizes that to sustain an innovation economy, there must be a strategy that fosters the birth, growth, and sustained presence of science and technology (S&T) companies and the talent they employ. Delaware has among the highest concentrations nationally of science, engineering, and health PhD's in the country, and is surrounded regionally by over 100 higher education institutions. It consistently ranks in the top 10 in national innovation indices.

Leadership in S&T has become both a State and national priority, catalyzed by a global knowledge-based economy and a shift to other countries of high labor content manufacturing and services. The pace of change in technology intensive businesses has dramatically increased, caused by new scientific discoveries and entrepreneurial innovation.

As the mature industries of Delaware decline or shift strategies, new market opportunities emerge. They must be identified early and appropriately supported for Delaware to be competitive, maintain a healthy environment and prosper. Economic growth will be driven by businesses and institutions that are on the cutting edge of science and technology. This requires a business environment that stimulates innovation, entrepreneurship, and knowledge-based partnership. Accelerated change is taking place in technology and in industries, which are repositioning themselves to become more competitive in the face of climate change and global competition. Such changes require a high-quality educational system that trains and fosters workforce development at every level.

Along with the emergent nature of new scientific discoveries and technologies there are often steep challenges for social acceptability and their adoption and sustained use by the intended stakeholders. To make an emerging technology sustainable, inclusive, trusted, and user-oriented, various stakeholders need to be engaged—starting from the scientific discovery and pre-development stage to the development of new technologies. This is imperative and emphasis should be given to methods that scientifically measure human behavior (instead of just stated behavioral intentions) related to initial adoption and decisions on whether to sustain use.

A productive and vibrant R&D capability that addresses social acceptability is critical to establishing a successful economy and relevant educational programs. Based on extensive review of Delaware's R&D strengths, the State has identified 9 critically important sectors with talent upscaling/workforce training and innovation & entrepreneurship as recurrent themes that apply to all:

- Agriculture
- Business & Financial Services
- Data Science, Data Analytics & Big Data
- Energy
- Environment
- Human Health
- Manufacturing & Materials
- Quantum Science and Engineering
- Space Sciences and Technology
- Talent Retention, Upskilling & Attraction

The identified sectors should not be considered silos but rather areas that will encourage multidisciplinary collaboration and innovation. Within these sectors, new and emerging research, education and innovation opportunities will arise that will enhance the ability to compete for sustained funding support and expansion of Delaware's research and workforce capacity. Through the S&T plan, the State has outlined critical R&D sectors and research/focal areas and has identified 6 strategies below to enhance Delaware's competitiveness and prosperity:

- Selecting and nurturing emerging S&T intensive business segments where the focus will be on developing a research and innovation base to create new partnerships, products, jobs and companies.
- Attracting top scientific and entrepreneurial talent to the State, capitalizing on the State's geographic compactness and convenience to mid-Atlantic markets to build internationally recognized, multi-institutional centers of excellence in targeted fields.
- Supporting and expanding the infrastructure for research at its two research universities, and a community college.
- Supporting technology transfer and, where appropriate, commercialization of inventions and innovations developed by universities.
- Fostering a culture of innovation, entrepreneurialism, and knowledge-based partnerships among private, public and academic institutions state-wide, regionally, nationally and globally.
- Enhancing the competitiveness of Delaware's existing industries through support of Corporate Innovation.
- Creating ways to increase awareness of the S&T capacity of the state, and to use it to develop regulatory policy based on sound science.

Agriculture

Relevance and Background: Agriculture is a major component of Delaware's economy, producing $1.5 billion in agricultural sales in the most recent census of agriculture activity. As a part of the Mid-Atlantic Coastal plain, agricultural research and education in Delaware is driven by questions in grain, fruit, and vegetable production. Due to the large influence of the poultry industry in Delaware, grain crop production for animal feed is a dominant land use. Grain crops have immediate needs in sustainable crop production, including the practice of precision agriculture, water quality for the wider region, and climate and coastal resilience.

The coastal soils of Delaware are variable and can benefit from precision application of seeds, fertilizers, and lime. The Delaware grain production community is largely underserved in precision agriculture applications, which includes needs in both science and engineering for established and newer technologies. Research in yield response for grid or zone soil sampling, variable rate application, and precision placement (seeds and fertilizer) is necessary for our region. Remote sensing, while an established field in agricultural production, is becoming more accessible to the ag industry through both drone and high-resolution satellite imagery. The interpretation of these images will require research in machine learning and model training, where algorithms may be specific to our soils and regional climate.

Precision agriculture can also play a role in improving water quality in the region, where variable rate applications may improve nitrogen use efficiency and reduce runoff and leaching to regional water

resources. This can include both sensor technology as well as nitrogen models which best fit our soil types. Managing soil quality and health through innovative methods such as cover crops or intercropping also deserves investigation and will overlap with maintaining Delaware water quality. The concentrated poultry industry benefits grain farmers, but the excess production of poultry litter must also be sustainably managed on the Delmarva peninsula. This can include both sustainable land application as well, engineering research in composting, energy production and byproducts, or other value-added products for poultry litter.

Precision Agriculture: The application of modern information technologies to provide, process and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production. At its core, it's about providing more accurate farming techniques for planting and growing crops. In turn, this results in less wasted seed, fertilizer, fuel, and time.

