Massachusetts Institute of Technology
Fall 2018

Spectrum

KENDALL /MIT

FRONT COVER
This detail of the cover illustration shows how new buildings and open spaces will transform Kendall Square—including a graduate student residence (far right) that will rise above a new Innovation and Entrepreneurship Hub just steps away from the MBTA subway station and new MIT Museum (far left). See page 6 for a special feature section on the Kendall Square Initiative.

Cover illustrator Marcus Martinez SM '12 is an alumnus of the School of Architecture and Planning. While at MIT, his projects included collaborating at the MIT Media Lab on the conceptual design of the Persuasive Electric Vehicle (which may be spotted at left). Now based in Houston, Martinez is a cofounder of the urban design and creative think tank UltraBarrio, and his work as a design professional and educator spans the disciplines of architecture, urbanism, and industrial design.

Wide Angle

Subjects

SPECIAL SECTION

Kendall/MIT

Breakthroughs and Insights

Inside the MIT Campaign for a Better World

BACK COVER
The first annual "Maker Break" was hosted by Project Manus at MIT's Johnson Athletics Center in spring 2018, featuring making activities and competitions for all skill levels.

PHOTO: KEN RICHARDSON

WATCH THE VIDEO
spectrum.mit.edu/makerbreak

Fall 2018

MIT Spectrum connects friends and supporters of the Massachusetts Institute of Technology to MIT's vision, impact, and exceptional community.

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Innovation Squared

Once or twice a year, I leave my neckties at home and travel to Northern California to meet with colleagues, alumni, and friends in and around San Francisco.

Every time I'm there, I'm struck by how differently the innovation ecosystems in Silicon Valley and Kendall Square have evolved. On the West Coast, academia and industry have space, and they've used it as an instrument for innovation. In Cambridge, where undeveloped land is scarce, we have made proximity into an asset.

An intense, close-knit, eminently walkable neighborhood, Kendall Square's density and richness in sectors and talent set it apart. With students, researchers, inventors, and entrepreneurs working so closely together, MIT's eastern neighborhood has emerged as a creative playground where promising ideas become world-changing innovations.

When I think back to the Kendall Square I knew when I arrived in 1980, it's almost impossible to believe.

I remember a Kendall Square that was gritty, industrial, and a ghost town at night. Over the last 38 years, that little rough patch has become, famously, "the most innovative square mile on the planet." If you've walked down Main Street recently, you know that more change is coming.

As part of MIT's Kendall Square Initiative, we're constructing six new buildings that aim to leverage the area's strengths for the benefit of our community and our neighbors. By interweaving student housing, classrooms, commercial space, innovation space, and maker space, we will bring the Institute's students and faculty closer to a host of potential collaborators. And by creating appealing modern homes for the MIT Admissions Office and the MIT Museum, and tying it all together with an outdoor communal space featuring dynamic programming, we will build a welcoming eastern entrance to our campus, transforming the way the world gets to know us.

This is an exciting—albeit, noisy—time to be at MIT. Once the jackhammers stop and the cranes leave town, we'll be left with a Kendall Square full of possibility—for the Institute, the region, the nation, and the world.

If you haven't been to Kendall Square recently, I hope you'll stop by for a visit. You'll be amazed by the progress we're making, and I think you'll be pleased with the direction we're headed. Hard hats encouraged. Neckties optional.

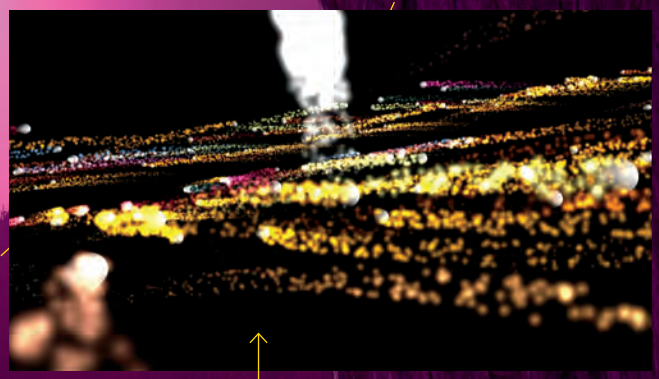
L. RAFAEL REIF

LEARN MORE
betterworld.mit.edu

The Medium Is the Meditation

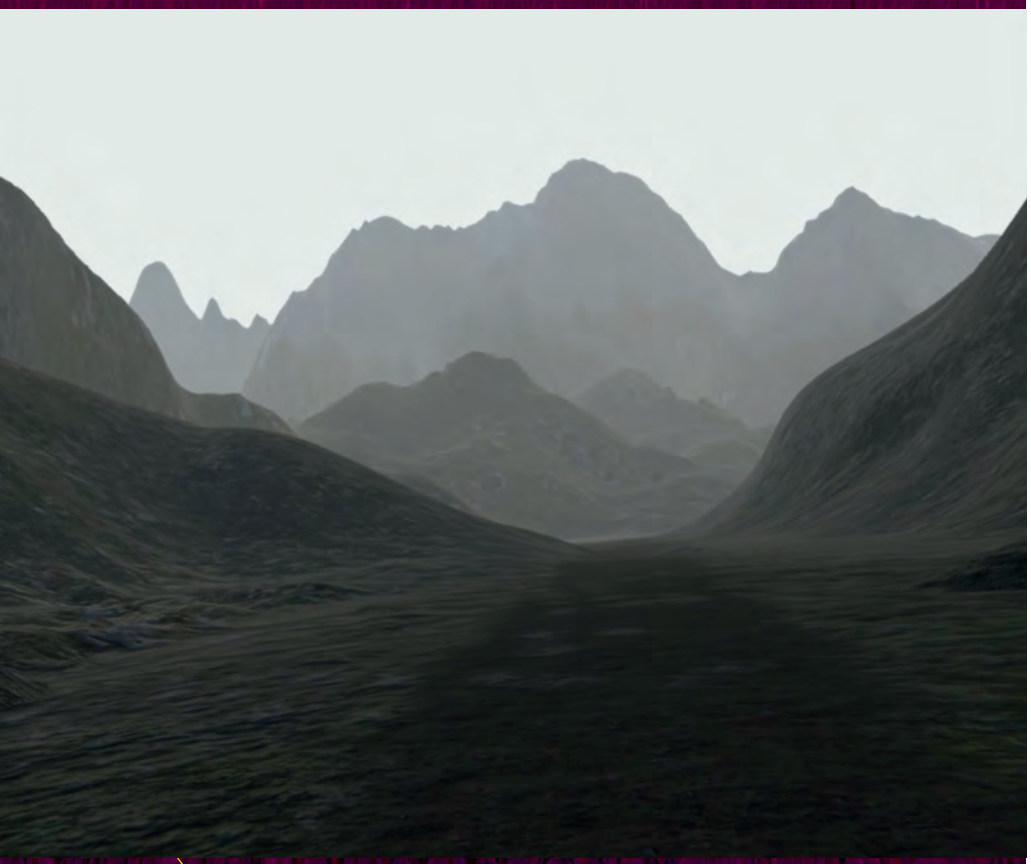
Gelman handled character design and animation, including the figures of monks in Sarnath: “I had to think about my 2-D work in a completely new way, knowing that it would be going into a 3-D virtual world.”

Greene used the game engine Unity to build the experience, and created all of the terrain and 3-D assets. He calls his first full VR project “a great learning experience, but it also presented a steep learning curve.”



25
HRS/WK

The project took the team three months, working an average of 25 hours a week to go from mood board to finished product.



Stepping into *Reveal* is to enter an introspective journey already in progress. The nine-minute virtual reality (VR) experience begins in a desolate valley surrounded by dark, imposing mountains. Then a small light appears, guiding the virtual pilgrim through an escalating series of scenes and sounds that culminate in a joyous, unified vision of shared human connection. Pushing the boundaries of art and technology, *Reveal*'s message is as intensely personal as it is universal.

The experience was conceived in spring 2018 by filmmaker and MIT Sloan graduate student Victoria Bousis MBA '18 for MIT's hands-on humanities class CMS.339 Virtual Reality and Immersive Media Production (aka "Hacking XR"). Bousis drew heavily from her experiences on a pilgrimage she had taken to India and Nepal in 2015. Along with a team of classmates, Bousis reimagined and recreated some of the locations she'd visited, such as the Himalayan Mountains and Dhamek Stupa in Sarnath, India, where it is believed that the Buddha gave his first teaching after achieving enlightenment.

Bousis initially wanted to create a "cool and edgy" experience for her VR project. Then, sitting in church, she had an epiphany: "I saw *Reveal* in its entirety and completed the entire mood board as soon as I got home," she recalls. "It all aligned into a higher story." Parker Greene '18 (who begins his graduate studies in computer science at MIT this fall) and undergraduate comparative media studies and computer science joint major Danny Gelman '20, along with visiting Boston University student Alicia Hong, signed on to help Bousis turn her vision into virtual reality.

Created in 2017 by instructor Sandra Rodriguez in collaboration with comparative media studies professor William Uricchio, Hacking XR introduces students to a holistic view of VR as a medium, giving as much weight to the craft of storytelling as to emerging technologies such as Oculus, Samsung Gear, and Hololense. "You need to understand the technical tools," says Rodriguez, a visiting scholar at MIT and head of creative reality at Montreal's Emmy-winning EyeSteelFilm. "But this class is about creativity, overcoming challenges, and contributing to the culture of pioneers."

Having completed her MIT studies, Bousis plans to establish a startup to explore the use of biometric data to create personalized, responsive VR experiences. "VR as a medium is incredibly powerful," notes Bousis. "It increases your neuroplasticity and can actually rewire the networking in your brain in very positive ways. Just imagine what we can do with it."

Credits
Directed and written by: Victoria Bousis
Produced by: Victoria Bousis, Parker Greene, Danny Gelman, and Alicia Hong
Creative and technical director: Parker Greene
Character design and 2-D animation: Danny Gelman
Sound design: Victoria Bousis and Alicia Hong

WATCH A TRAILER
spectrum.mit.edu/reveal

Following the Thread

Three years of project work yield NEET students an experimental model of the human gut—and preparation for their post-graduation goals

TITLE

20.051/20.052/20.053 Living Machines

INSTRUCTORS

- **Eric Alm** (thread co-chair), Karl Van Tassel (1925) Career Development Professor, Biological Engineering; Director, Center for Microbiome Informatics and Therapeutics
- **Linda Griffith** (thread co-chair), Teaching Innovation Professor of Biological and Mechanical Engineering; and Director, Center for Gynepathology Research
- **Timothy Kassis,** Lead Instructor, NEET

FIRST OFFERING

Fall 2017

ENROLLMENT

Cohort entering in 2017: 13

Cohort entering in 2018: 29

FROM THE CATALOG

A curriculum "thread" within the New Engineering Education Transformation program, or NEET (see sidebar), Living Machines is an **interdisciplinary project-centric program** emphasizing novel research output. Students will develop the intellectual and technical skills to create a "gut-microbiome-on-a-chip": a computational and highly instrumented in vitro experimental model of the human gut. They will build the device from stem cells and learn how to power and image it, as well as how to measure and computationally model the way drugs, microbes, and immune cells change its function. The vision is that this technology will ultimately replace the use of animals in drug research and development.

