MIT ILP
INDUSTRIAL LIAISON PROGRAM

# INDUSTRY BRIEF

## MIT AND FOOD/AGRICULTURE INDUSTRIES

*Like most industries, the food and agriculture industries are facing many challenges that demand innovation and investment in new and advanced technologies. Among the many issues to address are the impact of increasingly extreme weather and climate change, shrinking arable land and conservation of scarce natural resources, population growth and distribution, changing diets, food production and security, digital or smart fields, sustainability.*

*What makes MIT unique in its ability to generate advances in the aforementioned fields?*

- MIT is a world class research university: The 2017 QS World University Rankings identified MIT as the #1 university in the world in engineering and technology as well as the natural sciences.
- MIT is solutions-focused, entrepreneurial, and impact driven: as of 2014 MIT faculty and alumni had founded more than 30,000 companies and continues to spin-out 80-100 new companies each year.
- MIT is at the center of the Boston innovation ecosystem: its ability to engage and leverage this ecosystem is unmatched.
- MIT is a convener of global thought leadership: through this network MIT helps address strategic and technical solutions to the major challenges facing society.
- MIT's interdisciplinary culture: allowing thought leaders from multiple disciplines and fields to collaborate freely and reach for the previously unimaginable.

MIT Corporate Relations provides access to MIT through two integrated programs, the MIT Industrial Liaison Program (ILP) http://ilp.mit.edu/ and MIT Startup Exchange http://startupexchange.mit.edu/startupexchange/html/index.html

In the following pages, a selection of MIT centers, departments, groups, and labs are presented. These entities are actively involved with research and education related to topics of relevance to the defense industries bulleted below.

- Agriculture, Food
- Climate, Environment
- Fertilizer, Soil
- Health, Microbiome
- Manufacturing, Packaging, Product Design
- Plants, Ecological Systems
- Robotics, Autonomous Systems
- Sensing/Sensors
- Water
- Marketing, Digital Economy
- Supply Chains/Logistics

## AGRICULTURE, FOOD

The **Abdul Latif Jameel World Water and Food Security Lab (J-WAFS)** works towards environmentally benign, scalable solutions for water and food systems across a range of regional, social, and economic contexts by incubating technologies and fostering innovative regional collaborations. Research funded by J-WAFS draws on a number of disciplines that span all five schools at the Institute. J-WAFS promotes the development and commercialization of the next generation of technologies that can be broadly applied to food safety, urban water supply, agriculture and irrigation, and watershed protection.

The **Abdul Latif Jameel Poverty Action Lab (J-PAL)** was established in 2003 as a research center at the Economics Department at MIT. J-PAL is a global research center working to reduce poverty by ensuring that policy is informed by scientific evidence. Anchored by a network of 161 affiliated professors at 52 universities around the world, J-PAL conducts randomized impact evaluations to answer critical questions in the fight against poverty. J-PAL staff on research, policy outreach, and training. Program sectors include areas such as: Agriculture; Crime; Education; Environment & Energy; Finance & Microfinance; Health; Labor Markets; Governance.

Student Group: The **MIT Food and Agriculture Club (FAC)** brings together students—and other MIT community members—to coordinate and support work in the areas of food and agriculture. Members of the MIT FAC are actively engaged in advocating for and supporting the development of a more sustainable food system on campus, as well as enhancing MIT's role in contributing to global agricultural sustainability.

**MIT Open Agriculture (OpenAg)** Initiative is on a mission to create healthier, more engaging, and more inventive future food systems. The researchers believe the precursor to a healthier and more sustainable food system will be the creation of an open-source ecosystem of technologies that enable and promote transparency, networked experimentation, education, and hyper-local production. OpenAg brings together partners from industry, government, and academia in a research collective that's creating collaborative tools and open technology platforms for the exploration of future food systems.

**Department of Civil & Environmental Engineering (CEE): Resources & Sustainability** area research and education is focused on revolutionizing the resources that keep us functioning—food, water, air, energy, materials. The focus is on natural and human-made resources, their extraction, generation, and interaction with the environment. Key areas include: Water, atmosphere & air quality, food & agriculture, energy, material sourcing, coastal resilience.

