

# **NJIT: Collaborating in the Converging Fields of Engineering, Technology, and Life Sciences**

**Volume 1: Discussion of Convergence**

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## ***NJIT: Collaborating in the Converging Fields of Engineering, Technology, and Life Sciences***

### **Introduction**

NJIT, New Jersey's Science and Technology University, is one of the nation's leading public universities preparing students to be leaders in the technology-dependent economy of the 21<sup>st</sup> century. The university's multidisciplinary curriculum and computing intensive approach to education provides the technological proficiency, business know-how and leadership skills that future CEOs and entrepreneurs will need to succeed.

With effectiveness and efficiency, NJIT has recently achieved several significant milestones:

- A record fall 2011 total enrollment of over 9500 undergraduate and graduate students in STEM majors.
- A freshmen enrollment of over 1000 students with average math SAT scores of over 600, top 25%tile in the nation.
- A Dorman Honors College enrollment of 685 undergraduates in the top 10%, nationally.
- An Educational Opportunity Enrollment of 658 undergraduates, whose completion rates for underrepresented students in the STEM disciplines exceeds the national average.
- Research expenditures totaled more than \$100 million in FY 2011.
- As of FY 2011, 134 patents were issued to NJIT, of which 60 are licensed to third parties.
- Over 90 companies, employing over 300 people are part of NJIT's Enterprise Development Center (EDC), New Jersey's largest high-technology business incubator, and one of the largest in the nation. The EDC has attracted more than \$67 million in third-party funding and has revenues of \$82 million.
- A record 170 companies attended NJIT's fall 2011 Career Fair.
- This past year, NJIT's administration and faculty inaugurated a strictly performance-based system for compensation.

NJIT continues to be ranked a Top National University-*U.S. News and World Reports*; Top ten in research expenditures whose main research is engineering-*NSF*; Top ten among technological universities in faculty scholarly productivity-*Academic Analytics*; Top 25 producer of minority baccalaureate degrees in engineering and 4<sup>th</sup> in the nation for engineering master's degree to African American students-*Diverse Issues in Higher Education*; Reflecting value for return on investment (ROI), NJIT ranked 4th among public universities nationwide in alumni earning potential-*National Association of College and Employers*. For the second year, NJIT has been named to the President's Higher Education Community Service Honors Roll, one of the highest federal recognitions a college or university can receive for its commitment to volunteering, service-learning and civic engagement.

All of the above *milestones* resonate with the conclusions reached by the *University of Medicine and Dentistry Advisory Committee Interim Report*, September 20, 2011, citing the university's strong academic reputation. NJIT also concurs with the Committee's recommendation that it does not start its own medical school and has forwarded a letter to New Jersey's Board of Medical Examiners requesting the withdrawal of its application. As the Committee also noted, we intend to stay focused on our primary mission and "As New Jersey's lone technical research-focused public institution, NJIT [will] seek to achieve a comparable level of academic excellence achieved by the premiere technology education institutions of higher education in the country." NJIT has and continues its strong commitment to serving New Jersey and the nation with science and technology education and training, the catalyst to the majority of newly created jobs in the state, nation and globally.

NJIT's recent *milestones* also resonate with the most recent National Academy of Sciences, National Academy of Engineering, and Institute of Medicine report: "*Rising Above the Gathering Storm, Revisited*." Among the critically important recommendations of the report is to "Encourage more United States Citizens to pursue career in mathematics, science, and engineering." This has been NJIT's legacy since its founding in 1881 as the Newark Technical School, and its mission today, as New Jersey's Science and Technology University, particularly as we proceeds to achieve our strategic enrollment goal of 11,000 STEM students by 2015, and does so with "pipeline programs" for over 4,000 of New Jersey's K-12 educators and students annually who participate in NJIT's Center for Pre-College Programs. The report also makes an *additional observation*:

***Many of the findings of the Academies' study regarding the physical sciences, mathematics and engineering now pertain to the biological sciences as well. This is a particularly significant development given the evolving interdependency among disciplines—wherein, for example, automotive fuel and plastics are now being made using biological processes, and Biocomputing (the use of biological molecules to perform computational calculation) is in the early research stage. Also, there is a critical need for physicists and mathematicians to help mine the vast sea of data coming from genome studies being done to understand the development and treatment of cancers and other disease. During the past century life expectancy in America has increased by over 50 percent due in substantial part to the advances in the health science—indicating the impact of various types of innovation.***