Dorothy Szymkiewicz '20: "This can really show me what the intersection of mechanical engineering and biology entails."

Living Machines projects are highly interactive with local industry partners and merge clinical medicine, systems biology, microfabrication/microfluidics, tissue engineering, stem cell biology, sensors and optics, mechatronics, biomaterials, and immunology.

YEAR BY YEAR

Students complete three year-long Living Machines project classes:

- Sophomores: **Small groups** structured as startup companies compete to make simplified versions of the gut-microbiome-on-a-chip. If students come up with a novel approach, they may file a "patent" with an instructor to ensure no other team can copy it.
- Juniors: Individual students explore in-depth areas of the device in one of 17 labs around MIT. Each student's particular project is tailored to their **post-graduation intentions**.
- Seniors: Students reconvene as one large group and synthesize everything they have learned throughout the previous two years to create their final iteration of the device.

Kassis: "The goal of the first year is basically to get their hands wet, learn the lab techniques, and have them interact together in these interdisciplinary teams from different majors."

Kassis: "If a student is interested in a PhD program, they work on a project with publication potential. For people interested in starting their own company, we give them a project that has commercialization potential. People interested in med school work on a clinically oriented project."

SAMPLE COURSE LOAD

While class requirements are individualized depending on students' interests, some general recommendations beyond NEET seminar and project classes could include:

- 20.110J/2.772J Thermodynamics of Biomolecular Systems
- 20.309J/2.673J Instrumentation and Measurement for Biological Systems
- 2.00 Introduction to Design

Students should also fulfill the NEET Intellectual Diversity Requirement by taking at least one or two subjects offered by departments outside of their majors.

Despite their different focuses, students are united by their interest in biotechnology applications.

COMMUNITY

The Living Machines community encompasses anyone pursuing a technical degree; current enrollees are studying biological, chemical, mechanical, and electrical engineering as well as computer science and architecture. Despite their different focuses, students are **united** by their interest in biotechnology applications. Students work shoulder to shoulder with the **Living Machines faculty**, and gain career insights and professional connections through a rotating lecture series of industry leaders excited about the NEET approach.

Students surveyed during the pilot year listed "being part of a community" as one of the top benefits of NEET.

Rebekah Costello '20: "I believe that the program is a future direction for engineering education because it's interdisciplinary and teamwork based, which is reflective of what the workforce is going to be like."

Ronit Langer '20: "One of my favorite parts is the incredible mentors that you have access to. Working with Timothy Kassis has provided me with so much insight and guidance."

LEADERSHIP

The Living Machines thread has invited some students to take on **leadership positions**. An academic liaison helps bridge gaps between departments and schools. A communications liaison works to engage local media and other stakeholders interested in learning more about this initiative. An industry liaison brings the attention of local industry leaders to the students' projects to help them build relationships that will last after they graduate with the Living Machines NEET certificate.

This will be adopted by the other NEET threads in the 2018–19 academic year.

—Stephanie M. McPherson SM '11

Opposite: Ronit Langer '20, left, and Dorothy Szymkiewicz '20 are part of NEET's first Living Machines cohort.

PHOTO: KEN RICHARDSON

A NEET New Approach to Engineering Education

To succeed in today's engineering workforce, students need more than a grounding in theory: they also need the skills and confidence to bring new ideas into reality through interdisciplinary teamwork. That's what the MIT School of Engineering aims to provide with a hands-on curriculum called New Engineering Education Transformation (NEET).

"You have to jump in and learn by trying things, by making the mistakes that everybody makes the first time they try to solve problems," says Anette "Peko" Hosoi, associate dean of engineering and the Neil and Jane Pappalardo Professor of Mechanical Engineering. Hosoi is the faculty co-lead of NEET with Ed Crawley '76, SM '78, ScD '81, Ford Professor of Engineering in the Department of Aeronautics and Astronautics.

Learning by doing has always been an important ingredient of MIT education, but according to Amitava "Babi" Mitra, NEET's executive director, NEET's approach sets it apart. "Most engineering curricula in the world, including at MIT, focus on the more traditional machines"—for example, designing and manufacturing a 1950s-era plane such as a Boeing 707, he says, while consigning new technologies such as quadcopters and self-driving cars to a single class or two. In contrast, NEET aims to educate young engineers to build the new machines that will address social needs of the future.

The 120 students who have begun NEET since it launched in fall 2017 will earn a degree in their chosen major within the usual four years, while spending sophomore through senior years immersed in machines and systems under development in modern industry. Emphasizing disciplinary breadth as well as depth, NEET offers a rethinking of the existing engineering curriculum, while retaining the strengths of "mens et manus."

According to Living Machines lead instructor Timothy Kassis, a typical undergraduate series of labs, classes, and internships can add up to "experiences that are valuable but that don't necessarily tell a coherent story. When our NEET students graduate, they will have a story they can talk about."

In its first year, NEET piloted two cross-departmental threads, or learning pathways: Autonomous Machines and Living Machines (see opposite). Two more begin this fall: Clean Energy Systems and Advanced Materials Machines. The four threads were proposed and assessed by engineering faculty, assisted by faculty from MIT's other four schools. A students' chosen thread will be named on a NEET certificate bestowed as a new credential upon graduation.

"Before learning about NEET, I was having trouble choosing a major, because I saw interesting classes relevant to my field scattered across the aerospace engineering, mechanical engineering, and computer science curricula," says Gabriel Margolis, a Course 16 (AeroAstro) junior. "NEET's Autonomous Machines thread brings the most interesting parts of those majors together."

Each year of NEET focuses on a project of increasing complexity within a student's selected thread. Along the way, students acquire lab and collaboration skills and study the NEET Ways of Thinking—11 categories ranging from making and discovering to analytical and humanistic approaches—that enable learning on the job. They also participate in a seminar through which they actively help to shape this experimental program.

"NEET is already being acknowledged in academic, professional and industry forums as an initiative that is worth watching," says Mitra. "We hope others will join with us in the effort to create a transformational teaching and learning program for MIT, the engineering education community, and beyond."

LEARN MORE
neet.mit.edu

KENDALL /MIT

“Kendall Square is a vital source of opportunities, talent, and resources to help the people of MIT deliver their ideas to the world. Our future success depends on making sure that Kendall succeeds as a *place*—a place where people want to live, work, and play, and a place that makes our city stronger, too.”

—

MIT President L. Rafael Reif

An artist's rendering of the Kendall Square Initiative shows a vibrant new gateway to MIT.

IMAGE: BYENCORE

Architects

Childcare, Graduate Residence, Innovation and Entrepreneurship Hub, MIT Forum and Admissions Office: NADAAA (design architect); Perkins+Will (architect of record) / MIT Museum: Perkins+Will (base building architect of record); Höweler+Yoon (museum interiors); Weiss/Manfredi (base building design architect) / Open Spaces: Hargreaves Associates

Welcome to Kendall Square

The flourishing innovation district takes its place as a destination and a gateway

Cambridge, Massachusetts, the year 2028: You emerge from the Kendall/MIT train station, pausing to orient yourself. Your first impressions are of the interplay of brick and glass, and a pulse of activity. The kid next to you tugs her father's arm. "There's the museum! Can we go build robots again?" she begs. "I'm just swinging by home between classes," a passing man says into his phone as he halts to make way for a buggy full of toddlers from the nearby daycare. A group of teens and parents follows a purple-haired young woman who makes walking backwards look easy, as she narrates: "I first started working on my company at MIT's Innovation and Entrepreneurship Hub, next to where we began our tour, but after I graduate this spring we're moving down the road into lab space we'll be sharing with some other startups." You notice a small crowd in the plaza across the street gathering around what appears to be a musical sculpture. It's lunchtime, with workers spilling out of nearby buildings, and the café over there still has a few open tables on its patio, but you decide to get a sandwich to go so you can keep exploring. There's no mistaking this place for anywhere else: You are in Kendall Square—and you are at MIT.

If you visit Kendall now, in 2018, you'll see signs of a different kind of activity: towering cranes, scaffolding, construction crews who are building the foundations of that future scene. Over the course of the 20th century, while MIT grew outward from its original Main Group buildings along Massachusetts Avenue, nearby Kendall Square boomeranged from an industrial powerhouse churning out candy, soap, and rubber; to relative abandonment; to a burgeoning tech hotspot. Now, MIT has broken ground on a new chapter for Kendall Square that will transform it into a true portal to and from MIT.

Meeting the community

"We are creating the interface, the overlap, between the campus and the city," says Hashim Sarkis, dean of MIT's School of Architecture and Planning. Though MIT isn't a traditional enclosed campus, he says, it has been relatively isolated from its surroundings. In the new Kendall Square, campus and city "will be a little bit more blurred, deliberately so—it's the space where MIT meets the community."

MIT already has a strong biomedical research presence on its eastern threshold at the Koch Institute for Integrative Cancer Research and

Artists' renderings, above and opposite: adjacent to the new MIT Museum and graduate residence, open spaces for gathering will be programmed by MIT and open to all.

IMAGES: BYENCORE

the Brain and Cognitive Sciences complex, and through affiliations with the Broad, Ragon, and Whitehead institutes. The MIT Sloan School of Management, Computer Science and Artificial Intelligence Laboratory, and MIT Media Lab are among the destinations within a short walk from the Red Line "T" stop. Now, the Kendall Square Initiative will more tightly weave together these elements with new construction including a graduate student residence and childcare center (see page 14) and new homes for the Office of Admissions (page 11), MIT Museum (page 12), and Innovation Initiative (page 20). The plan, seven years in the making, adds lab and housing capacity to the area; incorporates flexible indoor and outdoor gathering spaces, new pockets for retail, and underground parking; and allows for easy passage between the square and the Charles River.

Begun in summer 2018, an "MIT Inspiration Station" held weekly at the Kendall Discovery Market in the Marriott Plaza showcases Institute activities for the public.

PHOTO: BEARWALK CINEMA

The plan also preserves three of the last vestiges of Kendall's industrial heritage, including a clock tower erected in 1925; the blocky white Suffolk Engraving & Electrotyping Building, which for many years housed the now relocated MIT Press bookstore; and the red-brick 1915 Hammett Building, upon which the new graduate residence will rise. Harmony between old and new was a major design consideration, says Sarkis. Architecturally speaking, the new buildings "are bold statements. Each is unique but respectful of the others."

According to Sarah Eusden Gallop—co-director of MIT's Office of Government and Community Relations and chair of the board of the Kendall Square Association (KSA)—respecting historical context was a key topic discussed at more than 100 community meetings MIT has held throughout the project.

The final plan draws on input from local groups such as the Cambridge Historical Commission and the East Cambridge Neighborhood Planning Team. When construction is complete, the square's new dynamic is meant to facilitate the kind of town-and-gown intermixing that was once epitomized by the F&T Restaurant. That landmark was long gone when Gallop joined MIT in 1990, but she still hears reminiscences about its heyday. "It was a symbol of openness," she says. "You could see Nobel Prize winners having lunch at the diner sitting next to anyone—an MIT student or staff member, a Kendall Square employee, or a Cambridge resident."

