MIT.nano

MIT.nano's mission is to build a better world by fostering education, innovation, and research on nanoscale phenomena, materials, devices, and systems.

MIT.nano is a world-class center for nanoscience and nanotechnology, a research facility that is open to the entire community of faculty, researchers, and students, as well as external academic and industry partners. The 214,000-square-foot facility provides broad and versatile tool sets for nanoscale advancements—from imaging to synthesis to fabrication and prototyping—entirely within the facility's protective envelope.

MIT.nano is a shared resource for the entire MIT campus. Located in the heart of MIT, we are an open-access, service-oriented facility. Any faculty member, researcher, student, or qualified partner may bring a project or unsolved problem to our specialized environments and conduct their work supported by highly qualified technical staff.

Researchers from MIT constitute our primary user community; individuals from other academic institutions, industry collaborators, MIT.nano consortium member companies, and other external organizations are also welcome. Every step of the way, our staff is here to enable researchers and educators to get their work done with as few barriers to progress as possible.

Sharing resources through MIT.nano enables the MIT community to acquire the state-of-the-art equipment that would be challenging for individual labs or departments to afford or maintain on their own. The ample size of our research facility also allows us to look beyond the present state-of-the-art by seeding dedicated lab spaces where new nanoscience and nanotechnology tools, instruments, processes, and techniques can be reinvented.

Two years since its October 2018 opening and one year since the first trained users entered MIT.nano in August 2019, the facility now supports over 350 active users from 31 of MIT's departments, labs, and centers (DLCs). With its central location and with the breadth of curated instruments, MIT.nano is proving to be a natural convening place for interdisciplinary research.

Supporting Intellectual Communities and Education

Key Activities

- Core: Provide user access to a curated set of shared tools and instruments
- New Equipment: Bring in new tools and instruments
- User Subsidy: Bring in funds to subsidize use of tools and instruments

Other Activities

- Bring in funds to support starting faculty, new users, and undergraduate users
- Bring in funds for programs that need MIT.nano tools and instruments

- Use MIT.nano as leverage to bring other programs to MIT
- Develop and support new intellectual communities
- Support new educational activities that utilize MIT.nano facilities
- Develop crosscutting education and outreach programs
- Serve as a repository and convener of technology futures studies
- Serve as a bridge between academia, industry, and national labs
- Support regional startup activity

Laboratory Spaces

MIT.nano provides high-performance, state-of-the-art research space equipped with an extensive assembly of tool sets and instruments.

Clean Room Complex

The clean room complex, spanning the first and third floor of the facility, encompasses over 40,000 square feet of class 100/1,000/10,000 clean room space for controlled processing of nanoscale structures. Inside the clean rooms, you will find tool sets for the design and fabrication of microscale and nanoscale structures, including synthesis, imaging and microscopy, and materials and thin film growth. The clean rooms are optimized for energy efficiency, airflow, and future flexibility.

Tang Family Imaging and Characterization Suites

Housed in the basement of MIT.nano—the so-called quietest place in the building, and perhaps in all of New England—are 11,000 square feet designated for metrology and characterization research including 12 highly-sophisticated suites for nanoscale observation with low vibration and minimal electromagnetic interference.

Tecnológico de Monterrey Prototyping Suites

Located on the fifth floor of MIT.nano, these suites are a unique set of interconnecting labs—the first of its kind at MIT—with capabilities for fabrication, prototyping, and packaging.

Immersion Lab

The Immersion Lab is a two-story, black box theater, a state-of-the-art immersive environment for visualizing advanced technology concepts, to connect the physical to the digital. The lab provides a space for visualization, augmented reality, and virtual reality, along with the activities supporting those fields.

Advancements and Milestones

During FY2020, the MIT.nano team continued to develop facilities in Building 12 and maintain the facilities in Buildings 39 and 24 to support nanoscale researchers from DLCs across campus. Progress included the installation of new tools in Building 12, relocation of tools from Building 39 into Building 12, and the structuring of systems for user services; updating policies, procedures, training, and other systems to support our community of researchers; establishing research, education, and entrepreneurship programs; and attracting consortium members. Some of the last year's significant achievements are described below.

