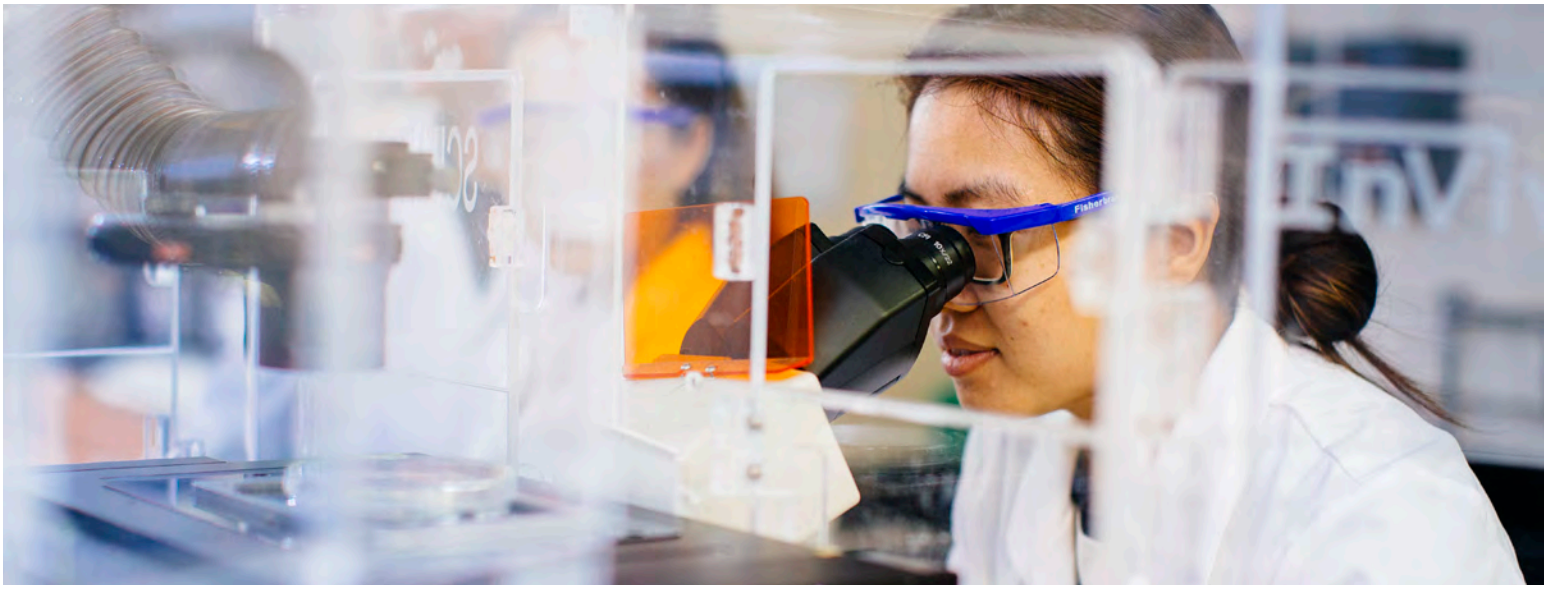


STRATEGIC VISION FOR REALIZING
THE ARMOUR RENAISSANCE

Executive Summary

The time is now to realize the **Armour Renaissance** as the engineering discipline enters a new era that will be marked by a fusion of the physical and the digital across all engineering domains and endeavors. The following vision lays out a comprehensive set of initiatives that will develop leaders to drive this physical-digital fusion. After affirming the college's **vision, mission, and core values**, we begin by articulating our conception for the traits of tomorrow's **Armour Engineer** as the goal for a comprehensive educational and experiential-learning platform for our engineering students. Intentional formation of the **Armour Engineer** is our overarching purpose that motivates and drives all other endeavors. The curricular, cocurricular, and extracurricular offerings that come together in an intentional, comprehensive, and personalized manner to build the stackable competencies that define each student will be realized through the **Armour Academy for Experiential Learning and Student Success.** This is followed by a plan for renewal of our infrastructure that will promote a **highly collaborative research culture** to drive the impact of our research and graduate education enterprise. Finally, a plan for **engaging our alumni and invigorating our industry partnerships** is laid out. All of our efforts in education, research, and practice will be informed by these broad initiatives, and they will be executed with a deliberate diversity, equity, and inclusion lens to ensure that Armour College of Engineering is known for its strong commitment to both equity and excellence.

The genesis of this strategic vision for Armour College of Engineering was the formation of a Strategic Planning Committee in spring 2021. The committee consulted faculty, staff, and students to determine the present state of the college and to make recommendations for our future. Their report formed the basis for the development of a comprehensive strategic vision to guide Armour in the years to come. Input has been incorporated from college leadership, including associate deans and department chairs, along with the Armour Board of Advisors in fall 2022.

Why a strategic *vision* and not a *plan*? There are elements of the foregoing vision that are well formulated and already being implemented according to a plan. However, the **physical-digital fusion**, **highly collaborative research culture**, and **alumni and industry partnership** portions are intentionally more open-ended and less prescriptive. The objective of these three sections is to outline an approach that is flexible and adapts to the changing landscape in engineering education, practice, and research. For the strategic vision itself, therefore, we are seeking to articulate the general framework and not the details. That is, we wish to articulate the *what*, not the *how,* as the *how* will require significant ongoing discussion across the college in order to flesh out the details and refine our approach in the coming years. In a real sense, therefore, this strategic vision represents the beginning, not the end, of a deliberate path toward bringing about the Armour Renaissance. Working groups for each major portion of the strategic vision will develop the specific steps and strategies for implementing the broad objectives outlined herein. This will require a great deal of research, reflection, and refinement and will leverage the collective input of the Armour community to define the details of *how* to accomplish our aspirations.

Preamble

The Armour Institute was founded more than 130 years ago on the premise that a technical education must be available to all at a time when such an education was primarily offered only to the elite.[1] In the intervening years, many other institutions have formed to provide a wide range of options for training engineers. However, Illinois Tech remains unique in being the only tech-focused university in the Chicago area, thereby providing a one-of-a-kind environment to learn and train, both inside and outside the classroom, to be engineers that contribute to society and their professions through industry innovations, entrepreneurial pursuits, and the research enterprise. Our alumni and faculty have been central figures in the public and private sectors for many decades, leading innovations that have driven numerous products, processes, and systems that make modern life safer, more fulfilling, and available to a broader spectrum of society by meeting the technological and societal needs of the last century.