Research/Focal Areas Including: Application of seed. fertilizer etc.; yield response from grid/zone sampling; variable rate application/precision placement; remote sensing-drone/high resolution satellite imaging; application machine learning and model training; and sensor technology; crop production; farm management; improved water quality

Poultry Enterprise

Relevance and Background: Delaware is one of the country's leading producers of broiler chickens, generating more than $1 billion in sales annually. Leading poultry processors such as Perdue, Allen Harim, and Mountaire have significant operations in the state, and the poultry industry represents approximately 70% of Delaware's cash farm income. (DPP, 2021). Southern Delaware has the highest output of broiler chickens in the US. Much of the State's agriculture sector serves the poultry industry, either through growing inputs such as grains or through the processing and the delivery of this low-cost protein to a growing population. However, this intense agriculture in Delaware takes place in a fragile coastal landscape with the State's long tidal shoreline, low elevation, and polluted waterways. These coastal areas are also of importance for conservation and face pressures of a growing human population. Protecting poultry health by developing and implementing strategies for disease surveillance, diagnosis, and control, applying fundamental knowledge gained from avian genomics to diagnose and control poultry diseases and improve the efficiency of poultry production, and integrating the latest advances in food science into innovative technologies that ensure the safety of poultry products consumed in human diets is critical. Key research questions exist on how best to encourage the adoption and persistence of nutrient and sediment management practices by agricultural producers and landowners in Delaware, while continuing to provide a robust and high-quality protein source.

Research/Focal Areas Including: Poultry Science including management of poultry mortality and litter quality, disease prevention, ventilation and energy, poultry house construction, animal standards of care and overall best practices in poultry management.

Controlled Environment Agriculture: In addition to the legacy and traditional agriculture which has been a long-standing strength in Delaware, additional attention is being paid to innovation in controlled environmental agriculture (CEA), which can sometimes result in indoor ag and growing operations. CEA allows traditional indoor growing techniques and new technologies to be focused on solving problems related to sustainable food production.

Research/Focal Areas Including: Plant phenotype responses to changing environmental factors and their interactions (including plant stress reactions); plant growth optimization via indoor vertical farms, greenhouses, and space exploration; crop yield improvements.

Behavioral Science and the Adoption and Sustained Use of New Technology

Relevance and Background: The emergent nature of new scientific discoveries creates steep challenges for social acceptability and their adoption and sustained use by the intended stakeholders. One historical challenge with wide adoption of new technology has been mistrust and lack of understanding among the stakeholders. Examples include the reluctance to accept vaccines, concerns about the use of bioengineering and hormones to increase agricultural production, and the hesitancy to invest in recycled wastewater projects that could improve environmental sustainability. Likewise, promising policy efforts to address emerging challenges with climate change, sea level rise, and the COVID-19 pandemic have been hamstrung by distrust, behavioral deviations from the policy prescriptions, and the fractured nature of public opinion. To make an emerging technology sustainable, inclusive, trusted, and user-oriented, various stakeholders need to be engaged—starting from the scientific discovery and pre-development stages. Involvement of the end-users and feedback from society and consumers during the development of new technologies is imperative and emphasis should be given to methods that scientifically measure human behavior (instead of just stated behavioral intentions) related to initial adoption and decisions on whether to sustain use.

Research/Focal Areas Including: Behavioral Science; Experimental Economics; Health Sciences; Randomized Controlled Trials; Development of new courses and interdisciplinary undergraduate minors and graduate programs, including new online certificates and micro credentials for workforce development.

Business & Financial Services

Relevance and Background: Delaware became a credit card and wholesale-banking center after the 1981 passage of the Financial Center Development Act, which lifted interest-rate limits (usury laws) and taxed bank profits at regressive rates (the more a company makes, the lower its tax rate.) The rise of fintech—the use of technology and innovation to provide financial products and services—is transforming the financial services landscape and will be a key growth opportunity for the Delaware economy in the years to come. The nearly 48,000 jobs in Delaware's broad financial activities sector today are distributed across firms of all shapes and sizes—with established financial services such as JPMorgan Chase, Bank of America, Capital One, WSFS, and M&T Bank operating alongside payments pioneers like PayPal and fast-growth, early-stage companies like Acorns, College Ave Student Loans, Fair Square Financial (recently acquired by Ally Bank), Marlette Funding (now Best Egg), and SoFi. (DPP FinTech Report, 2019)

Delaware ranks highly on measures of fintech innovation. Between 2009 and 2018, 199 fintech patents were assigned to Delaware-based individuals and companies, ranking first in the U.S. on a per capita basis, and fifth in absolute terms. While large states like California, New York, and Texas are home to the largest financial services workforces in absolute terms, Delaware has the highest relative concentration of financial services jobs of any U.S. state. The financial services sector accounts for 9% of all jobs in Delaware, a figure nearly twice the U.S. average. A focus of the Delaware banking industry is to use technology software and hardware tools, techniques and risk management processes that assure the confidentiality, integrity and availability of data and systems, thus providing the means to store and share information without undue risk of unauthorized disclosure, loss, or modification.

Research/Focal Areas Including: Cybersecurity; Blockchain and decentralized ledgers; broad FinTech research and commercialization (merging of finance and "technology" to enhance or automate financial services and processes that allow consumers to have more influence on their financial outcomes).