Development of Focus Facilities

The 100,000 square feet of clean room and laboratory spaces in MIT.nano accommodate a variety of technical thrusts, each supported by one or more MIT.nano focus facilities. Nearly all of the focus facilities house shared tools and instruments, and we refer to these as the Shared Experimental Facilities (SEFs). Few focus facilities house privately managed tools and instruments, which are stewarded by an MIT faculty on behalf of MIT.nano.

When choosing shared tools and instruments to include in the MIT.nano SEFs, the following criteria are being considered:

- Instrument requires performance of space that is available in MIT.nano
- Instrument provides long-term benefit for the MIT community
- Cost to facilitate the instrument at another MIT location is prohibitive
- Instrument extends an existing intellectual thrust of MIT.nano
- Significant number of PIs are interested in this capability
- Instrument opens new educational opportunity

The present MIT.nano focus facilities are listed below:

- Nano-Materials SEF—relocated from the Materials Research Laboratory (MRL) in Building 13 and enhanced with new tool sets for large-area coating deposition, and solar technology development and testing. The majority of funding for this tool set originated from the MIT Energy Initiative's Solar Frontiers Center, with installation costs provided by MIT.nano.
- Thin-Film Processing SEF—providing capabilities equivalent to the former Microsystems Technology Laboratories (MTL) Experimental Materials Lab (EML) that used to reside on the fifth floor of Building 39. Some of these tools were moved from EML and others were acquired by MIT.nano.
- Microfluidic Assembly and Testing SEF—in fall 2019, this SEF was utilized for the 3.155J/6.152J Micro/Nano Processing Technology course module instruction. This tool set was developed by MIT.nano in response to user demand and academic class needs.
- Cryo-Electron Microscope (EM) SEF—for atomic-scale investigation of complex nanostructures, with particular focus on biomaterial studies. Funding for this tool set originated from the Biology Department faculty, with installation costs provided by MIT.nano. The Department of Biology also provides funds that support salaries of the technical staff that run the facility.

- Aberration Corrected Scanning Transmission Electron Microscope (STEM) SEF—ultrahigh-resolution scanning transmission electron microscope. Funding for this tool set originated from the Department of Materials Science and Engineering faculty, with installation costs provided by MIT.nano.
- Lab for Education and Application Prototypes (LEAP) SEF—consists of a collection of electrical and optical packaging and interconnect tools. Funding for this tool set originated from the AMP Photonics Center, with installation costs provided by MIT.nano. Technical support for the facility operation is in part provided by AMP Photonics staff.
- Immersion Lab SEF—consists of tools for visualizing large data sets through the use of augmented reality (AR) and virtual reality (VR) environments and new computational tool sets. Funding for this tool set originated from the NCSOFT-sponsored grant program brought in by MIT.nano.
- Characterization.nano SEF—consists of general metrology and characterization tools in the basement of MIT.nano. Funding for these tool sets is brought in by MIT.nano.
- Integrated Circuits Laboratory (ICL), Technology Research Laboratory (TRL), and Electron Beam Lithography Laboratory (EBLL) SEFs—these legacy SEFs, located in Buildings 39 and 24, accommodate over 500 users. ICL, TRL, and EBLL legacy tool sets have been obtained by MTL and Research Laboratory of Electronics (RLE) over the course of the last 30 plus years of their operation. Many of the ICL and TRL tools will be relocated to Building 12 over the course of the next two years. Tools in EBLL will remain in their Building 24 location.
- MIT.nano digital gallery and physical exhibit spaces—contents of which we hope will broadly represent activities of the MIT research community. Galleries and exhibit spaces are curated by MIT.nano and have engaged scholars and researchers from the School of Humanities, Arts, and Social Sciences; School of Engineering; School of Architecture and Planning; and School of Science.
- Focus Facilities with Private Tools are limited spaces within MIT.nano that are stewarded by MIT faculty on behalf of MIT.nano, and contain privately-managed tools and instruments. The Equipment Support Program (ESP) defines the responsibilities of the faculty steward and defines the costs incurred by MIT.nano in support of these stewarded spaces. Prior to awarding an ESP, MIT.nano discusses the space needs with the Committee for Renovation and Space Planning. The stewarding responsibilities for each space are further described in the memorandum of understanding between MIT.nano and the steward, which would include the following information:
    - The initial agreement on stewarded space use for private tools will be at most seven years in duration, but could be extended with a follow-on agreement.
    - MIT.nano will be compensated to offset incurred costs for installation and maintenance of private tools.