That inclusive ethos is what Jessie Schlosser Smith, recently hired by MIT for the new role of director of open space programming, will seek to recreate in the areas between buildings. "Programming with a quirky, playful vibe does a lot to welcome people in," says Smith. She will look for unexpected ways to showcase MIT's strengths, ranging from science and technology to the performing arts, as well as introducing the MIT community to the inspiring activity beyond its doorstep. In the process, she hopes to prompt the kinds of unscripted encounters that feed innovation. Just as two people might have struck up a conversation at the F&T, a space designed for lingering can lead to "connecting with somebody you might have met once, but then you run into each other as you're grabbing a coffee or watching a performance. You reinforce that relationship and maybe have a conversation, and a new concept or solution could potentially come out of that."

What about those not already in the fabric of the innovation ecosystem? Gallop says that since the KSA's 2009 founding, the Kendall community has increasingly turned its attention to issues of workforce development, aiming to spread the benefits of Kendall's growth among its neighbors. Two job training centers, which will assist Cambridge residents in identifying and developing skills useful in the innovation economy, are set to open in the area next year, one to be created by MIT and another through a collaboration among several local organizations.

When the MIT Museum moves into its new Main Street home in 2021, Cambridge residents will

enjoy another perk: free admission year-round. John Durant, the Mark R. Epstein (Class of 1963) Director of the MIT Museum, describes this new policy as good citizenship. “We are part of the Cambridge community. And we would like to make what MIT represents as meaningful and as relevant to our immediate neighbors as we can.” To encourage repeat visits, the museum has already increased turnover of special exhibitions and programming related to content in the galleries. For example, this fall, an exhibition about MIT nautical engineer Nathanael Greene Herreshoff 1870 is accompanied by a workshop on boat design, complete with the opportunity to 3-D print a hull. But current facilities can’t fully meet the demand for such experiences. In addition to larger galleries, Durant looks forward to tripling the museum’s programmatic square footage, including a larger public makerspace called the Idea Hub. He’s also eager for the day that the annual Cambridge Science Festival, spearheaded by the MIT Museum, can finally be hosted on its own indoor and outdoor premises.

In all of this, Durant cites a guiding principle: “Museums should be first and foremost about what you do when you’re there, rather than what you see.”

Meeting the world

“In one sense,” says Durant, the dramatic new digs are “not a change for this museum, in terms of our mission: making research and innovation accessible to all.”

He really does mean “all.” Currently, 50% of the museum’s more than 169,000 annual visitors—a total expected to jump by at least 60% in the new space—come from outside the region. Some are tourists; many others are in town because a family member dreams of attending MIT. They may begin their visit at the Admissions Office, then round out their image of the Institute at the museum next door. Both admissions and the museum will utilize an adjoining 200-seat forum for presentations. There is a huge public appetite for engaging with MIT students and faculty, observes Durant—himself a faculty member in the Program in Science, Technology, and Society—and for access to “this extraordinary world of discovery, invention, and problem solving that MIT represents.”

Until now, visitors to MIT have tended to experience a single iconic gateway: 77 Massachusetts Avenue. There is nothing quite like climbing the steps toward the century-old doorway framed by grand pillars and getting your first glimpse through Lobby 7 down the Infinite Corridor. But Sarkis suggests that the growth of the campus requires multiple entry points. He sees this multiplicity of entrances as consistent with the diversity of MIT at large. “The notion of diversity in education is very strong at MIT. It has to manifest itself in spaces, as well.”

The reimagined Kendall Square will offer a metropolitan entrance to campus, with accessibility and amenities that increase what museum folk like Durant call “dwell time.” Gallop’s office did extensive research on what makes innovation ecosystems successful, “and we were pleased to see that Kendall knocks most of the elements out of the park: transportation system, diversity of industry, research presence.” The planners zeroed in on developing a less tangible ingredient: sense of place. It’s the feeling you are in a distinctive destination where collaboration can and does happen—“the concept of a civic living room, where ideas are shared that are going to allow all of us to address the world’s greatest concerns.”

As construction progresses, MIT is poised to welcome the world into its living room. When Smith began her job, she was inspired to hear about recent “Open House” events that celebrated the campus’s centennial with insider views behind Institute walls—a powerful example, Smith thought, of “turning MIT inside out.” In the new Kendall Square, MIT can do this every day by “bringing those incredible discoveries out into the public, into a place where you can stumble upon it. You don’t even have to open a door. You just walk by, and there it is.” —Nicole Estvanik Taylor

An artist’s rendering of the soon-to-be-realized view down Main Street. From left: the graduate residence rising from the 1915 Hammett Building, the preserved Suffolk Engraving & Electrotyping Building, and the new MIT Museum.

IMAGE: BYENCORE

Architects
Childcare, Graduate Residence, Innovation and Entrepreneurship Hub, MIT Forum and Admissions Office: NADAAA (design architect); Perkins+Will (architect of record) / MIT Museum: Perkins+Will (base building architect of record); Höweler+Yoon (museum interiors); Weiss/Manfredi (base building design architect) / Open Spaces: Hargreaves Associates

Two Front Doors

A Q&A with the dean of admissions and student financial services

Stuart Schmill '86 began his time at MIT with a degree in mechanical engineering and has held many roles here in the years that followed. Since 2008 he has served as dean of admissions, with his office steps away from Lobby 7, MIT's traditional entrance at 77 Massachusetts Avenue. *Spectrum* asked Schmill how transplanting the Office of Admissions to Kendall Square will enhance the visitor experience. —Nicole Estvanik Taylor

What are the advantages of re-centering admissions in Kendall Square?

ss: Kendall Square has really become a new front door for MIT. MIT will essentially have two front doors now. The ability to add a visitors' center and the forum presentation area is the main driver of why we're moving over there—we've never had that before. Right now, we welcome prospective students here in Building 10, and then we say: OK, now you have to go to a classroom somewhere on campus to have your information session. In Kendall it's all going to be in one space. It'll be a much more seamless and coherent welcome for students and their families.

In fact, we're thinking about ways to be more welcoming to anyone who sets foot on campus. We've recently had a very large increase in the number of visitors. This year, approximately 45,000 people have taken our admissions information sessions and tours. Three years ago, we were at 30,000 and a decade ago we had less than 15,000. In addition to that, MIT does get many more visitors who don't interact with the admissions office—for example, tour buses come by—and in Kendall Square there's going to be more of that.

How will starting at the new front door change the campus tours?

ss: We already take visitors through the Stata Center and the Koch Institute [on the edge of Kendall Square] and we talk about the neighborhood, but not quite in the way that we'll be able to when we're starting from there. Standing in Kendall Square as an urban center, you really get a feel for the vibrancy of this place. The tour script will evolve. Right now, we do a loop, but maybe we will end in Lobby 7 instead of back in Kendall Square. Certainly, we will still want students, parents, and visitors to see the iconic dome from Killian Court. There's no substitute for that—that's a must!

When you're talking to prospective students, do you get a sense that there are parts of the MIT story they are hungry to learn more about?

ss: I think visitors generally know that cutting-edge research goes on here. They tend to be more surprised about the strength and warmth of the community—the people, the quality of life, the vibrancy. Our student tour guides do an incredible job of showing that to them. That's one of the reasons Killian Court is a great space—it has this sense of place and community—and I think in Kendall we will be able to tell that story even better.

PHOTO: COURTESY OF MIT NEWS

GUIDING PRINCIPLES

Mathieu Medina '21, a Course 10B (Chemical-Biological Engineering) major, served on the admissions office's full-time tour guide staff during summer 2018. When he talks to visitors about the culture of innovation at MIT, he says, he likes to point to examples such as the construction of the new MIT.nano cross-departmental research facility, or the Undergraduate Research Opportunities Program (UROP). By the time Medina graduates, guides like him will begin their tours in Kendall Square, itself a vivid illustration of MIT's innovation ecosystem. Some things, however, are unlikely to change: "I think the most important task the admissions office has in making visitors feel welcome and in leaving them with a 'real' sense of MIT is including the perspectives of all the types of people across our highly diverse campus and community," Medina says, adding that his favorite part of the job is "meeting the hundreds of guests we welcome from across the world and being able to interact with and learn more about them as I introduce them to the Institute through my experience." PHOTO: KEN RICHARDSON

The Long View

Inspired by the Infinite Corridor, the MIT Museum's spacious new home will connect visitors with the Institute's past, present, and future

A few years ago, while they were drafting a strategy to renovate the MIT Museum's nearly 50-year-old home on Massachusetts Avenue, J. Meejin Yoon and Eric Höweler were invited to tour the museum's warehouse on Tyler Street in Boston. The warehouse is a repository for the many holdings not on display at its public headquarters across the river.

"They brought us there to give us a sense of the depth and breadth of the collection," says Yoon, who became head of MIT's Department of Architecture in 2014 (she will depart MIT this January to become dean of the College of Architecture, Art and Planning at Cornell University). "And it worked. There was a vast array of objects across all scales. Hundreds of slide rules. Decades of scientific instruments. Incredible drawings. Mainframe computers. Aircraft models. It was like experiencing the continuum of innovation and MIT's contribution to it."

Future visitors to MIT will be able to share that exhilaration—"we have very ambitious plans for what we're going to exhibit," says John Durant, the Mark R. Epstein (Class of 1963) Director of the MIT Museum—but it won't be at the original location. Today, Höweler and Yoon are designing the interior architecture for a new MIT Museum, a 57,000-square-foot medley of galleries, classrooms, and state-of-the-art program spaces scheduled to open to the public in late 2021 on Main Street in bustling Kendall Square. (For more about the museum's place in the evolving landscape of Kendall Square, see page 8.)

The new MIT Museum will be a magnet for local community members, for academics and prospective students, and for visitors from around the world. In addition to showcasing MIT's unique contributions to technologies of all stripes and sizes—from engineering to architecture to aeronautics—the Kendall Square venue will also present current work from MIT students and faculty and include open education and research spaces that will expose the public to the unique spirit

A grand lobby (artist's rendering, above) will welcome visitors and provide seating for events, and a large public makerspace called the Idea Hub (below) will tie exhibitions to hands-on activities.

IMAGES: HÖWELER+YOON

of innovation that powers MIT. "We think of the museum as a meeting ground," says Durant—"a place for being stimulated by galleries and then having a chance to discuss and exchange ideas. That fundamental role will be reflected in the layout of the new space."

Visionary spirals

Yoon is intimately familiar with the nuances of creating spaces that convey MIT's culture. She designed the on-campus memorial for Officer Sean Collier, an MIT police officer who was slain in April 2013 in the aftermath of the Boston Marathon bombings. That project culminated in a solemn five-way arch built out of 32 massive granite blocks. The monument is intended to represent an open hand, a gesture that symbolizes MIT's commitment to a culture of accessibility, and to its community ties.

