Defining and Implementing Intellectual Neighborhoods

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Throughout 2019, the University of Delaware College of Engineering engaged in a strategic planning exercise. This endeavor included a focused discussion designed to identify Intellectual Neighborhoods that describe common areas of research and educational activities that cut across traditional departmental boundaries. The goal was to identify Intellectual Neighborhoods, areas of interest that would guide strategic financial investments, faculty hiring, and space allocation, and help inform fundraising and philanthropic endeavors.

Intellectual Neighborhoods represent the intersection of our education, research, and service expertise; our location and partnership opportunities; our resources; and our societal needs and contributions. They facilitate convergence on transdisciplinary efforts to address current social challenges and opportunities. They are inclusive enough to bring together diverse contributors and stakeholders, yet focused enough to have significant impact. They should guide strategic collaborations that address key global and local challenges. Intellectual Neighborhoods define opportunities to enhance our educational excellence and will delineate activities that have high impact in the communities we serve. They will help with major personnel, resource allocation, investment, and fundraising decisions. They will provide opportunities for us to differentiate ourselves from our competitors. Differentiating strategies are hard to copy, create long-term value, make us unique, and are highly valued by our community.

This document provides detailed information about the Intellectual Neighborhoods, including specifics about the process that was used to identify and refine them. We also provide details about several other ongoing areas of interest that were discussed but ultimately determined to be not quite ready (as of late fall of 2019) to be identified as Intellectual Neighborhoods. Finally, we present answers to some Frequency Asked Questions (FAQs) about the Intellectual Neighborhoods and what role they are expected to play in our future endeavors.

The Associate Dean of Research and Entrepreneurship (ADRE) will act as the champion for these neighborhoods on behalf of the College of Engineering. The ADRE will continue to work closely with the Dean, faculty, staff, and students to ensure that these Intellectual Neighborhoods inform our decision-making processes. We anticipate that we will revisit the identity and description of these neighborhoods on a regular basis and have already committed to reevaluating them next year (2021). We welcome your thoughtful commentary on the neighborhoods as we begin to implement and integrate them into our activities and culture.

As of August 2020, the five UD COE Intellectual Neighborhoods are:

ENGINEERED THERAPEUTICS

The Engineered Therapeutics neighborhood is home to experts in nanomedicine, precision and personalized medicine, computational biomedicine, biomedical informatics, immunoengineering, therapeutic delivery, biopharmaceuticals and more. We're advancing the discovery, design, development, manufacture and delivery of lifesaving therapies to enable a healthier future for humans around the world.

ADVANCED MANUFACTURING AND MATERIALS

The Advanced Manufacturing and Materials neighborhood is home to experts in composite materials, 3D printing methods and software, process intensification and deployment, biopharmaceutical manufacturing, biomaterials, and quantum materials. We're advancing basic and applied research of advanced materials and manufacturing processes for use in a wide range of applications, from consumer product development to national defense.

COASTAL AND ENVIRONMENTAL ENGINEERING

The Coastal and Environmental Engineering neighborhood is home to experts in hydrology, coastal dynamics, microbiology, environmental engineering, ocean engineering, civil infrastructure, structural engineering, transportation engineering and more. We're elucidating the effects of climate change on the natural and built environments along coastlines.

TRANSLATIONAL BIOMECHANICS

The Translational Biomechanics neighborhood is home to experts in biological material testing and modeling, clinical imaging and bioimaging, human motion and movement science, mechanobiology, medical device design, rehabilitation, robotics and more. We're translating basic and applied research into clinical practice to help people move better.

SCHOLARSHIP OF ENGINEERING EDUCATION

The Scholarship of Engineering Education neighborhood is home to experts in pedagogy, field experiences, design of hands-on modules and laboratory exercises, capstone course development and more. We're ensuring that engineering graduates are well prepared for the 21st century workforce.

Procedures used for identifying and refining Intellectual Neighborhoods

A red-team meeting to develop candidate Intellectual Neighborhoods was held on October 9th, 2019 at Clayton Hall with broad participation across the college. Three breakout teams were assembled; these were focused on the broad areas of health; energy, environment, and water; and infrastructure / cyber. Each of these three teams were asked to generate four candidate areas that could be considered for creating Intellectual Neighborhoods. The 12 ideas generated, along with short descriptions for each, are listed below. An initial ranking of the ideas was received from the red team participants at the end of the meeting.

