MIT INDUSTRIAL LIAISON PROGRAM ILP

MIT Industry Brief

MIT and Aerospace Industries

MIT's Industrial Liaison Program (ILP) can bring the intellectual power of MIT to your organization by providing a direct connection to the knowledge, experience and resources at MIT in these areas – giving you the ideas to stay ahead. For more information about how the ILP can put the resources of MIT to work for you, call us at 1-617-253-2691, e-mail us at liaison@ilp.mit.edu, or visit http://ilp.mit.edu.

MIT and Aerospace Industries

The Massachusetts Institute of Technology (MIT) is a leading center of research and education on topics important to aerospace industries such as:

- *Autonomous systems & control*
- *Communications systems*
- *Energy, environmental impact, policy*
- *Engine design / propulsion systems*
- *Engineering complex high-performance systems*
- *Human-robot / human-vehicle interaction*
- *Materials*
- *Operations, management, safety*
- *Space vehicles & robotics*

Below are brief descriptions of a selection of MIT centers, departments, groups, and labs conducting research and education in these areas. Please note that this is not a comprehensive summary of research being conducted at MIT in the topic areas listed above and the center or lab, etc., may fall into more than one category.

AUTONOMOUS SYSTEMS & CONTROL

The goal of the ***Active Adaptive Control Laboratory*** is to investigate complex intelligent systems that require adaptation, learning, and control. Projects include energy distribution in smart grid, co-design of control and implementation platform for cyber-physical systems, adaptive flight control systems, autonomous aircraft, and adaptive technology for automotive platforms.

The ***Aerospace Controls Laboratory (ACL)*** researches topics related to autonomous systems and control design for aircraft, spacecraft, and ground vehicles. Theoretical research is pursued in areas such as: decision making under uncertainty; path planning, activity and task assignment; estimation and navigation; sensor network design; robust control, adaptive control, and model predictive control.

The ***Aerospace Robotics and Embedded Systems (ARES) Group***'s mission is the development of theoretical foundations and practical algorithms for real-time control of large-scale systems of vehicles and mobile robots. Application examples range from UAVs and autonomous cars, to air traffic control, and urban mobility. The group researches advanced algorithmic approaches to control high-dimensional, fast, and uncertain dynamical systems subject to stringent safety requirements in a rapidly changing environment.

The ***Mechatronics Research Laboratory (MRL)*** conducts research and development in the areas of design and control of atomic resolution systems, design of autonomous robots for the exploration of complex and unstructured terrains, and innovates on effective techniques to estimate and model physical systems.

Research in the ***Nonlinear Systems Laboratory (NSL)*** is on the analysis and control of nonlinear physical systems with emphasis on adaptation and learning in robots. Studies have included areas such as the synchronization of formation flying spacecraft; propellant-free tethered formation flight: nonlinear underactuated control; network controllability and observability.

The ***Robust Robotics Group*** aims 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. 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.

COMMUNICATIONS SYSTEMS

The ***Communications and Networking Research Group (CNRG)*** is working on a wide range of projects in the area of data communication and networks with application to satellite/space, wireless, and optical networks. An important aspect of the group's research is the development of architectures and algorithms that are optimized across multiple layers of the protocol stack. To that end, the group's research crosses disciplinary boundaries by combining techniques from network optimization, queuing theory, graph theory, network protocols and algorithms, hardware design, and physical layer communications.

The ***Laboratory for Information and Decision Systems (LIDS)*** is committed to advancing research and education in systems and control; communications and networks; and inference and statistical data processing. LIDS research spans the full range from fundamental research and the development of new methodologies, to applications of major significance. Sample areas include: Coordination of unmanned autonomous systems; energy information systems; intelligence, surveillance, and reconnaissance (ISR) systems; network scheduling and routing; sensor networks; ultra-wideband and other emerging communications technologies.

The ***Space Telecommunications, Astronomy and Radiation Laboratory***'s research focuses on: Space—developing new capabilities for satellites, especially CubeSats, so that the effects of weather (like hurricanes) and solar storms anywhere on Earth can be observed; Telecommunications—using laser communications and radio frequency communications to get data down fast, and also do some science; Astronomy—exploring the Solar System and imaging Exoplanets with advanced space telescopes; and Radiation—detecting and predicting how solar storms affect the Earth and satellites.

The ***Department of Aeronautics and Astronautics (Aero-Astro)*** community includes a former space shuttle astronaut, a former secretary of the Air Force, two former NASA associate administrators, a former Air Force chief scientist, and numerous National Academy of Engineering members and American Institute of Aeronautics and Astronautic fellows. Aero-Astro research and teaching range from silent aircraft to alternative jet fuels; to highly flexible space suits woven skin-tight on their inhabitants; to unmanned vehicles capable of complex maneuvers without human intervention; to constellations of tiny satellites that, in concert, far outperform the single, large satellites of the past; to the development of ultra-wide bandwidth communications.