The MIT Museum project was less emotionally charged, but no less delicate. The architects had to shape a space that could transmit a sense of the Institute and its mission, this time not as a memorial, but as a threshold. Working closely with the MIT Museum staff, and in even closer collaboration with Höweler, who earlier in his career had helped design Boston's Institute of Contemporary Art, Yoon eventually crafted a design that reflects not only MIT's values, but its feel. "I began thinking about one of MIT's most significant spaces—the Infinite Corridor. It is a space that runs through so much of the MIT campus, touches so many departments, and connects Massachusetts Ave. with Kendall Square," says Yoon. "And that led me to think about how we might bring that element of MIT-ness—the element of circulation and connectedness—to the museum."

In Höweler and Yoon's plan for the new museum, the Infinite Corridor is transposed into a spiral that connects the ground level with gallery spaces, performance spaces, and curatorial and administrative offices above. Glass walls will mute the barrier between museum and street.

While the museum staff will be able to control the illumination in the exhibition areas, there will be ample daylight streaming into every corner.

"These elements erase the sharp distinctions between public and private, between visitors and curators, and between MIT and the surrounding community," says Yoon. "The new space will be organized in a way that makes sense for a 21st-century museum. It will enable the museum to be visionary, adaptable, and generous in telling the MIT story, in a way that the current space cannot do."

Old and new narratives

Telling that story—an amalgam of many stories—will animate every aspect of the MIT Museum's new home, from its architecture to its programming to its temporary and permanent exhibitions. "We intend to present objects and achievements in the context of a narrative that will illustrate key moments of MIT," says Ann Neumann, Director of Galleries and Exhibitions at the MIT Museum. "Through these narratives, we can begin to chart the discoveries made at MIT that are changing our understanding of ourselves, and of the world."

Neumann, who came to MIT three years ago specifically to develop an exhibition program for the new museum, concedes that MIT's breadth will compel her staff to be quite agile. "From one era, we can display robots and airplane wings, technologies we can see and touch," she explains. "But so many of our current innovations aren't tangible, in areas like artificial intelligence, life sciences, or nanotechnologies. We need to design spaces in the museum that can serve as platforms for interchangeable and faster-paced stories. We don't want to be constrained by traditional museum forms or themes."

Along with illustrating MIT's past, present, and future, Neumann intends for the new museum to serve as a center of learning and debate about the role of innovation and technology. "We aspire to be much more than a series of exhibition spaces," she says. "Our educational and public assembly spaces will offer a venue for visiting students and the general public to examine the impact of some of these technologies that MIT is helping to develop, and to ask what kinds of choices we as citizens need to make to create a better future." —Ken Shulman

Larger gallery spaces will enable the museum to display more of its vast holdings as well as to conceive new kinds of exhibitions.

IMAGE: HÖWELER+YOON

"So many of our current innovations aren't tangible," says Neumann. "We need to design spaces in the museum that can serve as platforms for interchangeable and faster-paced stories."

Life on Main Street

A new residence for grad students will offer community and connections in a hard-to-beat location

Without its more than 6,800 graduate students, MIT would not be MIT. Grad students keep the Institute's labs and classrooms humming, and are an essential part of the Institute's efforts to answer important, complex questions. One of the first questions they face when coming to MIT, however, is: Where will I live?

As Kendall Square comes into its own as a 24-7 innovation neighborhood, more students than ever will make it their home base for success. Among the structures rising in Kendall now is a new residence for the Institute's graduate student population. Under its roof will be roughly 450 units that will house (for the first time at MIT) a mix of single students, couples, and families. On the same site, MIT's new Innovation and Entrepreneurship Hub will offer the building's inhabitants immediate access to five floors packed with resources—including multi-use spaces, potential mentors, and likeminded innovators—that can help them deliver their ideas to the world (see page 20). And just beyond their doorstep, residents can traverse city blocks teeming with local centers of industry and research.

"Having these resources right next door will help bolster the connections that will be necessary to get a job once you graduate, and it helps you make better collaborations," says George Chao, a PhD candidate in the Harvard-MIT Program in Health Sciences and Technology, who served as co-chair of the Graduate Student Council Committee on Housing and Community Affairs in 2016–17 during a pivotal time for the planning of the new residence. Chao's own research is aimed at tissue engineering for transplantation. "You can't do six years of graduate school without being passionate about the topic you're researching," he says, "and when you encounter someone equally passionate about that topic, it gets the juices in your mind flowing."

Community and connections

While proximity to Kendall Square will be a major draw for the new building, connections students make down the hall could be just as important—as residents of other graduate housing can attest.

According to Eastgate residents Grace and Will Kimball—a married couple who came to Cambridge from Washington, DC, so Will could pursue his PhD at MIT Sloan's Institute for Work and Employment Research—grad students tend to have a different and in some ways more limited social experience at MIT than undergraduates. Coming from all stages of life and career, often they must balance their academic

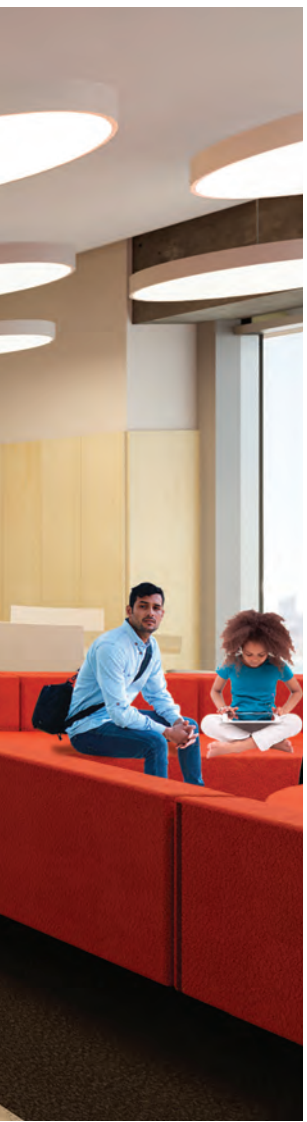
The new residence (artist's rendering) will include ample gathering spaces for events, such as educational programs for families (opposite, with Naomi Carton pictured at far left).

pursuits with a range of existing networks and commitments. The specialized nature of graduate study can make it harder to meet students outside their program. A large segment of MIT's graduate students—42% in the 2017–18 academic year—come from other countries and may face cultural and linguistic barriers; for their spouses, many with visa restrictions prohibiting employment, the sense of isolation can be even greater.

Residential life can help to overcome these issues, turning classmates into neighbors. "It's important to reach out and engage with our fellow residents in ways that might not happen through our academic work," says Will Kimball. To help promote such interactions, he and Grace recently assumed the role of Eastgate co-presidents. With the rest of the house team—which includes associate professor of biological engineering Katharina Ribbeck as head of house—they find ways to bring residents together to socialize, and to share struggles and successes.

"It's enriching and inspiring for me to see all these great minds living together," says Ribbeck, who feels that her experiences not only as a researcher but as a parent and international transplant "put me in a good position to mentor and motivate students." In the year since she moved into Eastgate, she has also recruited her colleagues to attend house brunches. "We had a physics professor help us make waffles for two hours," she recounts. "It exposed students to a faculty member in a nontypical situation and catalyzed interesting conversations."

MIT's associate dean of graduate residential education, Naomi Carton, spends much of her time planning educational and social activities that will enrich the lives of students and their families on campus. Cooking and exercise classes are popular programs, as are programs focused on cultural understanding and English as a second language. Among MIT's current graduate residences, Eastgate and Westgate serve another constituency: the more than 160 children who, with one or more parent enrolled at MIT, call this campus home. For them, offerings range from infant music classes to summer enrichment programs provided at a drastically lower cost than traditional camps.



"It's not always about the program as much as it's about the community," says Carton, who lives at Westgate with her own family. "It's about making students and their families feel that they're part of something bigger at MIT."

For this reason, Chao says that during the planning of the new Kendall Square residence, he and his housing committee co-chair Huma Gupta MCP '11, a PhD candidate in the Department of Architecture, advocated strongly for abundant gathering spaces. "We see how much that space is utilized in current dorms," he says. The new building's layout incorporates two floors of common areas, including quiet study rooms, a family lounge, a playroom adjacent to laundry facilities, terraces, and multipurpose rooms.

Quality of life, quality of work

Given the intense competition for desirable apartments in Boston and Cambridge, many graduate students look to MIT to provide a range of housing options. "Any progress toward meeting that need is important," Chao says.

Coming from DC and unsure where to begin their apartment hunt, the Kimballs gravitated to Eastgate as an affordable, low-risk option. They figured that, once familiar with the area, they might move off-campus; two years later, they're preparing to transfer with their new baby to a larger unit in the same building, which is perched at the edge of Kendall Square and just steps from MIT Sloan. "For us, it's a perfect location," says Grace, who is a staff member in the Department of Chemistry.

Like Eastgate, the new residence will be directly adjacent to public transit, and a quick scenic stroll across the Longfellow Bridge into Boston. In addition, the new building will offer students brand-new facilities with modern amenities, ranging from dishwashers in family apartments to air conditioning for all units, along with on-site childcare that will serve the entire Institute community. "These may seem like little things, but they make such a huge difference in quality of life," Chao observes.

Will Kimball, whose pre-MIT research dealt with work-life balance, is keenly aware of that dynamic. "A PhD program at MIT is tough and very demanding. To whatever extent our living situation can be as easy as possible and make it such that we can still have lives outside our work, that's an amazing opportunity," he says. Grace adds that their recent transition into parenthood was eased by the support of fellow Eastgate residents. "That makes our quality of life much better, in turn making the quality of work much better too, because there's less stress all around."

Whether they are concerned about the cost of housing or knowing their loved ones are happily settled, as Carton puts it: "When students know they can go home at night and everything there is all set, they don't have to worry about that aspect of life and it really allows them to focus on their work." To focus, in other words, on the questions and challenges that brought them to MIT in the first place.

And to bring their ideas and solutions to fruition—"to get to market and start benefiting people," as Chao puts it—there's no better place to be than Kendall Square. "It requires so many people," Chao says. "No one person can do it. Having all of these people in one place, people who can bridge each segment of the process, is huge."

—Nicole Estvanik Taylor

IMAGE: NADAAA

PHOTO: SARAH BASTILLE

Founders Forward

What's driving the new generation of biotech spinouts in Kendall Square?

As a graduate student at Harvard University in 1998, Angela Koehler recalls, she took the subway to attend a lecture at the Whitehead Institute. "You didn't want to get off the T at Kendall Square," she says. "I got lost among the parking lots and gravel pits, and it seemed dead."

Fast forward 20 years: Kendall Square is one of the hottest stops on the Red Line, a boomtown for biotech and other innovative industries. It's a transformation spurred not just by pharmaceutical industry giants like Novartis and Pfizer, but by MIT scientists and engineers like Koehler, the Goldblith Career Development Professor in Applied Biology in the Department of Biological Engineering, member of the Koch Institute for Integrative Cancer Research, and associate member of the Broad Institute of MIT and Harvard.

In 2017, Koehler cofounded Kronos Bio, which is developing tools to take on recalcitrant cancer targets. She is among a new wave of MIT faculty and researchers launching spinout companies a stone's throw from their academic laboratories.