These ideas were then organized and presented to the Dean's leadership team and were evaluated and ranked by that group. This list was then presented to the Department Chairs, resulting in identification of the top four areas. It was also determined that a separate Intellectual Neighborhood area focused specifically on the Scholarship of Engineering Education should be included to ensure that this important area of our activity was appropriately represented. Finally, the title of the Intellectual Neighborhood on Advanced Manufacturing and Applications was slightly modified to Advanced Manufacturing and Materials. After further consideration it was decided that "Applications" was not a sufficiently descriptive term (since Engineering is in some sense implicitly interested in applications). Also, over the past year, UD was awarded two large centers related to materials research, including an NSF MRSEC (CHARM) and DOE EFRC (CPI). The strong materials-focused research activity in the college needed to be more explicitly identified in the list of Intellectual Neighborhoods.

The following descriptions of the Intellectual Neighborhoods are based on the feedback from the Red Team meeting in October 2019. The top four of these, along with Scholarship of Engineering Education, created the final set of five currently identified. The remaining eight are also provided so that it is possible for those interested to see those other areas that were actively discussed, along with a brief description of the associated rationale. These other areas may become Intellectual Neighborhoods at some point in the future, or other areas of activity may also arise that are not yet envisioned.

1. Engineered Therapeutics

The Engineered Therapeutics Intellectual Neighborhood spans therapeutic delivery, nanomedicine, predictive modeling of disease, treatment impact and therapeutic mechanicms, precision or personalized medicine, immunoengineering, and biopharmaceuticals, with growing research and teaching expertise across multiple engineering departments (biomedical, chemical & biomolecular, computer and information sciences, materials science, and mechanical). Among these departments, a number of individual investigators are accomplished in the therapeutic world with growing reputations in both therapeutics (e.g., cell, peptide, DNA/RNA, antibodies, small molecule drugs) and how therapeutics are delivered (e.g., nanoparticles, self-assembled polymers, non-viral vectors). There is also much expertise in computational modeling and analysis of large amounts of patient data from electronic health records, creating predictive models for disease trajectory and the likely effects of intervention. This neighborhood is bolstered by the existing research strengths of NIIMBL, DE INBRE, and a COBRE in chemistry, and aligns with the UD strategic plan's commitment to biopharmaceuticals. An established neighborhood unites this community for

higher-impact engagement across campus and with local industry, in the presence of a growing national investment in new therapeutic discoveries for important human health applications.

2. Advanced Manufacturing & Materials

The Advanced Manufacturing Intellectual Neighborhood will focus on basic and applied research of advanced materials and manufacturing processes and their use for a wide range of cross-cutting applications. This neighborhood builds on existing strengths where UD is recognized as an international leader in advanced manufacturing research including the Center for Composite Materials (CCM), Rapid Advancement in Process Intensification Deployment (RAPID), and the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL). Over this past year UD has also received support for an MRSEC Center for Hybrid, Active, and Responsive Materials (CHARM) from the NSF, and an EFRC Center for Plastics Innovation (CPI) from the DOE. Advanced manufacturing and materials continues to be a strategic area of national interest and investment within many federal agencies (e.g., National Network for Manufacturing Innovation (NNMI), Defense-wide Manufacturing Science & Technology (DMS&T), Department of Energy Advanced Manufacturing Office, etc.) and private industries. This neighborhood leverages a substantial investment in UD's current state-of-the-art infrastructure including design and manufacturing equipment housed within CCM's 58,000 sf of shared research, development, and demonstration laboratories and the new digital manufacturing laboratory located within the renovated Pearson Makergym. These facilities provide a clear pathway for shared resources that can be used to better foster collaborative research programs throughout campus. From an educational perspective, UD is uniquely positioned to develop innovative manufacturing education programs at both the undergraduate and graduate level that are responsive to the needs of industry and builds on years of innovation and investment in manufacturing and materials research and education.