ENERGY, ENVIRONMENTAL IMPACT, POLICY

The ***MIT Energy Initiative (MITEI)*** is working on key elements of the complex energy challenge through multidisciplinary research activities shaped so as to address the linked supply and demand, security, and environmental challenges. MITEI's research program focuses broadly on: 1) Innovative technologies and underlying policy analysis; 2) transformational technologies to develop alternative energy sources that can supplement and displace fossil fuels; 3) global systems to meet energy and environmental challenges; and 4) tools to enable innovation, transformation, and simulation of global energy systems.

The ***Laboratory for Aviation and the Environment*** is working to increase the fundamental understanding of the environmental impacts of aircraft and fuels on a lifecycle basis, and to develop tools that policy-makers, researchers and designers use to assess the environmental and economic implications of aviation policy and engineering decisions. The MIT LAE hosts the operational headquarters of the outgoing (2015) FAA Center of Excellence for aviation noise and emissions mitigation (PARTNER), and co-hosts the headquarters for the replacement FAA Center of Excellence for alternative jet fuels and environment (ASCENT). The research areas in the LAE are: Aircraft design, alternative fuels air quality, emissions, climate change, noise, operations, policy assessment, uncertainty quantification.

Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER) is a leading aviation cooperative research organization sponsored by the FAA, NASA, Transport Canada, the U.S. Department of Defense, and the U.S. Environmental Protection Agency with operational headquarters at MIT's Laboratory for Aviation and the Environment. PARTNER comprises 12 universities and approximately 50 advisory board members (aerospace manufacturers, airlines, airports, national, state and local government, professional and trade associations, non-governmental organizations, community groups). PARTNER fosters breakthrough technological, operational, policy, and workforce advances for the betterment of mobility, economy, national security, and the environment. As of late 2015, PARTNER has completed almost all of its Center of Excellence mandate. Similar work is now being conducted by ASCENT, a new FAA Center of Excellence co-led by MIT and Washington State University.

ENGINE DESIGN / PROPULSION SYSTEMS

The ***Gas Turbine Laboratory (GTL)*** mission is to advance the state-of-the-art in fluid machinery for power and propulsion. GTL research is focused on advanced propulsion systems, energy conversion and power, with activities in computational, theoretical, and experimental study of: loss mechanisms and unsteady flows in fluid machinery; dynamic behavior and stability of compression systems; instrumentation and diagnostics; advanced centrifugal compressors and pumps for energy conversion; gas turbine engine and fluid machinery noise reduction and aero-acoustics; novel aircraft and propulsion system concepts for reduced environmental impact.

The ***Space Propulsion Laboratory (SPL)*** studies and develops systems for increasing performance and reducing costs of space propulsion. A major area of interest to lab is electric propulsion, in which the electrical, rather than chemical energy propels spacecraft. In the future these plasma engines will allow people to do such things as explore in more detail the structure of the universe, increase the lifetime of commercial payloads or look for signs of life in far away places. Other areas of research include microfabrication; numerical simulation, numerical simulation, Hall thrusters, space tethers, orbit optimization, spacecraft-thruster interactions and plasma waves emission and propagation.

The ***Wright Brothers Wind Tunnel (WBWT)*** is primarily used for student projects, research, and instruction, however it is also available for commercial research and development. The WBWT has played a major role in the development of aerospace, civil engineering and architectural systems. Faculty research has generated long-range studies of unsteady airfoil flow fields, jet engine inlet-vortex behavior, aeroelastic tests of unducted propeller fans, and panel methods for tunnel wall interaction effects. Industrial testing has included, for example, helicopter antenna pods, and in-flight trailing cables, the aeroelastic dynamics of airport control tower configurations, Olympic ski gear, space suits, and power-generating wind turbines.

ENGINEERING COMPLEX HIGH-PERFORMANCE SYSTEMS

The ***Center for Computational Engineering*** supports computational engineering research and education with an emphasis on the development of new computational methods relevant to engineering disciplines and on the innovative application of computational methods to important problems in engineering and science. Projects focus on several major methodology themes: High performance computation and computational foundations; multiscale, multiphysics, multifidelity simulations; computational design, optimization, and control; integration of data and simulation, and computational geometry and scientific visualization.