User Services

MIT.nano offers a new user training program composed of Fab.nano Orientation, Emergency Preparedness, and a hands-on Quick Start class for familiarization with fabrication processes. From August 2019 to June 2020, 366 new MIT.nano users were trained, with over 46 training sessions provided. New user trainings were postponed during the facility shutdown due to COVID-19 restrictions. Trainings resumed in June 2020, with modified virtual formats and small in-person groups to accommodate physical distancing and COVID-19 protocols.

Trained users have access to the clean room complex and the prototyping and packaging facility.

- MIT's trained users come from 31 DLCs: Aeronautics and Astronautics; Architecture; Biology; Brain and Cognitive Sciences; Biological Engineering (BioE); Center for Global Change Science; Chemistry; Chemical Engineering; Civil and Environmental Engineering; Comparative Media Studies/Writing; Earth, Atmospheric and Planetary Sciences; Materials Science and Engineering (DMSE); Electrical Engineering and Computer Science (EECS); Harvard-MIT Program in Health Sciences and Technology; Institute for Data, Systems, and Society; Institute for Soldier Nanotechnologies; Kavli Institute for Astrophysics and Space Research; The Koch Institute for Integrative Cancer Research; Lincoln Laboratory; Materials Research Laboratory; The McGovern Institute for Brain Research; Mechanical Engineering (MechE); MIT Environmental Solutions Initiative; MIT Media Lab; MIT Sea Grant College Program; Microsystems Technology Laboratories; Nuclear Science and Engineering; Physics; Research Laboratory of Electronics; System Design and Management Program; and Urban Studies and Planning.
- External trained users come from Harvard University, Massachusetts General Hospital, Broad Institute, and 10 companies.

In parallel with tool installations the MIT.nano team initiated the following series of user engagements:

- Developed a new section of the website specifically for MIT.nano users
- Initiated monthly user meetings led by the User Services directors
- Initiated quarterly faculty meetings led by the MIT.nano director
- Initiated a weekly newsletter in which we answer questions raised over the previous week and provide additional updates on tool status and upcoming tool installs
- Initiated weekly office hours for groups of up to 10 users with User Services directors
- Launched two faculty working groups whose responsibility is to advocate for new tools and instruments in Fab.nano and Characterization.nano, and identify sources of funding that could bring in those tool sets to MIT.nano

Classes—Fall 2019 and IAP 2020

Prior to the shutdown due to the pandemic, MIT.nano hosted a wide range of classes, including:

- 3.074 Imaging of Materials
- 3.65 Soft Matter Characterization
- 3.001 Introduction to Materials Science and Engineering
- 7.71 Structural and Biophysical Analysis of Biological Macromolecules
- 6.152J/3.155J Micro/Nano Processing Technology
- 12.373/12.777 Field Oceanography
- IAP: AIM Photonics Boot Camp

Students in the fall 2019 undergraduate class 6.152J/3.155J Micro/Nano Processing Technology.

- Sample class: 6.152J/3.155J Micro/Nano Processing Technology students have been using MIT.nano to fabricate and test silicon solar cells; building and testing microfluidic devices in the soft lithography clean room space on the third floor; using corrosive wet-benches on the first floor of the clean room to etch cantilever beams; and employing the LEAP facility on the fifth floor for electrical and photonic packaging.
- The New Engineering Education Transformation living machines thread was scheduled to start using the soft lithography room and the new MLA-150 tool for creating microfluidic channels for their spring 2020 labs. This has been postponed to 2021 due to the COVID-19 shutdown.

Tool Installations

We established a multistep process for the procurement and installation of tools in MIT.nano. Methodology defines the critical checkpoints, operational modes, schedule, and estimated costs required to operate and install equipment in MIT.nano. To enable financial benefits from the economy of scale and to leverage professional resources, we aggregate groups of tools into phases. The Phase 1 Tool Installation was completed in October 2019 and included over 115 pieces of equipment, including the ones listed below.

