UConn School of Engineering

Strategic Planning Report

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1. Mission Statement and Strategic Values of the School of Engineering

Mission

Mission I: Success of our Students

Broadly educate a diverse group of students and professionals with rigorous, theoretical, practical, and impactful training in engineering, mathematics, and the sciences; professional ethics; environmental and socioeconomic consequences; and exposure to the broader humanities, thus *preparing them* for successful careers as practicing engineers, technology leaders, entrepreneurs, policy makers, educators, and engaged citizens.

Mission II: Generation of Knowledge

Pursue a bold research agenda to address the grand challenges facing our society and the planet. Excellence will be the key driver of our research, and our focus will be on the fundamental and applied questions in the realm of complex and often interdisciplinary systems. Substantial progress can only be accomplished by inclusive, diverse, and highly collaborative research teams.

Mission III: Economic Impact

Serve the State of Connecticut, the Northeast, the nation, and society through innovation, knowledge generation and transfer, entrepreneurship, and public and professional engagement.

Our Values

The driving tenet in the Strategic Plan is to conduct trailblazing research and provide a modern and innovative engineering education to our students that maximizes the benefit to society and improves human life. Our faculty, staff, and students are driven by the following values and principles:

Be Bold: creative, innovative thinking must prevail over conventional and incremental ideas to enable real transformation of our society.

Deliver: we are proud of our drive and ability to deliver on our educational, research and public engagement commitments, and of our alumni that continue to be productive members of our society upon graduation.

Collaborate: today's interdisciplinary challenges can only be addressed by teams that collaborate intensely and purposefully, with shared credit being a core feature of collaboration, and have diverse mindsets.

Be Inclusive: diversity in all its aspects leads to more effective answers to the most acute problems that we face. We are steadfast in continuing to foster and increase the diversity of our community and strive for equity.

Be Impactful: we commit to engaging with relevant state, national, and global communities, public institutions, and private industry, to understand and address their needs for the highest impact.

Be collegial: the vitality and success of our School of Engineering community arise not just from individual scholarly achievements, but also depend upon the quality and quantity of collegial interactions and contributions to the mission of our community.

Figure 1: School of Engineering's Strategic Areas of Strength and Growth

Our Vision and Strategic Directions

We aim to develop the next generation of creative and innovative engineers and bold technological solutions needed to address the grand challenges facing our society and the planet in the 21st century. The School of Engineering has talented faculty, resourceful and capable students, successful alumni, and close partnerships with major companies in the region.

We are determined to align our resources and energy to achieve national and international recognition for transformative research in key areas, illustrated in Fig. 1, including:

- Manufacturing, Bio-Manufacturing & Materials
- Bioengineering, Biomedical Technologies & Digital Health
- Sustainability: Energy and Environment
- Engineering of Complex Systems and Resilient Infrastructure
- Cybersecurity, Data Sciences, and Computing
- Engineering Education, Diversity and Inclusion, and Innovation and Entrepreneurship.

Goals

Education

In line with our overall mission, the School of Engineering has established the following goals for our undergraduate and graduate programs:

- Evolve existing and develop new programs to meet the needs of future generations of engineering students as well as employers in the state and beyond
- Evolve existing and develop new experiential and life-transformational engineering education opportunities, which will instill a culture of lifelong learning
- Encourage and support innovative and inclusive teaching practices and content that recognize the diverse contributions of all learners, and instill in engineering graduates the tenets of diversity, equity, inclusivity, and social responsibility
- Improve undergraduate and graduate program reputations, including in U.S. and international rankings
- Increase and improve graduate student applicant pool of domestic and international students
- Expand the number of long-distance and in person content delivery masters and certificate programs, to meet the needs of regional industry
- Increase number of graduate students funded by scholarships
- Increase number of PhD students moving on to faculty positions

Research, Scholarship, Innovation and Discovery

- Increase and diversify funded research portfolio
- Increase number and size of large interdisciplinary research proposals and establish federally funded research centers especially in areas that are highly relevant to CT's economic priorities.
- Increase the number of high-impact scientific research/publications (e.g., Nature, Science, PNAS, and other highly impactful publication venues)
- Increase technology transfer through targeted innovation and entrepreneurship programs.

Culture, Diversity and Inclusion

- Work with UConn Admissions and the Foundation to explore new sources of highly qualified students and identify scholarship opportunities that make it possible for those students to "Choose UConn," with a goal of reaching gender parity in incoming classes by 2026
- Increase diversity of SoE faculty at all levels
- Increase programs and initiatives to support a diverse, inclusive, equitable and life-transformative culture within the school and beyond
- Increase diversity in graduate student recruitment by
    - Identifying appropriate conferences and have an impactful presence at these conferences
    - Interfacing with the Provost's office on their knowledge base
    - Leverage different professional societies representing underrepresented groups

Public and Professional Engagement

- Enhance public perception of engineering in the state and region
- Encourage and reward high profile faculty engagement in professional societies (direct impact on brand recognition)

Organizational Infrastructure

- Leverage new facilities and programs
- Reward portfolio of faculty contributions (PTR process)

2.1 Key Strengths – Education, D&I, and Development

Undergraduate Education

The School of Engineering successfully met its commitment to Next Generation Connecticut by increasing the engineering undergraduate population by more than 70%. From a population of approximately 2000 in Fall 2010, the undergraduate population of the school in Fall 2020 stood at 3621, an increase of nearly 83%. Several key programs helped support this growth and maintain high educational standards.

Teaching Faculty

The In-Residence Faculty program has had an enormous impact on the ability of the School of Engineering to grow due to their pedagogical skills and enthusiasm toward engineering education. In-Residence Faculty typically teach 5-6 courses per academic year, and their addition to the faculty ranks in the past decade has enabled the school to grow while still maintaining tenure-track teaching loads in line with peer and peer-aspirant schools. This, in turn, has allowed tenure-track faculty the ability to increase the research output of the departments and grow the profile of the School nationwide. As of the 18-19 academic year, In-Residence faculty made up approximately 20% of the total faculty headcount, but were responsible for teaching nearly 40% of all sections of undergraduate engineering courses.

Freshmen Cornerstone Engineering

Redesigned in the 2016-2017 academic year, the ENGR 1166 Foundations of Engineering course has become the cornerstone of the first-year engineering experience. Supported by faculty from across the School of Engineering, the course now supports nearly 500 students per academic year in a project-based first-year design experience. The course moved into its new space in the 2018-2019 academic year, a newly renovated 2000 sq. ft First Year Design Laboratory on the ground floor of the United Technologies Engineering Building. Featuring a collaborative workspace and access to tools and makerspace equipment, this space became central to the first-year engineering experience. The redesigned course also hosts a First-Year Design Expo at the conclusion of the spring semester, the same day as Senior Design Day, to showcase the projects.

Professional Advising

The School of Engineering transitioned to a hybrid advising model consisting of professional staff advisors with backgrounds in higher education and student development in a student's first two years, followed by a transition to a faculty advisor for their final two years. The academic advising team has grown to nine team members serving the first two years, as well as overseeing numerous other co-curricular and academic support roles.

Senior Design

This is the final experience of our students' undergraduate career, a year-long process that provides a hands-on application of the principles and theories they have honed during their previous three years. Students learn and apply the principles of design; the complex interplay among engineering solutions and societal, environmental, economic, and ethical considerations; the language of industry; and the power of engineering to catalyze new solutions to entrenched problems such as sustainable energy, access to clean water, agriculture, transportation, and health.

Each year, 75-plus organizations, large and small, partner with the UConn School of Engineering to not only fund projects, but also donate valuable mentorship time, as well as solidify the unique information-sharing pipeline that the School and University has with the engineering community. With the generous support of all our sponsors, our senior students get mentorship from talented engineers in the industry, as well as valuable hands-on experience in a group setting.

Those talented engineers from each of our sponsor companies provide a service that is crucial: the ability to tackle any engineering hurdle that comes their way by thinking through the lens of a business. This mentorship also gives companies direct visibility into the talent of our students, and a long look at their problem-solving abilities and group dynamics. Because of that opportunity, thousands of our students have received job offers from their company sponsors, and others have gained crucial experience and references that have helped them during their job searches.

By solving real-world problems, and creating innovative solutions for companies, the School of Engineering, and its students, drive significant economic impact towards the sponsoring companies and the state of Connecticut as a whole, making Senior Design a crucial yearly program.

Graduate Education

Quality Students & Programs

Accompanying the growth in research, UConn Engineering's graduate education has grown in both quality and quantity. Last year, UConn Engineering had 894 graduate students, including 294 female and 359 international graduate students. Of those enrolled in the Ph.D. program in 2019, 22 percent were supported by federal fellowships; 8 percent were supported on teaching assistantships; 62 percent received research assistantships; and 7 percent were supported from other sources.

Recruitment Initiatives

To address our challenges in recruiting enough graduate students to fully staff our rapidly growing research programs, in Fall 2018, the school embarked on a graduate recruitment marketing campaign, encompassing email marketing, marketing automation, offline components, virtual conferencing, and social media advertising. In Fall 2019, nearly 25% of our admitted students came from this campaign. This program was expanded in the past year, and by January 2020 our Ph.D. applications were up again nearly 30% year-over-year, but the effects of the COVID-19 global pandemic have significantly eroded Fall 2020 graduate enrollment, particularly for our incoming international students. By 2022, our Ph.D. applications had surpassed 2019 numbers by over 50%.