Building on this legacy requires a new level of interdisciplinary training and entrepreneurial thinking in undergraduate and graduate education and research. Now is the time to recommit ourselves to the founding mission and historical legacy of the Armour Institute and reclaim our place of preeminence in the higher-education ecosystem. Rethinking the education of tomorrow's engineers to enable them to be future leaders in the technological landscape requires bold thinking, bold action, and bold resourcing. In order to fulfill our mission; provide our unique blend of experiential learning to a broader, more diverse, and larger cohort of students; and maximize our impact; we must execute a new level of investment to provide the curricular, cocurricular, and extracurricular ecosystem necessary to train the engineers of tomorrow to tackle global challenges.

As has been our legacy, we must innovate and lead in order to develop and train engineers who will meet the local, national, and global challenges of tomorrow through the application of the entrepreneurial mindset to all areas of engineering pursuits. While engineering by itself does not hold the answers to all of humanity's challenges, it provides a methodology for identifying the essential aspects of exceedingly complex issues and marshaling the existing technologies, as well as inventing the new ones, that are required to address the grand challenges of today and tomorrow. We must not be content to simply follow industry trends; we are not training engineers for the jobs of today but to drive the development of new products, processes, systems, entrepreneurial ventures, and even whole industries to provide the solutions of tomorrow.

Fulfilling our educational and research missions as an institution of higher education begins and ends with people; it begins with an academy of scholars and practitioners who are leaders in their respective fields, educating cohort after cohort of tomorrow's engineering leaders. In order to regain our preeminence in the landscape of engineering higher-education institutions, we need to continue hiring and developing the best and brightest faculty, attracting the students that will most benefit from our unique hands-on experiential learning environment, and house all of our activities in state-of-the-art facilities that are infused with industry-centric resources in order to unleash our full potential. Additional resources will allow us to expand our capacity to deliver our programs to an even more expansive spectrum of future engineering leaders and scale this model to serve a broader audience of students through increased access, diversity, equity, and inclusion. Robust investments in our people, programs, and facilities will enable us to more fully realize our educational ideals by further refining our unique hands-on approach to experiential learning. We must be limited only by our creativity and ingenuity, not our physical and human resources.

As you read this strategic vision, you will notice that it emphasizes those aspects of our activities that we can control. By focusing our energy and resources on those initiatives that directly impact our students' success, faculty's productivity, and staff's effectiveness, the concomitant enrollment growth, revenue growth and diversification, growth in research volume and impact, continued improvement in student success metrics, and national program rankings will be the marks of our renaissance. Although input has been sought from a broad range of constituents in formulating this strategic vision, it represents the beginning of an ongoing discussion among the entire Armour College of Engineering community to formulate an actionable plan to realize our objectives and bring about the Armour Renaissance. Executing this plan will strengthen "Illinois Tech's proven legacy as a vehicle for individual empowerment, community engagement, social progress, and economic impact."[2]

[1] In the "Million Dollar Sermon" of 1890, Reverend Frank Gunsaulus challenged the Chicago community "to give students of all backgrounds the opportunity to have a meaningful role in a changing industrial society."
[2] President Raj Echambadi's inaugural speech on September 17, 2021.

Vision, Mission, and Core Values:

Executing the following strategic vision will enable the Armour College of Engineering to fulfill its **vision**:

> **"To be the leader in fusing the physical and digital in engineering practice, education, and research."**

Armour College of Engineering's vision is central to Illinois Tech achieving its institutional **mission**:

> **"To provide distinctive and relevant education in an environment of scientific, technological, and professional knowledge creation and innovation."**

Our plans and initiatives, as well as their execution, will be guided by the following **core values**:

- **Engineers** are responsible for developing solutions that are economical, ethical, safe, sustainable, and accessible to all.
- Maximizing **engineering impact** requires technical excellence and inclusive innovation that are driven by diversity of thought, experience, and demographics and requires deep integration with our other colleges and disciplines.
- Ensuring student success and accelerating upward economic mobility requires **equity** in access, education, and outcomes.
- The college will exhibit technical and operational **excellence** in all that we do.
- The success and reputation of the College is inextricably linked to the **success** of our students, alumni, staff, and faculty.

The Armour Engineer:

Leading with Purpose in Preparing Engineers to Meet Tomorrow's Challenges

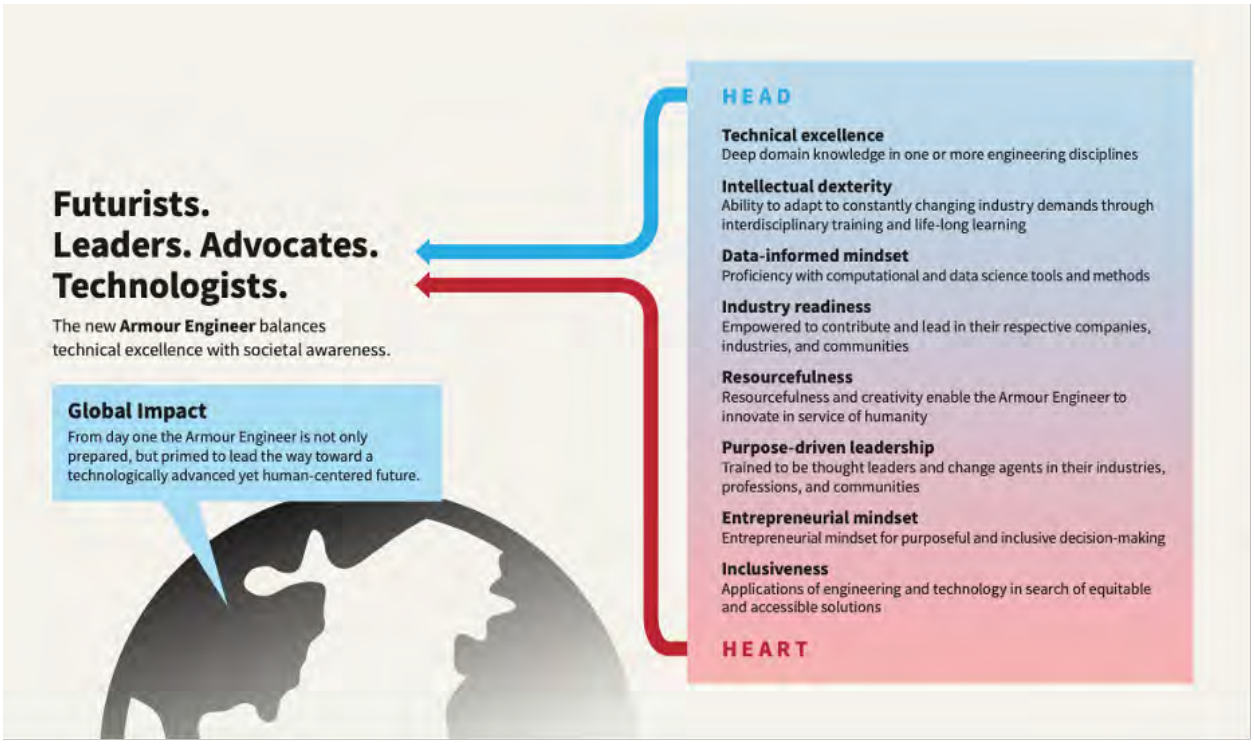
More than any other profession, the engineer possesses the tools, principles, approaches, and mindsets necessary to directly address the grand challenges of today and tomorrow. Engineering is not fundamentally about producing products and processes, it is about creating solutions. The purpose-driven **Armour Engineer** will create solutions that meet the highest ethical standards and safely, sustainably, efficiently, and economically meet the demands of a company, customer, or client. In addition, the **Armour Engineer** will be sensitive to the needs of society and our environment by creating specific solutions that are sensitive to our global context and challenges.