## AUTONOMOUS SYSTEMS, DRONES, ROBOTICS

Work in the **Distributed Robotics Laboratory (DRL)** spans computational design and fabrication of robots; algorithms for perception, planning reasoning and control with guarantees; algorithms for auditable machine learning; and algorithms for collaborating machines and people. The lab's innovations enable new applications in smart living, transportation, healthcare, manufacturing, monitoring, exploration, and much more.

The **Robust Robotics Group**'s research goals are to build unmanned vehicles that can fly without GPS through unmapped indoor environments, robots that can drive through unmapped cities, and to build social robots that can quickly learn what people want without being annoying or intrusive. Such robots must be able to perform effectively with uncertain and limited knowledge of the world, be easily deployed in new environments and immediately start autonomous operations with no prior information. The group specifically focuses on problems of planning and control in domains with uncertain models, using optimization, statistical estimation and machine learning to learn good plans and policies from experience.

The **SPARK (Sensing, Perception, Autonomy, and Robot Kinetics) Lab** works at the bleeding edge of robotics and autonomous systems research for air, space, and ground applications. The lab develops the algorithmic foundations of robotics through the innovative design, rigorous analysis, and real-world testing of algorithms for single and multi-robot systems. A major goal of the lab is to enable human-level perception, world understanding, and navigation on mobile platforms (micro aerial vehicles, self-driving vehicles, ground robots, augmented reality). Core areas of expertise include nonlinear estimation, numerical and distributed optimization, probabilistic inference, graph theory, and computer vision.

## BIG DATA / ANALYTICS

**BigData @ CSAIL** researchers are investigating how to transform big data into big insights. The initiative's approach brings together world leaders in parallel architecture, massive-scale data processing, algorithms, machine learning, visualization, and interfaces to explore all the challenges and opportunities presented by big data, from cloud computing, data management, massive scale data analysis, algorithms, data mining, machine learning, security, privacy and visualization to all of big data's applications in fields such as finance, medicine, biology, artificial intelligence and social networking.

The **Database Group (DBg)** at MIT conducts research on all areas of database systems and information management. Projects range from the design of new user interfaces and query languages to low-level query execution issues, ranging from design of new systems for database analytics and main memory databases to query processing in next generation pervasive and ubiquitous environments, such as sensor networks, wide area information systems, personal databases, and the web.

The **Mathematics Department** at MIT is one of the top-ranked mathematics departments in the US— a world center in Pure and Applied Mathematics. In pure mathematics, the department explores exciting current research directions in most of the major fields. The pure math group studies many aspects of algebra, analysis, geometry, mathematical logic and foundations, number theory, probability and statistics, and representation theory. The applied math group focuses on combinatorics, computational biology, computational science & numerical analysis, physical applied mathematics, theoretical computer science, theoretical physics.

The **MIT Geospatial Data Center (GDC)** brings together applied computation research in data science, cybersecurity, simulation, augmented reality, the Internet of Things (IOT), blockchain, and educational technology (EdTech). The GDC is researching security, financial, social networks, storage, and general purpose application of blockchains.

The **MIT Institute for Data, Systems, and Society (IDSS)** is committed to addressing complex societal challenges by advancing education and research at the intersection of statistics, data science, information and decision systems, and social sciences. IDSS applies state-of-the-art, analytical methods in information and decision systems, statistics and data science, and the social sciences to address complex societal challenges in a diverse set of areas such as finance, energy systems, urbanization, social networks, and health.

The **MIT Statistics and Data Science Center** is an MIT-wide focal point for advancing research and education programs related to statistics and data science. The Center was created in 2015 with the goal of formalizing and consolidating efforts in statistics at MIT. Project areas include: nonparametric Bayesian statistics, causal inference and applications to learning gene regulatory networks, combinatorial learning with set functions, online learning, and statistical and computational tradeoffs.