Fellowships Awarded to Supplement and Offset the Cost of Graduate Assistantships: In the past few years, SoE focused on developing philanthropic-based graduate fellowships or training grant fellowships to offset the cost of graduate education for tuition-paying graduate students or for principal investigators. The success in these areas has been significant, totaling over $1.2M in the AY19-20 and includes the following fellowships. (Our students directly receive many other fellowships, not reported here):

- Federal: 7 NSF Bridge to the Doctorate, 36 ED GAANN, 7 NSF PIRE, 1 Naval STEM Coalition
- Industry: 10 Cigna, 15 Eversource, 11 GE Innovation, 3 Synchrony Financial, 3 UTC
- UConn-Internal Competitions: 3 Giolas-Harriott & Crandall-Cordero fellowships and 1 Taylor-Booth fellowship

John Lof Leadership Academy for Graduate Engineering Students: Without culturally competent visionaries that can efficiently communicate, collaborate, and create, there would be no progress in society. The John Lof Leadership Academy strives to inform and inspire these next-generation leaders in academia, industry, and beyond.

Through a "for us, by us" philosophy, John Lof Scholars aim to develop themselves through focused training, specialized workshops, and active learning through outreach and enterprise on and off the UConn campus.

Professional Education

The UConn School of Engineering Professional Education (PE) program at the University of Connecticut School of Engineering delivers coursework required by graduate students toward completion of an engineering degree or certificate; courses of interest to students and corporate partners who wish to expand their knowledge and those of their employees, with

offerings of specific engineering subjects relevant to their current needs; and courses for practitioners and students who are interested in advancing their knowledge of specific engineering subjects in a non-degree path.

The PE program is currently focused on providing Master of Engineering (MENG) Degrees in 15 areas of concentration, Advanced Engineering Certificates (AEC) in 9 specialized areas, as well as several non-credit programs and specialized boot camps that are highly sought after by industry.

Professional education has also strengthened UConn-industry collaborations in research and development. We actively pursue ongoing discussions with our industry partners regarding their training and development needs to adjust and update our program offerings.

Globalization

UConn Engineering's graduate programs attract a diverse population of students from across the globe, enriching the UConn Engineering community, building cultural bridges with other nations, and enhancing our reputation globally. The UConn International Engineering Programs offer an unparalleled experience for students looking to become truly global engineers. Graduates of this program typically receive two degrees within a five-year span (a B.S. in an engineering discipline and a B.A. in French, German, Chinese, or Spanish). In addition, the Engineers As Global Leaders for Energy Sustainability (EAGLES) program established at UConn in 2011 provides a prestigious transatlantic dual-degree program with the objective of producing engineering graduates who are able to confront developing global challenges in energy sustainability. Participating partners are the Politecnico Milano and the Universidad Politécnica de Madrid.

Diversity and Inclusion

Faculty Diversity Initiatives

Recognizing the need for greater diversity in our faculty, the SoE has focused on outreach and active recruiting of outstanding faculty that enhance the diversity of the School. In recent years we have had significant success in recruiting outstanding female faculty. Since Fall 2018, 50% of our new hires were women. In Fall 2019, 26 out of 145 T/TT faculty and ten out of 29 APIR are female. Women now account for more than 18% of our faculty, which exceeds the national average. Additionally, in the last few years, we have been able to hire two exceptional Hispanic faculty as well as the School's first African American female faculty member.

In Summer 2018, the School chose its first ever female department head (in the Civil and Environmental Engineering Department). In addition, in August 2019, Prof. Leslie Shor assumed the role of Associate Dean for Research and Graduate Education. In addition to building multidisciplinary research teams, she is working to promote gender parity and diversity in our faculty and graduate student populations.

Student Diversity Initiatives

Our aim is to create an environment where differences are considered assets that make us better learners, teachers, scholars, researchers, extension educators, employees, and students.

A number of SoE initiatives are part of a cultural shift that builds on these differences. For example, the focus of a new NSF-funded project in the School of Engineering aims to improve higher education for students on the neurodiversity spectrum.

Universities nationwide are struggling to attract and retain a diverse graduate student body. We recognize that successful recruitment of minority students requires a sustained national presence at conferences and other recruitment venues, so we worked to establish a presence at these conferences. In addition, we continued our mentoring and support of our existing minority graduate student population through our Bridge to the Doctorate program, the JLLA, the Student Association of Graduate Engineers (SAGE), Women in Math, Science, and Engineering (WIMSE) and Women in STEM Frontiers in Research (WiSFiRE).

Bridge to the Doctorate

We supported six minority students through our Northeast Louis Stokes Alliance for Minority Participation (NELSAMP) Bridge to the Doctorate Fellowship grant, awarded by the NSF in March 2017. The Bridge to the Doctorate provides mentorship and professional development tailored to the needs of minority students. At the GEM Grad Lab hosted by the NELSAMP, UConn's Bridge to the Doctorate (BD) fellows participated as panelists and shared their experiences as underrepresented minority (URM) students in STEM. Our BD fellows also served as judges in the poster session hosted by NELSAMP, where about 100 LSAMP scholars presented their research. Our current BD fellows from University of Puerto Rico in Mayagüez (UPRM) visited UPRM in November 2019 and January 2020 where they held workshops and talked to STEM students about graduate studies at UConn.

Recruiting Efforts

In Fall 2019, we attended local chapters and national conferences such as NSBE and SHPE, and oSTEM (Out in STEM- LGBQTi+). Aida Ghiaei gave a presentation at the GEM GRADLab on "Applying to Graduate School," with information on the UConn Graduate School and the BD program. In addition, we worked to recruit female students from local colleges, including Trinity College and University of Saint Joseph, both of which have a high female student ratio, and Smith College in Massachusetts. As a result of these efforts, 29 URM students applied to UConn Engineering in 2019 and six were accepted.

Graduate Chapter of the National Society of Black Engineers (NSBE)

The first graduate chapter of NSBE started in late Fall 2019. Six members were supported to attend the 2020 NSBE national conference and presented their efforts to the NSBE board.

Vergnano Institute for Inclusion (VII)

The Vergnano Institute for Inclusion (VII) in the SoE Undergraduate Programs Office runs diversity and outreach initiatives targeting K-12 and undergraduate students. In the past year, we appointed Dr. Stephany Santos as Associate Director of VII. In her work with the School, she has already spearheaded the following initiatives:

- BOSS LADI (Building Our Sistas' Strength, Leveraging Adversity, Diversity, and Intellect): This new initiative was offered as a one-credit course during the Spring 2020 semester.
- Sisters in STEM (SiS): In the fall semester Engineering Ambassadors collaborated with NSBE and SHPE to host its inaugural one-day conference for tenth grade high school Black and Latinx female students to show the allure of STEM fields. Representative role models lead laboratory tours, engaging experiments, and self-development workshops.

Undergraduate Student Organizations Promoting Diversity and Outreach

- Engineering Ambassadors (EA)
- Society of Women Engineers (SWE)
- National Society of Black Engineers (NSBE)
- Society of Hispanic Professional Engineers (SHPE)
- Engineering Student Leadership Council (ESLC)

Undergraduate and K-12 Diversity Initiatives

- BRIDGE Mentor/Mentee
- SPARK
- Pre-Engineering Program (PEP)
- Multiply Your Options (MYO)
- Northeast Science Bowl
- Engineer Your Future (EYF)
- Explore Engineering (E2)
- Connecticut Invention Convention (CIC)
- DaVinci Program
- Joule Fellows

Development & Endowment

In 2020 the endowment of the School of Engineering reached $50 million, almost twice its value of $26.8 million seven years ago. This growth has allowed the School to award $527,000 in scholarship support to 230 students in AY20-21 in addition to the scholarships awarded by the University that are available to engineering students. The endowment also secured 24 chaired and named professorships and 20 term professorships.

Programs Cultivating Donor Relationships

The SoE supports several initiatives that steward external relationships throughout the year. Events such as the Academy of Distinguished Engineers Induction Ceremony, GE Night, General Dynamics Electric Boat Alumni Reception, and Lockheed Martin- UConn Day are just a few examples of engagement between the School and our partners. SoE administrators have also held frequent donor events and alumni receptions around the country. Furthermore, UConn Engineering is launching the Engineering a Better Connecticut Scholarship Initiative dedicated to need-based scholarships for Connecticut students underrepresented in the field of engineering.

2.2 Key Research Strengths

The School of Engineering has particular strengths in five core areas, demonstrating the current success of these arenas while also affirming their continued relevancy and impact. Critical investment, in terms of additional faculty, resources and institutional commitment, will allow UConn to leverage current excellence to build programs that are recognized nationally and internationally.

Advanced Manufacturing & Materials

Over the last decade, UConn Engineering has made significant strides in the area of Advanced Manufacturing and Materials in terms of research capability, research funding, number of faculty in closely related areas, as well as educational programs. The SoE has taken the lead to support the University in working with industry to establish impactful partnerships at the Innovation Partnership Building (IPB) in the UConn Tech Park.

UConn Engineering has dozens of tenured/tenure-track faculty within four departments who are active researchers in relevant areas. High performance materials, high temperature materials, metallurgy, and composites are especially relevant to our region's leadership in aerospace and undersea systems. Electronic systems and sensors, additive manufacturing, and materials for energy are strong contributors to the Connecticut and indeed world economy as well. Because of this, the SoE has increased its focus in those relevant areas and grown research funding tremendously to support those industries.