The ***MIT Strategic Engineering*** group's is focused on developing new integrated approaches based on the principles of systems architecture and systems engineering, design theory, complexity science, management of technology, project management, as well as strategy and economics. The group calls its integrated approach Strategic Engineering, which is the process of architecting and designing complex systems and products in a way that deliberately accounts for future uncertainty and context in order to maximize their lifecycle value.

The ***System Architecture Lab (SAL)*** studies the early-stage technical decisions that will determine the majority of the system's performance. SAL has helped architect systems from earth observation networks to lunar surface exploration vehicles. SAL has advanced the state of the art by developing a unique and generalizable approach to structuring complex systems architecting problems that can be applied across disciplines. The lab's work is divided into five research areas: System architecture, space communications, architecting exploration, stakeholder analysis, and commonality and platforming.

The ***Systems Engineering Advancement Research Initiative (SEAri)*** performs collaborative research to address advanced systems engineering challenges. The research group has a strong foundation in the space system and defense design and architecture domain, with more recent work branching into the transportation and infrastructure systems domain. While these domains represent past work and ongoing areas for case study analysis, the methods and practices developed by SEAri aim for truly cross-domain applicability.

HUMAN-ROBOT / HUMAN-VEHICLE INTERACTION

The ***Computer Science and Artificial Intelligence Laboratory (CSAIL)*** researchers have been key movers in developments like time-sharing, massively parallel computers, public key encryption, the mass commercialization of robots, and much of the technology underlying the ARPANet, Internet and the World Wide Web. CSAIL's approximately 50 research groups are organized into three focus areas: artificial intelligence, systems, and theory. Research is conducted in almost all aspects of computer science, as well as exploring revolutionary new computational methods for advancing healthcare, manufacturing, energy and human productivity.

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 ***Man Vehicle Laboratory's (MVL)*** goal is to better define the physiological and cognitive limitations of pilots and passengers of aircraft and spacecraft, and to optimize overall human-vehicle system effectiveness and safety. Research is interdisciplinary, utilizing techniques from manual and supervisory control, estimation, signal processing, biomechanics, cognitive psychology, artificial intelligence, sensory-motor physiology, human factors, and biostatistics. Projects focus on advanced space suit design and dynamics of astronaut motion, adaptation to rotating artificial gravity environments, spatial disorientation and navigation, teleoperation, design of aircraft and spacecraft displays and controls and cockpit human factors.

MATERIALS

The ***Institute for Soldier Nanotechnologies (ISN)*** is a team of MIT, Army and industry partners working together to discover and field technologies that dramatically advance soldier protection and survivability capabilities. Team members collaborate on basic research to create new materials, devices, processes, and systems, and on applied research to transition promising results toward practical products useful to the Soldier. Strategic research areas include: Lightwieght, multifunctional nanostructured materials; soldier medicine; blast and ballistic threats; hazardous substances sensing; and nanosystems integration.

The ***Nano-Engineered Composite aerospace STructures Lab (NECSTLAB)*** explores new concepts in engineered materials and structures. The group's mission is to lead the advancement and application of new knowledge at the forefront of materials and structures understanding, with research contributions in both science and engineering. Applications of interest include enhanced (aerospace) advanced composites, multifunctional attributes of structures such as damage sensing, and also microfabricated (MEMS) topics. A significant effort has been to use nanoscale materials to enhance performance of advanced aerospace materials and their structures through the industry-supported NECST Consortium.

The ***Space Nanotechnology Laboratory (SNL)*** is the premier laboratory in the world for research in interference lithography and diffraction grating fabrication. The lab's expertise is in the fields of nanofabrication, nanometer-accuracy x-ray optics fabrication, assembly and metrology, ultra-high resolution lithography, nanometrology, and nano-accuracy diffraction grating fabrication. SNL's scientific focus is on high-performance space instrumentation for x-ray astronomy and the physics of the magnetosphere and the sun, but technology developed along the way has also been used to address questions in fields such as quantum mechanics (wave-particle duality) and more.

Research in the ***Department of Materials Science and Engineering (DMSE)*** ranges from the purely scientific to applied studies, and involves perspectives of chemistry, physics, electronics, the artistic and historical aspects of materials, design, and entrepreneurial ventures. Interests span the entire materials cycle from mining and refining of raw materials, to production and utilization of finished materials, to disposal and recycling.

OPERATIONS, MANAGEMENT, SAFETY

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 ***Consortium for Engineering Program Excellence (CEPE)*** is a research group that brings the wisdom of lean thinking to the management of large-scale engineering programs by integrating program management, systems engineering product development and systems engineering approaches to ,build engineering programs that consistently delight their stakeholders.