NJIT recognized and embraced this model for innovation - one that expands beyond practices rooted in the traditional disciplines. For more than a decade it has invested in connecting its traditional STEM disciplines to the needs of the life-science community. It built a Bio-Engineering Department that quickly grew to be a national leader in graduating masters'

students in this fast growing area. More recently it created a department of biological (computational) sciences while continuing to add faculty to the traditional disciplines that work on research topics pertinent to healthcare and medicine. Our Enterprise Development Center (EDC) is one of the largest university hosted technology business incubators in the country and has attracted life-science start-up companies from around the world. We are the hub for statewide programs working to transform healthcare delivery through next-generation information technology.

## **Background**

In the 1980s, even as personal computing was in its infancy and the World Wide Web was not yet created, it was accepted that the *digital convergence* of telecommunications, data systems and broadcast entertainment would redefine those markets. Twenty five years later, the companies that did not recognize the implications have disappeared. Today, we note that the national conversation is on a different form of convergence – the *convergence of the life Sciences, physical Sciences, and engineering*. A recent MIT study proclaims this as “The Third Revolution” in biomedical research, one with the potential to eclipse the impact of molecular biology and genomics revolutions. The product of this convergence will be critical advances in a broad array of sectors, from health care to energy, food, climate and water. These are the frontiers upon which we must build innovative, forward looking companies that will recreate the formula by which New Jersey enjoyed a century or prosperity as the anchor for modern American industry. As has long been observed, innovative companies locate near research universities because of the talent and knowledge pools that are locally available.

This convergence positions NJIT as an *important resource* to enrich the education of future doctors, health care professionals, and others; a *vital partner* conducting research that embraces convergence; and a *strong leader* in developing new models to support rapid commercialization of emerging science and technology. **These goals can be accomplished in partnership with our sister institutions in Newark. They do not require restructuring as much as refocusing on the strong basis of collaboration that once defined University Heights.** A decade of conversation about mergers and acquisition has led these universities to neglect what we were together in pursuit of what each might become on their own. The material that follows is offered as NJIT’s contribution to a shared mission in higher education that prepares our students, our professionals and our companies to dominate a world of convergence in the life sciences, physical sciences, and engineering.

The knowledge developed from convergent research must be distilled to form **new pedagogies** for all the fields involved in biomedicine. It is essential that a free standing autonomous medical school has access to the supporting disciplines that will drive new approaches to medicine, and it is fundamental to the growth of the realigning disciplines that they incorporate

expertise from those who practice (and teach) medicine. This means strong partnering across special purpose autonomous, adaptable, nimble institutions such as we have in Newark, and there is a strong basis of successful curricular collaboration upon which to build.

### **Instructional Program Collaboration**

Contemporary healthcare delivery requires supportive educational programs that encourage innovation, creativity, and responsibility in use of the increasingly sophisticated tools of practice. Such pedagogy is not available in traditional curricula. Commitment to multi-disciplinary collaboration in healthcare, engineering, science, and business augments education. Needed is the opportunity to offer interested and qualified students academic and research opportunities outside of, yet complementary to, their traditional education.

A Newark-based collaboration, a “soft structure,” can be created through memoranda of agreements (MOAs) between the University of Medicine and Dentistry of New Jersey and New Jersey Institute of Technology, **offering joint degree programs and joint faculty appointments** in focused interdependent disciplines, allowing students to gain insights and skills in cross-cutting domains that will enrich their medical and health science education. The following are potential areas for the creation of **joint UMDNJ-NJIT degrees**: Biology; Biochemistry; Bioinformatics; Biophysics; Biostatistics; Business; Computational Biology; Environmental Science; Neuroscience, and Mathematical Biology. The current PhD in Biomedical Engineering, offered jointly via a MOA between UMDNJ and NJIT, serves as a model for collaboration at all levels. Indeed, joint sponsorship of a program for the training of medical scientists leading to the **MD/PhD** will prepare students for intensive medical research that is combined with engineering, science, and management of scientific research. Medical students who wish to expand their educational experiences but do not wish to pursue a PhD may opt for a concurrent master's degree. The MS program can be completed within one additional year. Students who want to develop practical skills in a related engineering or scientific area will benefit from such a degree.