From 2019-2022 funding from several strategic sources has supported our mission, including $17.8M through the AFRL – Research in Advanced Materials, the $5.5M SHAP3D Center for Science of Heterogeneous Additive Printing of 3D Materials, the nearly $40 million in research grants secured through the National Institute for Undersea Vehicle Technology (NIUVT), and many millions more through the Pratt & Whitney Additive Manufacturing Innovation Center and the UTC Institute for Advanced Systems Engineering.

The research and educational facilities supporting the development of next generation advanced manufacturing & materials have also experienced significant growth through the development of lab space at the IPB, the state-of-the-art materials characterization laboratories (CAMMA), and the new collaborative research space located on the first floor of the Engineering Science Building that is focused on Cyber-Physical Systems.

The new graduate Master of Engineering program in Manufacturing launched in Mechanical Engineering, as well as the growing undergraduate program in Management and Engineering in Manufacturing, are complemented by the hiring of multiple tenure-track faculty members in Mechanical Engineering in the area of Advanced Manufacturing.

Advanced manufacturing, Industry 4.0, and functional and architected materials and systems are poised to continue to dominate the state's manufacturing sector. Bio-manufacturing is also poised to continue to grow globally in terms of size and impact as the market size of biopharmaceuticals is now bigger than the market size of commercial aerospace.
To adequately support the state's research, educational, and workforce development needs, SoE must therefore grow its leadership position in the development and deployment of these state-of-the-art manufacturing technologies and materials.

Bioengineering, Biomedical Technologies & Digital Health

Biomedical engineering is one of the fastest-growing interdisciplinary areas in the nation and is predicted to grow faster than the average for all occupations.

The Bureau of Labor Statistics stated in 2019 that:
"Bioengineers and biomedical engineers are expected to see employment growth because of increasing technologies and their applications to medical equipment and devices. Smartphone technology and three-dimensional printing are examples of technology being applied to biomedical advances.

As the baby-boom generation lives longer and stays active, the demand for bioengineers and biomedical devices and procedures, such as hip and knee replacements, is expected to increase. In addition, as the public awareness of medical advances continues, increasing numbers of people will seek biomedical solutions to their health problems from their physicians."

UConn's department of Biomedical Engineering (BME), which was formed in 2012, offers one of the most popular undergraduate degrees in engineering and has one of the largest undergraduate student populations in the school of engineering. Its 48 core faculty work closely with the medical and dental faculty from the UConn Health Center as well as with researchers from Jackson Laboratory's genomic medicine institute in Farmington, CT.

BME faculty perform cutting edge research that spans from regenerative engineering and biosensors to digital health. From 2019-2021, BME faculty members' research has generated more than $42M in funding from NIH, NSF, DoD and private industries. In 2021, the department had a record research funding year as BME faculty were successful in securing nearly $18M in grants. Among these grants, there are more than 14 NIH R01 type grants, one T32 grant from NIH and six faculty who won a NSF CAREER award. BME faculty continue to publish high impact work as evidenced by publishing in top journals in their fields including PNAS, Science Advances, and Nature Materials to name a few. The department currently has faculty with memberships in prestigious national academies including NAE, NAS, NAM and NAI. In addition, several faculty members are fellows of IEEE, AIMBE, IAMBE and BMES. BME PhD students have been placed as postdocs in prestigious universities and BME postdocs have also secured tenure-track positions at various top American and international universities.

Other faculty across SoE have strong and externally funded research programs in critical areas of biomedical engineering and system genomics, such as bio-informatics, biodegradable sensors, flexible electronics, tissue mechanics, fluid-structure interfaces, and advanced bio-compatible materials.

Cybersecurity, Data Sciences, and Computing

Cybersecurity

The tremendous growth and ubiquity of the computational infrastructure and of the universal reliance of human activity on computer systems over the last four decades elevated the critical nature played by two related focus areas—cybersecurity and data science. The Connecticut Advanced Computing Center (CACC) supports much of the advanced computing research in the School of Engineering.

CACC includes a number of industry-focused cybersecurity research centers including the Comcast Center of Excellence for Security Innovation ($7.5M total funding), the Synchrony Financial Center of Excellence in Cybersecurity ($3.2M total funding), the Center for Hardware and Embedded Systems Security and Trust IUCRC ($4.5M total funding), and the Voter Center ($400K annually in state funding). Other cybersecurity industry relationships include UTC, Pratt & Whitney, Electric Boat, NXP, and others. Over 10 faculty and 50 graduate students from the Computer Science and Engineering and Electrical and Computer Engineering departments are involved in cybersecurity research. UConn has received several GAANN awards in support of cybersecurity fellowships and has also been designated as a Center of Academic Excellence in Cyber Defense Research by the NSA

Data Sciences and Computing

The recent convergence of big data, cloud computing, and novel machine learning algorithms and statistical methods is causing an explosive interest in data science and in its widespread applicability. This

convergence has already enabled the automation of a number of tasks that better human performance. The innovations we derive from data science will treat disease, enhance our mobility, and keep us safe.

In the past couple of years, the School of Engineering has hired a number of machine learning specialists both in software and hardware areas building on existing expertise. Specifically, the number of faculty members with AI and machine learning expertise has doubled from 2019-2022. The CSE department has created a new data science minor and is in the process of creating a data science major. The School is part of a new initiative surrounding a M.S. in Data Science. Recently, we have seen a significant over enrollment in computer science and engineering (increasing by >25% each year), especially in the data science and AI study areas. The CSE faculty are developing high-quality and scalable flipped courses to creatively meet teaching load demands. The department is also actively designing a CyberLEAP program to bridge non-CSE-majored students with necessary backgrounds to get a Master of Engineering (MENG) in Data Science. The curriculum for MENG in Data Science is also in the process of flipping by faculty. A majority of CSE federal grants over the past five years have come from the data science (including bioinformatics) or AI related funding programs, including large grants from NSF's BigData program, and NIH R01 programs on big data science for understanding biological underpinnings of complex disorders.

The CSE faculty have a strong track record on algorithm development. Some of the best-known algorithms for some of the world's fundamental problems have been developed by our faculty in areas such as out-of-core computing, data structures, online algorithms, parallel computing, data mining, and image analysis and modeling, large-scale stochastic optimization. UConn's bioinformatics research was ranked 8th worldwide according to csrankings.org, based on the past 10 years of data.

SoE faculty have used machine learning (ML) and AI to drive automobiles, improve 3D printing, localize and navigate objects, and create wireless-powered Internet of Things (IoT) systems. Especially in medicine, ML is used by our faculty to automatically interpret diagnostic images, design chemical compounds for drug discovery, or integrate behaviors, biomarkers, and genetics to investigate the epidemiology of disease such as COVID-19. The SoE faculty are designing trustworthy, accountable, explainable, and fair AI tools to increase the societal impact of AI technologies. They have secured multiple NIH grants as well to use ML in biomedical informatics. Especially given the growing importance of data sciences across all fields of engineering, further partnerships including new joint faculty positions bridging our disciplines are necessary to compete with our peer institutions.

Engineering of Complex Systems

The unique industrial climate in Connecticut has been dominated by the need to design, fabricate and maintain complex engineered systems, from the nanoscale to the macroscale, being developed by the state's flagship aerospace and the undersea water vehicle industries. Moreover, complex engineered systems will continue to be needed in addressing many if not all Grand Challenges faced by humanity.

Complex systems engineering continues to rapidly expand as a multidisciplinary field that focuses on improving the design, management, performance, and safety of complex systems or processes over their life span. Systems engineering uses both holistic and targeted analysis, control, and diagnostics to ensure the expected performance and reliability of these components and to develop new technologies and methods that help companies reduce costs, increase reliability and innovate more quickly.

UConn Engineering has developed both breadth and in-depth expertise in diverse aspects of complex systems engineering across all departments. Testifying to the current strength and future potential of complex systems engineering at UConn, The University of Connecticut and United Technologies Corporation (now Raytheon Technologies Corporation) unveiled in 2013 the $10 million UTC Institute for Advanced Systems Engineering.

The UTC-IASE now serves as a hub for world-class research, project-based learning by globally distributed teams of students, and industrial outreach activities focused on model-based systems engineering (MBSE) of complex systems that are built from, and are dependent on, the synergy of computational and physical components. Motivated by the increasing complexity of advanced products and the digital revolution, the 40 SoE faculty affiliated with UTC-IASE perform cutting edge systems engineering research fueled by $10M in funding. The UTC-IASE faculty train engineers in systems engineering aspects that are pivotal to innovation and product enhancement in the globally competitive economy. The Institute is positioned to advance the science of systems engineering and to accelerate its technological translation into sustained industrial growth.

Sustainability: Energy and Environment

Energy remains a crucial engine of economic growth that fuels both poverty reduction and shared prosperity. One of the central questions of our time is how to satisfy our energy needs without continuing the massive degradation of our environment. SoE faculty continue to address complex sustainability challenges, such as clean energy, climate change, water quality, and pollution, through research and educational efforts that span multiple departments and disciplines.