Phase 1

- Soft Lithography Suite
- New SAMCO plasma-enhanced chemical vapor deposition (PECVD) and reactive-ion etching tools
- Solar Frontiers Lab Growth/Metrology
- Hydrogen generators (two units) and distribution
- Large-scale solvent processing for solar applications
- LEAP packaging facility
- EML (relocated from the fifth floor of Building 39)
- Aberration-Corrected STEM (stewarded by Professor James LeBeau)
- Vibration telemetry systems for real-time monitoring of critical imaging spaces
- Interference lithography, provided by Nanostructures Laboratory (NSL), and managed by Professor Karl Berggren
- Professor Farnaz Niroui's lab glovebox accommodation project (design initiated)
- Additional new equipment: ovens, hot plate towers, spin rinse drier, tabletop microscopes, and scribe tools
- Operational enhancements: pass-through in the clean room, bottle washer, card readers, and new epoxy flooring for dust mitigation and management

During the execution of Phase 1 Tool Installation we obtained several tools that could not wait until the planned Phase 2. This new equipment was grouped into an intermediate plus phase, which was completed in June 2020 and included the following:

Phase 1+

- MLA 150 Direct Write Laser Lithography
- Barrel Asher
- Agilent 5500 Atomic Force Microscope
- Raith Focused Ion Beam with Scanning Electron Microscope
- Materials Sample Prep Plasma Cleaner
- Zeiss Scanning Electron Microscope with Metrology
- Professor Farnaz Niroui's Lab glovebox accommodation project (construction initiated)

The Phase 2 design effort—as required to produce engineering construction documents—began in December 2019. MIT.nano and an outside engineering firm were able to work through the COVID-19 shutdown and maintain our schedule, by initiating weekly design review meetings and leveraging the on-site critical walkthroughs of FAB.nano staff to collect as-built, tool-specific information.

Phase 1 data

- Design duration: seven months
- Design documents: 84 drawings, 193 pages of specs, 31 Requests for Information
- Construction duration: 183 days
- Average number of contractors on site: 11 (daily; non-MIT)
- Construction coordination meetings: 29 (two hours each)
- Number of trades and vendors contacted: 19
- Process gas and liquid sticks: 168
- Process piping and tubing installed: 8,345 feet (1.6 miles)
- Electrical conductors installed: 17,500 feet (3.3 miles)
- Unistrut, brackets, and hardware: 4,100 feet (0.8 miles)
- Safety procedures and Department of Facilities coordinated shutdowns: 70
- Recordable accidents: 0

COVID-19 Response

In response to the COVID-19 pandemic, on March 13, 2020 the MIT.nano technical team rapidly initiated a strategic plan to safely close MIT.nano to all users. By March 18 the last of the MIT.nano users was completing their activity within MIT.nano, and the facility was brought to a stand-by condition by March 20. This included securing MIT.nano labs in Buildings 12, 24, and 39, powering down equipment, and reinspecting emergency response equipment and procedures to ensure our preparedness if emergencies arose during the shutdown period. We also identified the COVID-19 related research projects that required the tools of MIT.nano and developed protocols for safely supporting COVID-19 research. During the shutdown, the team executed daily safety checks and walk-throughs of the building, oversight that was critical to ensure labs, equipment, and building infrastructure remained secure, operational, and in a safe state during this period of reduced occupancy.

Research Continuity Plan

During the shutdown, MIT.nano supported two essential COVID-19 research projects. This included provisions to ensure safe research activities (training, social distancing, disinfection, and physical or remote buddy procedures), and we identified staff support and backups with cross-training where appropriate. Below are descriptions of the two projects:

- Parylene thin film deposition in Fab 39 for COVID-19 high-throughput screening devices (Professor Paul Blainey's group, BioE and the Broad Institute). In collaboration with the Pardis Sabeti and Deborah Hung labs, the Blainey group adapted its droplet-in-microwell array platform from bacterial growth assays to perform viral surveillance and diagnostic assays. The team developed test panels encompassing all circulating viruses including coronaviruses and COVID-19. In particular, the team is readying a respiratory virus panel suitable for surveillance and diagnostic applications in the current pandemic.