"Kendall Square is the center of the universe when it comes to biomedical research," says Alec Nielsen PhD '17, CEO and cofounder of newly launched Asimov, a company designing microprocessor-like biological circuits for applications in food, materials, and therapeutics. The company, like Kronos Bio, is located in LabCentral, a 100,000-square-foot, nonprofit Kendall Square coworking facility that serves as a biotech launch pad. (Among LabCentral's cofounders is MIT alumnus and Cambridge Innovation Center CEO Tim Rowe MBA '95.)

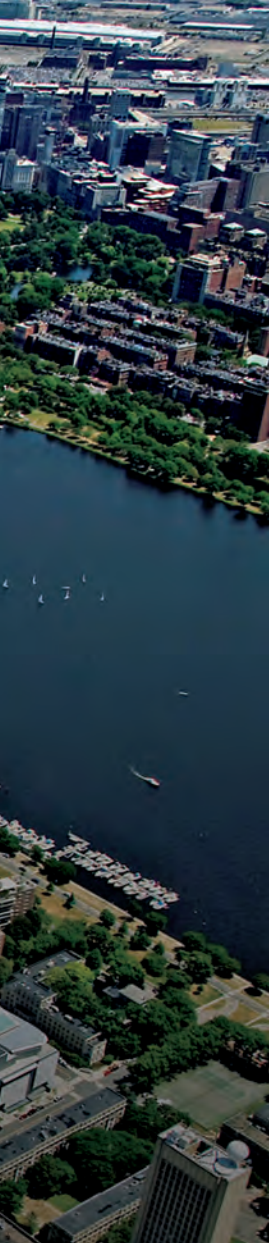
"You can feel something special here," says Nielsen, a research affiliate at the Department of Biological Engineering. "People are incredibly driven, working on ideas that are going to change the world, and they want to be in the middle of this nexus of innovation."

Even biotech business veterans appreciate the new energy: "Kendall Square feels like the Silicon Valley for biotech, and is certainly the place people and companies want to be," says David Bartel, professor of biology and member of the Whitehead Institute for Biomedical Research, and cofounder of Alnylam.

Seventeen years after its founding, with 750 employees, Alnylam might be considered middle-aged. "But we still have a startup culture," says Bartel. With tools based on RNA interference (RNAi), the company has just achieved commercial release of its first drug and is in late-stage trials for medicines to treat hemophilia and high cholesterol.

Alnylam can trace its lineage to Biogen, one of the very first biotechnology firms. Cofounded in 1978 by one of Bartel's fellow Alnylam cofounders, Institute Professor and Nobel Laureate Phillip A. Sharp, Biogen has focused on therapeutics for such diseases as multiple sclerosis, leukemia, and lymphoma. Today, it is a sprawling multinational with revenue upwards of $12 billion. But it still makes its home on Binney Street in Kendall Square.

A view over Kendall Square and the Charles River, toward Boston (2011).
PHOTO: LES VANTS



“We see ourselves as tool builders,” says Koehler, “running proof-of-concept experiments in an academic environment, and every once in a while, lightning strikes.”

From left: Alec Nielsen PhD ’17 and Raja Srinivas PhD ’17 are cofounders with MIT professor Christopher Voigt of biotech startup Asimov.

PHOTO: MONIQUE BROUILLETTE/ MIT TECHNOLOGY REVIEW

Limits of the lab

In an industry where surviving beyond the first year can be a challenge, Biogen’s success might appear a beacon for the latest generation of biotech founders. But according to MIT entrepreneurs, spinning out a startup is less an issue of reward than a matter of driving forward a mission.

“I didn’t have a burning desire to start a company,” says Bartel. “But our research suggested we could use our RNAi technology to block production of disease-causing proteins, and we saw that we couldn’t accomplish this in the context of an academic lab.”

Venture capital groups (VCs) also saw the potential, and encouraged the scientists to start a company, recalls Bartel. “They came to us and made it easy for us to continue our academic research and just focus on the science.”

The basic discoveries that gave rise to Alnylam involved the biochemical mechanisms behind the control of gene expression. In labs at MIT and elsewhere, Alnylam’s principals figured out how to harness a natural, biological pathway in which short RNA molecules target messenger RNAs producing proteins, including proteins that underlie a number of disorders.

“We were hoping this technology could be used to help patients with diseases for which there were no drugs available,” says Bartel, whose cofounders in addition to Sharp include Paul Schimmel PhD ’67, the John D. and Catherine T. MacArthur Professor of Biochemistry and Biophysics Emeritus at MIT, and former MIT postdocs Thomas Tuschl and Phillip Zamore. “And the scientists at Alnylam, who all share this dream, have begun to make it a reality.”

Alnylam’s therapeutics come in the form of synthetic RNA molecules that reduce the production of disease proteins. Designed to find their way into the liver—a production hub for proteins integral to regulating cholesterol, blood pressure, and other physiological processes—some of these drugs under development can knock down a disease-causing gene for three to six months. The company has just released Onpattro (patisiran), a drug that treats a rare disease involving protein buildup in organs—marking the first approval by the US Food and Drug Administration of a therapy based on RNAi.

A bolt from the blue

“What I’ve always cared about is coming up with a path to translate ideas and inventions from our group to the wider world via some vehicle,” says Koehler. “We see ourselves as tool builders, running proof-of-concept experiments in an academic environment, and every once in a while, lightning strikes.”

The research that galvanized the launch of Kronos Bio evolved over the course of a decade. Koehler, who is a founding member of the new MIT Center for Precision Cancer Medicine at the Koch Institute, had been working on a technology to help identify compounds that might interact with certain proteins. Using robotics, she could print minute

quantities of drug-like compounds, 10 to 20 thousand at a time, on a glass slide, and then analyze swiftly whether any of these compounds interacted with a protein of interest introduced onto the slide. The tool, called a small-molecule microarray (SMM), was essentially a drug screen on a chip.

"With this chemical probe discovery, we could look for pinches of magic dust that would modulate the function of the protein," she says.

But Koehler found an even neater twist on this technology. She could use her arrays to screen not just for any proteins, but for those most challenging from a drug discovery perspective, such as transcription factors, which determine when genes get turned on and off. A specific target of her work was MYC, a prolific oncoprotein associated with solid cancers and leukemias.

"MYC is like Bruce Banner," Koehler says. "It regulates normal cellular function but when something goes wrong, it turns into the Hulk, wreaking havoc in cells."

The platform Koehler designed could deliver high-throughput testing of hundreds of thousands of compounds with the potential to block MYC and other previously intractable targets, such as the androgen receptor, a transcription factor whose dysregulation can lead to prostate cancer. Recognizing the potential of this technology, big pharma companies and VCs came knocking.

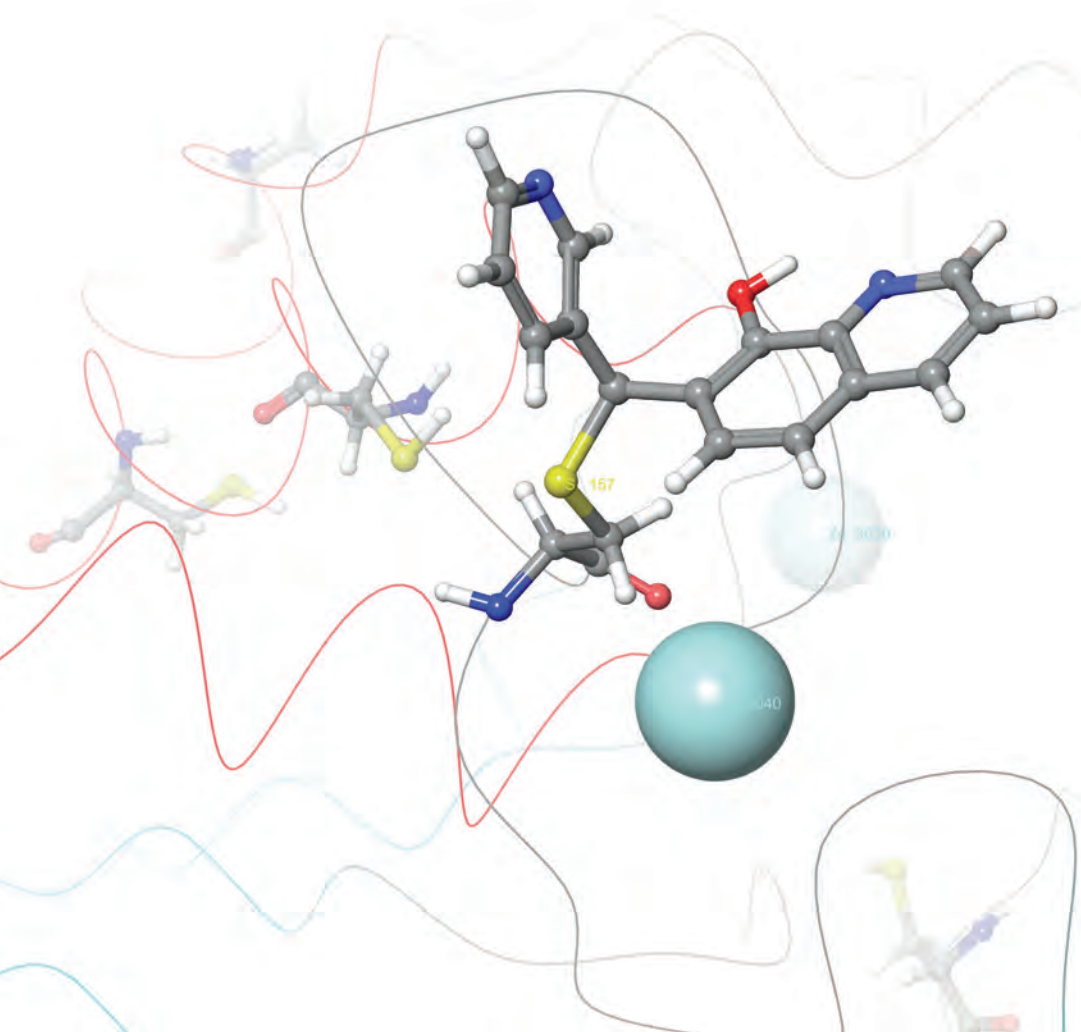
Uncertain of the best way to move her research forward toward real-world applications, Koehler applied for a grant from the MIT Deshpande Center for Technological Innovation. "Mentors there gave us critical advice on patents, hiring, the scope of what to commercialize, and what we needed to do on the academic side before discussions with outside funders," she says. "This kind of granular involvement, advice, and input really enabled me to think about translating my ideas."

Koehler also found "an MIT guy whose vision aligned with mine," she says. Chris Wilfong MBA '12, operating partner at the VC firm Two River, is now chief operating officer at Kronos Bio. Since settling into LabCentral space in late 2017, the company has moved swiftly to develop "hits" from Koehler's SMM platform into potential anticancer therapeutics.

"It's amazing to see how Kronos professionals wearing the hat of medicinal chemistry have advanced these compounds," says Koehler. "In just a couple of months, they've reached a stage that an academic lab could never have reached."