Much of the research focused on sustainable technologies for energy and the environment is associated with several UConn centers. Specifically, UConn's Center for Clean Energy Engineering (C2E2) comprises faculty and researchers involved in the discovery of new materials, devices, and systems to enable more efficient and environmentally friendly energy conversion and storage technologies. This includes power production via fuel cells, electrolyzers, and combustion systems; energy storage using lithium-ion batteries and flow batteries; synthesis of fuels through power to gas (P2G) and waste conversion (waste to fuel); power electronics for renewable integration; and micro/smart-grids. The Connecticut Center for Applied Separations Technologies (CCAST), formerly known as the Fraunhofer USA Center for Energy Innovation (Fh USA CEI), is dedicated to supporting the separations industry by providing contract R&D services that identify energy and cost-efficient solutions for separations needs through thoughtful consideration of innovative materials, differentiating techniques and robust process design. The Eversource Energy Center (EEC, garnering $31.5M in grants through 2028) is a hub for interdisciplinary research, technology, and software development, delivering important benefits for communities, businesses and municipalities by continually improving reliability and emergency response, and minimizing storm and other security event impacts. Important regional growth areas, piggybacking on symbiotic strengths or proposed future investments across the rest of SOE, include power generation based on wind, water, and solar technologies.

All these centers are closely involved in the educational aspects of developing a new generation of engineers who understand the sustainability of energy production and its impact on the environment. In addition, SoE has developed a Master of Engineering program in Advanced Manufacturing for Energy Systems that is supported by a $1.2M grant from the Department of Energy. This program produced its first graduates in Spring 2020. The EEC is offering a Grid Modernization Certificate for the utility industry with the first cohort to complete by Spring 2022.

2.3 Key Strengths in Entrepreneurship

UConn and the School of Engineering are inextricably tied with the economic development of Connecticut and play a crucial role in underpinning innovation and entrepreneurial activities by providing the environment, facilities and talent that are needed to develop breakthrough ideas.

Over the past six years, the SoE has strategically pursued initiatives that promote a culture of technology entrepreneurship and provide entrepreneurship training and resources to students, faculty, and post-doctoral researchers. The School has been particularly successful in developing SoE entrepreneurial education capacity through development and deployment of state-of-the-art entrepreneurial infrastructure and facilities. The Proof of Concept Center (POCC) at the UConn Tech Park provides facilities for rapid prototyping, reverse engineering, and CNC machining, as well as a consumer experience evaluation laboratory. Additionally, SoE has the CMSC (Connecticut Manufacturing Simulation Center) for digital design and prototyping through computer modeling and simulations. This center also facilitates product design through Finite Element Modeling and Simulation. Combined, these facilities enable students and faculty to master technologies and innovations that are the pillars of Industry 4.0, and provide valuable resources to small- and medium-sized manufacturers in the region.

The School's efforts have significantly contributed to the UConn entrepreneurial ecosystem and have led to led dozens of faculty-student startups. The School's entrepreneurship initiatives are a direct response to Connecticut's need to support innovation and entrepreneurship as drivers of economic growth.

Current Entrepreneurial Ecosystem

Global Entrepreneurship Network in Connecticut

The SoE established a Global Entrepreneurship Network aimed to energize Connecticut's innovation economy by attracting and retaining science and technology entrepreneurs from around the world. So far, the participating high-tech startups have multiplied the State's investment by a factor of 10 in terms of funding, awards, grants and in-kind contributions. For example, the startup company "Encapsulate" received a Technology in Space Prize by NASA/ International Space Station National Lab in partnership with Boeing in late 2019 for $653,000. Since Fall 2019, the startup company "QRFertile" has won $300,000 in Amazon web credit, Google cloud credit, and a UConn Innovation fund investment. The startup company LandMaverick has also attracted over $150,000 in competitive awards and private investment.

Master of Engineering in Global Entrepreneurship (MEGE)

A unique Master of Engineering in Global Entrepreneurship was established to cultivate student entrepreneurs capable of responding to emergent global trends in business and technology and to embed student-led start-up companies in Connecticut. MEGE provides structure and support to de-risk students' technologies, build a minimum viable product, develop their exit strategies, and win their first round of investments. Our MEGE participants have been leading the State in personal awards and recognition. In both 2019 and 2020, our participants represented Connecticut and were named finalists at the marquis innovation event in the region, MassChallenge. Also, Leila Daneshmandi and Armin Rad, Encapsulate's COO and CEO, are the 2020 winners of the CT Entrepreneurship Award in the Scalable Venture Entrepreneurs category.

Courses in Entrepreneurship

SoE established a two-semester engineering course, Experiential Technology Entrepreneurship I and II (ENGR/MGMT 5300), for graduate students. This course sequence has led to several dozen student- and faculty-led startup companies. The School also created two undergraduate courses on Technology Entrepreneurship, cross-listed with the School of Business (ENGR/MGMT 3500 and 3501). These

courses are the foundation for a new undergraduate minor in technology entrepreneurship which was established in collaboration with the School of Business.

UConn Engineering Startups
Since 2017, the SoE supported the launch of approximately 40 startups through individual mentoring and entrepreneurship courses.

New Entrepreneurship Research Facilities and Infrastructure
The Proof of Concept Center (POCC) is utilized for workforce development and educational purposes. POCC continues to provide prototyping resources to the University. UConn Engineering and School of Business students were trained in rapid prototyping as well as proof of their innovative ideas emanating from their entrepreneurial courses. The students were also trained at the POCC in consumer usability and consumer experience protocol. POCC also hosted a three-day 3D systems Geomagic Control X training.

The Peter J. Werth Institute for Entrepreneurship and Innovation and The Entrepreneurship and Innovation Consortium
For the first time in the University's history, this initiative, led by the deans of Schools of Engineering and Business brought together more than 30 university units with activities in the entrepreneurship space. The Consortium's success, activities, and achievements became the foundation for securing a gift (amounting to $22.5M) from Peter J. Werth to establish the Peter J. Werth Institute for Entrepreneurship and Innovation in December 2017. The Institute will bring together student and faculty programs fostering entrepreneurship and innovation that have potential commercial applications and can be used to create new companies. In addition to nurturing innovation, the Institute facilitates entrepreneurship speaker forums and hosts an entrepreneur-in-residence to instruct students.

Entrepreneurship Faculty hiring
The new cluster hiring led by the Office of the Provost in innovation and entrepreneurship will bring to the school several research-active faculty who are deeply connected with industry and are also successful entrepreneurs.

2.4 Key Strengths in Professional and Public Engagement

Engineering programs nationwide struggle with ways to bring visibility to the impact of engineers on society, and with the challenge to fill the educational pipeline so critical to industry. UConn Engineering has a strong presence within the professional community, K-12 schools, and beyond. Areas of strength include:

- Engineering faculty members are highly active and well recognized in professional societies
- Creation of the Innovation Partnership Building has enabled more engagement with industry and federal agencies through several new centers including AFRL RAM, CMSC, QCIC, NIUVT, AMIC, amongst others
- Industry supports almost 20% of UConn Engineering research with over 70 projects coming from small- and medium-sized enterprises.
- Industrial companies sponsor and collaborate with UConn Engineering seniors on over 250 capstone design projects annually.
- Well established and highly effective pre-college recruiting programs
- Strong success in securing NSF REU grants with one currently active site and several other sites in recent years
- Large number of prestigious graduate fellowship programs offered including GAANN, NSF GK-12, NSF Bridge to the Doctorate and DHS-STEM
- Significant growth in professional education programs that have direct ties to need from industry, revenue topping $3 million and one of the top ranked online programs in New England
- Strong service-learning programs particularly through the Engineering House Learning Community and the recent Technical Assistance for Brownfields program, sponsored by the EPA
- A variety of K-12 outreach efforts are supported throughout the School and our engineering centers, including activities through our Pre-Engineering, Multiply Your Options, Explore Engineering, and Engineering Ambassadors programs
- High quality continuing education programs for Connecticut Municipal Agencies (3,000+ each year)
- Significant involvement by the majority of Engineering faculty members in providing technological and scientific support as consultants and mentors to state and national industries as well as state and national government agencies

3.1 Key Opportunities in Education

Undergraduate Education

A key goal for SoE is to offer programs that are in line with current and future industry needs, preparing our graduates for rewarding careers. To provide a flexible platform for new program development, SoE eliminated the Undecided Engineering track for students in 2020 and established a new major degree in Multidisciplinary Engineering. This offers the opportunity to add new concentrations that will allow students to obtain a fundamental engineering education while specializing in niche, interdisciplinary areas, such as industrial design, and climate engineering. These programs can attract out-of-state students who are looking for unique opportunities and want to maintain flexibility in their education. Expansion of 4+1 programs that allow students to obtain their Master's degree in five years is another opportunity to attract both in- and out-of-state students.

Providing more flexibility to students in terms of course availability and modality is a persistent need that has intensified with the pandemic. The pandemic also substantially enhanced faculty ability to develop high quality online content, presenting an opportunity to expand engineering course offerings to regional campuses, winter, May and summer terms, Early College Experience, and Non-Degree students outside the UConn Community. The increased number of teaching-focused faculty and expertise of the Center for Excellence in Teaching and Learning will be leveraged towards this goal.

While online learning is useful in providing flexibility to students who commute, work, and have work-life balance needs, the pandemic has also highlighted the need for hands on, experiential learning that connects learners to practice and community needs. The Senior Design experience provides this opportunity to all students but is inherently focused on the senior year. While many students have summer internships in their junior year, they pursue such opportunities individually, which may exacerbate disparities between disadvantaged students. Expanding the limited co-op program and facilitating internships for underrepresented minorities will achieve multiple goals set forth by the school. Research-focused internships in faculty laboratories that are supported and coordinated at the department or school level can also engage students in innovation and assist with graduate student recruitment.