Tourism

Relevance and Background: Delaware's tourism contribution to the state's GDP (the total market value of goods and services produced) was $3.5 billion. Delaware is a "drive-to" state and in 2018, there were 9.2 million visitors. The Delaware tourism industry is the 4th largest private employer in the state, accounting for 44,030 jobs. The tourism industry generated $545.1 million in tax revenue. Without tourism, each Delaware household would pay an additional $1,562 in taxes. (De Tourism, 2018). Delaware seeks increased tourism that can lead to new or improved roads and highways, development of parks, improved public spaces, and in some instances better schools and hospitals. Tourism provides a stimulus for the development of ancillary businesses that encourages entrepreneurs to establish new services that would not be sustainable with local communities of residents alone. A productive and thriving tourism industry helps to support Delaware's infrastructure.

Research/Focal Areas Including: Infrastructure improvement; Beach replenishment; Small business development; Hotel industry; land/real estate development; insurance industry; restaurant industry

Data Science, Data Analytics, & Big Data

Relevance and Background: As the vast resource of new and diverse datasets are rapidly becoming available in nearly every aspect of life, data science has the potential to advance human understanding in all branches of science and humanities and address grand challenges facing society. Data Science is an interdisciplinary field that integrates statistics, computer science, engineering, communications, design, and ethics and to create the societal capability for conversion of data into actionable knowledge. It offers a real potential for Delaware that has a global reach and can strengthen every type of organization in the state, from healthcare, education, banking, energy, tourism, agriculture and the environment. We seek to catalyze interdisciplinary science and engineering research to understand and build the human-technology relationship; design new technologies to augment human performance and predictive abilities; illuminate the emerging socio-technological landscape; and foster lifelong and pervasive learning with technology; pursuit of fundamental research in data science and engineering, the development of a cohesive, approach to research data infrastructure, and the development of a 21st century data-capable workforce. Delaware seeks to be recognized as a:

- a data-driven state, where decision support is based on data available to all citizens and stakeholders;
- a data-empowered state, where a diverse data science savvy workforce has well-paid jobs supporting every sector of the economy.

Research/Focal Areas Including: Data Analytics; Data Science; Artificial Intelligence; Machine Learning; High Performance Computing; Augmented Reality; Development of sensors and sensor networks for enhanced inputs to data analysis through high performance computing; Development of new courses and interdisciplinary undergraduate minors and graduate programs, including new online certificates for workforce development. These and other digital sciences which power innovation in financial services provide overlap between this sector and Business & Financial Services, mentioned above.

Energy

Relevance and Background: Energy challenges define our world. Two primary themes of the global, national, and local energy markets are the conservation of energy and replacement of carbon based sources for fuel and power with renewable forms of energy. From global competition and lightning-quick advances in technology to climate change and fossil fuel depletion, crises in production and consumption threaten our environment, our prosperity, and our future. Now more than ever, it is imperative that Delaware face these energy challenges and opportunities head on.

Electric Power: Electrification of energy uses, and developing clean, low-cost and sustainable sources of electricity are a critical societal need. Present day challenges include improving renewable generation, vehicle electrification, storage and transmission of electricity from renewable energy sources, and security of the electrical grid**.**

Research/Focal Areas Including: Systems engineering on strategies for electric power with sustainable energy sources; distributed energy storage; power electronics (circuits and devices for power conversion); efficiency of power devices - SiC and GaN based devices and devices based on gallium oxide and diamond materials. EV automotive system engineering for controls, interconnection rules, and standards to allow EVs to provide grid storage and participate in grid power markets. Management of distributed power for grid support (i.e. via charging stations with enhanced controls). Development of state and Federal laws and regulations governing this new, low cost, clean energy storage resource. Development of professional and international standards (IEEE, SAE, IEC, UL) regarding communications and safety requirements and establishment of V2G Hubs.

Offshore Wind Power

Relevance and Background: The US mid-Atlantic and NorthEast coastal states have now committed to 42.7 GW of offshore wind purchases, 9 GW of which is already under signed contracts between utilities and wind developers. This implies a $100 Billion investment into our region over the next 10 years. Additionally, the Biden Administration has committed to 30GW on a faster schedule than the states so far, along with at least $3.2B to support industrial, vessel, and port development. The technology that new offshore wind turbines are using is changing very rapidly, with many opportunities for R&D in mechanical engineering, superconducting generators, aerodynamics, blade materials and structures, grid integration, electricity policy, meteorology, oceanography and floor geology, and many other fields. There will also be tens of billions of dollars in construction of factories, ports, vessels, and testing facilities with many economic opportunities for the region. The University of Delaware is arguably held in the highest regard of US universities in Offshore Wind research, reports, and training, used for example by US DOE, Dept of Interior, the US Congress, the States of New York, Massachusetts, and New Jersey, but little utilized by the state of Delaware. A new Offshore Wind Training Center (Funding Boost, 2022) will provide specialized training and certification in Global Wind Organization (GWO) standards to workers in the wind industry, including wind technicians, who install and later maintain wind turbines in the ocean, suppliers, port workers and sea survival and rescue personnel. UD will team up with Delaware Technical Community College and its Delaware Pathways Initiative, which allows students to participate in work-based learning opportunities while providing credit toward many DTCC degree and workforce training programs. In 2024, the Delaware Energy Solutions Act was introduced in the Delaware General Assembly, legislates the necessary steps to procure offshore wind in Delaware in alignment with reducing greenhouse gas emissions to at or below net-zero by Jan. 1, 2050 under the Climate Change Solutions Act of 2023.