- Cryo-EM sample prep and imaging of nanoparticle vaccine in Building 12 Cryo-EM SEF (Professor Mark Bathe's group, BioE). The Bathe BioNanoLab worked on generating a DNA-based nanoparticle vaccine for COVID-19 that can be translated to human trials. The goal is to transform this work into a rapid vaccine production platform to mitigate any future coronavirus threat.

Opportunities in the Time of COVID-19

The MIT.nano team took advantage of the lab's shutdown to work on ancillary activities, such as engaging users, faculty, and DLCs by way of virtual update meetings and assorted informational webinars, enhancing the user website, finalizing plans for Phase 2 of the tool and instrument installation, developing online training programs, establishing the Nano Explorations student seminar series, and finding new ways to connect to our industry members.

Following MIT protocols, MIT.nano began the first steps of ramping up the facility on June 8, 2020, welcoming the first regular users back to MIT.nano for retraining on June 15.

Operational Model and Financial Sustainability

MIT.nano operations are financially supported by user fees, together with MIT.nano Consortium membership dues, MIT nonrecurring support, donations, and funding dedicated for support of MIT.nano programs. During the last year, MIT.nano received support from the Lord Foundation, NCSOFT Gaming Program, and Tecnológico de Monterrey program.

The MIT.nano Leadership Council oversees the operation of the facility. The council met once a month during AY2020 and continued meeting during summer 2020. Council members include the following individuals:

- Brian Anthony—MIT.nano, MechE, Institute for Medical Engineering and Science (IMES)
- Robert Atkins—Lincoln Laboratory
- Karl Berggren—NSL, EECS
- Kathleen Boisvert—MIT.nano
- Vladimir Bulović—MIT.nano
- Dennis Grimard—MIT.nano
- Pablo Jarillo-Herrero—Physics
- Hae-Seung Lee—MTL, EECS
- Will Oliver—RLE, EECS
- Katharina Ribbeck—BioE
- Frances Ross—DMSE
- Thomas Schwartz—Biology
- Carl Thompson—MRL, DMSE

MIT.nano Faculty Advocates Working Groups

These two working groups give guidance on, and promote the need for, the next tool sets to be introduced in Fab.nano and Characterization.nano, and help identify ways to secure funding for these tools and instruments. The working groups commenced their meetings in July 2020, with the faculty leads of the two working groups joining the MIT.nano Leadership Council.

- The Fab.nano Working Group is steered by Professor Tomás Palacios (EECS) as the faculty lead, along with two technical leads: MIT.nano assistant director of User Services for Fabrication, Jorg Scholvin; and MTL associate director of Operations, Vicky Diadiuk.
- The Characterization.nano Working Group is steered by Professor James LeBeau (DMSE) as the faculty lead and MIT.nano assistant director of User Services for Characterization, Anna Osherov.

MIT.nano Internal Advisory Board

The Internal Advisory Board (IAB) is an advisory group with membership composed of intellectual leaders of the MIT community, reflecting the Institute-wide perspective on the utility of MIT.nano. Meeting once or twice a year, the IAB provides strategic advice to the MIT.nano faculty director and to the vice president of research on the tactical issues related to MIT.nano. The first two IAB meetings were held on September 13, 2019, and May 13, 2020. The next meeting is scheduled for February 17, 2021.

Current IAB members are as follows:

- Marc Baldo—director, RLE; EECS
- Anantha Chandrakasan—dean, School of Engineering; EECS
- John Deutch—former MIT provost, Chemistry
- Elazer Edelman—director, IMES
- Jeff Grossman—department head, DMSE
- Paula T. Hammond—department head, Chemical Engineering
- Susan Hockfield—President Emerita, Neuroscience
- Craig Keast—MIT Lincoln Laboratory
- Chris Schuh—DMSE
- Michael Sipser—dean, School of Science; Math
- Krystyn Van Vliet—associate provost, DMSE
- Evelyn Wang—department head, MechE

MIT.nano Consortium

As of June 30, 2020, MIT.nano has 13 member companies. Drawn from different industries and operating around the globe, the members of the MIT.nano Consortium share our belief that advancements in nanoscience and nanotechnology have brought humanity to the dawn of the nano age, an exciting new era for discovery, invention, and progress. The MIT.nano Consortium is rooted in MIT's deep commitment to bring our discoveries to the marketplace—pushing knowledge and technology far beyond the boundaries of our campus to where they will have the most impact.