Experiential learning may also be integrated into individual courses, for example by incorporating service learning or real-world problem solving. Promotion of innovative and inclusive teaching practices among all SoE faculty can be pursued by offering incentives, through the PTR and merit processes, or by offering professional development opportunities (travel or discretionary funds) and additional TA support to implement innovative and inclusive teaching practices. Engaging faculty in educational research can also provide incentives by assisting with developing their PTR portfolio while improving teaching practices.

Recent research assessing the efficacy of online education in the context created by the pandemic are generally consistent with past research, according to the Brookings institute. Specifically, the studies conclude that online courses generally lead to worse student performance than in-person courses, an effect that is more pronounced for undergraduate students and those that are "less-academically prepared." This suggests that maximizing the in-person modality for the SoE courses will benefit the engineering students.

Our student to faculty ratio is higher than that of many of our peers, which places a burden on the quality of the education that we can provide. This is amplified by the relatively low funding available to teaching assistant positions supporting our educational activities.

Graduate Recruiting Education

UConn's initiative to dramatically expand faculty hiring in strategic arenas presents the School of Engineering with an unprecedented and concomitant opportunity to expand and improve our graduate education programs, particularly for PhD students.

Furthermore, through UConn's strong commitment to a more gender-diverse faculty, UConn Engineering will have greater opportunities for success in recruiting and retaining a more diverse pool of graduate students.

As UConn's ranking continues to rise among PhD granting institutions, the School of Engineering will be better positioned to successfully recruit top students from among our undergraduate populations and from across the nation for graduate study at UConn. This will help to counter the trend in UConn Engineering of an inordinately high ratio of international to domestic graduate students.

Thoughtful professional development workshops aimed at equipping our doctoral candidates with strong communications, grant-writing, teaching and collaborative skills will increase the likelihood of our graduate students seeking – and succeeding in – highly competitive academic careers. This will enhance UConn Engineering's reputation and prestige as a research institution.

Targeted and sustained investments in recruiting activities need to be amplified along several directions to expand the pool of high-quality graduate students and postdoctoral scholars with the ultimate goal of making UConn a more attractive destination to top graduate students and postdoctoral scholars:

- Prioritize personalized, interactive marketing and use multiple forms of publicity
- Establish an increased number of high-profile graduate and postgraduate fellowships; aim for establishing fellowships for all domestic incoming PhD students and all outstanding international PhD students during their first year, as well as several outstanding postdoctoral students. Scholars; one possibility is to develop and implement 50% SoE fellowships to all 1st year PhD students supported by external grants.
- Develop career placement and career advising; identify and develop (alumni) networks and recruiting events
- Enable scientific and professional development through internships, training and collaborations
- Sponsor campus visits
- Maximize involvement of our faculty and current graduate students

3.2 Key Research Opportunities

Manufacturing, Bio-Manufacturing, and Materials

A 2011 report by the U.S. President's Council of Advisors on Science and Technology states that the Nation's historic leadership in manufacturing is at risk noting that "Manufacturing as a share of national income has declined, as has manufacturing employment, and our leadership in producing and exporting manufactured goods is in question. The loss of U.S. leadership in manufacturing, moreover, is not limited to low-wage jobs in low tech industries, nor is it limited to our status relative to low-wage nations. The United States is lagging behind in innovation in its manufacturing sector relative to high-wage nations such as Germany and Japan, and has relinquished leadership in high-tech industries that employ highly-skilled workers."

One idea that the Council recommended was for the U.S. to encourage and support a robust basic research enterprise in advanced manufacturing to benefit the entire nation. As a result, the federal government launched the Advanced Manufacturing Initiative consisting of a network of regional manufacturing centers and concerted funding efforts. Connecticut and its universities and industries continue to be positively impacted by this federal investment in the advanced manufacturing space.

In 2011, President Obama introduced the Materials Genome Initiative as a modern version of the Apollo moon landings or the Human Genome project and declared, "Advanced materials are essential to economic security and human well-being, with applications in industries aimed at addressing challenges in clean energy, national security, and human welfare, yet it can take 20 or more years to move a material after initial discovery to the market. Accelerating the pace of discovery and deployment of advanced material systems will therefore be crucial to achieving global competitiveness in the 21st century."

UConn SOE has aligned with the national vision for manufacturing and materials innovation as many of its faculty continue to actively pursue and receive research funding through Advanced Manufacturing and Advanced Materials centers, the Department of Defense, and the National Science Foundation.

Enhanced Reputation and Recognition: The opportunity to continue to enhance the school's visibility and ranking in manufacturing, bio-manufacturing, and materials hinges upon building and supporting an integrated core of research active faculty in these areas. The strong manufacturing base in Connecticut provides myriad synergies, particularly for aerospace and naval applications.

Over the last decade, UConn gained a critical mass of faculty with expertise in advanced manufacturing and materials by hiring a group of outstanding young faculty colleagues. However, there have been issues with retention of this talent, as well as recruitment challenges with those that have developed well-established research programs in advanced manufacturing and materials.

Although improvement of UConn's reputation and recognition requires sustained and prolonged efforts, in the short term we can increase our visibility through target hiring and competitive retention policies, including salary, effective spousal hire policies, and facility upgrades. Furthermore, attracting academics of international recognition requires a competitive research infrastructure, access to industrial funding mechanisms, and the establishment of endowed yet targeted chaired professorships. One potential mechanism for the latter is to establish university-industry research centers in advanced manufacturing and materials in cooperation with Connecticut corporations, including those under the RTC umbrella, Sikorsky, and Electric Boat. To help seed the next generation of major research centers and industry partnerships, cluster hires built around a senior-level faculty member are also encouraged in target innovation areas, e.g., promising topics include composites, digital twin technologies, additive manufacturing, and robotics.

Research Infrastructure and Output: The Innovation Partnership Building at the UConn Tech Park is a premier center for high-tech research and industry collaboration and innovation. The IPB provides an ecosystem where cross-disciplinary research teams develop novel approaches to critical real-world problems in fields ranging from manufacturing to biomedical devices to cybersecurity. The IPB can serve as a platform to connect leading industries with outstanding research facilities and foster new partnerships with entrepreneurs and companies of all sizes. IPB is an ideal location to develop facilities that support innovative manufacturing research that will attract researchers and industry partners to engage in technology transfer and entrepreneurial activities.

The research funding and output in advanced manufacturing and materials has grown significantly at UConn through several large grants from the Air Force Research Lab, NSF, ONR, and DOE. Efforts to expand the funding mechanisms to other agencies within the DOD are ongoing. SOE has reached a point in which the establishment of an interdisciplinary research center dedicated to advanced manufacturing and materials aligns with the School's strengths. A center focused on these technologies would help direct research efforts towards a substantial increase in faculty research output resulting in more visibility and recognition for the School. In order to accomplish this goal, SOE's key needs include the digitization of existing facilities, cloud and IoT infrastructure, and AR systems (to remotely demonstrate the investments).

Key New Directions

Bio-Manufacturing. "The market for biopharmaceuticals has been rising rapidly in recent years. It is now a multibillion dollar industry with its own ecosystem of suppliers, medical professionals, drug delivery systems, and regulators." In addition, there are growing markets for novel bio-materials, smart biomedical devices, and implantable bio-sensors. Therefore, a new strategic direction that is poised to dominate the manufacturing field is bio-manufacturing. Its market size is estimated to exceed that of aerospace manufacturing and continue growing in size, importance, and impact to society.

The manufacturing knowledge and expertise that exists at UConn, and specifically the expertise in smart manufacturing, is a solid platform to develop a strong and impactful research portfolio in bio-manufacturing. If complemented by target hiring, this platform is expected to open up remarkable new opportunities for collaboration between faculty from Storrs and UCHC, in addition to significant external funding. As a result, this would position UConn as one of the national leaders in bio-manufacturing research and education.

The Digital Enterprise and Industry 4.0. More flexible production, greater productivity, and the development of new business models are all possible today thanks to the advances made through modeling and simulation capabilities, commonly known as "digital twin technologies." However, the future of industry offers more untapped potential in which innovative digital technologies will create new opportunities for OEMs to fulfill an increased level of customization in their products and processes. The future of industry is the integration of automation, software, and cutting-edge technologies leading to what is known as "digital transformation."

An important part of this digital transformation is the so-called Industry 4.0, which is tasked with converting traditional operator-controlled systems into smart Cyber-Physical Systems. Industry 4.0 embodies a new industrial revolution, one that marries advanced manufacturing techniques with the Internet of Things to create manufacturing systems that are not only interconnected but communicate, analyze, and use information to drive further intelligent action back in the physical world. W.P. King, the chief technology officer of the Digital Manufacturing and Design Innovation Institute, stated that "manufacturing generates more data than any other sector of the economy." The benefits and competitive edge brought by the digital thread and big data, are widely acknowledged. However, achieving these

benefits requires the ability to understand, model, securely store and retrieve, and analytically process information in a way that is conducive to informed decision-making.

Machine self-awareness and decision support are key requirements, which modern data-driven or hybrid digital twins promise to enable. Furthermore, robotic automation has led to robots working alongside humans in manufacturing/assembly/repair facilities; although currently a lack of safety assurance precludes human-robot symbiosis. The size and heterogeneity of data and the need for cognition are key roadblocks and unique research opportunities in the future of manufacturing digitization.

The future of industry is the convergence of information technology and operational technology. The School of Engineering has to continue to position itself as a key enabler of this digital transformation in the state and the region through bold research and effective educational activities.