Research/Focal Areas Including Wind energy; offshore wind management; offshore wind testing sites; ocean regulation and governance; spatial planning; public preferences and economics of offshore wind;

continental shelf and estuarine geophysics; mapping and prediction of offshore wind; offshore wind ecosystem Impact; robotics, smart sensors. Potential to develop workforce training programs to sustain a highly skilled workforce necessary to support the offshore wind industry.

Solar Power: Agrivoltaics: symbiosis between solar photovoltaic energy and shade crop production
Relevance and Background: Agrivoltaics is an emerging nexus of food and energy that is gaining attention for its ability to increase income for farmers and keep cropland in production while increasing the generation of clean solar electricity. Agrivoltaics or agrophotovoltaics is co-developing the same area of land for both solar photovoltaic power as well as for agriculture. The coexistence of solar panels and crops implies a sharing of light between these two types of production. As the climate becomes hotter and wetter, loss of vegetable and fruit crops is expected to increase due to heat stress and damage from heavy rains. A sun-tracking solar array system can generate electricity for sale to the grid while providing controllable shading for the crops underneath, opening up existing agricultural land for large scale PV installations by giving individual farmers and rural communities a way to remain financially solvent while retaining their agricultural heritage. This provides an opportunity to meet the Governor's goal of 40% renewable energy by 2035 without sacrificing tomorrow's farm production. The co-location of PV and agriculture could offer win-win outcomes across many sectors, increasing crop production, reducing water loss, and improving the efficiency of PV arrays. Adopting such synergistic paths forward can help build resilient food-production and energy-generation systems (NREL, 2019).

Research/Focal Areas: Sustainable Agriculture; solar arrays; development of new courses and interdisciplinary undergraduate minors and graduate programs; workforce development in electrical and construction trades; new approach to agricultural economics with additional solar electricity revenue stream.

Solar Power: Microgrids for Low-carbon Electricity and Resilience
Relevance and Background: Microgrids are emerging as the most cost-effective way to achieve simultaneously a greener and a more resilient grid by providing clean, mission-critical power on-demand to corporate and academic campuses, disaster-prone communities, military bases and data centers when the grid goes down. They are self-contained electric networks that integrate diverse clean energy sources (solar arrays, fuel cells, microturbines), batteries, advanced sensing and control strategies, and local energy management to provide reliable low-carbon electricity independent of the electrical grid. A microgrid not only provides backup for the grid in case of emergencies, but can also be used to cut costs, or connect to a local resource that is too small or unreliable for traditional grid use. A microgrid allows communities to be more energy independent and, in some cases, more environmentally friendly.

Research/Focal Areas Including: Microgrid development; smart cities; cybersecurity; global studies; First step grand challenges and sustainability.

Solar Power: Next Generation Solar Energy Towards a Carbon-Free Energy Future
Relevance and Background: Delaware is among the states most vulnerable to the impacts of climate change and, therefore, has a tremendous stake in a transition to carbon-free energy. While solar energy implementation has grown rapidly as costs have plummeted in recent years, accelerated development and deployment of solar energy is needed to meet a national goal of 100% clean electricity by 2035 and a statewide goal that 40% of all energy be renewable by 2035. Delaware has a long history and international reputation for excellence at the forefront of research and development in the science and technology of photovoltaic solar energy. The existing multi-disciplinary expertise in materials, engineering, electronic systems and manufacturing can be harnessed to continue to play a big part in

the development of next generation solar technologies that will be required to reach these goals. Increased investment in solar energy approaches and their increased deployment can bring many jobs in areas ranging from R&D, manufacturing, and deployment including installing solar from rooftops to utility-scale solar power stations.

Research/Focal Areas Including: New materials and processes for low-cost, high-performance solar cells and modules; design and validation of new solar cell and module architectures; approaches for integration of photovoltaics to buildings or agricultural applications; power electronics and control systems for integrating high levels of solar into the grid; development of hydroxide exchange membrane fuel cells (HEMFCs), and AEM electrolyzers that produce green hydrogen (Versogen); education in the science and technology of solar energy and workforce development

Hydrogen Energy

Relevance and Background: Delaware is emerging as a leader in the hydrogen sector, driven by its commitment to clean energy and technological innovation. The state's strategic location, coupled with robust infrastructure and research capabilities, positions it as a pivotal player in the hydrogen economy. The University of Delaware's Center for Clean Hydrogen is a cornerstone of the state's research efforts, emphasizing innovations in hydrogen production, storage, and usage. Their work spans fundamental research to practical applications, aiming to develop cost-effective and scalable hydrogen solutions. Furthermore, Delaware's active participation in national initiatives, like the regional MACH2 program, supported by the US Department of Energy underscores the region's dedication to transitioning towards a hydrogen-based energy system, contributing to both environmental sustainability and economic growth.

Research/Focal Areas Including:

Delaware is focusing on the development of hydrogen fuel cells and electrolyzers, specifically hydroxide exchange membrane fuel cells (HEMFCs) and anion exchange membrane (AEM) electrolyzers, which are pivotal for producing green hydrogen. This green hydrogen can be used across various applications, including energy storage, transportation, and industrial processes, contributing to a reduction in carbon emissions and enhancing energy resilience.

In addition to technological advancements, Delaware is also investing in research and development to improve hydrogen production and utilization efficiencies. Key research areas include the design and validation of new materials and processes for hydrogen production, development of hydrogen infrastructure, and integration of hydrogen technologies into the existing energy systems.