Because innovation is driven by diversity of thought, experience, and demographic, developing solutions for the grand challenges of today and tomorrow will require drawing talented students, faculty, and staff from all backgrounds. Training a diverse student body is necessary to meet future workforce needs in engineering, and this can only be achieved by developing pathways that lead to equitable access to the engineering profession. Similarly, attracting a diverse cohort of students into the engineering profession provides for their upward economic mobility by enabling more people to pursue engineering careers.

Not only is it necessary to ensure that all students have equitable access to the engineering profession itself, but a diverse profession is necessary to ensure that our engineering solutions meet the needs of all people in all settings and circumstances. That is, all people must have equitable access to our engineering solutions, and in this way, the engineering profession itself will promote the upward mobility of all citizens, particularly the underserved and disadvantaged. The **Armour Engineer** will be uniquely prepared, based on their background and training, to make such an impact on our society through the engineering solutions that they develop.

The traditional engineering approach of yesterday has served society well in realizing the products, processes, and systems that make modern life possible. However, addressing current and emerging global challenges requires an engineer with experience on interdisciplinary teams who pivots seamlessly in response to the rapidly changing landscape of society. Students are increasingly driven by a natural desire to help address society's greatest challenges to achieve a more equitable and inclusive world for all and are therefore demanding educational experiences that position them to achieve this higher calling in service to humanity.

To address this need, we will differentiate ourselves by committing to training the **Armour Engineer** of tomorrow by developing and unifying their *head* and *heart* to maximize their *impact* as follows:



The traits of the Armour Engineer[3]

To meet our bold aspirations of training the **Armour Engineer** of tomorrow, we must innovate in all aspects of our operations, engineering pedagogy, undergraduate laboratory spaces and equipment, and student success mechanisms; that is, engineering education must be re-engineered. We must reimagine the classroom of the future that renders technology as a tool in service to pedagogy by enhancing teaching and learning methodologies. Undergraduate laboratories must be modern, flexible, and adaptable spaces that can meet the needs of tomorrow's students, including those of all abilities, and prepare them for the industry environments that they will work in and lead by facilitating the continual renewal of equipment, methods, and processes.

Our teaching and learning aspirations will require significant investment to support flexible programs, facilities, and infrastructure that are nimble and can change with the student-centric, industry-aware, and technology-infused educational model required to meet the ever-changing demands of students and industry partners. Drawing on our creativity, experience, and technical excellence, we will execute a vision for our future that adjusts to the changing needs of our multidisciplinary profession and train our students to excel in such changing environments. We will institutionalize an ability to collect, analyze, and make decisions based on data; to learn from our mistakes; to address challenges head-on; and to be decisive as we strive for continuous improvement and demonstrable excellence.

Core to achieving our goals will be tight collaboration and integration with both internal and external partners, particularly industry. Internally, a critical partnership must be forged with the **Ed Kaplan Family Institute for Innovation and Tech Entrepreneurship** as a unique resource for imbuing the entrepreneurial mindset in *every* Armour student, from first-year student to Ph.D., and strategically cultivating and amplifying these skill sets throughout their educational pathway to yield mastery.

[3] For those familiar with ABET Student Outcomes, which define the attributes of an engineering student when they graduate, you will notice that the traits of the Armour Engineer given here are more expansive and far reaching. They are intended to convey those attributes that will be developed while an undergraduate at Illinois Tech to prepare them for an impactful career in engineering, not just in their entry-level position.

In this regard, we pledge to work collaboratively with the Kaplan Institute to realize the level of academic integration originally envisioned but not yet fully realized.

The Armour College of Engineering will be intentional in developing customized plans for each student to participate in a broad portfolio of curricular, cocurricular, and extracurricular opportunities that will lead to their individual manifestation of the **Armour Engineer**. Accomplished through the **Armour Academy for Experiential Learning and Student Success**, a team of professional advisors, engineering mentors, and faculty partners will guide each student through the development of their personalized plan and provide the resources necessary for them to realize it. Key to this approach will be the integration of industry-relevant experiences and equipment across our curricula to ensure that our graduates meet workforce needs from day one. Industry and society need more of our brand of engineer; the grand challenges of today and tomorrow demand more of our engineering leaders instilled with an entrepreneurial mindset; engineering practice needs more of our data-infused engineers to maximize use of modern tools and methods to tackle the most challenging problems.

Armour Academy for Experiential Learning and Student Success:

Elevate Your Future with the Armour Academy

Much has changed institutionally and in the engineering profession since the formation of the Armour Institute, but the Armour College of Engineering has remained steadfast in its commitment to providing modern, industry-relevant curricula and allied experiential learning and training opportunities to prepare our undergraduate students for impact in industry, research, and society.

Moreover, Illinois Tech has presciently exemplified what the Boyer 2030 Commission Report[4] calls the *equity-excellence imperative,* which is "a belief that excellence and equity are inextricably entwined, such that excellence without equity (privilege reproducing privilege) is not true excellence, and equity (mere access) without excellence is unfulfilled promise." In other words, excellence without equity leads to elitism, while equity without excellence leads to defeatism. They challenge universities to "commit to *equity* as a necessary and defining precondition of *excellence*." Consequently, the Commission is exhorting all universities to move toward a mindset that Illinois Tech has epitomized since its founding.