Given the economic, organizational, and political changes impacting the practice of medicine and related industries, UMDNJ and NJIT have the additional opportunity to prepare student for leadership positions in this domain through the **MD/MBA** route. Such a program would allow medical students to complete the master of business administration (MBA) degree program in one additional year by allowing students to transfer 9-12 credits from their medical school education into the MBA program, thus reducing the credit requirement to a number of credits that is manageable in one year. The MBA degree would provide graduates the tools needed to affect change in medical/health management, finance, and policy areas.

## Research and Development Collaboration\*

Convergence of this type represents a fundamentally different viewpoint on the conduct of medical research that is only made possible through the understandings developed in the first two revolutions in biomedicine. The discovery of DNA led to the Molecular Biology Revolution in which the understanding of disease was learned to lie in behaviors at the cellular and molecular level. The decoding of the human genome gave rise to the second revolution in which science began to link the form of biological structure to the performance of living structures in a direct and deterministic manner with reproducibility and predictability. Imperfect statistical correlation is giving way to mechanistic understanding and rigorous modeling. With the knowledge of form and function combined the life sciences are suddenly transformed to look and feel like the physical sciences and they become amenable to the tools and techniques honed over the last century in those disciplines. Conversely, deep understanding of the most complex of all structures – man – provides new insights that profoundly affect the way in which we will synthesize the man-made world in the future.

The research activities at NJIT, and the collaborations with UMDNJ and other medical schools align precisely with nationally recognized priority areas in which convergence is accelerating biomedical knowledge. The activities can be broadly categorized as regenerative medicine, neuroscience and engineering, medical device technology, pharmaceutical processes and medical informatics. The faculty researchers come from virtually every disciplinary background. As you will learn from the profiles in the *appendices*, the investigators are not isolated in our departments of biology or biomedical engineering. They are chemical, mechanical, electrical and industrial engineers; they are chemists, physicists, mathematicians and computer scientists; they are also architects and business faculty- all working across departmental, college and university boundaries.

**Cellular Engineering** is a natural progression from molecular biology and genomic research. It includes everything from regenerative medicine technologies offering hope to those suffering from traumatic or chronic loss of function to genetic engineering that can fix congenital deficiencies or produce pharmaceuticals through bio-synthetic pathways. NJIT researchers are at the forefront. Faculty like Presidential Early Career Award winner Treena Arinze have learned to create tissue, tendon and bone replacement using a patient's own, non-embryonic stem cells. Colleagues are creating vascularized organ tissues that serve as improved media for evaluation of new drugs. Together, breakthrough work in this area will redefine transplant

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\*This section and those that follow reflect NJIT's alignment with best practices detailed in **New Jersey Policy Research Organization's** recent publication, ***"Building Bridges Between Academic Institutions, Business and Government to Bring Innovation to the Marketplace."***

surgery by eliminating the need for donor organs and the problems of tissue rejection that limit today's practice. The work builds on partnership that were forged or strengthened as NJIT mobilized the Newark universities to form the Institute for Regenerative Medicine that was designated for a \$50M construction grant as part of the state's \$250M proposed investment in stem-cell facilities. Although that money was never dispersed, the appendix material will show that the key faculty members have continued to build research and instructional alliances across institutional boundaries.

NJIT designated **neuroscience and engineering** as an academic priority in its 2004 strategic plan. The understanding of brain function and neural behaviors has produced new therapeutic approaches for both chronic and traumatic brain injury. Under the leadership of Prof. Richard Foulds NJIT has been the home of the Rehabilitation Engineering Research Center Technology for Children with Orthopedic Disabilities, funded by a \$4.75 million grant from the National Institute on Disability and Rehabilitation Research. Biomedical Engineering Prof. Bryan Pfister, an NSF Career Award winner, uses his cellular stretching technique to find clues to repairing traumatic injuries to the spinal cord and other nerve tissue. His team includes investigators from UMDNJ, Rutgers-Newark Biology, and the VA Hospital. Prof. Mesut Sahin's conducts pioneering work in the field of Neural Prostheses where he conceived the idea of using the neural activity of the descending tracts in the spinal cord as a form of brain-computer interface. Prof. Tara Alvarez is conducting neuroscience research that could help stroke victims recover their vision but also lead to diagnosis of other visual diseases. The appendices document an extensive set of collaborations with our university partners and local hospitals.