3. Translational Biomechanics

The Translational Biomechanics Intellectual Neighborhood is built around the interdisciplinary study of the structure, function, and motion of biological systems across all size scales, from whole organisms to organelles and molecules, translating basic and applied biomechanics research into clinical practices that improve health and the human condition. Translational biomechanics is fundamentally relevant to the understanding, diagnosis, and treatment of human disease, and is an explicit focus area of numerous government agencies (DoD, NASA, NIH, NSF, etc.), clinical entities (Christiana Care, Nemours/AI duPont, UD PT, Veterans Admin, etc.), and of existing and potential corporate partners (Gore, Johnson & Johnson, Medtronic, etc.). UD has an established reputation for excellence in fundamental and translational clinical biomechanics supported by world-renowned Translational Biomechanics research encompassing biological material testing and modeling, clinical-imaging and bioimaging, human motion and movement science, mechanobiology, medical device design, rehabilitation and clinical practice, and the use of robotics and autonomous systems (BME, MSE, MEE). Research in Translational Biomechanics builds upon existing partnerships across campus resources, and is well-aligned with Physical Therapy and Kinesiology (CHS); and Biological Sciences, Chemistry and Biochemistry, Mathematical Sciences, Physics, and Psychology and Brain Sciences (CAS). Thus, UD and the College of

Engineering have existing and unique strengths in basic, applied, and translational biomechanics that will continue to differentiate us from other institutions that have not horizontally-integrated basic, applied, and clinical multi-scale research in Translational Biomechanics. From an educational perspective, Translational Biomechanics is integrally-aligned with graduate and undergraduate programs in BME, ME, and MSE, as well as with the interdisciplinary BIOMS program.

4. Coastal and Environmental Engineering

The Coastal and Environmental Engineering Intellectual Neighborhood addresses coastal specific issues between the built and natural environments and the challenges created by climate change as articulated in the National Academies *Grand Challenges in Engineering* and *Environmental Engineering for the 21st Century* reports. The coasts have disproportionally high population densities (relative to the rest of the country) that reside in heavily urbanized environments, which alter landscapes and exert influences on the surrounding environment. Climate change will result in further disruptions through coastal erosion processes, alterations to civil infrastructure, salt water intrusion of freshwater supplies, and sea level rise as examples. The University of Delaware possess unique strengths and expertise in numerous areas specific to coastal science and engineering along a continuum from the built to the natural environment *that are not present in most other universities*. We have faculty with expertise in the built (e.g., civil infrastructure, transportation, and structural engineering) and natural environments (hydrological, coastal, environmental, and ocean engineering). The interdisciplinary nature of our faculty enable us to pursue convergent science and engineering research opportunities (one of NSF's "10 Big Ideas") specific to coastal issues with many other units within the University of Delaware e.g., Delaware Environmental Institute, the Colleges of Agriculture and Natural Resources and Earth, Ocean, and Environment, and the Delaware Biotechnology Institute.

5. Digital Transformation

The Digital Transformation intellectual neighborhood encompasses leading-edge development in machine learning, artificial intelligence, data science and high performance computing that are fundamental to science and engineering. Creating excellence in this intellectual neighborhood is critical for UD to play a key role in the American AI initiative being implemented by NSF, DOE, DOD and NIH, while at the same time addressing the challenges and societal impacts of digital transformation. Building on the research networking and cyber-infrastructure being established through the UD Data Science Institute, this neighborhood will create a focal point for collaborative activities within COE, across UD campus and with a broad range of regional and national industries and government agencies. The intellectual neighborhood may inspire the development of new courses and interdisciplinary undergraduate minors and graduate programs, including new online certificates for workforce development.