## CLIMATE, ENVIRONMENT

The **Center for Global Change Science (CGCS)** seeks to better understand the natural mechanisms in the ocean, atmosphere and land systems that together control the Earth's climate, and to apply improved knowledge to problems of predicting global environmental change. CGCS fosters studies on topics as varied as, for example, oceanography, meteorology, hydrology, atmospheric chemistry, ecology, biogeochemical cycling, paleoclimatology, applied math, data assimilation, computer science, and satellite remote sensing. Parallel activities incorporate the insight gained into climate prediction models, and climate policy analysis, with the aim of providing it in a useful way to decision-makers confronting the coupled challenges of future food, energy, water, climate and air pollution (among others).

The **Joint Program on the Science and Policy of Global Change** is MIT's response to the research, analysis and communication challenges of global environmental change. The program combines scientific research with policy analysis to provide independent, integrative assessments of the impacts of global change and how best to respond. The Joint Program's integrated team of natural and social scientists studies the interactions among human and Earth systems to provide a sound foundation of scientific knowledge to aid decision-makers in confronting future food, energy, water, climate, air pollution and other interwoven challenges.

The **Department of Earth, Atmospheric, and Planetary Sciences (EAPS)** work encompasses atmospheres, climate, geobiology, geochemistry, geology, geophysics, oceans, and planetary sciences. Through fieldwork, theory, experimentation, and modeling, EAPS seeks to advance understanding of the natural world. EAPS research falls into eight distinguishable categories: atmospheric science, climate, geobiology, geochemistry, geology, geophysics, oceanography, and planetary science.

The **Environmental Solutions Initiative (ESI)** mobilizes the substantial scientific, engineering, policy, and design capacity of MIT to create solutions to today's environmental challenges through diverse activities in education, research, and convening. ESI's priorities for research fall into three domain areas: Climate Science and Earth Systems, Cities and Infrastructure, and Sustainable Production and Consumption. Each domain draws upon engineers, natural and social scientists, designers, and arts & humanities to understand and address critical challenges. ESI is pursuing collaboration with a diverse array of partners in industry, government, and civil society, with the aim of building robust research programs in all three priority domains.

The **MIT Science Impact Collaborative (MIT SIC)** is a research team within the Department of Urban Studies and Planning that is developing and testing new ways to harmonize science, politics and public policy in the management of natural resources and the resolution of environmental disputes. The team's focus is on testing the effectiveness of a range of collaborative planning and decision-making techniques. The tools and approaches for doing this include collaborative adaptive management, joint fact-finding, scenario planning, mediated multiparty negotiation, and the use of role-play simulation exercises.

## FERTILIZER, SOIL

The **Laboratory for Process-Based Biogeochemistry** measures and deciphers biogeochemical processes responsible for controlling the fate and cycling of nutrients, contaminants, and trace gases in soils, sediments, and natural waters. These biotic and biotic reactions are often chemically intertwined and transpire within complex systems containing aqueous solutions, mineral assemblages, gases, and microorganisms. The lab performs experiments to understand the importance of specific (coupled) processes, and use variety of analytical tools, including conventional and synchrotron-based techniques, to understand mechanisms at the molecular scale. A goal of our group is to understand how these reactions "scale-up," and this is accomplished by linking molecular-scale reactions and processes with observed field measurements using computational tools such as reactive transport modeling.

The **Sustainable Materials Extraction & Manufacturing Group** is focused broadly on sustainable materials extraction and manufacturing and materials chemistry. One area of exploration is the synthesis of new materials that can release the right nutrients at the right rate needed by crops to grow. The group's processing methods are devised to minimize the number of unit operations, the amount of chemical consumed as well as water. The research program strives to incorporate chemical elements that are beneficial for the soils or the plants and derives the optimal process parameters to achieve microstructures that deliver the best performance. The group is also developing a new set of experimental microfluidic tools to investigate and understand soil processes.

## HEALTH, MICROBIOME

The Media Lab's **Advancing Wellbeing Initiative** addresses the role of technology in shaping our health and explores new approaches and solutions to wellbeing. The program is built around education and student mentoring; prototyping tools and technologies that support physical (including food-related), mental, social, and emotional wellbeing; and community initiatives that will originate at the Media Lab but be designed to scale.