**Medical device technology** is at the nexus of advances in micro- and nano-scale electronics, biologics and high speed computation. It is a natural meeting ground for the disciplines and NJIT's involvement extends from medical imaging to implantable, biologically fueled power systems. In collaboration with Boston Children's Hospital and Harvard Medical School, NJIT biophysicist Gordon Thomas is taking to clinical testing the first genuine advance in decades for brain shunt technology used to treat hydrocephalus and related maladies. Prof. Zafar Iqbal has harnessed nanofabrication technologies to build a biological fuel cell that develops electric power from the sugars metabolized in the blood stream creating enough energy to power a pacemaker for a lifetime and offering the potential for previously unattainable concepts in patient monitoring, real time control of chronic conditions and even next-generation prostheses. Another nanotechnologist, Prof. Haim Grebel, has harnessed graphene networks of molecular dimension to create affordable detection systems that can discriminate subtle structural differences such as exist between human and avian viruses thus providing important tools to detect and respond to potential mass casualty outbreaks. Electrical Engineer, Prof. Atam Dhawan, has adapted advanced signal processing techniques to create three-dimensional

(3D) imaging technology that can detect early skin-cancer called melanoma. The appendices document the extent of collaboration that made this work possible.

**Pharmaceutical processes** are another domain that is ripe for focus by convergent research teams. For most of its existence, the pharmaceutical industry has been dominated by drug discovery and those discoveries have been rooted in chemical synthesis of new drugs. There are two aspects of change that must be noted. First, experience across every other industrial sector teaches that manufacturing considerations must be addressed concurrently with product design issues to be successful, elevating process engineering to much higher level of concern to this industry. Second, the increase in reliance upon bio-synthetic pathways to drug formulation, deeper knowledge of the importance of drug formulation and micro-structure relative to efficacy, new concepts in personalization of dosage and the development of novel drug delivery schemes all require expertise in next generation manufacturing technologies that lie outside of the core expertise of the current pharmaceutical industry. NJIT researchers are among the leaders helping industry adapt. Our researchers are programmatic leaders in the National Science Foundation Engineering Research Center for Structured Organic Particulate Systems, a ten-year \$30M partnership between Rutgers, NJIT, Purdue and the University of Puerto Rico Mayaguez for science-based development of nano-scale products and their manufacturing processes in the pharmaceutical, nutraceutical, and agrochemical industries. The Polymer Processing Institute, an NJIT-hosted industrial development center adapted traditional plastics technology to become a leader in the emerging field of pharmaceutical hot melt extrusion. They use their pilot-scale facilities to assist the pharmaceutical industry in creating new formulations that enjoy the efficiency of the process while maintaining the scrupulous integrity required for drug production.

Information technology has revolutionized some many other practices and it is clear that **bio-medical informatics** is another convergent field with huge potential to inform medical research while drawing inspiration from biologic processes. The national dialog on reducing healthcare costs makes it abundantly clear that medical progress cannot be sustained without developing new efficiencies in the delivery of healthcare. NJIT is at the forefront of activities in New Jersey to re-engineer the business processes of healthcare delivery with a strong infusion of information technology as the enabling force. NJIT was awarded \$23M, the largest university hosted grant in the national program, to provide support and assistance to New Jersey's primary care providers in the selection, implementation, and achievement of Meaningful Use of an EHR system. It is host to one of four regional Healthcare Information Exchanges linking Newark Beth Israel Medical Center (Barnabas Healthcare), Christ Hospital, East Orange General Hospital, St. Michael's Medical Center, UMDNJ Hospital, Jersey City Medical Center, Meadowlands Hospital Medical Center, St. Joseph's and the areas Federally Qualified Healthcare Centers. NJIT is the lead proposer to form the New Jersey Health Information

Exchange with partners IBM, Citibank (Citi), IGI Health, and Optum Insight – an approach that will change the way health care is delivered - and paid for - in the State of New Jersey. The approach will embrace IBM’s new “Watson” supercomputer technology and techniques for managing “big data” to provide new insights to patient diagnosis and prescription of care regimen. Each of these activities are advanced by the faculty expertise at NJIT in business systems modeling, computer network technology, mathematics of pattern recognition and new concepts in natural language processing.