6. Bio-Inspired Materials

The Bio-Inspired Materials Intellectual Neighborhood will focus on the study and macromolecular design of (bio)materials that have advanced functionality, including responsive materials, biomimetic materials, sustainable materials, self-assembled materials for tissue engineering, biomanufacturing, and biotherapeutic applications. Our strength in

biomaterials development and application spans multiple departments including Biomedical Engineering, Chemical Engineering, and Materials Science, and is well supported by National (NIH, NSF) and Corporate (Chemours, LiteCure, DuPont) collaborations and grants. This neighborhood builds on an existing research strength and reputation at the University of Delaware in material systems design and bio-inspiration (PIRE) and bio-derived materials (DEI/CCI), with an increasing convergence of interdisciplinary interests in this cutting-edge field. The neighborhood is likewise supported in terms of applications connected to NIIMBL (biopharma) and CCM (manufacturing). In addition to concentrated links to materials/biomimetic design and applied biomaterials in the undergraduate and graduate curricula of the three departments, including the new MSEG undergraduate curriculum, this area is growing a positive reputation and demonstrated community engagement with partners such as the Delaware Natural History Museum and Art in Science.

7. Natural & Built Environment

The Natural & Built Environment Intellectual Neighborhood will focus on the pressing needs of a global society at the intersection of soil, water, air and the infrastructure contained on and within these environments. Research will focus on: mitigating the effects of chronic, episodic, and acute natural processes in urban and rural settings (particularly coastal regions where more than 40% of the global population resides); methodologies for ensuring clean waterways, providing clean drinking water and alternative and/or efficient energy generation; and sustainability and resilience principles through novel building design and construction methodologies. The University of Delaware has acknowledged excellence in disaster studies, applied coastal research, civil and environmental engineering and alternative energy with world-renowned expertise in several areas serving as differentiators from other institutions. The Natural & Built Environment neighborhood builds on existing units at UD including the Center for Applied Coastal Research, Disaster Research Center, Center for Innovative Bridge Engineering, Delaware Environmental Institute, Delaware Center for Transportation and the Delaware Energy Institute, and numerous other faculty in CEOE, A&S, and CANR engaged in environmental research.

8. Mobility

The Mobility Intellectual Neighborhood will focus on society's critical and pressing needs surrounding the movement of people, goods, services, and knowledge. Transformative change is coming in our transportation and mobility networks that will benefit humanity as well as the environment. Innovative research in individual mobility, movement, and locomotion also will transform human efficiency as well as access for those with disabilities. Innovative research areas include: (1) connected & autonomous vehicles (including energy systems, batteries, energy production and storage, logistics); (2) innovative long distance human and freight transport (hyperloop, maglev rail, high speeds trains, autonomous freight shipping); (3) autonomous flying drones, and automated ocean-bound shipping and submarines; and (4) Human mobility and sensing (biomechanics, wearables, specific technologies focused on equality of access for those with disabilities). This neighborhood can leverage off of a number of existing college research centers, including: Delaware Center for Transportation (DCT), Center for Fuel Cells and Batteries (CFCB), Center for Applied Coastal Research (CACR), Center for Biomechanical Engineering Research (CBER), and the Center for Catalytic Science and Technology (CCST). It can also leverage off of a

number of university level centers and institutes, including: Catalysis Center for Energy Innovation (CCEI), Center for Carbon-Free Power Integration (CCPI), Delaware Environmental Institute (DENIN), Delaware Rehabilitation Institute (DRI), Delaware Energy Institute (DEI), and Institute of Energy Conversion (IEC). This neighborhood would also have unique opportunities for partnership with the university's largest state-level supporter of research, the Delaware Department of Transportation. This is important for the "community impact" and local importance of what we do.

9. Quantum Materials & Devices

The Quantum Materials and Devices Intellectual Neighborhood will focus on the growth and fabrication of materials and devices with a focus on applications in quantum information science and quantum sensing. Quantum information science focuses on secure communications and quantum computing (in which new computing paradigms are based on fundamentally different approaches to computing which are more appropriate for certain critical classes of problem, the most widely known of which is cryptography), but a wider view of quantum materials and devices enables a variety of new technologies to solve bigger engineering problems. Quantum Engineering is a new focus area for many government agencies (Defense, Energy, NSF, etc.) and a variety of potential corporate partners (Google, IBM, Microsoft, Northrup-Grummann, etc.) Our strength at Delaware is in materials and devices, and this differentiates us from other institutions that focus more on algorithms or proof-of-concept (but not scalable) quantum bits, and our expertise in this area is widely acknowledged and makes us a prime strategic partner for bigger consortia. This neighborhood builds on existing strengths at UD such as our Materials Growth Facility, the UD Nanofabrication Facility, and the research interests of many faculty in engineering, physics, and mathematics. From an educational perspective, it is well-aligned with the nascent Quantum Science and Engineering graduate program and has been an area of excitement for students and parents for the new MSE Undergraduate Program.