Owing to our institutional commitment to equity and excellence, Illinois Tech is a tremendous value for the educational dollar. For example, we are:

- #1 in Illinois and #32 in the U.S. for lifting students from families in the bottom 20 percent of income to the top 20 percent; we are also #3 in the nation among highly selective private colleges (Opportunity Insights)
- #1 in Illinois and #59 in the U.S. for net present value of 40-year earnings after graduation (Georgetown University Center on Education and the Workforce)
- #2 in Illinois for 10-year post-college earnings (*Crain's Chicago Business*, PayScale, The Equality of Opportunity Project, and the *New York Times*)
- #2 in Illinois and #83 in the U.S. for 20-year net return on investment (ROI) after financial aid; we are also #1 in Illinois and #39 in the U.S. among private colleges (PayScale)

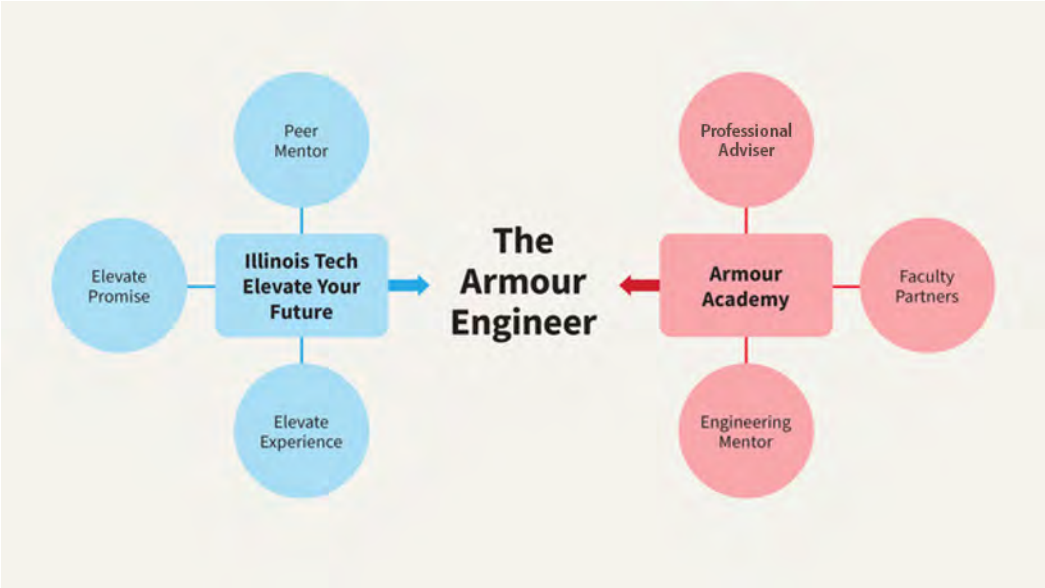
This demonstrated excellence is attributable to the inherent advantage of being a "tech school," with STEM fields dominating the upper echelon of upward mobility measures. Even more so, it is a testament to our unwavering commitment for over 130 years to our founding mission and resourcefulness in the face of constrained budgets and resources. With proper resourcing, we will be first in the state and in the top ten in the nation by these upward mobility and ROI measures. Illinois Tech will be known as *the* place to come nationally and internationally if one wants to fulfill their dream of being a change agent in their community, nation, and world through the discipline of engineering practiced and differentiated with a data-informed and entrepreneurial mindset.

The Armour College of Engineering must reclaim its leadership role in the engineering education landscape, not being followers but leaders in how to prepare engineers to be change agents at all levels of society and embracing the entrepreneurial mindset in order to creatively develop those technologies that address society's greatest challenges. Armour College of Engineering must become more agile in meeting the needs of the marketplace that both students and industry demand, through modernized and flexible curricular offerings and non-traditional educational approaches focused on upskilling/reskilling as well as life-long learning.

[4] "The Equity-Excellence Imperative - A 2030 Blueprint for Undergraduate Education at U.S. Research Universities." The Boyer 2030 Commission, Association for Undergraduate Education at Research Universities (2022).

The new **Armour Academy for Experiential Learning and Student Success** will be informed by our history and experiences since our founding but reimagined to meet the needs of today's and tomorrow's undergraduate students and engineering industry. It will be a framework that permeates all aspects of our undergraduate student-facing activities. Consequently, bringing it to fruition will require us to rethink all of our student success support structures.

The **Armour Academy** will be tightly integrated with the Illinois Tech **Elevate Your Future** program as illustrated below. The professional advisors, faculty partners, and engineering mentors that comprise the Armour Academy will augment the peer mentors, Elevate experiences, and Elevate promise that are available to all undergraduate Illinois Tech students. This layered approach to student success will ensure that all engineering students have the resources and support that they need to fully realize their potential as an **Armour Engineer**. Intentional on-ramping to promote access to our programs for students following various pathways into Armour followed by personalized guidance to promote student success in the completion of our programs and career preparation will be implemented in a unified fashion.



Armour Academy for Experiential Learning and Student Success and its integration with the **Illinois Tech Elevate Your Future** initiative to form the **Armour Engineer**.

The goal of the **Armour Academy** is to provide equity in access, education, and outcomes. *Equity in access* to an engineering education requires outreach to increase awareness of the engineering profession and careers as well as generous need-based financial aid to remove the financial barriers to pursuing an engineering education. *Equity in education* requires support structures and people to come alongside students to bridge the gap between where they are and where they need to be, to provide the academic and non-academic support necessary to enable all students to realize their full potential as engineering students. *Equity in outcomes* requires an intentional and personalized approach to developing a plan for each student to have equitable access to all curricular, cocurricular, and extracurricular opportunities that support their pursuit of becoming an **Armour Engineer**.

Engineering has always been a hands-on profession, and that is reflected in traditional undergraduate engineering education. The **Armour Academy** that produces the **Armour Engineer**, however, will take this to a whole new level by being centered around a holistic student-centric, experiential-learning-focused set of activities that are infused with

industry relevance and structured around an entrepreneurial mindset. The **Armour Engineer** will be realized through a technically-anchored engineering curriculum enhanced by a personalized, comprehensive, and integrated experiential learning and training ecosystem that cuts across all aspects of our curricular, cocurricular, and extracurricular activities as follows:

- **Curricular**: majors, undergraduate laboratories, introduction to the profession courses, interprofessional projects (IPRO) program, capstone design, minors, combined competencies, accelerated masters programs
- **Cocurricular** (directly augment engineering curriculum): undergraduate research (Armour R&D, Summer Immersion), Kaplan Institute, internships, engineering-focused study away, engineering professional societies, engineering-centric student competitions, stackable competencies
- **Extracurricular** (non-engineering activities that produce well-rounded graduates): First-Year Elevate, study away, student organizations, athletics, student government, VanderCook College of Music, volunteer, Chicago

While all of these experiential learning activities are currently available to our students, realizing the traits of the **Armour Engineer** equitably for all undergraduate students will require a new level of intentionality. A unified team of student success partners composed of professional advisors, engineering mentors, and faculty partners will encourage, motivate, model, ensure equitable access, and resource a personalized set of pathways for each student. The professional advisors will coordinate the development of each student's personalized plan that assists them in selecting the various activities that intersect with their interests and comprehensively developing each attribute of the **Armour Engineer**. In this way, the **Armour Engineer** will be defined by the combination of their core engineering curriculum, augmented and enhanced by their personalized experiential learning portfolio.