The **Center for Environmental Health Sciences (CEHS)** studies the biological effect of environmental agents, individually and in combination, with specific emphasis on how such exposures affect human health and the health of the ecosystem. CEHS research can be sorted into five research themes: DNA damage, DNA repair and genomic stability; inflammation chemistry and biology; microbiomes and environmentally induced diseases susceptibility; bioengineering for environmental health; and chemistry and transport of pollutants in the atmosphere, water, and soil.

The **Center for Microbiome Informatics and Therapeutics** is working to improve human health by diagnosing, treating, and preventing diseases associated with the human microbiome. The researchers develop non-invasive ways to monitor individuals for signs of disease, and precision methods to manipulate the microbiome to restore health. This is done by fostering high-risk translational research designed to positively impact patient lives, and collaborating on clinical studies to reveal how the microbiome impacts human physiology, immune system, metabolome, and the course of disease.

The **Erdman Laboratory** at MIT studies microbe triggered inflammatory processes and cancer. The laboratory collaborates with world-leaders pioneering research in the fields of GI tract microbiome and immunology in systemic health and disease.

The mission of the **Department of Biological Engineering (BE)** is to educate leaders and generate new knowledge at the interface of engineering and biology. Research areas in which BE faculty are recognized as pioneering leaders include: Biomaterials; biophysics; cell & tissue engineering; energy; environment; microbial systems; macromolecular biochemistry; nanoscale engineering; pharmacology; synthetic biology; systems biology; toxicology; transport phenomena.

The **Department of Biology** explores a wide range of fundamental biological questions with a focus on molecular cell biology at all levels, from molecular structure to human disease. For over 50 years, the department has played a central role in the growth of molecular life sciences and the revolution in molecular and cellular biology, genetics, genomics, and computational biology. Areas of research in the department include: biochemistry, biophysics, and structural biology; cancer biology, cell biology; computational biology; genetics; human disease; immunology; microbiology; neurobiology; stem cell and developmental biology.

## MANUFACTURING, PACKAGING, PRODUCT DESIGN

The **Ideation Laboratory** at MIT aims to deepen the theoretical foundations of early stage design process across product design, engineering design, system design, and beyond in order to develop transformational strategies for creating compelling products and systems that address challenges of global competitiveness, sustainability, and emerging markets.

The **Industrial Performance Center (IPC)** studies innovation, productivity and competitiveness in the U.S. and around the world. The IPC brings together teams of researchers in engineering, science, management and the social sciences at MIT and beyond to carry out innovative, applied research often from the "bottom up." Core research areas include: Innovation Ecosystems, Advanced Manufacturing, Energy, Globalization.

The **Interactive Robotics Group** is developing innovative methods for enabling fluid human-robot collaboration. The group's vision is to harness relative strengths of humans and robots to accomplish what neither can do alone. The focus is on developing robots that work in teams with people in high-intensity and safety-critical applications, including industrial manufacturing, disaster response, and space exploration.

The **MIT International Design Center (IDC)** is a community of faculty, researchers, labs and students from across all 5 schools at MIT focused on understanding and enhancing the methods, tools, and outcomes of diverse design activities. Together with sister organization Singapore University of Technology and Design, the IDC focuses on design and invention, with an emphasis on knowledge generation (science) and entrepreneurship (implementation).

The **Mechanosynthesis Group** converges expertise in materials, manufacturing, and mechanical design. Focus areas include additive manufacturing (spanning from nano to macro scales), carbon nanotubes and 2D materials, roll-to-roll processing, printed electronics, and resource-efficient sensors and diagnostics. These technical areas connect both to fundamental principles and applications in a variety of domains.

The **Operations Research Center (ORC)** is the world's premier graduate program in operations research (OR). ORC education and research draws upon ideas from engineering, management, mathematics, and psychology to apply scientific methods to decision-making. ORC faculty contribute to a wide range of application domains such as flexible manufacturing systems; financial engineering services; air traffic control; transportation systems; public services, such as urban emergency systems; safety and risk analysis in air transportation; and more.