Environment

Relevance and Background: Global climate change, land use change due to population growth, and air and water pollution are major environmental challenges facing Delaware. Environmental conditions have a significant impact on quality of life and human health, and also affect major Delaware industries, including tourism and agriculture. Ecosystem services, such as the state's water supplies provide a powerful engine for the economy, contributing up to $6.7B, including more than 70,000 jobs, providing over $2 billion in wages (Narvaez and Kauffman, 2012). Tourism, including beach resorts is the third largest employer in the State. Tourism in Delaware has grown to a $2.1B industry, employing 39,000 people and attracting more than 7M visitors to Delaware each year. Agriculture, propelled by the large poultry industry, provides a total economic contribution of nearly $8B to the State.

Delaware is the lowest lying state in the U.S. an average 60 feet above sea level. The state is vulnerable to Atlantic storms and impacts of sea level rise (SLR) due to climate change. Sea level is rising faster in our region than other parts of the world (Sallenger, 2012), with significant projected impacts on the natural and built environment, including degraded wetland habitats that buffer floodwater, and saltwater intrusion effects on water. A large part of the state's infrastructure including factories, wastewater treatment plants, bridges, and roads are located in flood-prone and low-lying areas. The state is also faced with subsidence of coastal areas and failing century-old dikes. The latter issue impacts cities, such as historic New Castle and Delaware City, where the dikes also protect two industrial sites contaminated with hazardous waste from tidal flooding.

Coastal Resiliency
Relevance and Background: Building a community's ability to "bounce back" after hazardous events such as hurricanes, coastal storms, and flooding – rather than simply reacting to impacts is a critical need as climate change is exacerbated. A community that is more informed and prepared will have a greater opportunity to rebound quickly from weather and climate-related events. Understanding where and how communities are vulnerable to coastal hazards, and adapting planning and development practices to compensate for these vulnerabilities will ultimately result in lives and dollars saved.

Research/Focal Areas Including: Salinization; Soil biogeochemistry; Crop rotation; Wetland transition; Coastal Flooding and Modeling; Coastal Resiliency; Coastal Hazards; Water Quality; Water Security; Engineering with Nature and Green Infrastructure Approaches

Water Security
Relevance and Background: In Delaware, threats to water security relate primarily to water quality and arise largely due to human behavior-whether from excess nutrients from agriculture and households, increased salinity due to groundwater pumping and sea-level rise, or degradation of ecological systems from an expanding human footprint. Thus, improving water security is fundamentally about making better decisions, based on clear scientific understanding, reliable methods and models for predicting future outcomes, improved technologies, and evidence-based policies and programs that cost-effectively invoke positive behavioral change.

Water Quality
Relevance and Background: As a coastal state, Delaware is already experiencing the effects of a changing climate. Saltwater intrusion is inundating fields more frequently through both stormwater surges and saline groundwater. Most soil salinity research has been performed in drier climates with less leaching and different soil types. Research in soil biogeochemistry, alternative crop rotations, and wetland transitions are necessary to serve Delaware landowners and farmers and can provide a model for the Mid-Atlantic.

Research/Focal Areas Including: Salinization; Soil biogeochemistry; Crop rotation; Wetland transition; Coastal Flooding and Modeling; Coastal Resiliency; Coastal Hazards; Water Quality; Water Security; Engineering with Nature and Green Infrastructure Approaches

Blue Economy and Blue Tech
Relevance and Background: Research off of Delaware's coast often falls into the "Blue Economy", or the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of the ocean ecosystem, realm. Specifically, there is 'BlueTech' work taking place at the University of Delaware's Lewes Campus, with the Robotics Discovery Lab and collaboration

between the University and Ocean Infinity to launch several projects using autonomous surface vessels (ASVs) as well other projects using underwater autonomous vehicles (UAVs). UD's College of Earth, Ocean, and Environment has also collaborated with UD's Horn Entrepreneurship program and the Ratcliffe Foundation to create the Ratcliffe Eco-Entrepreneurship Fellows (REEF) program. A new Blue Economy Tech Center (Funding Boost, 2022) will develop autonomous underwater robots and remote sensing systems to address needs relating to the marine environment, energy and climate change while promoting economic development and career training in Sussex and Kent counties. It aims to ignite both economic growth and environmental stewardship in the First State and beyond and will introduce underrepresented students to environmental robotics and other marine technologies

Research Focal Areas: Marine Science and Policy, Ocean Engineering, Eco-Entrepreneurship

Human Health

Relevance and Background: Over the past decade, Delaware has successfully enhanced its biomedical research and biopharmaceutical manufacturing capabilities by taking full advantage of the institutional networking, research collaboration, and infrastructure-building initiatives supported by the National Institutes of Health (NIH) Institutional Development Award (IDeA) program. The IDeA program provides catalytic funds to states like Delaware with the goal of creating a sustainable and impactful biomedical research capability across the nation.

Delaware has benefited greatly from its growing collection of IDeA programs. The IDeA network consists of Six Centers of Biomedical Research Excellence (COBREs), one IDeA Clinical and Translational Research (CTR) program and one IDeA Network of Biomedical Research Excellence (INBRE). The COBRE programs, as well as the INBRE and CTR programs, generate, complement, and enrich Delaware's research strengths by leveraging NIH investment in personnel, equipment, core facilities and student programs to solve health problems, build research capacity, and build a better student pipeline for the next generation of physicians, healthcare workers, and scientists. Clinical and translational research supported by the CTR program seeks to reduce health disparities in underserved and understudied populations. Together, these programs have mentored research experiences to over 70 graduate students and 600 undergraduate students, received greater than $300M in NIH funding which has led to greater than 1000 additional awards totaling more than $500M in additional biomedical research funding.