Biomedical Engineering and Systems Genomics

Enhanced Reputation and Recognition: The formation of the new Biomedical Engineering (BME) Department has increased the national visibility of the nascent department and UConn's breadth of excellence in this arena. The strong integration with programs residing within the UConn Schools of Medicine and Dental Medicine as well as the Jackson Laboratory further increases the visibility, reputation, and relevance of the BME department.

Over the past several years, the BME faculty have received a large number of National Institutes of Health (NIH) research grants. The NIH is the largest funding source among all government agencies to fund BME-related and systems genomics research.

Opportunities for Collaborative Research: Increased opportunities for collaborative research with the state's medical device and biotech industries and personalized medicine companies should be pursued through strategic partnering within the UConn Tech Park. If bioscience and genomics companies and startups can be courted for collaborations within the Park, they may catalyze the establishment of a regional – and possibly national – bioscience industry in the area of Systems Genomics (e.g., information handling related to personalized medicine; small business spin-offs for genomics/clinical data analysis).

Additionally, to advance understanding, design, and applications of digital health and systems genomics technologies requires collaboration with multidisciplinary research partners in the School of Medicine, School of Dental Medicine, College of Liberal Arts and Sciences (e.g., MCB, Kinesiology, Psychological Sciences), the School of Pharmacy, the College of Agriculture & Natural Resources (e.g., Nutritional Sciences, Pathobiology), the School of Nursing, and other units.

Collaborations with the Jackson Laboratory may bring additional genomic and biomedical research opportunities to UConn Engineering and UConn in general.

Research Output and Infrastructure: Personalized monitoring devices that require a facility for flexible and compact biosensors fabrication and testing is currently one of the School's shortcomings to advance bio-manufacturing technology. However, access to a facility such as a health clinic or nursing home to quickly test and collect important data from non-invasive devices and biosensors would significantly add a competitive edge to the current strengths in sensor and digital health research by BME faculty. These facilities will be crucial to facilitate the goal of attaining an NSF- or NIH-supported center in digital health.

Cybersecurity and Data Sciences

We live in an era of data explosion. For instance, the size of metagenomic data from multiple samples could be petabytes. The Internet is another source to generate big data on a daily basis. Advances in analytics tools have not caught up with the rate at which data gets generated in science and engineering. Engineers, especially computer scientists, can improve this situation drastically through foundational research and growing expertise. The ability to analyze voluminous datasets can result in transformative advances in every domain of science and engineering. The economic growth that forms as a result of the adoption of data science in the healthcare sector is estimated as $300 billion per year. Artificial intelligence (AI) impacts every scientific discipline and is quickly becoming ubiquitous in our daily lives. It is increasingly deployed in healthcare, social sciences, education, cybersecurity, and countless other disciplines. As AI expands into almost every aspect of modern life, the risks of AI misbehavior increase significantly. Cybersecurity continues to be a critical component of most federal agencies as well as industry. The Biden administration recently issued a key executive order addressing the nation's cybersecurity needs. NIST has been tasked with identifying critical infrastructure susceptible to cybersecurity attacks, and agencies such as the Department of Energy, Department of Transportation, and Department of Homeland Security have been and will likely continue to support research efforts to address infrastructure cybersecurity. The School of Engineering is poised to be a major contributor in these efforts with internal collaborations between CACC faculty and those from EEC, C2E2, and CTI.

Research Output and Infrastructure: There is an improved High-Performance Computing (HPC) outlook at UConn. As the volume of data-intensive, multi-variable and computation-intensive research projects (e.g., molecular modeling, genome analysis, neural data analysis and modeling, numerical modeling, climate modeling, quantum chemistry, cryptographic analysis, and systems engineering studies, etc.) expands at UConn, the university recognizes a significant and urgent need for HPC capabilities offering university-wide access. UConn's investment in larger scale HPC equipment with sufficient support staff will propel UConn's research programs to the international stage and establish UConn's leadership in HPC.

UConn Engineering's computational capabilities reside primarily within the Connecticut Advanced Computing Center (CACC). CACC has historically focused on cybersecurity, and the HPC capabilities, originally housed in BECAT, are now primarily supported by ITS. However, with the growth of data science and machine learning, CACC needs to take a more active role in leading research initiatives in HPC and provide research support for other centers such as the Pratt & Whitney Additive Manufacturing Innovation Center at UConn, the UTC Institute for Advanced Systems Engineering, the Eversource Energy Center, and other research centers at UConn.

UConn SOE faculty have collaborated to form interdisciplinary teams (e.g., with College of Liberal Arts and Sciences faculty) and submit proposals for NSF's recent AI Research Institutes funding opportunities; these efforts must continue to support Industry 4.0 research connections and output.

Complex Systems Engineering and Resilient Infrastructure

Complex Systems Engineering

Complex industrial systems are increasingly dependent on embedded "smarts" for their design, control, monitoring, safety, autonomy, and increased productivity. Four examples of complex systems engineering are as follows: (a) smart manufacturing, aka Industry 4.0, involves humans, machines, robots, and computer systems working together and interacting with big heterogeneous data streams through IoT networks; (b) aviation relies increasingly on machine learning (ML) and data analytics to design, operate, and maintain aerospace systems; (c) applications of AI in the automotive sector target autonomy as a

frontier goal; and (d) chemical process industries rely heavily on big data analytics and machine learning to support decision making at disparate timescales.

A common theme across these industries is the use of digital twins that continuously adapt to dynamic, uncertain, and "big" data generated by modern and complex Cyber-Physical Systems (CPS). One approach to combat the size, velocity, veracity, and heterogeneity of big data is to learn human interpretable representations (models, abstractions) of the phenomena that generate these data. Models (descriptive, physics-based, data-driven, and domain knowledge-based) are, thus, becoming system clones, virtual testbeds, data generating functions, and feasible means of ensuring performance of CPS. Modern CPS are defined by the National Science Foundation, the National Institute of Standards and Technology, and the National Academy of Engineering as "engineered systems that are built from, and depend upon, the seamless integration of computation and physical components."

The NSF recognizes that CPS will transform the way in which we interact with the physical world in the same way the internet transformed how we interact with each other. According to the NSF CPS program, "the integration of artificial intelligence (AI) with CPS, especially for real-time operation, creates new research opportunities with major societal implications." Engineered CPS are complex, dynamic, and uncertain, and require sensing, computation, information management, learning, decision support, and (re)configuration in real-time. Complex system dynamics can be captured and explained through physics-informed AI, which can enable the design, situation awareness and anticipation, and resilient (i.e., absorb internal and external disturbances by adaptation and recovery) operation of CPS.

UConn has a strong track-record in research and education on cyber-physical systems engineering with applications that address critical infrastructure needs and opportunities, such as smart manufacturing, aerospace and naval systems, and the food-water-energy nexus.

Significant opportunities in this space exist in the connection and automation of these systems (with demonstration test beds at UConn facilities), the visualization of data and information, illustration of cyber cloning capabilities and results, and cognition in the form of diagnostics, prognostics, and health management. The overarching goal of successful deployment of cyber-physical systems engineering is to enable self-awareness and self-configuration capabilities in systems of our critical infrastructure. Impending gaps in our talent base include lack of experts in: verification and certification, VR/AR capability, life cycle analysis, hardware-in-the-loop and software-in-the-loop validation, and infrastructure that relate to the digitization of our critical virtual testbeds.

Sustainability: Energy & Environment

There is a rapid shift from non-renewable fossil sources to renewable sources due to climate change. There are many challenges and opportunities as a result of the rapid shift in energy sources and increased conversion of various commodity products (e.g., fertilizer and cement) from fossil fuel based processes to renewable processes. On June 7th, 2021, Secretary of Energy Jennifer M. Granholm said, "The Energy Earthshots are an all-hands-on-deck call for innovation, collaboration, and acceleration of our clean energy economy by tackling the toughest remaining barriers to quickly deploy emerging clean energy technologies at scale."

First of the Energy Earth Shots, **Hydrogen Earth Shot** intends to decrease the cost of clean hydrogen from $5 to $1/kg in one decade. **UConn's Center for Clean Energy Engineering (C2E2)** has a very strong expertise throughout the entire hydrogen value chain. Through C2E2, SOE will contribute to this goal significantly.

Energy Storage is a key component of renewable transition. We will continue to build our portfolio and our capabilities in all forms of energy storage, but focus on electrochemical based devices, including improved safety of lithium-ion batteries and enhanced performance of flow batteries.

Renewable fuels: Conversion of renewable sources (including waste) into fuels is a significant portion of near-term research agenda. Collaborations with various disciplines including Agriculture, Economics, and Law, will continue in an effort to develop solutions that are immediately deployable.

Thermo-chemical to electro-chemical processes and non-carbon chemical feedstocks: Many industrial processes rely on high-temperature, high-pressure operation due to availability of heat from fossil fuels. As use of fossil fuels decreases, there is an opportunity to transition many thermo-chemical processes to electro-chemical processes. Similarly, many commodity products (e.g. ammonia and fertilizer) start from fossil fuels today, and as the world transitions away from fossil fuels, there is opportunity to develop processes that do not rely on fossil fuel feedstocks.

Another significant societal challenge is securing **sustainable and resilient green energy and environments**. This challenge stems from intensifying natural hazards due to climate change, environmental and biodiversity pressures, and societal uncertainties such as policy and market scenarios (e.g., aggressive decarbonization plans, EV adoption, rates, etc.). Additionally, climate change will increase the need for new technologies for water treatment and reuse and UConn is well positioned to contribute significantly to these technologies through the existing core of faculty researchers in water-related technologies.