The **Self-Assembly Lab** is a cross-disciplinary design research center inventing self-assembly and programmable material technologies. The lab's work is in the areas of Self-Assembly & Self-Organization, Phase Change Materials, Programmable Materials & 4D Printing, and Transformable Structures.

## PLANTS, ECOLOGICAL SYSTEMS

**Department of Civil & Environmental Engineering (CEE): Ecological Systems** area research and education is focused on integrative ecology, doing field, experimental, and theoretical work. The faculty in this area develop quantitative tools and combine them with field and lab experiments to increase understanding about the functioning of ecosystem services and the maintenance of biodiversity. They also investigate the intricate relationship between environmental conditions and living organisms, ranging from individuals to entire ecological communities. Key areas include: Community ecology, Mathematical/quantitative ecology, Microbiomes, Ecological networks, Terrestrial ecology.

The primary focus of research in the **Des Marais Lab** is to understand the mechanisms of plant-environment interaction. The group uses tools from molecular, quantitative, and population genetics to identify the physiological basis of plant response to environmental cues and ask how these mechanisms constrain or facilitate plant breeding and evolutionary change.

The **Synthetic Biology Center** conducts foundational research in the areas of genetic programming, DNA synthesis and assembly, genome design, simplifying genetics; and systems bioengineering in areas of analog synthetic biology and systems biology, and genetic circuits. Grand challenge application areas include medical, materials, industrial, and agricultural. In the agriculture area–biological sensing and circuitry enables agricultural organisms to see and respond to their environment. For example, "smart" plants could be programmed to identify and respond to multiple threats, such as pathogens, toxins, desiccation, and nutrient availability. Microbes in the rhizome associate with plants and could be engineered to implement similar functions.

The **Weng Laboratory** has broad interests in understanding the origin and evolution of plant specialized metabolism at enzyme, pathway, and systems levels, as well as how plants exploit discrete small molecules to interact with their surrounding biotic and abiotic environments. The lab actively seeks opportunities to utilize plant natural products as unique chemical probes to query human physiology and disease biology. In the long run, we also aim at elucidating the molecular mechanisms underlying the "matrix effect" known from many traditional herbal remedies used for thousands of years.

## SENSING / SENSORS

The **Center for Environmental Sensing And Modeling (CENSAM)**, a Singapore-MIT Alliance for Research and Technology (SMART) Interdisciplinary Research Group, is monitoring and modeling Singapore's climate as well as air and water quality. CENSAM models can accurately predict climate change events (such as extreme rainfalls, increased air temperature, sea level rise, etc.) based on various realistic economic scenari (business-as-usual energy usage, carbon mitigation, geo-engineering, etc.). The center's fleet of biomimetically-enhanced autonomous vehicles can search Singapore Harbor for harmful algae blooms, inspect through turbid waters, give precise three-dimensional chemistry of marine waters, etc.

**SENSE.nano** focuses on sensors, sensing systems, and sensing techniques. The research in sensing science and sensing engineering leads to groundbreaking innovations in advanced manufacturing, healthcare, environmental remediation, smart infrastructure, and the creation of advanced machines and materials. Novel sensing technologies offer unprecedented opportunities for advancing understanding and use of nanoscale phenomena, for instance, massively distributed networks of inexpensive smart sensors enable large-scale, global, data collection important to agriculture and water distribution, and environmental monitoring.

The aim of the **Signals Kinetics** group is to program natural and man-made networks in order to extend human and computer abilities in communication, sensing, and actuation. The group draws on tools from computer networks, signal processing, machine learning, and hardware design to uncover, analyze, and engineer these networks.