The people, programs, and activities comprising the **Armour Academy** require a strong commitment to campus-based curricular, cocurricular, and extracurricular experiences for Armour College's undergraduate engineering students centered around hands-on practice-based learning and deep interaction with the student's academic programs, faculty, the Kaplan Institute, the College of Computing, and other campus people, resources, and facilities. This will require significantly upgraded and updated facilities, equipped with modern laboratories and innovative design and build spaces.

In addition to physical facilities and resources, a student-centric application of our ideals will demand financial resources to provide funds to students for whom financial considerations are limiting their engagement in opportunities that will further their pursuit of becoming an **Armour Engineer**. For example, what about the student who does not even consider cocurricular and extracurricular activities because they have to work to put themselves through college? What about the student who does not think study away is an option for them because they haven't had many opportunities to travel? Professional advisors will be empowered to make on-the-spot allocations of funds to students in order to ensure that they have equitable access to our unique experiential learning and training opportunities. This will enable students to develop their skills, strengthen their confidence, and be equipped to tackle any challenge.

All of this will be infused with an agility not normally found in academic institutions that is driven by an entrepreneurial mindset that continuously reevaluates and innovates all aspects of our experiential learning and training landscape of opportunities. This will ensure equitable access for all of our students and continuously redefine the attributes of the **Armour Engineer**. We will live the values of the entrepreneurial mindset that we instill in our students by how the **Armour Academy** is conceived, executed, structured, and staffed in order to meet the evolving needs of students, engineering education, and industry.

This entrepreneurial agility will be augmented by our engineering resourcefulness. Meeting the global grand challenges of today and tomorrow requires engineers that are equipped and resourced at an unprecedented level. Students will become change agents at all levels of society and embrace the entrepreneurial mindset in order to creatively develop those technologies that address society's greatest challenges. Tomorrow's challenges demand engineers that are no less

resourceful than those that have built our legacy, but maximizing one's impact now requires sufficient resourcing. Closing the digital divide requires more resources. Providing upward mobility through education for disadvantaged students requires more resources. Maximizing innovation and entrepreneurial impact requires more resources. Armour students display a resourcefulness that arises from each student's own life experiences, overcoming various challenges to pursue their engineering education, and will be strengthened by the **Armour Academy** that undergirds their educational pathways.

Physical-Digital Fusion:

A Revolution in Engineering Practice, Education, and Research

Underlying all of our engineering endeavors has always been a desire to conceive, design, and realize *physical* products, processes, and systems. Doing so has required engineers to harness every resource in a growing arsenal of tools and techniques. However, enabled by tremendous advances in both digital hardware and software capabilities, along with ubiquitous high-speed networks, we can now begin to imagine a seamless integration of the physical and digital worlds in ways never before possible, which will enable new approaches to engineering. Powerful distributed computing capabilities that sit at the core, *i.e.* in the cloud, and at the edge of ubiquitous high bandwidth, low latency wireless 5G networks, provide the ingredients to seamlessly integrate the physical and digital through the Internet of Things (IoT), real-time sensing and monitoring of engineering systems, and digital manufacturing, for example. This fusion also poses numerous challenges and opportunities in data communications, cybersecurity, sensor-actuator technologies, and optimizing collocated data and computing power for real-time decision-making.

Unlike previous revolutions, this transformation is taking place simultaneously in all sectors of engineering, including research, industrial, manufacturing, commercial, and service sectors. Therefore, we must not only embrace but lead this transformation across our educational and research missions in order to realize the ultimate vision of this physical-digital fusion. It will inform how we educate our students, how we house our researchers, how we upgrade our facilities, and how we construct research collaborations.

Glimpses of this revolution are visible in the development of augmented reality applications. Computer graphics and virtual reality (VR) provide an alternative world – a digital world – that is wholly separate from the physical world. Augmented reality (AR) seeks to seamlessly integrate the digital and physical worlds in such a way that it is not always possible to distinguish one from the other. In addition, machine learning and artificial intelligence are increasingly being used to augment computational methods and solve complex engineering and interdisciplinary problems. Similar to AR, a seamless integration of our theoretical models, model-driven and data-driven computational methods, and experimental techniques will lead to a revolution in engineering and enable new applications that have not yet been imagined. A fusion of the physical and digital worlds, along with the mathematical models that undergird our physical understanding, will bring about the Fourth Industrial Revolution.

In physical-digital fusion, integrated physics-based mathematical models, computational simulations, and data from onboard sensors will be integrated to develop a single representation of the system or process that assimilates the most accessible and trustworthy elements of each. In this way, computational and digital tools will shift from being *complementary* to a physical system to being *integral* to it. Therefore, the discussion shifts from deciding between computational modeling *or* physical prototyping to fusing the best that both have to offer to form a single model of the system that is more detailed, comprehensive, and accurate than either the physical or digital model could provide by itself. This requires models that are not only multidisciplinary but seamlessly integrate the physical and digital representations of a system.

Let us illustrate physical-digital fusion using an example from industry, education, and research.

Industry Example

A *digital twin* is a digital representation of a physical product, process, or system spanning its entire lifecycle; for example, consider the commercial aircraft industry. When aircraft come off the assembly line, they each have identical airframes, engines, and associated systems. However, the life of each aircraft is as unique as the pilot's fingerprint. What if when an airline takes delivery, they receive two versions of the aircraft: the physical aircraft and a digital twin of all of its respective systems? The digital twin takes in real-time performance and operating data from the aircraft's various systems via onboard sensors, ongoing inspection data, as well as information that characterizes each flight taken that is assimilated and used to monitor the health of each system and predict maintenance and part replacement needs for that specific aircraft over its

entire lifecycle. Such a digital twin requires real-time sensor data from the actual aircraft and its systems and a computational model that encompasses predictive, physics-based, multidisciplinary models along with artificial intelligence and machine learning data analysis of large volumes of lifecycle data for the entire fleet of aircraft to optimize the service life of each aircraft and maximize in-service time, performance, and safety. In addition, digital twins will provide large volumes of aggregated fleet data, including off-design flight data, that will inform improvements in the design of new systems as well as the next generation of aircraft.