For MIT, our potential to build a better world is dramatically enhanced through external partnerships. The financial support of the MIT.nano Consortium funds our operations, purchases of equipment, and seeds relevant research directions. As important, our industrial colleagues also introduce us to practical problems blocking the path to a better world, and when we overcome the challenges, they help to deliver insights and innovations to the market. For our corporate collaborators, joining the potent problem-solving culture of innovation at MIT energizes their efforts and offers early awareness of the technological advances that will help shape the world of tomorrow.

Industry members of MIT.nano include Agilent Technologies, Analog Devices, Dow, Draper, DSM, Edwards, Fujikura, IBM Research, Lam Research, NCSOFT, NEC, Raith, and Waters.

Programs and Initiatives

MIT.nano draws researchers, inventors, and educators from departments and disciplines across our campus. In conjunction with our technical facilities and research spaces, MIT.nano offers programs to convene this diverse community of interests, to spark interdisciplinary interactions and collaborations, and to bolster MIT's ability to advance knowledge and innovation in service to a better world. Examples include:

The NCSOFT Immersion Lab Gaming Program is supported by a four-year, $5 million grant from MIT.nano founding member NCSOFT. The grant funds equipment that outfits the Immersion Lab SEF and provides for annual seed grants for hardware and software technologies related to gaming in research and education, new communication paradigms, human-level inference, and data analysis and visualization.

The following five projects were awarded the 2019 seed grants, totaling $750,000:

- Project VISIBLE: Virtuality for Immersive Socially Impactful Behavioral Learning Enhancement, led by Professor D. Fox Harrell, Comparative Media Studies, and Computer Science and Artificial Intelligence Laboratory (CSAIL)
- An art-inspired movement generator for game AI- and VR-based training of artists, led by Professor Luca Daniel, EECS, and Micha Feigin-Almon, research scientist, MechE
- Increasing Immersion in AR Games through Dynamically Generated Game Props, led by Assistant Professor Stefanie Mueller, EECS and CSAIL
- Reproducing Light Fields Using Phase-Only Holograms for Virtual/Augmented Reality, led by Professor Wojciech Matusik, EECS and CSAIL
- Extremely-wide, field-of-view, ultracompact, high-resolution AR/VR displays based on metasurface optics, led by Professor Juejun Hu, DMSE; and Tian Gu, research scientist, MRL

In addition, there are many undergraduate projects taking place in the Immersion Lab, such as the following:

- Visualizing scientific climate and planetary data in 3D
- Building haptic robotic devices to enhance the realistic perception of virtual worlds
- Measuring the physiological and behavioral reactions to scary virtual environments
- Developing a virtual heart for teaching electro-cardiology
- Animating virtual characters with motion capture data from the physical world

Nanotechnology Seminar Series and Mildred S. Dresselhaus Lecture

In fall 2019, the MIT.nano Nanotechnology Seminar Series, organized by Professor Farnaz Niroui, was established to offer monthly technology talks from research luminaries working across the spectrum of nanoscience and nanoengineering. The pinnacle of the seminar series is the annual Mildred S. Dresselhaus Lecture, held each November honoring the contributions and legacy of one of MIT's most cherished professors—the Queen of Carbon, Institute Professor Mildred Dresselhaus (1930–2017).

Inaugural Dresselhaus Lecture.

On November 13, 2019, Paul McEuen, John A. Newman Professor of Physical Science at Cornell University and director of the Kavli Institute at Cornell for Nanoscale Science delivered the inaugural Dresselhaus Lecture, titled "Cell-Sized Sensors and Robots," to a packed audience in Huntington Hall (Room 10-250), MIT's 425-seat lecture room.