The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) project grew within Delaware's thriving biomedical research community. NIIMBL is a part of NIST's Manufacturing USA network of institutes. It is a public-private partnership whose mission is to accelerate biopharmaceutical innovation, support the development of standards that enable more efficient and rapid manufacturing capabilities, and educate and train a world-leading biopharmaceutical manufacturing workforce, fundamentally advancing U.S. competitiveness in this industry. NIIMBL will lead a project that will support the design-build and engineering work necessary for the construction of a current Good Manufacturing Practices (cGMP) facility to support biopharmaceutical innovation for clinical research and a process development testbed will be implemented to explore continuous manufacturing of therapeutic proteins and vaccines. These activities will support the anticipated need for enhanced workforce training efforts in biopharmaceutical manufacturing (Funding Boost, 2022).

Research/Focal Areas Including: Nursing, Human Health; Neuroscience; Cardiovascular; Cancer; Gene Editing; Bioinformatics; Musculoskeleta: Advanced Biomaterials; Membrane Protein Production; Pediatric Research; Osteoarthritis; Sickle-Cell disease.

Manufacturing & Materials

Relevance and Background: Advanced Manufacturing integrates innovative technology in the production process or within an end product itself. Advanced Materials drive higher levels of end-use performance while also making more efficient use of inputs such as energy and raw materials. Coupling materials and manufacturing advances enables increased productivity and sustainability, enhances global competitiveness, and provides enhanced value to the customer through products.

The chemical revolution and population growth have increased the demand for energy, water, food, and goods, with little attention paid to how we manufacture and supply these goods and the fate of materials at the end of their lifespan. Single-use plastics, such as face masks, and food, exemplify the challenge; most of them end up in landfills. This has created a tremendous waste stream from plastics, food waste, paper industry, biorefineries, biologics, and municipalities that threaten the globe due to global warming and numerous other health aspects. Developing breakthrough technologies and processes that will decrease environmental impacts and boost energy productivity especially related to chemical manufacturing is critical.

Advanced manufacturers assess, investigate, and invest technology areas across a wide spectrum of scientific, engineering, and information technology fields. Delaware is the center of the largest consumer market in the U.S. with more than 50 million people within 250 miles, close proximity to major airports with international and domestic cargo capacity, a major international port four hours from the Atlantic Ocean and an intermodal transfer point and rail freight facilities throughout the region.

The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL), part of the Manufacturing USA network of institutes, is headquartered at University of Delaware's STAR Campus and lives at the nexus of advanced manufacturing and biopharmaceutical development. It is a public-private partnership whose mission is to accelerate biopharmaceutical manufacturing innovation, support the development of standards that enable more efficient and rapid manufacturing capabilities, and educate and train a world-leading biopharmaceutical manufacturing workforce. By leading a coalition of 190 biopharmaceutical companies, universities, community colleges, and nonprofits, NIIMBL creates advanced manufacturing technologies and supports high wage job creation with an estimated 480 jobs created in Delaware since 2017. The University of Delaware is also leading a major research project in the Rapid Advancement in Process Intensification Deployment (RAPID) Manufacturing Institute, led by the American Institute of Chemical Engineers (AIChE). The U.S. Department of Energy announced RAPID as the newest and tenth member of the national network of Manufacturing USA Institutes and the project will focus on catalysis and reactors. Delaware seeks to be a leader in advanced manufacturing by supporting manufacturing systems that reuse, refurbish, remanufacture and recycle in order to create a closed-loop system, minimizing the creation of waste, pollution and carbon emissions, and to drive the commercialization of inherently sustainable advanced materials through novel manufacturing processes.

Composite materials are advanced materials formed by combination of two or more dissimilar materials to impart a new set of characteristics that neither of the constituent materials could achieve on their

own. Advanced composites replace traditional materials such as metals in numerous applications such as aerospace and construction. Delaware's seeks to continue to be a leader in designing new composites to accomplish multiple performance objectives in a single system; developing models and simulations in a "virtual manufacturing" environment for process optimization and improved quality, affordability, and innovative new composite manufacturing processes; connecting industry with researchers through creating new materials, concepts, and technologies and inserting those elements in new products and applications; and providing access to potential employees with the capability to make immediate contributions to new products and applications.

Research/Focal Areas Including: Plastics: Chemically transforming plastic waste into fuels, lubricants, and other valuable products; Municipal and food waste (Food Science, Biology, Civil, Chemical and Environmental Engineering): Additive or Distributive Manufacturing: Catalysis and reactors; Materials synthesis; Multifunctional materials; Materials mechanics and design; Processing and manufacturing sciences; Advanced materials and characterization; Sensing and control; Scale-up of next generation advanced composites, which can be handled like metals in manufacturing processes; Therapeutic protein manufacturing; Coronavirus; gene therapy and cell therapy manufacturing; vaccine development and manufacturing Education and workforce development platforms

Quantum Science and Engineering

Relevance and Background: Quantum Information Science technologies have recently emerged as powerful tools of critical importance to the FinTech sector. For example, quantum cryptography provides a fundamentally secure means of communication and is therefore of critical importance to cybersecurity. Similarly, it has been proven that quantum computers can outperform all classical computers (even supercomputers) for certain types of computations, including optimization problems that are critical to the FinTech industry. Importantly, the development of practical and deployable quantum technologies has seen explosive growth in the past 5 years. Delaware's FinTech industry (e.g. JP Morgan Chase) is heavily invested in the use of quantum technologies. Areas of current importance for the state include the development of quantum algorithms for NISQ systems (Noisy Intermediate Scale Quantum systems) that can best exploit the limited quantum computing hardware capabilities currently available, the development of more advanced quantum computing platforms, and the development of quantum hardware for secure information transmission.