> A spinout "takes what starts as a crazy idea and sees it fully implemented, which frees you to pursue higher-risk research," Voigt says.

MORE ONLINE
A map of biotech in Kendall Square
spectrum.mit.edu/biotechfounders



Ideas that could change the world

For Christopher Voigt, the Daniel I.C. Wang Professor of Biological Engineering and cofounder of Asimov, a spinout can be liberating. "You take what starts as a crazy idea and see it fully implemented, which frees you to pursue higher-risk research," he says. "What might have been simply an academic paper can turn into something with impact."

Asimov's technology is a pathbreaking platform for computer-aided design of genetic circuits for the purpose of creating new biological constructs.

"We're the first to focus on design automation in biology, and no one else is doing anything like it," says Voigt. Where other companies might place genes into cells to make one product, or turn a single gene on or off, the Asimov platform "goes after the dynamics of gene expression, turning a sequence of genes on and off at certain times, in certain conditions," in a process that mirrors the way nature

PORTRAITS: GRETCHEN ERTL/WHITEHEAD INSTITUTE (BARTEL), MARIA NEMCHUK (KOEHLER), M. SCOTT BRAUER (VOIGT)

operates “to create complex structures, intricate materials, and delicate organisms,” he explains.

It is a singular, foundational toolkit that will make significant and wide-ranging impacts, predicts Alec Nielsen.

“We could engineer living cellular therapeutics and patrol the body for disease, or make smart plants that sense extreme climate change conditions like drought or cold and respond appropriately, or set up enzymatic assembly lines in cells to create complex molecules,” he says. “Our stance is that 50 years from now, every single new biotechnology will have engineered genetic circuits running.”

As a graduate student, Nielsen accompanied Voigt to MIT from the University of California, San Francisco, to pursue this work. A self-described technological optimist, Nielsen spent six years learning to harness the dynamics of gene expression and devising a programming language for cells much like that used to design circuits for semiconductors.

“On our platform, the cell boots up a sequence like a computer boots up software,” explains Nielsen. “The cell is now imbued with new functionality.”

The Voigt lab made a point of ensuring that the designs would work as expected, where the software could reliably design DNA that would function in the cell as simulations predicted. Having proven the efficacy of the platform, the researchers recognized that they had “reached the point in the life cycle where the idea required implementation,” in Voigt’s words. It was time to start a company.

Nielsen, who had earlier participated in the MIT $100K Entrepreneurship competition, took the leap. “In my mind, the question had always been what would be the best way to make a positive impact in the world through synthetic biology,” says Nielsen. “I had been focused on the academic track, but after a lot of soul searching, I felt confident a company would be the most impactful way to disseminate our ideas in the world.”

With funding and strategic guidance from the legendary Silicon Valley VC firm Andreessen Horowitz, CEO Nielsen, just two years out from receiving his doctorate, is rapidly staffing up and refining the design platform. Having recently inked the company’s first deals, Nielsen expresses near-boundless enthusiasm for Asimov technology.

“One hundred years from now a lot of the most interesting applications of engineered gene circuits will be things we can’t predict, in the same way it was impossible to imagine things like mobile phones or Instagram at the start of the semiconductor era,” says Nielsen. “I think it’s hard to overstate how important biotech will be this century.”

Nielsen already anticipates outgrowing his startup space. “We’ll soon be busting at the seams and will have to find our own headquarters,” he says. “We’re looking at Kendall, because it’s the place to be.” —Leda Zimmerman

Opposite: A compound discovered in the Koehler lab using a high-throughput binding assay involving small-molecule microarrays.

IMAGE: COURTESY OF THE KOEHLER LAB

Kendall’s Key Ingredient

Kendall Square in the 1970s was desolate, effusing the smells of oil and boiling rubber from its waning industrial factories. Add to that the ongoing controversy in Cambridge over the use of recombinant DNA (rDNA)—which had some city officials calling for an outright ban on genetic research—and Kendall seemed like an unlikely place to launch a biotech revolution in the next decade.

But the neighborhood had one thing going for it: people. More specifically, proximity to the right people, says Robin Wolfe Scheffler, the Leo Marx Career Development Professor in the History and Culture of Science and Technology at MIT. To a greater extent than the more established electronics industry, Scheffler says, biotech required a highly specialized researcher, with a PhD in molecular biology and probably a postdoc as well. “That’s the kind of expertise that only a few hundred people initially had.” With the uncertainty over whether the industry would take off, they wanted to stay close to their academic lab connections at MIT or Harvard, pulling companies such as Biogen to Kendall Square.

These dynamics are at the center of Scheffler’s current research on the early history of biotech, which he is pursuing with support from the 2018 James A. (1945) and Ruth Levitan Prize in the Humanities. “It’s fascinating that these factors of lifestyle and academic stability combine to counterbalance all of the other reasons why a biotech company might want to go as far as possible away from Cambridge,” says Scheffler. “It makes it much more complicated than a simple economic analysis would suggest.” Even apparent weaknesses eventually became strengths: Kendall’s abandoned industrial infrastructure provided ample room for expanding companies, and the eventual rDNA regulations gave predictability to companies in their relationship with local government, says Scheffler. By the time big drug companies began moving into Kendall in the late 1990s, its status as a biotech hub was assured.

For his project, Scheffler is plumbing unusual sources to uncover Kendall’s past, for example, examining sewer records from the Cambridge Public Health Commission to learn about how early labs were set up. He is also making ample use of MIT’s Recombinant DNA History Collection, which contains oral histories from the time, and hopes to add to MIT’s archives with oral histories of his own—from not just top-name scientists in biotech, but also support staff who were crucial to the field’s success. His goal is to understand how seemingly small decisions by individuals tipped the scales for an underdog neighborhood like Kendall Square.

“It’s a snowball effect,” Scheffler says. “The initial differences may not have been great, but by the time the process has developed over a generation, they become immense, and a sort of inevitability builds. I am interested in unpacking how that set of advantages develops over time.” —Michael Blanding

PHOTO: JONATHAN SACHS/ SCHOOL OF HUMANITIES, ARTS, AND SOCIAL SCIENCES

Running Start

Students who hatch their companies at MIT are well-positioned for impact

In his 2013 charge to the newly formed MIT Innovation Initiative, MIT President L. Rafael Reif wrote: "The Innovation Initiative will amplify the MIT community's powers of innovation and our passion for progress. By focusing on innovations, not simply ideas, and by emphasizing the importance of impact and the challenge of delivering at scale, we will expose our students to demanding, inspiring activities all along the innovation chain, in contexts from the developing world to industry."

Five years later, a headquarters for that initiative is under construction in Kendall Square. The Innovation and Entrepreneurship Hub will occupy the top five floors of the new E38 with multiuse spaces for student makers and entrepreneurs, researchers, and staff. Several of MIT's flagship entrepreneurship programs will move into the building, including the Legatum Center for Development and Entrepreneurship, the Translational Fellows Program, Project Manus, the MIT Deshpande Center for Technological Innovation, and MIT Sandbox. Centralizing such programs will accelerate the journey of aspiring MIT entrepreneurs.

Of course, students aren't waiting for the grand opening of this new facility to take advantage of the Institute's array of innovation resources—those listed above, along with many others both formal and informal across campus. Here are examples of how some of MIT's many student founder teams have charted their own paths from concept to startup.

(↗)
SEE MORE
Track student startups
from idea to impact
innovation.mit.edu/all-pathways

Throughout their time at MIT, students are encouraged to team up and pursue innovative ideas. Pictured at top: Jessica Shi '17 (left) and Charlene Xia '17 work during their senior year on a prototype for Tactile, a portable real-time text-to-Braille converter. With four fellow cofounders from the Class of 2017, they are now beta testing their device in Boston.

PHOTO: LILLIE PAQUETTE/SCHOOL OF ENGINEERING

Yellowstone Energy

MIT founders

MATTHEW ELLIS PHD '17
(Nuclear Science and Engineering)

SAMUEL SHANER SM '14, PHD '18
(Nuclear Science and Engineering)

Mission

Yellowstone Energy is developing an advanced nuclear reactor designed to exploit the existing nuclear supply chain for quick and cost-effective deployment.

Status

The startup filed for patent protection in January for its key technical innovation: a novel reactor control technology that enhances passive safety and reduces costs for their molten salt reactor. In June, Yellowstone received almost $2.6 million from the Department of Energy's Advanced Research Projects Agency-Energy program. Its next steps will be creating a detailed computational model for the plant and beginning experiments on key components.

MIT pathway

Yellowstone Energy is an outgrowth of Shaner's time as a 2015 MIT Energy Fellow. Through the **MIT ENERGY INITIATIVE (MITEI)**, he received a year of funding from Exxon-Mobil to examine challenges in the nuclear supply chain—and found a need to fill.

"I looked at the landscape of new reactors and saw that everyone wants to use the new fuel form," he says. Most advanced reactor designs rely on new material compositions and/or fuel that is between 5% and 20% Uranium-235—a more highly enriched fuel than is typically used today.

"While the new material compositions and higher enrichments enable compelling reactor designs, the commercial supply chains required to produce these new fuel forms are incomplete and would require significant time and investment to construct," Shaner says.

To shorten development time and cut costs, Shaner joined with Ellis to develop a molten nitrate salt reactor that takes advantage of the existing supply chain by using uranium oxide fuel that is less than 5% enriched. Yellowstone Energy was born.

In December 2016, **MIT SANDBOX** awarded the company $25,000, which enabled it to file its first provisional patent. Shaner says the team

PHOTO (ELLIS AND SHANER): OAK RIDGE NATIONAL LABORATORY, US DEPT OF ENERGY

received valuable feedback from Sandbox mentors, as well as the **MIT VENTURE MENTORING SERVICE.**

Even before Yellowstone Energy, "MIT provided me with a great breadth and depth of opportunities to prepare me for starting a new clean energy venture," Shaner says. For example, in fall 2012, he took **15.366 MIT ENERGY VENTURES**, a class focused on creating energy companies, and he served as co-managing director of the 2013 **MIT CLEAN ENERGY PRIZE.**

Advice for fellow student entrepreneurs

"The entrepreneurial support system of MIT goes beyond your diploma date," says Ellis.

Shaner agrees: "Don't be afraid to reach out to other founders and other members of the community. We've been pleasantly surprised by the generosity and support we've received—not only from our professors, but from the broader MIT engineering and entrepreneurship community, as well as from MIT alumni."

—Kathryn M. O'Neill

"MIT provided me with a great breadth and depth of opportunities to prepare me for starting a new clean energy venture," Shaner says.

Ellis, left, and Shaner

Biobot Analytics

Ghaeli, left, and Matus

MIT founders

NEWSHA GHAELI, former MIT research fellow

MARIANA G. MATUS PHD '18
(Computational and Systems Biology)

Mission

A stream of data flows beneath our feet. In city pipes, raw sewage carries microscopic information on residents' health, in the form of gut microbes and chemical compounds—traces of food and drugs—we as a society are constantly excreting. Biobot Analytics seeks to harness this data stream by deploying robots into the depths of the sewer, constantly sampling the city like a doctor closely monitoring the health of a patient. "We see wastewater as being such a rich resource—and it's currently untapped," says Matus. "Our vision and our mission is to promote a more data-driven response to public health and government policy making."