SENSE.nano

SENSE.nano—the first Center of Excellence powered by MIT.nano—hosts an annual symposium followed by an external advisory board meeting. The technology space for SENSE.nano includes sensors, new instrumentation, remote sensing, and other measurements solutions. The 2019 SENSE.nano Symposium on September 30, 2019 was co-sponsored by the MIT Industrial Liaison Program. This full-day symposium attracted over 150 participants and highlighted two research streams: sensing for AR/VR and sensing for advanced manufacturing.

SENSE.nano Seed Grants

Each year, SENSE.nano seeks proposals for seed grants related to sensing technologies. The response to the 2019 SENSE.nano call for proposals was overwhelming, yielding 38 submissions. The SENSE.nano External Advisory Board met in October 2019 to review the proposals and provide input.

Two seed grants were awarded (at $75,000 each):

- Nanostructured Optical-Field-Samplers for Visible to Near-Infrared Time-Domain Spectroscopy—Professor Karl Berggren and Research Scientist Phillip Donald Keathley, EECS
- Interactive Manufacturing Enabled by Simultaneous Sensing and Recognition—Professor Jeehwan Kim, MechE and DMSE

ARTS.nano

The central location of MIT.nano with the visual connectedness both inside and outside the building enables us to utilize MIT.nano's galleries and public spaces as exhibit venues. We have reached out to the Center for Art, Science & Technology; the LIST Visual Arts Center; and the MIT Museum to consider the programs we can jointly develop and launch.

For this academic year we developed an updated version of the *One.MIT* art project, which anchors the ground-level, south-corridor gallery space. Building on the impact of the *One.MIT 2018* art piece, the *One.MIT 2020* art piece celebrates the never-ending drive of MIT's remarkable community, and was revealed during the May 2020 graduation week as a tribute to the latest MIT graduates. A team of faculty, students, and staff created *One.MIT 2020* by incorporating the names of over 316,000 people associated with the MIT community from 1861 to January 2020 to form a mosaic that resembles the shape of the MIT seal. The mosaic will be etched onto a 6-inch silicon wafer using the tool sets of MIT.nano and displayed next to the 6-foot-tall image of the mosaic. The wafer will be installed in MIT.nano's first-floor gallery, replacing the physical installation of *One.MIT 2018*, which was etched as an image of MIT's Great Dome. The new design for 2020 adds 46,000 names (which our team collected over the past two years) to the previous version.

Tecnológico de Monterrey–MIT Nanotechnology Program

Tecnológico de Monterrey (TM) is a private, nonprofit university in Mexico. The Tecnológico de Monterrey–MIT Nanotechnology Program supports extended stays of TM students, postdoctoral researchers, and professors at MIT. Postdocs and professor are typically embedded in an MIT research group, while students are typically taking a week-long course of hands-on nanotech labs offered by MTL and MIT.nano. During AY2020, MIT hosted one professor and three postdocs with four faculty in four different DLCs. Because travel to and from Mexico was prohibited due to the ongoing pandemic, the summer nanoLab program was modified to allow for virtual lectures. Luis Velasquez-Garcia taught five sessions, each one week in length, composed of three, 90-minute lectures. Two hundred and fifty-two personnel from TM took the course, averaging 50 attendees per week (a near sixfold increase from prior courses which accommodated eight people per course). The attendees included faculty, postdocs, and graduate students.

Tool Talks

The Tool Talks series was launched in 2017 as a monthly event designed to introduce the latest transformative technologies, tools, methods, and new science understandings that are emerging from technical research innovations. The talks are technical presentations presented and sponsored by individual tool suppliers, sometimes including tool demonstrations. Tool Talks are geared toward the entire MIT community, but applicable to a generalized scientific audience for broadest impact, and aimed to provide educational value for all levels of students, postdocs, staff, faculty, and collaborators. MIT.nano continued to host the monthly, in-person Tool Talks up until the shutdown in March. They are now held virtually, which supports an even larger audience.