Digital twins could be applied to transportation systems (infrastructure and/or vehicles); chemical processing plants; buildings; structural systems; energy generation, transmission, and storage systems; biological systems and processing facilities; medical devices; and manufacturing processes. That is, any large and/or complex product, process, or system could benefit from digital-twin technology. For example, what if we could form a digital twin that ingests genetic, environmental, and ongoing clinical testing data for each human? This would revolutionize patient care by optimizing testing and interventions for individual patients, accelerate drug development and testing, and inform therapeutic treatment and surgical intervention decisions. A good example of such technology is the Living Heart digital twin developed by an industry-academia consortium led by Dassault Systèmes, which facilitates medical device design and the planning of surgical and pharmaceutical interventions of cardiac diseases.

On the historical Illinois Tech Mies Campus, Armour faculty and students have developed and are continuously refining a digital twin of the Illinois Tech Campus Microgrid (ICM), which covers the entire campus-wide electric power distribution system and includes three building-level nanogrids at Keating Sports Center, Stuart Building, and Crown Hall. The flagship ICM is the world's first fully functional campus microgrid that started in 2007 and has been constantly evolving since. Using such a digital twin, we can study special control strategies, such as energy restoration from a complete blackout using the real electrical load data and renewable generation data on campus, which is not easily tested in the purely physical system without causing disruption. We can also use the ICM digital twin to study a futuristic scenario in which all of our electricity is provided by renewables, such as solar and wind, with the support of battery energy storage and flywheel energy storage along with real-time operational data fed from the current ICM.

Education Example

Fusing the physical and digital in the educational realm will prepare our students to be leaders in their organizations by helping them fully embrace this revolution. A current example of this is the EcoCAR EV Challenge, for which Illinois Tech was selected to participate from 2022 to 2026. The EcoCAR Challenge is sponsored by the United States Department of Energy, General Motors, Argonne National Laboratory, and MathWorks. Teams of students are tasked with modifying a current GM vehicle according to criteria specified by the competition team. Execution of these modifications requires integration of various project components into the undergraduate curriculum, the use of digital tools that simulate various physical systems of the vehicle, the design of the modifications using CAD renderings from GM, realizing the modifications in an actual vehicle, and testing against other competitors. Projects such as this allow our students to experience the entire design-build-test cycle and exemplify the physical-digital fusion that will characterize the future of engineering.

Research Example

For many years, computational biology consisted of modeling idealized geometries and assumed boundary conditions and material/tissue properties, and the results were compared with clinical measurements to validate the computational models. Such an approach provides an improved understanding of underlying biological and physiological mechanisms and may lead to general guidelines for clinical and medical decision-making. More recently, computational models have been based on patient-specific geometries utilizing image processing to generate a digital patient-specific model of the human brain and heart starting from high-resolution medical imaging data (e.g. via Magnetic Resonance Imaging). In addition, *in vivo* and *ex vivo* measurements are used to inform the specification of boundary conditions and properties in the computational model.

Coupled with digital twins of various organs, this approach has provided an improved understanding of the full range of possibilities within a patient population and leads to patient-specific guidelines for clinical and medical decision-making. While this approach is currently state-of-the-art in research, it remains aspirational in clinical practice.

This ability to incorporate patient-specific geometries and data into our computational biology models hints at a new era in physical-digital fusion that will dramatically revolutionize biomedical research and clinical practice. Rather than a clinical, medical, or surgical standard of care applied uniformly to all patients with a particular medical condition, individuals will receive customized patient-specific clinical care and surgical intervention recommendations that are based not only on a patient's unique physiology and medical history but informed by an assimilation of this clinical information with predictive models applied to the particular patient, along with aggregated large-scale data from similar patients. In this way, computational modeling can mitigate the need for detailed and comprehensive *in vivo* property data, which are typically largely unknown. While this physical-digital fusion holds great promise, it requires significant advances in clinical monitoring, computational biology modeling, aggregation of large-scale and anonymized patient data, and new techniques for integrating and processing such data.

Impact on Engineering Practice, Education, and Research

We must be creative in how we expose our students to carefully curated, meaningful experiences in which the physical and digital components of the engineering process are thoroughly integrated in level-appropriate ways. Undergraduate and graduate students will be prepared for an increasingly multidisciplinary engineering profession in which the physical and digital are seamlessly fused. Doing so for both research and practice will require us to completely rethink the objectives of our undergraduate laboratories and design experiences as well as the facilities and equipment that are necessary to realize this vision. Currently, digital courses and facilities are distinct from traditional experimental ones. Seamlessly integrating the physical and digital will require us to fully blend these aspects of our curriculum and facilities. This will enable our graduates to act as change agents by bringing physical-digital fusion to their respective organizations and exemplifying an entrepreneurial and data-driven mindset that will distinguish them among their peers.

The EcoCAR EV Challenge described previously is a template for additional projects that provide hands-on experiential learning opportunities that fuse the physical and digital. Existing curricular elements, such as IPROs, undergraduate laboratories, and design projects/competitions will provide a broad platform for fusing digital tools into the design and realization of physical products, processes, and systems that will be the hallmark of the engineering profession.

By doubling down on our historical strength in our students' educational ROI and by emphasizing the physical-digital fusion across our curricular, cocurricular, and extracurricular offerings, we will distinguish our full ecosystem of offerings and uniquely prepare our students to be leaders in the engineering profession for many years to come. Training our students to be the leaders that bring this physical-digital transformation to their organizations, industries, and communities will require a new level of intentionality in developing their attributes holistically.

Infrastructure to Support a Highly Collaborative Research Culture:

Driving the Next Century of Impact

Those institutions that will lead in the fusion of the physical and digital will be those that establish highly collaborative cultures and frameworks that are agile and flexible in order to best accommodate the inevitable changes in the way that engineering is practiced, taught, and researched. Increasingly, engineering innovations are being made at the interface between traditionally distinct disciplines. Realization of the full potential of physical-digital fusion in the research enterprise will require us to place our faculty and students in a highly collaborative environment that does not simply *encourage* multidisciplinary research but truly *facilitates* a seamless integration of the physical and the digital, such that revolutionary advances will be made in our engineering disciplines and applications. This will not only allow Armour College researchers to enhance their national and international distinction in such multidisciplinary fields, it will also allow us to distinguish ourselves as *the* model for how engineering research is to be conducted in the future. Leading in this way will not only raise our visibility, it will also attract the best faculty and student researchers, thereby setting up a virtuous cycle that will be the keystone of our renaissance.

The key to facilitating this highly collaborative culture is to break down academic silos and colocate faculty and their research laboratories to promote interdisciplinary research collaborations. Armour College currently reflects the traditional academic norm in which faculty are housed within their home departments, which are centered around engineering disciplines. Each of our eleven engineering disciplines is housed within one of our five academic departments, and the corresponding faculty are physically housed within their respective departments; five departments, five buildings. This structure facilitates oversight of our educational mission in each discipline within each department; however, it does not recognize that faculty are more likely to collaborate with other researchers in similar or complementary research areas, regardless of department or even institution.