10. Sustainable Chemical & Energy

The Sustainable Chemical and Energy Intellectual Neighborhood will focus on the sustainability of energy and chemical production and utilization. This neighborhood aims at promoting sustainability in the energy and chemical-related research at Delaware, which includes the development of renewable energy technologies (e.g., advanced photovoltaic materials and devices, energy storage materials, devices and systems, fuel cell devices and systems) and sustainable fuel and chemical productions (e.g., biomass and CO_2 upgrading to valuable products and sustainable plastics). Our strength at Delaware relies on the legacy in catalysis (e.g., CCEI is the only EFRC center focusing on catalysis that has been renewed for three times) and a well-recognized chemical engineering program consistently ranked in top ten in the U.S., which differentiates us from many other institutions that focus on sustainability research. This neighborhood builds on existing centers at UD such as CCEI, CCST, CRiSP, CFCB, and IEC, and the research interests across the College of Engineering (such as CBE, MSEG, ME, ECE, and CEE).

11. A Connected World

Our physical world, today, is interconnected, observed, and driven by information technology, to a degree that is unprecedented. Developments of cyber-physical systems,

high-performance computing, data processing, and artificial intelligence have moved to the center of this revolution. Understanding and advancing this connected world will be transformational, with enormous societal impacts. It brings together diverse teams from all areas of science and engineering that study the physical world with those that create innovations in computer and information science and engineering.

12. Computational Medicine

This Intellectual Neighborhood draws together existing research strengths in bioinformatics, systems biology, precision medicine, imaging, and health records management. These topics are reflected in popular coursework and programs across campus, especially at the graduate level (Data Science Institute). Computational data analysis could be an important differentiator at UD as a driver for all designs. This field represents important societal & national priority. Health records management stands out as an area for aspirational collaboration with the State of Delaware to model demographics and disease, both for State-level decision-making and as a National indicator. Faculty in computational medicine could leverage partnerships with Thomas Jefferson, UPenn, South Carolina, and teaching hospital like Nemours.

Frequently Asked Questions (FAQs):

Q: I don't see my particular area of research obviously represented in the Intellectual Neighborhoods. Does that mean that the COE does not appreciate what I do?

A: Absolutely not. We hope and expect that faculty will continue to pursue their individual intellectual activities in the manner they best see fit. As academics, we should all value and appreciate the freedom that comes from holding a faculty position. Our purpose is simply to identify areas of strength that deserve particular attention for potential strategic investment at this point in time.

Q: If our department wants to hire new faculty, do they need to be coupled to a particular intellectual neighborhood?

A: Not necessarily, but we hope that these areas will represent those areas of activity that are most likely to present opportunities for strengthening our current excellence and building strategically for the future.

Q: What kinds of resource allocations are expected be associated with activities related to the strengthening intellectual neighborhoods?

A: In addition to financial support, other resources, including space and personnel will be strategically assigned to the Intellectual Neighborhoods. However, the Intellectual Neighborhoods will only be part of the rationale for allocating resources.

Q: For how long will these neighborhoods be defined?

A: We expect to revisit the list of intellectual neighborhoods on a recurring basis, likely every three years, to ensure that they properly represent the current state of activity in the college. We fully expect them to change as research interests evolve.

Q: Why is there no obvious Intellectual Neighborhood associated with Data Science, Catalysis or Cybersecurity?

A: The purpose of this initiative is not to sideline established and thriving research areas that already exist in the College but rather to strategically supplement them. With the spotlight now falling on these five suggested topics, the intention is to help them reach the level of nucleation, maturity, and cohesion observed in our other existing areas. Once interdisciplinary ideas start to percolate in our new Intellectual Neighborhoods, the hope is that they will also connect with, draw from, and contribute to our intellectual strength in our other well-established research areas.