Status

Biobot is focused on growth. The company has five full-time employees, including an expert in spatial epidemiology, Noriko Endo SM '14, PhD '17. The Somerville-based company is working with its first city partner: Cary, North Carolina. There, the team is deploying robots in 10 locations to measure opioid drug metabolites as part of the city's efforts to monitor and address its opioid crisis. The city will leverage the data to evaluate the success of intervention programs.

The project in Cary is just the beginning of what the company hopes to accomplish. "We see this technology being implemented in every city around the world," says Ghaeli.

MIT pathway

The startup began in 2014 as the Underworlds research project, the brainchild of MIT faculty members Eric Alm of the **DEPARTMENT OF BIOLOGICAL ENGINEERING** and Carlo Ratti of the **DEPARTMENT OF URBAN STUDIES AND PLANNING**. Matus, then a graduate student in Alm's lab, and Ghaeli, a research fellow in Ratti's group, led the interdisciplinary project, which garnered a $4 million grant from the **KUWAIT-MIT CENTER FOR NATURAL RESOURCES AND THE ENVIRONMENT** and grew to include 20 researchers from six different labs across MIT.

On its way to launching, Biobot participated in numerous MIT programs, including the **MIT $100K COMPETITION**, **MIT FUSE**, **DESIGNX**, the **SANDBOX INNOVATION FUND PROGRAM**, **MIT IDEAS GLOBAL CHALLENGE**, **MIT WATER INNOVATION PRIZE**, and the **DELTA V** accelerator at the **MARTIN TRUST CENTER FOR MIT ENTREPRENEURSHIP.**

Through all these experiences, the resource that has made the biggest difference to Biobot, says Ghaeli, is the MIT network. Sandbox director Jinane Abounadi SM '90, PhD '98 encouraged Ghaeli and Matus and put them in touch with other MIT staff, including School of Engineering Dean Anantha Chandrakasan. That led to broader opportunities, such as an invitation for Matus to present Biobot to Canadian Prime Minister Justin Trudeau during his visit to the Institute in May of this year.

"That's the main reason for us to move back to Boston—to stay within this ecosystem," Ghaeli says. "It's been such a huge benefit to us."

Advice for fellow student entrepreneurs

"Take advantage of all the resources on campus," Matus says. "They help you think and refine your ideas, and along the way, you'll meet people you'll stay connected with through your entire entrepreneurial journey." In 2015, when the team pitched Biobot's business concept at the $100K competition, they didn't know that, listening in the audience, was someone who would become a mentor and supporter—and, 10 months later, their first investor. —Alison F. Takemura PhD '15

PHOTO (GHAELI AND MATUS): COURTESY OF BIOBOT


Alawode


Bhattacharyya

dot Learn

MIT founders

TUNDE ALAWODE SM '15, PHD '17 (Mechanical Engineering)

SAM BHATTACHARYYA MBA '16

Mission

Dot Learn's consistent goal has been to make online video learning accessible in the developing world, but its approach has shifted. Originally, the founders started an online learning platform that was geared toward students in Sub-Saharan Africa, but they've evolved their focus to provide software that compresses educational videos. They can package an hour of video in as little as 1MB, about 100 times smaller than the average YouTube video, and deliver content to areas where data accessibility is an issue.

Status

Educational providers like Coursera and Khan Academy as well as companies in the developing world have already approached dot Learn about working together. The video compression technology is being developed now, and the founders hope to begin rolling it out to companies in late 2018. In the next year, Bhattacharyya and Alawode hope to address issues of scaling the business, with the aim that dot Learn will help to provide data-light online learning to 50 million students by 2022.

A development ventures class showed Bhattacharyya "I wasn't crazy—this was a path others were following and this is something I could do, too."

MIT pathway

Alawode and Bhattacharyya met in 2015 in **MIT D-LAB'S DEVELOPMENT VENTURES** class. Bhattacharyya felt driven to address global education inequality after working in the Peace Corps, and Alawode shared that passion.

After that class, the founders entered the **$100K ENTREPRENEURSHIP COMPETITION**. The **LEGATUM CENTER FOR DEVELOPMENT AND ENTREPRENEURSHIP**, **D-LAB**, and **MIT-AFRICA INITIATIVE** all provided financial support, and through the **MIT-AFRICA PROGRAM AT MIT INTERNATIONAL SCIENCE AND TECHNOLOGY INITIATIVES (MISTI)** they were able to perform market research directly in Ghana. Bhattacharyya and Alawode received an award from the **MIT IDEAS GLOBAL CHALLENGE** and the **MIT INCLUSIVE INNOVATION CHALLENGE**, and further developed their ideas through **MIT SANDBOX** and the **TRUST CENTER**'s **DELTA V** accelerator.

Bhattacharyya credits the combination of all of these resources for dot Learn's progress. Early on, the D-Lab class in which he met Alawode "helped me learn that I wasn't crazy—this was a path others were following, and this is something I could do, too," he recounts. Further along their road, the delta v accelerator helped to focus their energy in a new way. "For the first time, I had the full day to work on the project. I thought, 'This is my job now.' It was amazing," he recounts. Even now, after graduation, MIT mentors have continued to help him and Alawode as they build, shift, and scale.

Advice for fellow student entrepreneurs

"Entrepreneurship is like running a marathon through a maze," says Bhattacharyya. "To get this far and keep going requires persistence, extreme optimism, and a nearly compulsive paranoia." But he insists that the perseverance and grit pay off: "If you're truly passionate to spend the next 5 to 10 years working on your idea, keep going. You'll make it happen." —Katherine J. Igoe

PHOTOS: TECH CRUNCH (ALAWODE); DOT LEARN (BHATTACHARYYA)

Bloomer Tech

MIT founders

ALICIA CHONG RODRIGUEZ SM '18 (Electrical Engineering and Computer Science, Integrated Design and Management)

ACEIL HALABY SM '17 (Integrated Design and Management)

Mission

"Our mission is to transform everyday clothing to manage chronic disease. Heart disease is the number-one killer for women. Women wear bras. We thought the idea was very obvious," says Halaby. Washable sensors, comfortably embedded in undergarments, continuously track cardiac behavior and connect to an app via Bluetooth, so users can monitor their health in real time and share it with their physician.

Bloomer aims to take the guesswork out of cardiovascular health, especially for women feeling symptomatic or recovering from cardiac events. Sensors analyze important metrics such as heart rate variability, respiratory rates, and heart rhythms. They can detect irregularities, such as an arrhythmia, and alert doctors to take preemptive action. An app provides interactive tools to help women modify behavior based on this personalized data, and they can opt for emailed personal reports.

From left, Chong Rodriguez, Abarca, and Halaby

PHOTO: TONY LUONG

Status

Today, along with third cofounder Monica Abarca, Chong Rodriguez and Halaby are collaborating with cardiologists to provide relevant information, and running clinical trials to ensure medical-grade quality, comfort, accuracy, and washability of the device. They aim to bring it to market in 2019.

MIT pathway

MIT played an instrumental role in Bloomer's launch, says Halaby. "We got access to a lot of resources with MIT programs," she notes.

MISTI enabled them to conduct primary market research in Peru and India. The **SANDBOX INNOVATION FUND** provided the team with $25,000, which they put toward building prototypes and initial product and market testing. The **LEGATUM CENTER** also fueled the launch. "Legatum provided us funds for travel and prototyping. It also provided mentorship, entrepreneurship workshops, and a strong network of impact-driven founders," Halaby says.

Additional product development was done on campus at the **MIT MEDIA LAB**, **INSTITUTE FOR MEDICAL ENGINEERING AND SCIENCE**, and **INTERNATIONAL DESIGN CENTER**. The team also completed **MIT KICKSTART** (now the **MIT ENTREPRENEURSHIP AND MAKER SKILLS INTEGRATOR**), an immersive hardware boot camp at the **MIT HONG KONG INNOVATION NODE**.

Participation in the **DELTA V** accelerator at the **TRUST CENTER** later allowed them to refine their business model, build a staff, and take risks in a supportive space. "We basically lived there," Halaby says. "We had a strong network of mentors, and we were able to dedicate ourselves full-time to exploring what our business could be. We could be fearless."

They also learned real-world business lessons.

"We got our first slap in the face when we realized it was probably too early for interns," Halaby says with a laugh.

Professors also provided practical advice—particularly Matt Kressy, director of the **INTEGRATED DESIGN AND MANAGEMENT** program, and Collin Stultz, a principal investigator and cardiologist in the **RESEARCH LABORATORY OF ELECTRONICS**, under whom Chong Rodriguez wrote her thesis about female-specific computationally generated cardiac biomarkers.

"We were working with professors who are very experienced in this field and industry, so we were able to get a successful framework to implement prototypes and analyze software and business strategy," Halaby says.

Advice for fellow student entrepreneurs

"Don't be afraid of failure, and don't try to do anything alone," Halaby says. Thanks to MIT's resources, she adds, Bloomer didn't have to. —Kara Baskin

Breakthroughs and Insights

LIKE THIS WORLD OF OURS

An MIT science writer traces the hunt for extrasolar planets

Adapted from chapter 10 of Dispatches from Planet 3: 32 (Brief) Tales on the Solar System, the Milky Way, and Beyond, *by Marcia Bartusiak, a faculty member in MIT's School of Arts, Humanities, and Social Sciences (Yale University Press, 2018).*

In 2017 an international team of astronomers [including a scientist from MIT; see sidebar, page 27] thrillingly revealed, after examining a collection of data gathered by both NASA's Spitzer Space Telescope and an array of telescopes around the world, that they had found an extrasolar planetary system with at least seven members—all roughly the size of the Earth. These newfound celestial bodies were closely circling a red, Jupiter-sized star known as TRAPPIST-1. The star had been named after the TRAnsiting Planets and PlanetesImals Small Telescope network in Chile and Morocco, which first encountered this extrasolar system. At least three of TRAPPIST-1's rocky planets are likely to harbor liquid water, but so could all seven.

An artist's illustration of the possible surface appearances of some of the Earth-size planets of TRAPPIST-1, based on properties calculated as of February 2018.

IMAGE: NASA/JPL-CALTECH/R. HURT, T. PYLE (IPAC)

More exciting is that these terrestrial-like worlds are located a relatively scant 39 light-years away in the direction of the Aquarius constellation. In cosmic terms, that's practically next door. Such proximity will allow astronomers to achieve one of their fondest dreams: eventually using current and future telescopes to study the planets' atmospheres in search of gases conducive to life, such as oxygen, ozone, and carbon dioxide.