While maintaining the same academic appointments and formal departmental structure, we propose to physically house faculty, research laboratories, and related undergraduate laboratories in “collaborative clusters” or “collaboratories” centered around broad multidisciplinary research areas. These provide state-of-the-art collaboration and laboratory spaces that reflect the multidisciplinary nature of today’s research by physically colocating the people, facilities, and tools necessary to promote physical-digital fusion. Each collaboratory will be formed based on overlapping research areas, regardless of departmental affiliation. That is, the faculty will be *organizationally* clustered around discipline-based departments, as is the case currently, and *physically* clustered around research areas. As such, each faculty will have an academic home, *i.e.* their department, and a research home, *i.e.* their collaboratory.

Each collaboratory will consist of faculty offices, research laboratories, associated undergraduate laboratories, collaboration and seminar spaces, communal graduate student office space, as well as associated user facilities where appropriate. Research labs will consist of open-concept, shared spaces that allow for collaboration, equipment sharing, and expansion and contraction based on evolving research needs and funding levels. Related undergraduate laboratories will be located adjacent to associated research laboratories so that undergraduate students see the continuum from undergraduate laboratories to state-of-the-art research in that area. All of these facilities will be highly visible in order to put *engineering on display*.

Many universities, including Illinois Tech’s **Wanger Institute for Sustainable Energy Research**, are constructing such facilities around application areas, such as health sciences or sustainable energy research, that draw researchers from multiple disciplines. However, the growing physical-digital fusion demands a finer-grained demarcation of the collaboration clusters, thinking about them more as a continuum rather than discrete application areas.

Our model will focus on organizing the clusters around those research aspects in which collaboration is most fruitful and natural. For example, the physical-digital fusion occurs primarily in the methods that are used and in our specializations. Insofar as these will evolve over time, we need an agile framework that allows the collaborative clusters to form and evolve organically with the needs of the researchers involved and the facilities that they require. Twenty years ago, for example,

robotics research would have been clustered with manufacturing; today, however, it would most naturally be clustered with dynamics and controls and/or transportation systems. Where will it fit in another 20 years? What new methods and applications have not even been conceived of yet?

Evolving research trends will be crowdsourced in such a way that collaboratories naturally adapt to not only accommodate these trends but drive them. This organic approach will enable us to identify research trends early in order to inform faculty hiring initiatives that allow us to embrace and lead in such emerging areas as well as coalesce existing resources to maximize our impact and increase our research volume. Faculty hiring will be focused on interdisciplinary efforts that broaden, deepen, and/or catalyze existing areas of strength to focus on convergence and relevance-inspired research and grow our footprint and excellence in the fusion of physical and digital methods and applications.

By breaking down traditional departmental and disciplinary silos, Armour will form highly collaborative research clusters around physical-digital fusion that lead to deep, lasting, and impactful progress in engineering research. Not only will this accelerate our research productivity, it will also prepare graduate students for the broader set of roles that they might encounter throughout their careers in industry, research laboratories, academia, and/or entrepreneurial ventures. Mentoring our graduate students within this highly collaborative culture that is replete with physical-digital fusion will prepare them to be leaders and disseminate the Armour approach to research in their respective companies, national laboratories, and academic institutions.

Engineering on Display

This transformation in the way students learn and how we conduct research will drive a comprehensive renewal of our entire infrastructure, including remodeling existing buildings and constructing a new state-of-the-art education and research facility. As suggested previously, a common theme in our infrastructure renewal is our desire to put *engineering on display*[5]. This will be exemplified by the new **Student Fabrication Center**, but it will also be a common theme for all of our educational, laboratory (undergraduate and research), design/build, student organization, and fabrication facilities. We seek to put engineering on display, not hidden away, but out front and celebrated for all to see and experience. We want our engineering students and faculty and their engineering endeavors to be marveled at and highlighted.

Students and visitors should see our campus and infrastructure as an advertisement for high-tech industries and engineering solutions. For example, advances in the built environment, smart-grid technology, and autonomous systems should be highly visible and used as teaching and learning tools as well as examples of engineering on display for visitors and prospective students. Accomplishing this will require modern instructional and research infrastructure that is flexible and adaptable to the ever-changing needs of the engineering enterprise.

[5] We seek the equivalent of Crown Hall for engineering. The building itself is a monument to architecture, and the interior of the building is replete with students engaged in architectural pursuits. The building and its occupants are putting *architecture on display*.

Invigorating Alumni and Industry Partnerships:

Engaging With and Serving Our Local and Global Constituents

Partnering with Chicago

The reinvented Armour College of Engineering will be firmly rooted in our Illinois Tech and Chicago communities. We must consistently fulfill our role as indispensable partners of Bronzeville and the greater Chicago community where we build pipelines with local high schools and community colleges, provide interns, and open up pathways of success for a diverse set of students. This couples with our mission to provide equitable access to disadvantaged students to enable upward economic mobility. Partnering with Chicago in these ways will play a central role in developing the unique traits of **Armour Engineers**, both because of our students' diverse backgrounds and their unique training at Illinois Tech.

It is critical that we fully leverage our place in the Chicago educational and technological landscape to become an indispensable, life-long asset to our alumni and industry partners. Not only does Chicago provide a ripe opportunity for student recruitment, but industry partnerships also lead to opportunities for community outreach and engagement as well as applied research. Armour is a conduit to Chicago that provides invaluable and practical experience for our students partnering with business and industry to accelerate technology and foster inclusive innovation. Armour can and must be a major contributor to Chicago's continued rise as a global technology and innovation hub and an indispensable partner with local industry and government agencies. Chicago needs Armour and Illinois Tech to help it meet the global challenges of today and tomorrow.

We will embrace Chicago as a living laboratory for our students and faculty and as a partner in our renaissance. As we provide an educational experience that accelerates student success, we will further Chicago's position as a global leader of diversity in technology and propel the future of global problem-solving.

- Industry and community partners will provide curricular links and engagement with student organizations.
- Local industry will feature prominently in our upskilling and reskilling activities, both as drivers of and participants in our offerings.
- Industry partnerships will be used to help students secure internships and job opportunities, develop collaborations with faculty to increase research opportunities, and build and maintain laboratory resources to ensure that students have access to modern engineering tools.
- Armour College will work to develop outreach projects with the local community to strengthen those ties and create recruiting pipelines so that Armour's student body reflects the community's diversity. That pipeline will direct this diverse talent back into Chicago, helping the city enhance its standing as a leader in technology and engineering.
- Chicago is our living laboratory to develop, deploy, and test creative solutions for global challenges. Once refined locally, Armour will apply our solutions globally.