The ***Global Airline Industry Program*** is a multidisciplinary team of faculty, staff, and students drawn from the Schools of Engineering, Management, and Humanities and Social Sciences to study the global airline industry. The goal of the program is to develop a body of knowledge for understanding develop ment, growth and competitive advantage in this industry. The Program includes research focused on five themes: safety and security; industry structure and competition; labor relations; infrastructure; and alternative business models.

The ***International Center for Air Transportation (ICAT)*** works to improve the safety, efficiency, and capacity of domestic and international air transportation and its infrastructure, utilizing information technology and human-centered systems analysis. Information technology systems of interest include: global communication and positioning; international air traffic management; scheduling, dispatch and maintenance support; vehicle management; passenger information and communication; and real-time vehicle diagnostics. Areas of research include: Air traffic management; air transportation

infrastructure and economics; aviation safety and weather; airline management and operations; human factors; flight instrumentation; and environmental impact of aviation.

The ***Laboratory for Manufacturing and Productivity (LMP)*** is an interdepartmental laboratory dedicated to the development and application of the fundamental principles of manufacturing systems, processes, and machines. Research and education is focused in the areas of design, analysis, and control of manufacturing processes and systems.

The ***Operations Research Center (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 ***Partnership for a Systems Approach to Safety and Security (PSAS)*** group's goal to create new tools and processes that implement systems thinking approaches. Engineering safer systems require multi-disciplinary and collaborative research based on sound system engineering principles. PSAS affiliates are working on safety in aviation (aircraft and air transportation systems), spacecraft, medical devices and healthcare, automobiles, railroads, nuclear power, defense systems, energy, and large manufacturing/process facilities.

SPACE VEHICLES & ROBOTICS

The ***MIT Kavli Institute for Astrophysics and Space Research (MKI)*** is an interdepartmental center that supports research in space science and engineering, astronomy, and astrophysics. MKI plays a leading role in the design, construction, and utilization of instruments placed aboard space vehicles launched by NASA or other agencies. MKI faculty, research staff, and students develop technology & instrumentation with a focus on an engineering and technical core. Experimental programs are supplemented by closely related programs of ground-based research, theoretical investigations, and laboratory development of instrumentation for space-based and ground-based experiments.

The goal of the ***Model-based Embedded and Robotic Systems Group (MERS)*** is to develop robots that are able to think and act much like humans do. The group is focused on allowing robots to be programmed by humans by being given high-level goals instead of low-level scripts, to team with a human to accomplish some task, and to reason about themselves and the environment to detect unanticipated changes or hazardous situations. Sample research areas include human-robot teamwork in manufacturing, personal transportation system, autonomous underwater vehicles, and deep space exploration.

The ***Robot Locomotion Group*** builds machines that exploit their natural dynamics to achieve extraordinary agility and efficiency. Project examples: dynamics and control for robotic manipulation, and dynamic walking over rough terrain, flight control for aggressive maneuvers in unmanned aerial vehicles, feedback control for fluid dynamics and soft robotics, and connections between perception and control.

The ***Robotic Mobility Group*** focuses on the modeling, design, control, motion planning, and sensing for robotic systems operating in unstructured environments. Project examples: Human-inspired autonomous vehicle highway navigation; terramechanics for small, lightweight robots; classification and modeling of forested terrain from unmanned ground vehicles.

The ***Space Systems Laboratory (SSL)*** uses comprehensive mission analysis to identify key enabling technologies and mature them through terrestrial and on-orbit testing. The laboratory has flown experiments on the Space Shuttle, Mir space station, and International Space Station (ISS). The objective of the laboratory is to explore innovative concepts for the design and integration of future space systems, and to train the next generation of researchers and engineers. The laboratory encompasses expertise in structural dynamics, control, thermal, space power, propulsion, microelectromechanical systems, software development and systems.

The ***Department of Mechanical Engineering (MechE)*** conducts research in a range of areas, such as mechanics, product design, manufacturing, energy, nanoengineering, ocean engineering, controls, instrumentation, robotics, and bioengineering, that allow for rich collaboration both within the department and with other engineering and science disciplines at MIT and beyond. These broad areas of focus and the department's commitment to multidisciplinary research results in an exciting variety of innovative projects, including among many other things the design of miniature robots for extraterrestrial exploration.

The mission of the Massachusetts Institute of Technology is to advance knowledge and educate students and others in science, technology, and additional areas of scholarship. MIT is committed to generating, disseminating and preserving knowledge and to working to bring this knowledge to bear on the world's great challenges. As part of its mission, MIT maintains relationships with industrial organizations that enable the exchange of ideas in the context of real-world problems and demonstrate how principles studied at MIT are applied to generate practical benefits for industry and society. MIT's Industrial Liaison Program helps develop these relationships by facilitating industry's access to MIT and its vast resources.