The Eversource Energy Center (EEC) at UConn is a foremost industry-academia partnership between a major regional utility (Eversource) and the University of Connecticut that works advance innovative interdisciplinary research and technology to ensure reliable power during extreme weather and security events. The Center is a hub for interdisciplinary research, technology, and software development. The hub delivers important benefits to local communities, businesses, and municipalities by continually improving reliability and emergency response, and minimizing storm and other security event impacts. Within the framework established by EEC, SOE's objectives for the next ten years are to:

- Accelerate research and adoption of blended energy sources in the power grid, including solar, wind, and hydro, hydro-driven fuel cells, and evaluate how these renewable energy sources impact the reliability of the grid
- Develop technology to assure system resilience to extreme events under future renewable integration and gas-fired decommissioning plans
- Modernize the regional power grid – through simulation of new power sources and movement of power throughout the grid – to ensure constant supply (load) and resilience under future climate, policy, and market scenarios

Another critical energy area is resilient transportation. **UConn's Connecticut Transportation Institute (CTI)** is well equipped to tackle critical research and educational challenges associated with electric vehicles and connected and automated vehicles (CAVs). The ability to build a testing facility on the Depot Campus will open doors to significant research opportunities and industry partnerships. This facility would allow for research and development of smart cities, drones, microgrids, sustainable energy, electric vehicles, and future transportation applications.

Moreover, the Connecticut Transportation Safety Research Center (CTSRC) at CTI will continue work on safety and expand our research into asset management and data collection systems to help the state and towns streamline and manage their infrastructure data. Vehicles and cities of the future will need to know where every asset is located along with any other data associated with that asset (i.e., the date of

install, list of repairs, data collected, life cycle, maintenance cost, operational costs, etc.); the CTSRC is working to develop these future systems for the state.

The CT T2 Center (Training and Technical Assistance) that is housed at CTI, provides comprehensive professional development and technical assistance programs to municipalities and CT DOT employees throughout Connecticut. The CT T2 Center trains thousands of professionals each year to help build the transportation workforce that will support our state's critical infrastructure well into the future.

To support a sustainable future SOE must align with the following key existing and emerging opportunities:

- Sustainable water resources management and climate change
- Reliable energy and extreme events
- Power generation (solar, wind, hydro, thermal)
- Power grid modernization
- Smart buildings and eco-communities
- Sustainable green transportation and energy
- Renewable energy and grid integration as well as their environmental and ecological impacts
- Renewable and carbon-free energy carriers
- Power systems and power management at municipality and community scale

Opportunities for enhanced success will be realized through the ambitious and energetic submission of proposals in response to new federal programs focusing on energy and environmental sustainability (NSF-SEES, NOAA, NASA, DoE, DoD, NRL, etc.).

With an increased energy research focus, UConn Engineering will be poised to respond to growing industry needs for sustainable and resilient green energy and environments that include low-or-zero carbon energy generation, consumption, conversion, distribution and storage and waste-to-energy recovery processes; treatment of water and air and other environmental applications; and harvesting energy from wind, solar, ocean, wastewater, etc.

Other opportunities in which UConn Engineering will be poised to respond include growing State interest in sustainable transportation, cost-effectiveness, economy-wide transition to a decarbonized future and more resilient, reliable, and secure access to electric power, adaptation and improvement of societal resilience to climate change and the associated intensification of extremes; growing industry support for research in power grid modernization, systems engineering, nano-materials and manufacturing, such as the pending agreement with Alstom in the area of solar power; and increased interest by visiting scholars to expand learning opportunities in the area of hazards and storm impact predictive analytics, sustainability, power system optimization, energy storage, and environmental applications.

Engineering Education Research

The National Academy of Engineering issued a report in 2013 on "Opportunities in Engineering Education: Pathways to Better-Prepared Students" which supported a pedagogical switch to a student-centered education model in which the instructor "asks key questions and acts as a coach, and students develop their own individual learning program to address the questions, working alone or in groups." Students that pursue formal Engineering Education research activities at UConn will greatly benefit from the School's innovative pedagogical resources in conjunction with SOE's expertise and infrastructure. With a focus on Engineering Education research, UConn will spark a new era of Engineering Education at UConn, in Connecticut, and in the Northeast.

Enhanced Reputation and Recognition: The creation of critical infrastructure to support formal Engineering Education research will position UConn as a leader in the Northeast Region in the field. In recent years, several highly ranked public universities have added Engineering Education to their portfolio of activities, including Purdue, The Ohio State University, The University of Florida, Virginia Tech, and North Carolina State University.

Opportunities for Collaborative Research: Engineering Education is inherently collaborative, as best practices and research products are often discipline-agnostic. Additionally, Engineering Education bridges the divide between engineering research, both quantitative and qualitative, research in the social sciences, as well as research work in diversity, equity and inclusion in STEM settings. This approach provides robust settings for developing multidisciplinary teams across schools and colleges, and pursuit of funding from numerous sources, both inside and outside of traditional engineering funding sources.

Research Output and Infrastructure: Engineering Education has the potential to significantly increase research output in a field where the School currently has a small but growing presence. Individual and small teams of researchers have been successful with programs through NSF such as IUSE (Improving Undergraduate STEM Education), REU (Research Experiences for Undergraduates), and RED (Reimagining Engineering Departments), as well as larger STEM initiatives such as GAANN, Bridge to the Doctorate, S-STEM, and LSAMP.

An Engineering Education faculty hire (or hires), as well as a graduate program in Engineering Education would attract top talent to the University and enable many of the programs and activities described in this report. As the laboratory for engineering education is typically integrated into the normal educational activities of the university, specialized space, equipment, and infrastructure is typically not needed, making the return on investment for Engineering Education activities quite high.

Key Opportunities

- Cross-disciplinary work in STEM education best practices
- Educational Program Evaluation for research grants
- Support of large, cross-disciplinary education proposals (e.g. S-STEM, LSAMP, etc.)
- Novel pedagogy and active learning research
- Future Faculty Development Programs
- Program Measurement and Assessment (including in support of program accreditation)
- Cross-disciplinary work supporting DEI initiatives in STEM
- Development of school-wide educational supports
- First Year Engineering
- Multidisciplinary Engineering
- Engineering Ethics, Technical Writing, Professional, and Research Skills

3.3 Key Opportunities: Entrepreneurship

UConn Engineering's demonstrated commitment for an entrepreneurship culture pervades all levels and programs, affording us the opportunity to extend and expand our support for innovation within the curriculum and outside of the defined academic environment.

During the last decade, the School of Engineering and UConn have developed a strong entrepreneurial ecosystem, resulting in the following opportunities to expand our entrepreneurial footprint:

- Widespread adoption of innovation and entrepreneurship initiatives across UConn affords us the opportunity to attract greater numbers of agile and creative prospective students, faculty, and staff who are interested in commercialization, innovation, and entrepreneurship.
- Growth in the innovation ecosystem at UConn is posed to produce a cultural change in terms of entrepreneurial activities for faculty and students alike. Moreover, this change is expected to attract venture capitalists and other investors which will help bolster UConn's image as an appealing destination for new business creation through strategic investment.
- Entrepreneurially oriented academic experiences help create entrepreneurs. Successful entrepreneurs are more likely to have taken part in academic programs and classes that helped shape their entrepreneurial careers; relevant entrepreneurship courses, competitions, and programs stimulate technical innovators and founders.
- Engagement of entrepreneurial alumni and endowments to support business startups that offer the greatest potential for commercial success. Additionally, the establishment of an "Entrepreneurship Corner" where external entrepreneurs would gain access to specific UConn facilities, such as the IPB Proof of Concept Center, could provide an excellent opportunity to attract successful entrepreneurs and stimulate collaborations for UConn faculty and graduate students.
- The planned Center for Creativity, Innovation, and Entrepreneurship will contribute enormously toward enabling, supporting, and nurturing a strong entrepreneurship community at UConn. The School could additionally enhance the success of this effort by engaging entrepreneurial alumni and seeking endowments to support student startups that offer the greatest potential for commercial success.
- To increase the number and impact of the technology transfer based on the IP generated by the School faculty, the SOE can focus on a more streamlined invention ownership and licensing process (starting with the invention disclosure and leading to the patent application) and facilitate a supportive incubator program.
- The University could provide more integrated infrastructure to support faculty entrepreneurs during the early stages of their start-up companies. For example, having support staff to help manage the company administration (payroll, legal, contracts, etc.) would not only incentivize the entrepreneurial faculty, but also increase the chance of success for their start-ups. "Rapid sabbaticals" could provide further support as the faculty would have dedicated time to submit proposals for funding opportunities.

3.4 Key Opportunities in Professional and Public Engagement

- The SOE Professional Education program has increased its potential for growth due to its new certificates and non-degree offerings. The program's emphasis on online courses will increase its reach beyond local industry and students and towards a larger and more diverse audience.
- The SOE's recent focus on large proposals has shown promise; a focus on interdisciplinary faculty clusters in the research centers should provide more collaboration that can lead to more large proposals and strong foundations for future ERCs.
- The SOE faculty are extremely productive and generally well recognized in their fields. However, individual recognition has not actualized into recognition of the school. The SOE should increase efforts to strengthen its brand and build on current communications that reach into the public consciousness, i.e., social media and local print and broadcast outlets.
- The SOE currently has 24 endowed chairs and named professorships for a faculty size of approximately 170. The School's increased engagement with industry over recent years provides an opportunity to increase the number of endowed professorships.