Life-Long Learning—Upskilling and Reskilling

The fusion of physical and digital approaches across engineering will require upskilling and reskilling of our alumni and practicing engineers. This presents a unique opportunity to become a leader in the space to accelerate this transformation in the way we think about and approach our profession. We will actively pursue partnerships that further physical-digital educational, experiential, and research interactions for our students and faculty in ways that meet the upskilling and reskilling needs of our industry partners as well. This mutually beneficial approach to such partnerships will lead to deeper and more impactful collaborations and result in revenue diversification opportunities for Armour College of Engineering.

We will develop an **Armour Partnerships** umbrella to fully support a range of alumni and industry engagements that can enhance our curricula, build internship and career pipelines for our students, promote student club sponsorships, develop upskilling/reskilling relationships, identify applied research opportunities, and satisfy the recruitment needs of industry. This industry consortium approach will support a broad menu of all types and levels of engagement.

Such an effort begins with instilling our **Armour Engineers** with an appreciation for, and ability to engage in, *life-long learning*:

- Fostering a culture of life-long learning will create life-long members of the Armour College and Illinois Tech community. This begins by changing the culture within the college to create a community that provides support to the college's diverse student body throughout their time on campus and beyond
- Upskilling and reskilling for engineers to maintain leadership and growth in rapidly advancing fields and technologies to enable physical-digital fusion
- Leveraging industry partnerships to facilitate additional equipment sharing for research needs, student workforce development, and upskilling/reskilling opportunities

Satisfying the upskilling and reskilling needs of our alumni and industry partners, both near and far, will require enhanced online and hybrid options for select masters programs as well as non-degree options, such as stackable credentials/certificates, for upskilling and reskilling efforts. These are also our greatest opportunities for **technology-enabled, mission-aligned revenue diversification**. In addition, we will innovate by developing non-traditional business models for such operations, including the possibility of a recurring revenue subscription model or by implementing a model in which participants pay for the credential, not the content.

With regard to select master's programs:

- We will leverage our extensive experience in remote learning and online education at the graduate level, which has been enhanced during the pandemic.
- Armour will continue to enhance and expand online and hybrid options for improved access and reach.

While we have had fully online master's degrees for quite some time, they have not always been effectively marketed as such. In addition, various attempts at offering certificate programs and short courses have only been marginally successful owing to our inability to market them to people seeking upskilling and reskilling.

To effectively address the upskilling and reskilling needs of alumni and industry partners, we must establish an agile framework for non-degree programs, such as certificates, modular programs, and stackable competencies. We will implement an entrepreneurial, demand-driven, nimble mechanism to identify such opportunities so that we are leaders in this space. This requires deeper interactions and collaborations with alumni, Chicago-centric industries, and others that are closely aligned with our areas of expertise. For example, we will leverage our alumni as corporate insiders in their industries along with being potential students in our upskilling and reskilling programs. We will work with the Office of Professional and Continuing Education to design and implement an array of non-degree credentials for upskilling and reskilling by maximizing flexibility in terms of content, format, and modality. The **Armour Partnerships** program will provide the necessary support, resources, and marketing to substantially grow these efforts to maximize the reach and revenue potential of targeted programs. Additionally, hybrid and online options will be leveraged for diversity, equity, and inclusion enhancement.

Summary and Outcomes

As a medium-sized engineering college, we must seek to have a disproportionate impact through targeted initiatives and agile execution that build on our strong history of research all along the continuum from fundamental to applied; unwavering commitment to student success, the upward mobility of our graduates, and their educational ROI; and deep engagement with Chicago and its industries. As stated at the outset, our strategic vision provides a roadmap for achieving the Armour Renaissance, which will maximize the impact of the Armour College of Engineering. The impact *on* and *of* our students; the impact *on* and *of* our faculty; the impact *on* and *of* our research; the impact *on* and *of* our community and industry partners. This impact will be measured through **outcomes**, such as enrollment growth, excellence in upward mobility and ROI metrics, increases in research volume, a vibrant community of alumni and industry partners, revenue growth and diversification, improved rankings, etc.

In order to achieve these outcomes, we will **focus** on the initiatives outlined in this strategic vision along with fundraising and resourcing priorities that enable our physical and human infrastructure renewal. Although our people's talent, skills, hard work, determination, and resourcefulness will form the foundation for defining, refining, and executing our strategic vision, the pace at which we achieve our goals will depend in large part on resourcing through philanthropy, institutional investment, research funding, industry partnerships, and human resourcing.

Our Focus:

F-AA Realizing each student's manifestation of the **Armour Engineer** through the **Armour Academy for Experiential Learning and Student Success**

F-PDF **Physical-digital fusion** in education, research, and practice

F-CRC Infrastructure to support a **highly collaborative research culture**

F-AIP Reinvigorating **alumni and industry partnerships**

F-PIR **Physical infrastructure renewal**

F-HIR **Human infrastructure renewal**

Our Outcomes:

O-USE Grow **undergraduate student enrollment** by filling unutilized capacity and strategically growing capacity in certain areas, e.g. through partnerships, with a focus on those students that will most benefit from our hands-on, experiential-learning approach.

O-GSE Grow **graduate student enrollment** through competitive Ph.D. fellowships, online masters programs, and large-scale educational and workforce development initiatives.

O-SS Increase **student success**, upward mobility, and ROI metrics (#1 in Illinois and top 10 in the nation).

O-F Resource and support **faculty** to excel in their education and research missions along with faculty hiring, development, and retention in targeted areas of research growth.

O-RE Grow **research enterprise** through funding and impact by investing in large-scale research collaborations and interdisciplinary centers.

O-CE Broaden and deepen **corporate engagement** through upskilling/reskilling programs, internship and career opportunities, applied research collaborations, etc.

O-RD **Revenue diversification** through growth in online masters programs, local and global partnerships, upskilling/reskilling of alumni and industry partners, fundraising, etc.

O-R Increase departmental and college **rankings**, which feed back into student and faculty recruiting efforts.

Table showing which **outcomes (O)** will be substantially influenced by each **focus (F)** area.

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F-AA Realizing each student's manifestation of the **Armour Engineer** through the **Armour Academy for Experiential Learning and Student Success**	■		■			■		■
F-PDF **Physical-digital fusion** in education, research, and practice	■	■	■	■	■	■	■	■
F-CRC Infrastructure to support a highly **collaborative research culture**		■		■	■			■
F-AIP Reinvigorating **alumni and industry partnerships**	■	■	■	■	■	■	■	■
F-PIR **Physical infrastructure renewal**	■	■	■	■	■	■	■	■
F-HIR **Human infrastructure renewal**	■	■	■	■	■	■	■	■

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