Each area represents a beachhead at the forward edge of convergent medical research that are already established in Newark. We expect the number and technological diversity of partnerships to grow naturally as science moves further down the path to convergence. Organizational structure is not the impediment as good will exists across the academic enterprises accompanied by mutually agreed upon MOAs. The largest single barrier is outside of local control and that is the collection of funding policies established at a national level. Cited as an obstacle by the MIT study, funding models that make single investigator studies pre-eminent and give highest priority to researchers with a long established track record in traditional medical research must give way to new models that support teams and cross-over researchers.

### **Collaboration in Technology Commercialization**

One area that does beg for new structural models relates to the interface between academic research and commercialization. Myths about technology transfer and translational research abound. Thought leaders on innovation recognize that academic research is driven by the quest for new knowledge. Scientific discovery represents a fundamentally different activity than new product or process innovation. Since World War II, the seat of American innovation has been large-scale, industrial research centers with iconic organizations like AT&T’s Bell Laboratories, RCA Sarnoff Labs, Westinghouse Research or Exxon Research & Engineering. Over the last twenty years these enterprises have largely disappeared or have been downsized or refocused on the short-term priorities of the operating divisions as the US model of globally dominant, vertically integrated businesses has given way to new models based on narrow core competencies and flexible, international supply chains.

Throughout the world, countries have developed models of public–private partnership that sustain innovation across a commercial sector rather than a single company. These are serving as anchors for innovation that are portals to university based competencies and facilities but cluster industry-specific and market-specific expertise, pilot-scale equipment and other physical resources, timescales of accomplishment that are inappropriate to faculty-student conducted research and protection of confidential and proprietary information. Germany has institutionalized this approach through the Fraunhofer Institutes that are university hosted,

jointly funded by government redirection of industrial sector tax revenues and direct, corporate contract support. In China, governmental funds flow to major corporations to support industry-specific R&D centers that include supply chain partners and relevant university partners, and they are many other models all borne of the necessity that we now face – growing and supporting industrial sectors as an element of national policy.

As convergent research churns up new insights to the form and function of all that makes us sentient beings, there still needs to be a focus on the type of research and development that harnesses this knowledge in the form of new products or services. NJIT has a deep appreciation for this model of activity and a culture of hosting mission-relevant organizations that serve the commercial sector in ways inappropriate to the traditional mechanisms available to a university. It has created two, major statewide extension programs – one for manufacturing and more recently one for healthcare IT – that bring leading edge thinking to the practitioner community. The Polymer Processing Institute was created as a domestic version of the Fraunhöfers. The Newark Institute for Regenerative Medicine was to have been the meeting ground for all of the commercial elements necessary to move stem cell technology from manual laboratory procedures to reliable, reproducible, and scalable systems that would form the basis of a regenerative medicine industry.

New Jersey has an opportunity to jumpstart the rest of the country in recognizing the importance of fostering what Donald Stokes refers to as “Pasteur Quadrant” research. It would be a bold step, but a meaningful one, for example, to establish a soft structured “Bell Labs” for biomedical research through an MOA of Newark based universities. University Heights Science Park would be an ideal location offering all the benefits of a well situated urban location with easy access to international points of connection. It is proximate to the energy and services of NJIT’s Enterprise Development Center (EDC) and the highly successful Public Research Health Institute (PHRI). It would have ready access to the human and physical assets of four colleges in easy walking distance. Most importantly, it would be a true business magnet that would anchor both existing life science companies and those that emerge from the new world of **convergent science** because the business relationship to the activities in that center would demand frequent interchange. As proposed, this is how we can build jobs with a strong leverage factor across multiple sectors of employment and create the foundation for the next hundred years that will be as robust as the industrial base that sustained for the last century.

### **Closing Note**

An *appendix* is included as a separate document that describes substantial activity in NJIT’s academic, research and commercialization programs for convergent life sciences. Descriptions are provided for over 30 unique degree programs, 85 research collaborations, over 30 relevant incubator companies and 125 disclosures of intellectual property in the convergent fields.