4. Key Challenges Faced by SOE

Over the coming decade, the SOE anticipates a number of challenges detailed below. These challenges are the result of continued increases in the UConn Engineering undergraduate and graduate student populations, significant opportunities for further expansion in professional education and industry engagement, and an ongoing institutional effort to bolster the funded research enterprise.

Personnel

The SOE student population has grown dramatically at both the undergraduate and graduate levels. Moreover, the increased workforce needs of the regional industry calls for further expansion of the SOE student population. The School recently hired professors-in-residence (with a teaching focus) to support its students and programs, however the student-to-faculty ratio continues to increase beyond the School's capacity. Successful schools of engineering maintain a ratio of under 15 undergraduate students per faculty; UConn SOE's ratio is currently 19.3 with some departments having a significantly higher ratio. Dedicated adjunct faculty play a key role in bridging this gap, with their unique expertise, industry contacts, and real-world case studies. However, the SOE struggles to attract and retain qualified instructors given the limited financial benefits it offers to its instructors when compared to peer institutions. Moreover, the SOE established a critical professional advising corps for early stage SOE undergraduates, but the advising staff across the SOE has become increasingly overburdened by the current demand. As personnel shortages continue, there could be increased negative impacts on recruitment, research, and student academic experiences.

School of Engineering Majors and Exploring Engineering ACES Students
21-22 AY

Major	AVYPT	HRTFD	STMFD	STORRS	WTBY	TOTAL	2nd Majors
Biomedical Engineering	1		2	367	3	373	
Biomedical Engineering (2nd Major)	0		0	1	0	1	1
Chemical Engineering	3		2	250	5	260	
Civil Engineering	2		6	270	10	288	
Civil Engineering (2nd Major)	0		0	2	0	2	2
Computer Engineering	1		2	70	2	75	
Computer Science	1		84	561	9	655	
Computer Science and Engineering	0	1	19	310	1	331	
Comp. Sci. & Engineering (2nd Major)	0		0	4	0	4	4
Electrical Engineering	1		14	260	2	277	
Electrical Engineering (2nd Major)	0		0	10	0	10	10
Engineering Physics	1		3	42	0	46	
Environmental Engineering	1		4	108	0	113	0
Environmental Eng. (2nd Major)	0		0	2	0	2	2
Management and Engineering for Manufacturing	0		2	150	1	153	
Materials Science and Engineering	0		3	80	0	83	
Materials Sci. & Eng. (2nd Major)	0		0	3	0	3	3
Mechanical Engineering	8		12	734	5	759	
Mechanical Engineering (2nd Major)	0		0	7	0	7	7
Multidisciplinary Engineering	1		1	28	1	31	
Undecided	0		6	46	2	54	
TOTALS	**20**	**1**	**160**	**3305**	**41**	**3527**	**29**
TOTALS Without 2nd Majors	**20**	**1**	**160**	**3276**	**41**		

MAJOR	AVYPT	HRTFD	STMFD	STORRS	WTBY	TOTAL	
Exploring Engineering (ACES)	1	17	6	175	70		269

Faculty Data Fall 2021									
Dept.	**BME**	**CBE**	**CEE**	**ECE**	**CSE**	**ME**	**MSE**	**Multidisciplinary**	**Total**
T/TT	13	17	22	25	28	25	17	0	147
Teaching	3	2	4	0	10	8	1	7	35

In order to provide hands-on research, well-functioning labs, meaningful faculty-student interactions, and smooth department operations, an increased number of SOE faculty and staff, including staff supporting the IT infrastructure, is crucial. Additional personnel are especially valuable for helping the SOE continue to embrace and leverage the benefits of more programmatic offerings, life-transformative educational opportunities, online learning, and targeted and certificate programming, all while upholding a high standard to engender life-long attachments to UConn for our future alumni.

Budgetary Challenges

Over the past seven years the School of Engineering's budget has been reduced annually, with an increasingly negative impact on our operations. The impact can be seen across the gamut of SOE activities, including faculty and staff salary levels (augmented by the salary compression), number of staff positions supporting educational and research missions and alumni operations, significantly reduced funding for educational initiatives, and the levels of the matching funds available for research proposals.

Diversity

The School of Engineering remains determined to improve the diversity of our faculty, staff, and student cohorts. The percentage of non-males, especially in our undergraduate ranks has risen laudably, and is mirrored in the gender balance among our recent faculty hires. Continual improvements in our PTR process, and broader culture shifts across the university, catalyzed by leaders from across Engineering, are collectively leading us towards improved equity and inclusivity. However like many U.S. schools of engineering, diversity across students, faculty, and staff are lamentably low compared to the national population; at nearly all R01 institutions, this is particularly acute for minoritized students, faculty, and staff, resulting in negative widespread impacts on talent recruitment and retention.

Retention

The SOE's staff retention and the corresponding programmatic efficiency and constituent satisfaction are growing concerns. There are near-term predictions of high staff turnover across campus due to state-encouraged retirement deadlines and consistently insufficient opportunities for promotions or job recharacterizations among our administrative personnel. Faculty retention is also a critical challenge, particularly if substantive promotions and growth in faculty leadership portfolios are only matched when job-offers surface elsewhere instead of being proactively offered internally. The sustained salary compression that faculty and staff have experienced over the last decade is only compounding the challenges associated with faculty retention. Currently, spousal hiring initiatives are a key contributor to attracting and retaining dedicated faculty and staff.

Space

The SOE has benefitted from the recent completion of both the Engineering Sciences Building and the IPB. The opening of Science One in 2022 is another crucial step in combatting the SOE's space challenges. Despite the SOE-affiliated offices, labs, and teaching spaces across the three facilities, there is still a lack of space for educational, research, and administrative functions based on the latest data. Due to these challenges, the SOE will face undue stress as it continues to offer quality and life-transformative experiences as effectively, efficiently, and safely as possible for its growing student population, and additionally supports its institutionally-crucial research portfolio.

Sponsored Research Data Summary FY22 (up to Q3; reported in March 2022)	
$75M	Total FY22 research expenditures
$337K	Average research expenditure per faculty
372	Proposals submitted
519	Active grants

Support Services

Centralized university units such as Sponsored Program Services, Purchasing, Travel, Facilities and Maintenance, Human Resources, Student Health and Wellness, and the Division of Public Safety greatly benefit the day to day operations and mission of the School of Engineering. Additional key partners include the Registrar, Center for Excellence in Teaching and Learning, Office of Institutional Research and Effectiveness, Office of Institutional Equity, Office for Diversity and Inclusion, and the UConn Foundation. However, as the school grows and these units evolve and implement new systems and programs, it can be difficult to maintain standards and efficiency. Recent specific pressure points include overworked SPS pre-award staff, restrictive post-award expectations, burdensome travel policies, purchasing delays, and deferred maintenance.

Facilities

There are persistent challenges for university units to maintain or invest in our infrastructure, personnel, and programming. However, with limited support units must rely on overburdened IDC reinvestments, occasional federal grant opportunities, and campus research centers (e.g., the IMS, C2E2, etc.) in order to upgrade or add new equipment. The recent university-wide decision that restricts programs from assigning materials fees for lab classes adds even greater pressure on available indirect cost returns or other soft money sources to cover expenses crucial to our teaching mission. Matching funds, especially planning support for major grant opportunities, are stretched when compared to many of UConn's peer and aspirant institutions. On a larger scale, the SOE has a goal to establish and reinvigorate shared infrastructure and support personnel to advance our growing research mission. The ongoing effort would focus on new and existing university-wide partnerships with industry and public sources to further support evolving and emergent research centers.

Academically, the SOE benefits from several service courses and laboratories that have been historically offered by departments outside of SOE, e.g., the College of Liberal Arts and Sciences offers chemistry, physics, philosophy, and math and statistics to SOE undergraduates. At universities nationwide, the schools of engineering carry the similar burdens of personnel and student recruitment and facilitation of programs that encourage more growth in their school. However, there is an increased need in the corresponding efforts for growth including additional TAs and faculty lines and overall hiring alignment to support course development and in-person instruction.

The areas of concern described above (personnel, diversity, retention, space, equipment, support services, and facilities) need to be continually reassessed, prioritized, and addressed in order for the SOE to achieve high-impact research portfolios, curriculum offerings, and personnel development and retention.

5. Key Strengths & Opportunities Beyond Engineering Warranting Review by the University Academic Vision Committee (UAVC)

- **Additional quality research space** is needed; lack of space is a critical bottleneck in the research enterprise, as evidenced by Payette's Fall 2018 space assessment which concluded that the SoE has no available space to support its growth.
- **Additional educational programs** are needed to help prepare the state for future economic shifts due to growth in technological areas such as biomanufacturing, infrastructure resilience (due to climate change); autonomous driving and robotics; aerospace engineering; and security (data and hardware). The growth in these areas will increase undergraduate engineering enrollment, resulting in a need for additional SoE teaching capacity, space, and infrastructure.
- **Hiring and retention of top research faculty at all levels** should be continued to maintain School competitiveness.
- **Identification and improvement of inefficient and bureaucratic procedures** is needed**.**
- **Adequate access to research support staff** is needed; both pre and post-award support has not kept pace with the growing SOE research enterprise. A larger portion of the associated administrative work is placed directly on faculty, which is a poor use of their time and impacts faculty and staff morale.