Community Engagements

MIT.nano serves as a resource to the members of the MIT community, providing support and working collaboratively to advance their research objectives. Some of the interdisciplinary and external engagements in the last year include the following:

Shape Your MIT.nano

On June 16, 2020, the first Shape Your MIT.nano meeting was held. The primary goal of these monthly meetings is to educate faculty members on how to utilize MIT.nano for their individual program's needs. We also seek feedback on which tools and instruments are needed for faculty research; discuss how funds can be jointly raised to obtain them; and get input on other programs and activities that MIT.nano could support.

Facility Tours

Each year, MIT.nano hosts hundreds of personal tours of the facility. Guests have included MIT students, faculty, staff, industry titans, foreign dignitaries, and researchers from institutions around the globe. Each tour is unique and always engaging, delivered by MIT.nano staff or a cohort of trained student tour guides.

MARC2020

Co-sponsored by MIT.nano and MTL, the Microsystems Annual Research Conference (MARC) is a yearly, off-site gathering of students, faculty, and industry partners designed to bring colleagues together to exchange ideas, get to know each other, and launch new collaborations. MARC2020 was held on January 28–29, 2020, in Bretton Woods, New Hampshire. This year's conference included over 90 poster presentations and seven technical demos. Reed Sturtevant—general partner of The Engine—and Mark Rosker—director of DARPA Microsystems Technology Office—were the keynote speakers.

Attendees at MARC2020 held January 28–29, 2020, in Bretton Woods, New Hampshire.

Lam Research Technical Symposium

On October 9–10, 2019, MIT.nano and MTL co-hosted the annual Lam Research Technical Symposium. The two-day conference highlighted research in smart systems for semiconductor manufacturing with talks by industry and academic leaders, multiple panels, presentations by startups, and student poster sessions. Among the attendees were delegates from Lam's key academic partners: MIT, Stanford University, Tsinghua University, and University of California at Berkeley.

Other MIT Collaborations

- MIT Nanomedicine Hackathon at MIT.nano—July 22, 2019
- MIT.nano Member Showcase recruiting event—October 1, 2019
- Compressed Gas Safety Course, co-sponsored by MIT.nano and Chemical Engineering—October 9, 2019
- MIT.nano and the MIT Industry Liaison Program continue to partner, working to expand the MIT.nano consortium

Awards and Recognitions for MIT.nano

2019 "Go Beyond" Award

MIT.nano received the International Institute for Sustainable Laboratories 2019 "Go Beyond" Award for excellence in sustainability in laboratory and other high-technology facility projects. This recognition adds to a string of other awards, including the R&D World 2019 Lab of the Year Award for excellence in research lab design, planning, and construction; and the 2020 AIA New England Honor Award for Design Excellence.

LEED Platinum Certification

MIT.nano received the US Green Building Council's LEED Platinum certification for sustainable practices in new construction. The Leadership in Energy and Environmental Design (LEED) designation is an assessment of a building's positive and negative environmental impacts through its design, construction, and operation. Earning the council's highest designation of platinum is a remarkable achievement because research centers like MIT.nano consume significantly more energy per square foot than a typical office building or even a traditional laboratory.

At all levels (certified, silver, gold, and platinum) the LEED certification process is based on a number of points that correlate to sustainability measures. MIT.nano earned points across all seven sections of the LEED scorecard: location and transportation; sustainable sites; water efficiency; energy and atmosphere; materials and resources; indoor environmental quality; innovation; and regional priority. The building notched 84 points in total, with 80 points or more needed to earn platinum certification.

MIT.nano rated highly in several categories, including: optimizing energy performance; water use reduction; indoor environmental quality; and innovation in design. The building's overall efficiency is supported by extensive indoor environmental controls and monitoring systems. The clean room, for instance, senses user occupancy with motion and particle detectors and adjusts air recirculation rates accordingly.

Conclusion

In recent decades, we have gained the ability to see into the nanoscale with breathtaking precision. This insight has led to the development of tools and instruments that allow us to design and manipulate matter like nature does, atom by atom and molecule by molecule. MIT.nano has arrived on campus at the dawn of the nano age. In the decades ahead, its open-access facilities for nanoscience and nanoengineering will equip our community with instruments and processes that can further harness the power of nanotechnology in service of humanity's greatest challenges.

Vladimir Bulović
Founding Director
Fariborz Maseeh (1990) Chair in Emerging Technology