The **Tangible Media** group's explores the tangible bits and radical atoms visions to seamlessly couple the dual world of bits and atoms by giving dynamic physical form to digital information and computation. The goal is to go beyond the current mainstream of painted bits (pixels) to enrich human interactions and to take advantage of the multimodal human senses and dextrous skills developed through a lifetime of interaction with the physical world. In one project, students in the group successfully implemented inflatable sugar and cheese products, using both an engineering approach and a biological approach; to solidify the inflated food they introduced both heat via the oven, and coldness with liquid nitrogen.

## WATER

The **Eltahir Research Group** is interested in understanding how regional land use/land cover change as well as global climate change may impact society through changes in the patterns of water availability, extreme weather, and spread of vector-borne diseases. The group develops sophisticated numerical models that are used for predicting such impacts at regional scales and tests these models against satellite observations and archived data sets of hydrologic and atmospheric variables, as well as data collected in our own field campaigns.

The **Tata Center for Technology and Design** trains and supports MIT researchers working to solve challenges facing communities in India and the developing world. The center's work spans six overlapping areas: agriculture, energy, environment, health, housing, and water. Projects go beyond

the lab and seek real-world impact, guided by the core principles of relevance, practicality, and sensitivity to context. Working with collaborators throughout India, and with sister-center at the Indian Institute of Technology, Bombay, the Tata Center creates solutions designed to serve human needs.

Student Group: **MIT Water Club** is the premier network for water research and innovation at MIT to explore ways by which research, innovation, and policy can help solve the most pressing challenges in the water sector. The group organizes conferences, lectures, research showcases, outreach events, and entrepreneurship competitions throughout the year, including its three flagship events: The MIT Water Summit, MIT Water Innovation Prize, MIT Water Night.

## MARKETING, DIGITAL ECONOMY

The **Initiative on the Digital Economy (IDE)** examines how people and businesses work, interact, and will ultimately prosper in a time of rapid digital transformation. Drawing on MIT Sloan School's strengths in technology and innovation and its internationally recognized faculty, IDE research helps companies adapt to new ways of doing business in the digital economy. It helps NGOs and other organizations understand how the digital transformation is affecting society and everyday life.

The **MIT Sloan Neuroeconomics Lab** is a multidisciplinary research center studying problems at the intersection of economics, management, and cognitive neuroscience. The lab's projects are stimulated by economic theory and decision analysis, which provide an ideal standard, as beautiful conceptually as it is flawed empirically. The group studies behavior that appears anomalous in light of the rational model, focusing especially on financial, medical and consumption choices. Methods include functional MRI, lab experiments, game theory, Bayesian modeling, and machine learning.

Members of the **MIT Sloan School of Management Marketing** group have pioneered research methods, marketing models, and decision-support systems that have enhanced new product development, identified customer desires, predicted customer behavior, and have led to enhanced understanding of marketing strategy. The concept of marketing science, established and popularized at MIT Sloan, remains a critical component of marketing strategy in corporations across the globe.

## SUPPLY CHAINS/LOGISTICS

The **Center for Transportation & Logistics (CTL)** is widely recognized as an international leader in supply chain management education and research. Along with basic contributions to the understanding of transportation system planning, operations and management, its efforts include significant contributions to logistics modeling and supply chain management for shippers; to technology and policy analysis for government; and to management, planning and operations for trucking, railroad, air and ocean carriers.

The **MIT Forum for Supply Chain Innovation (the Forum)** is a unique community composed of academics and industry members whose support allows Forum researchers to provide customer-focused solutions to design and manage the new supply chain. The rigorous approach used by MIT Forum guides businesses through the latest innovations in supply chain management, technology and implementation techniques. Members of the supply chain community have the flexibility and opportunity to participate in both industry–wide research into the supply chain as well as initiating their own specific research project.

The mission of the **MIT Humanitarian Supply Chain Lab** is to understand and improve the supply chain systems behind public services and private markets to meet human needs. The Lab combines MIT expertise in engineering, management, information technology, social science, economics, urban planning and other disciplines to drive practical innovation for humanitarian interventions. The lab has a diverse portfolio of projects including, for example, Decision Support for Post-Harvest Loss, Food Aid Packaging Evaluation, Cost Drivers in Food Aid Transportation, and Food Aid in Less Secure Regions.