OFFICE OF RESEARCH AND ECONOMIC DEVELOPMENT
2017 STRATEGIC PLAN
Materials Sciences & Engineering (MS&E)

The Battelle report to the State's Department of Economic Development, Louisiana Innovation Council, and the Board of Regents' **Master Plan Research Advisory Committee** ranked *Advanced Manufacturing and Materials* as the State's first priority for investment. The Board of Regents' external review panel further reached the same conclusion, for it directly aligns with the national priorities.

LSU has a strong and diverse faculty working on materials and manufacturing. The Board of Regents approved the Institute of Advanced Materials (IAM) in Feb. of 2015. The IAM represents approximately 100 faculty members in 13 departments and 2 colleges. The Shared Instrument Facility, housed in the Chemistry and Materials building on campus, as well as the CAMD synchrotron light source serve this community and the industrial partners in the State.

Introduction: The discovery, understanding, and exploitation of new materials are at the heart of a revolution that has changed our daily lives and will continue to do so in the future. Examples are ubiquitous. Advanced magnetic materials make it possible to store vast amounts of data in our computers, improvements in microfabrication and control of semiconductor properties on small scales are the drivers of faster and more reliable electronics. Cell phones and DVD players use new materials to develop technologies that did not exist two decades ago. Composite and carbon reinforced materials are used in a number of industries ranging from aerospace, to automotive, to civil infrastructure. Single crystal and shape memory alloys have applications in aerospace, automotive robotics, telecommunications, and medicine. New materials have resulted in long-term, high-performance joint replacements and prostheses. These applications would not have been possible without concomitant progress in our understanding of the physical world and development of novel technologies. Indeed, pure and applied aspects of materials science and engineering are opposite sides of the same coin. The challenges for creating a sustainable energy future will require the discovery or design of materials with better performance for energy transmission, energy storage, and energy generation. What if we can develop a new material for use in electrochemical cells that can convert waste CO_2 into a usable fuel? What if we can discover a new superconductor that can transmit electricity on a new grid system without loss? What if we can realize a much more efficient thermoelectric material to convert the heat from our automobiles into electricity? What if we can engineer an environmentally friendly, durable, and economical material for structures that will protect our coastlines from erosion? What if we can discover materials that will enable point-of-care pathogen and disease agent diagnosis? What if we can use these new technologies to develop atomically precise molecules and to design drugs to treat persistent health threats?

A simple example can illustrate the importance to everybody of research and development in new materials. Consider a typical automobile. Regardless of whether it is electric or hybrid, contains 220 lbs. of rare earths (Cerium, Neodymium, Yttrium, etc.), mostly in electro-magnets. Mining rare earths is very environmentally unfriendly, releasing radionuclides, rare earth elements, and dust and metals. In the early 1980s, the US was the prime producer of rare earths, but in 2016 the Molycorp, Inc., filed for bankruptcy. Now almost all rare earth materials come from China. This initiative would affect energy, environment, and homeland security, and we have the expertise on campus to compete.

At the ORED Retreat, held October 27, 2016, faculty participants identified specific areas as critical to enhancing the Materials & Engineering efforts at LSU. Additional town hall meetings were convened to discuss these thematic areas resulting in this "white paper" report.

Ongoing LSU research and development efforts: The following illustrates existing strengths in Materials Science and Engineering at LSU, which offer a foundation on which an internationally recognized program can build. Such a program will positively influence renewable energy (battery, thermoelectrics, and solar cells). It will have applications in biomedical technologies (drug delivery, imaging cellular ultrastructure, killing malignant cells) and soft-hard material interfaces (disease therapies, energy conversion, and autonomous detection devices). It will benefit energy transmission (superconductors); information technology (interfaces, spintronics); sensing (magnetism, hard-soft materials, nanoclusters); petrochemical engineering (catalysis, nanoclusters), novel materials for durable components and structures (high entropy and other advanced alloys), and advanced manufacturing (micro-/nano-scale manufacturing, smart and bio-mimetic composites, and additive manufacturing).

Electronic and Magnetic Materials: LSU researchers are internationally recognized for their ability to synthesize, fabricate, characterize, and simulate high quality novel materials with desirable functionality, including superconductivity, magnetism, ferroelectricity, magnetocaloric, thermoelectric, and topological protective effects, etc. LSU research teams synthesize high quality single crystals, atomically defined interfaces, thin films, superlattices, and nanoparticles. This area of electronic, magnetic, and optical functional materials is at the frontier of quantum materials, as identified by NSF and DOE. Quantum materials have remarkable properties that hold great promise for a wide range of applications — potential to revolutionize energy and energy-related technologies, and not only for storage and processing of data but for applications in advanced storage systems and computer architectures such as, quantum and neuromorphic computers. The realization of quantum materials carrying spin and charge in a dissipation-free manner would revolutionize nearly every energy-relevant technology.

Interface Hard to Soft materials: LSU researchers have a history of successes with soft materials synthesis and their application to solve challenges in biotechnology, biomedicine, and materials science. These accomplishments place us in a privileged position to explore and define the up-and-coming transdisciplinary research field that focuses on the *soft–hard materials interface*. Our teams have ongoing efforts to revolutionize applications that employ hybrid soft–hard materials systems—targeted disease therapies, flexible visualization elements, optoelectronic energy conversion, and autonomous detection devices.

Advanced Manufacturing and Associated Materials Research: Significant research occurs across a spectrum of advanced manufacturing technologies (e.g., laser-based metals/alloys 3D printing and development; custom powders production for 3D printing feedstock, micro/nano scale metal/ polymer structure and device fabrication; surface engineering of manufacturing tools, and joining of materials). Manufacturing technology development coupled with fundamental studies on alloy design, microstructure development, small-scale plasticity, interfacial mechanical integrity, and material life assessment. State-of-the-art materials characterization and mechanical testing combined with physics-based modeling and simulation to identify mechanisms that may accelerate technology development.

Chemical Processing: The role of chemical processing in material synthesis is ubiquitous. Continually spurred by the surrounding petrochemical industry that permeates our State's as well as our nation's economy. At LSU, we have a strong tradition in understanding and developing new catalysts, which adapt to and enrich the changing energy-related market. Our focus is on materials-based research that experimentally elucidates and theoretically predicts/confirms heterogeneous catalytic properties at the atomic and sub-nanometer scale. Employing multidisciplinary based on synthesis, characterization and modeling allows for the rational design of new catalysts with judiciously nano-engineered physical and chemical properties, combined to provide new platforms of competitive energy-production.

Needs of the MS&E community: LSU must meet critical needs of the materials and manufacturing community to advance to the next level as a national and international center of excellence. All facets of this venture need a state-of-the-art scanning transmission electron microscope (STEM) with atomic resolution in microscopy and spectroscopy. The Shared Instrumentation Facility (SIF) offers an existing organizational structure to house such state-of-the-art instruments. Additional facilities in materials and life testing will further strengthen the ongoing advanced manufacturing effort. Combining such a new STEM with our existing capabilities would distinguish us nationwide. In addition, to build a strong interdisciplinary materials program, we need to offer better cross-functional graduate student training and fellowship opportunities, convene key faculty member into an interdisciplinary consortium, and build a multipurpose research building that facilitates this synergy in research and education.