Research/Focal Areas including: Quantum Computing, Quantum Cryptography;

Research/Focal Areas: Data Science, Data Analytics, & Big Data: Development of sensors and sensor networks for enhanced inputs to data analysis through high performance computing, including new paradigms for quantum sensing that offer increased precision and sensitivity. Quantum computing, which offers alternative means for more efficiently deriving actionable conclusions from large data sets.

Research/Focal Areas: Solar Power and Agrivoltaics Including: Development of strategies and materials to efficiently share light between crops and solar photovoltaic power. Plants likely want one part of the solar spectrum (e.g. visible – near infrared frequencies) but don't effectively utilize other parts (e.g. UV, far infrared). PV materials designed to harvest the part of the spectrum the plants don't want while letting through the part they do could be very useful.

Relevance and Background: Manufacturing & Materials*:* Semiconductor devices are at the heart of all modern electronics and the US has invested heavily in the growth of domestic semiconductor

manufacturing via the CHIPS and Science Act. The University of Delaware is a member of the Mid-Atlantic Semiconductor Consortium that both conducts research targeting current limitations of semiconductor devices and seeks to train the workforce needed to support the planned rapid growth of domestic semiconductor manufacturing. *[Jamie Phillips can provide more detail on this.]* Similarly, advancing quantum device technologies and industries is a high priority for both NSF (Quantum Leap) and the US government (National Quantum Initiative). Quantum mechanics underlies the behavior of all of the materials that comprise our world, from the origin of atomic energy levels to what makes a metal different from an insulator. However, we do not encounter quantum mechanical effects at the macroscopic level of our everday life. We are now in the midst of the ``Second Quantum Revolution,'' which originated in the recognition that quantum mechanics can be exploited to create computing, communication, and sensing paradigms that can drastically outperform devices built on classical technologies. The most common example is the quantum computer, which has been theoretically proven to outperform any possible classical supercomputer for certain types of computational problems. These opportunities have driven an explosion in investment in quantum technologies by companies such as Microsoft, Google, IBM, Northrop Grumman, and JP Morgan Chase. A recent International Data Corporation analysis projected that the global quantum-computing industry will grow from $412 million in 2020 to $8.6 billion in 2027, which is approximately a 50% annual growth in the size of the industry and the required workforce. Delaware universities have invested heavily in new research capabilities and workforce training initiatives designed to advance this national priority.

Research/Focal Areas Including*:* Semiconductor materials and devices; magnetic materials and devices; new materials and devices for light-driven information processing and secure information transmission; quantum information science, including material foundations and device implementations.

Space Sciences and Technology

Relevance and Background: National priorities and global interests increasingly are based on understanding the space environment, accessing it and exploring it, and making use of the knowledge gained from studying it. A broad range of expertise and research is involved in these activities. On the scientific side, essential areas of study examine the physical processes occurring everywhere outside the earth's atmosphere, both near and far, in Geospace, the Heliosphere, the Sun, in the Galaxy and beyond. This involves disciplines such as space plasma physics, solar and heliospheric physics, cosmic ray and astroparticle physics, astrophysics and astronomy. Each of these contribute to fundamental knowledge as well as practical applications. An excellent example is Space Weather, which exerts many influences on a technological society, including impacts on communications and both human and robotic exploration. Access to space and development of instrumentation for studying it involves expertise in diverse technological capabilities, ranging from innovative semiconductors and novel materials to development of advanced computational methods, applied mathematical physics, and data science. These fields also offer excellent opportunities for advanced education and training for improved competence in our technological workforce and in society in general.

Balance between science and technology/industry: Scientific research ranging from near-Earth space to the cosmos necessarily involves numerous disciplines including distinct areas of fundamental physics (hydrodynamics, plasmas, radiation, optics, mechanics, particles and their interactions), applications of physics (solar, interplanetary, astrophysics, astronomy and high energy astroparticle physics), and a strong reliance on engineering and technology (materials science, chemical and electrical engineering, instrumentation, fabrication) and computer and data science. The State of Delaware is host to current expertise in essentially all these areas, in basic science, applied technologies, and industry. A goal of the

State is to support and develop the great potential in these areas, maintaining growth and balance in fundamental sciences, applications, industrial activity, and education. An equally important goal is to further encourage cross-disciplinary and cross-institutional connections related to various facets of Space Science and Technology within the jurisdiction and the region.

Research/Focal Areas: Space plasma physics, heliophysics, astrophysics, particle astrophysics, astronomy, Space Weather, material sciences, advanced semiconductors, high performance computing, data science, facilities for instrumentation development. Each of these areas involve elements of innovation/entrepreneurship and workforce training. These areas offer possibilities for participation in large national and international projects advancing the limits of knowledge about space and the universe.

Talent Retention, Upskilling & Attraction, & Entrepreneurship

Relevance and Background: Continuous learning and education are required to stay competitive in today's job market. Transforming education and career pathways to help broaden participation in science and engineering is critical. In Delaware, ensuring that our citizens are provided with occupational training and employment service opportunities to help them obtain sustainable employment is a high priority. A study conducted by McKinsey & Company found that 40 percent of American business leaders are having trouble finding employees with in-demand skills, even for entry-level positions. An additional 20 percent of employers claim that most of their new talent is underprepared for the job that they're entering. The discrepancy between the demand for skilled talent and the supply of talent available represents a "skills gap." This gap has widespread negative effects on economic growth (McKinsey & Company, 2017).

Talent upscaling programs can close the gap and lead to improved employee performance, improved satisfaction and morale, address employee workplace weaknesses, ensure consistency and Increased productivity as well as potentially lead to Increased innovation in products and strategies. We seek to design programs to provide students with necessary skills to make them successful in the workplace, for those who want to upgrade their skills, change their career path, secure a higher paying job or one that they enjoy more. The objective is to create economic prosperity for individuals, businesses, and communities. Workforce training and development should be an ongoing process of educating and empowering the workforce so that they can tackle the industry problems of the future. Delaware has a robust network of technical education, including college, vocational high schools, trade schools and certificate programs.

In the area of IT/data/fintech, Delaware is home to a wide range of targeted education and training initiatives, from K-12 programs like Delaware Pathways to a range of postsecondary offerings. These include innovative short-term programs like Zip Code Wilmington, Code Differently, associate degree programs at Delaware Technical Community College, and bachelor's and advanced degree programs at the University of Delaware, Delaware State University, Goldey-Beacom College, and Wilmington University. The number of graduates across tech-related programs at the University of Delaware has increased by approximately 30% since 2015, with Zip Code Wilmington nearly doubling its cohort size between December 2015 and July 2018.

Compared with their proportions in Delaware, racial and ethnic minority groups are significantly underrepresented in the Delaware STEM workforce. According to the 2021 NSF Science and Engineering Indicators, the Delaware growth rate for STEM occupations is slightly higher than the national average.

Black and Hispanic workers remain underrepresented in STEM programs, and current trends in Delaware's STEM higher education pipeline appear unlikely to narrow these gaps. In light of this shortage, we seek to develop policy guidance to track and increase awareness of Delaware's higher education's progress towards STEM diversification and create strategic partnerships with programs that support curriculum change and address disparities in underrepresented student support. The policies will focus on student factors to increase the identification, recruitment, persistence and graduation of underrepresented students in STEM with a specific goal of encouraging underrepresented student group interest in STEM fields.

In recent years, the specific importance of the Life Science sector within Delaware's STEM workforce efforts has been recognized, and after a white paper was co-authored by the Delaware Prosperity Partnership and the Delaware Bioscience Association (DE Bio), steps have been taken to address the opportunity in this field. These include the appointment of a dedicated position to develop and implement a comprehensive strategy to deliver a talent pipeline for the diverse range of career opportunities in the region's thriving biotech ecosystem, jointly hosted by DE Bio and the Delaware Biotechnology Institute at UD. Secondarily, in 2023 the Delaware Center for Life Science Education and Training was established to accelerate the engagement, training, and delivery of a life science workforce – at every level – for Delaware's growing life science sector. This center works closely with key stakeholders to develop recruitment and training programs leveraging regional expertise and local community partnerships to produce individuals with the specific skills needed to be successful in current and future Delaware life science businesses.

In the area of Quantum Science and Engineering there are several quantum-relevant programs here, including the new MS and PhD program in Quantum Science and Engineering. We are considering adding certificate programs in this field as well, which would offer a nice upskilling opportunity without the commitment to a full MS or PhD.

Research/Focal Areas: Internships; Experiential learning; On the job training; Course embedded research; Professional career development activities; Delaware Technical Community College: Workforce Development and Community Education Division; Delaware Department of Labo**r:** Registered Apprenticeships State Summer Youth Employment Program. Work Opportunity Tax Credits; Veterans Services, Foreign Labor (Alien) Certification Program, Bonding Program, Migrant & Seasonal Farm Worker Program, Dislocated Worker Program; UD Continuing and Professional Studies programs; Biopharmaceutical Processing Workforce Development Continuum;

Entrepreneurship: As added focus on workforce development becomes a clear part of economic development strategy, particularly as it is related to Science and Technology, added opportunities and programming to educate and encourage entrepreneurship is also important. The broader Delaware Innovation and Startup ecosystem has grown significantly over the past seven years, and the new programming that is in place has helped launch many new businesses, some with the potential to scale into large employers with significant operations in Delaware. As Delaware has adjusted to the current pandemic and phases a return to 'normal', there will be increased focus on new technologies and business opportunities which naturally partner with them.

Focal Areas/Programming:

- Educational Programming:
    - Horn Entrepreneurship (https://www.udel.edu/research-innovation/horn/):
        - Blue Hen POC; NSF I-Corps Hub

    - DE Innovation Space (https://innovationspace.org):
        - Science Inc. Accelerator; SPARK; First Fund
    - DESCA (https://desca.net):
        - Entr. Roundtable; Tech2Market
    - Fintech Innovation Hub at STAR Campus (https://www.udel.edu/research-innovation/star/fintech/)
        - Center for Accelerating Financial Equity (CAFÉ): https://ftcafe.org/
    - Bronze Valley/Gener8tor – Venture Lab Delaware: https://www.gener8tor.com/gbeta/bvvl-delaware

- Funding Opportunities:
    - DTIP Grants
    - EDGE Grants (https://business.delaware.gov/edge/)
    - Startup 302 Pitch Competition (https://neofest.org/startup-302)

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