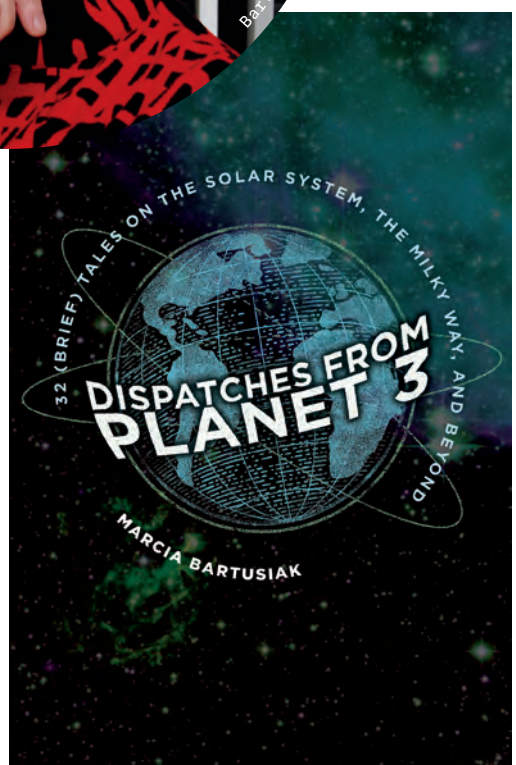
According to the Extrasolar Planets Encyclopedia, the number of extrasolar planets so far revealed in our galaxy now totals in the thousands. The TRAPPIST system was only one of the latest finds in the burgeoning field of exoplanetary astronomy. But speculation that planetary systems circle other stars started long, long ago—in ancient times. In the fourth century BCE, the Greek philosopher Epicurus, in a letter to his student Herodotus, surmised that there are "infinite worlds both like and unlike this world of ours." As he believed in an infinite number of atoms careening through the cosmos, it only seemed logical that they'd ultimately construct limitless other worlds.

The noted 18th-century astronomer William Herschel, too, conjectured that every star might be accompanied by its own band of planets but figured they could "never be perceived by us on account of the faintness of light." He knew that a planet, visible only by reflected light, would be lost in the glare of its sun when viewed from afar.

But astronomers eventually realized that a planet might be detected by its gravitational pull on a star, causing the star to systematically wobble like an unbalanced tire as it moves through the galaxy. Starting in 1938, Peter van de Kamp at Swarthmore College spent decades regularly photographing Barnard's star, a faint red dwarf star located six light-years away that shifts its position in the celestial sky by the width of the Moon every 180 years, faster than any other star. By the 1960s, van de Kamp got worldwide attention when he announced that he did detect a wobble, which seemed to indicate that at least one planet was tagging along in the star's journey. But by 1973, once Allegheny Observatory astronomer George Gatewood and Heinrich Eichhorn of the University of Florida failed to confirm the Barnard-star finding with their own, more sensitive photographic survey, van de Kamp's celebrated claim of detecting the first extrasolar planet disappeared from the history books.

The wobble technique lived on, however, in another fashion. Astronomers began focusing on how a stellar wobble would affect the star's light. When a star is tugged radially toward the Earth by a planetary companion, the stellar light waves get compressed—that is, made shorter—and thus shifted toward the blue end of the electromagnetic spectrum. When pulled away by a gravitational tug, the waves are extended and shifted the other way, toward the red end of the spectrum. Over time, these periodic changes in the star's light can become discernible, revealing how fast the star is moving back and forth due to planetary tugs.

In 1979, University of British Columbia astronomers Bruce Campbell and Gordon Walker pioneered a way to detect velocity changes as small as a dozen meters a second, sensitive enough for extrasolar planet hunting to begin in earnest. Constantly improving their equipment, planet hunters were even more encouraged in 1983 and 1984 by two momentous events: the Infrared Astronomical Satellite (IRAS) began seeing circumstellar material surrounding several stars in our galaxy; and optical astronomers, taking a special image of the dwarf star Beta Pictoris, revealed an edge-on disk that extends from the star for some 37 billion miles (60 billion kilometers). It was the first striking evidence of planetary systems in the making, suggesting that such systems might be common after all.



About the author and the MIT Graduate Program in Science Writing

Marcia Bartusiak is professor of the practice in MIT's Graduate Program in Science Writing (GPSW), based in the School of Humanities, Arts, and Social Sciences. Since 2002, the program has provided a unique home within a world-class research university for some of the nation's most distinguished journalists, authors, and scholars working to advance the public understanding of science, medicine, engineering, and technology. GPSW trains humanistic writers—with one foot in the sciences and the other in the arts—to probe the values and practices of science and technology, and to narrow the gap in modern society between citizens and wielders of scientific expertise.

Combining her training as a journalist with a graduate degree in physics, Bartusiak has been covering the fields of astronomy and physics for more than three decades. Her six previous books include *The Day We Found the Universe*, which received the History of Science Society's 2010 Davis Prize for best history of science book for the public; and *Einstein's Unfinished Symphony*, a chronicle of the international attempt to detect cosmic gravity waves, which was updated in light of new discoveries and republished in the summer of 2017. In 2006 Bartusiak received the prestigious Gemant Award from the American Institute of Physics, and in 2008 was elected a Fellow of the American Association for the Advancement of Science for "exceptionally clear communication of the rich history, the intricate nature, and the modern practice of astronomy to the public at large."

The first indication of an actual planet orbiting another star arrived unexpectedly and within an unusual environment. In 1991, radio astronomers Alex Wolszczan and Dale Frail, while searching for millisecond pulsars at the Arecibo Observatory in Puerto Rico, saw systematic variations in the beeping of pulsar B1257+12, which suggested that three bodies were orbiting the neutron star. Rotating extremely fast, millisecond pulsars are spun up by accreting matter from a stellar companion. So, this system, reported Wolszczan and Frail, "probably consists of 'second generation' planets created at or after the end of the pulsar's binary history."

The principal goal for extrasolar planet hunters, though, was finding evidence for "first generation" planets around stars like our Sun—planets that formed from the stellar nebula itself as a newborn star is created. That long-anticipated event at last occurred in 1994 when Geneva Observatory astronomers Michel Mayor and Didier Queloz, working from the Haute-Provence Observatory in southern France, discerned the presence of an object similar to Jupiter orbiting 51 Pegasi, a sunlike star 45 light-years distant in the constellation Pegasus. They first revealed their discovery at a conference in Florence, Italy, and their fellow astronomers declared it a "spectacular detection." Unlike our own solar system, this extrasolar planet is located a mere four and a half million miles (seven million kilometers) from its star (far closer than Mercury is to our Sun) and completes one orbit every four days. Planet hunters had assumed it would take years of collecting data before detecting the subtle and gradual stellar wobbles caused by a planet orbiting its parent star, but the small orbit of 51 Pegasi b enabled them to spot its variations quickly.

Other discoveries followed swiftly. Astronomers found even bigger planets, some many times the mass of Jupiter, closely circling their parent stars. These finds challenged theorists, who had not imagined giant planets with eccentric orbits so close to their sun. These unusual planets, though, were quickly overshadowed by the discovery of a large planet orbiting 47 Ursae Majoris at a more distant 200 million miles (around 320 million kilometers). This companion of 47 Ursae Majoris thus gained special distinction for being more "reminiscent of solar system planets." And by 1999, scientists started to find extrasolar systems with multiple planets.

> These terrestrial-like worlds are located a relatively scant 39 light-years away. In cosmic terms, that's practically next door.

The floodgates were opened, and over the succeeding years thousands of exoplanets were (and continue to be) found. While at first only the biggest exoplanets were revealed (as it was easier to detect them), improved technologies and additional planet-hunting methods at last enabled the discovery of smaller exoplanets, including Earth-like planets like those in the TRAPPIST system. Space-based missions, such as the Kepler space telescope, were especially productive in spotting these extrasolar planetary systems. "We've gone from the early days of thinking maybe there are five or ten other planets out there, to realizing almost every star next to us might have a planet," says astronomer Jennifer Burt at MIT's Kavli Institute for Astrophysics and Space Research. Indeed, one team of astronomers in 2012 estimated that there might be one or more planets orbiting each and every Milky Way star. That means at least 200 billion potential homes for ET to call. —Marcia Bartusiak

PHOTO: ELISE CHEN

The Search Continues

In February 2017, Julien de Wit PhD '14 was a member of the international team, led by University of Liège colleague Michaël Gillon, that announced the discovery of seven temperate Earth-sized planets orbiting the red dwarf star TRAPPIST-1. Soon afterward, the team found evidence bolstering the supposition that the outer planets in the system could hold significant stores of water. "It's amazing how quickly our perspective on this [system] has changed," de Wit—then a postdoc in the group of Sara Seager, Class of 1941 Professor of Physics and Planetary Science—told MIT News in 2017. "It's a steep learning curve that is really exciting." In July 2018, de Wit began a faculty appointment as assistant professor in MIT's Department of Earth, Atmospheric, and Planetary Sciences (EAPS).

De Wit now leads the effort to characterize the atmospheres of the newly discovered TRAPPIST-1 planets. So far, using the Hubble Space Telescope, his team has ruled out the presence of hydrogen-dominated atmospheres (which would be typical of inhospitable, gaseous planets such as Neptune) for the five innermost planets of the system. These results strengthen the case that Earthlike conditions could potentially exist within the system, and lay the groundwork for more targeted observations via NASA's James Webb Space Telescope, scheduled to launch in 2021.

De Wit is also involved in the effort to establish an observatory in the Northern Hemisphere (part of a project whimsically dubbed SPECULOOS, after a popular cookie from de Wit's native Belgium). This new network of telescopes will expand upon the TRAPPIST prototype, continuing the search for new potentially habitable systems.

According to de Wit, "The door now stands open to expanding our understanding of planetary systems, habitats, life, and ultimately our own planet, through the discovery and study of new terrestrial exoplanets that can be characterized in-depth. This has the potential to be paradigm-shifting." —Nicole Estvanik Taylor

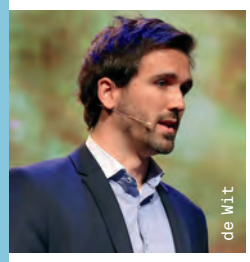


PHOTO: DAVID SILVERMAN

Down to Earth

How can technologies invented for space advance sustainable development goals?

There was a moment last April when Danielle Wood ’05, SM ’08, PhD ’12 could go no farther. In her research she often looks toward the cosmos, but on this day, she was confronted by an earthbound obstacle: if she and her companions pushed their motorboat ahead, the outboard engine would strangle itself on a thick tangle of roots, stems, and leaves. Open blue water should have rippled before her, “but instead it was fully green,” says Wood, one of MIT’s newest faculty members. A thick mat of water hyacinth was choking this section of the So River in the West African country of Benin.

An invasive species from the other side of the world, the plant is wreaking havoc across the waterways of Africa. “It creates areas of standing water that allow mosquitos to breed and spread disease,” Wood says. “And it also blocks fishing, boating, and other economic activities.”

Wood, whose background includes satellite design, systems engineering, and technology policy, traveled to the coastal city of Cotonou to meet with Beninese entrepreneur Fohla Mouftaou, cofounder of Green Keeper Africa, which has a creative approach to managing the water hyacinth. The startup pays community members to harvest the plant and converts it into an absorbent fiber called GK-SORB that removes oil-based waste. Green Keeper Africa delivers GK-SORB kits to West African companies who use them to clean small and large oil spills, and then it collects the used kits for proper disposal.

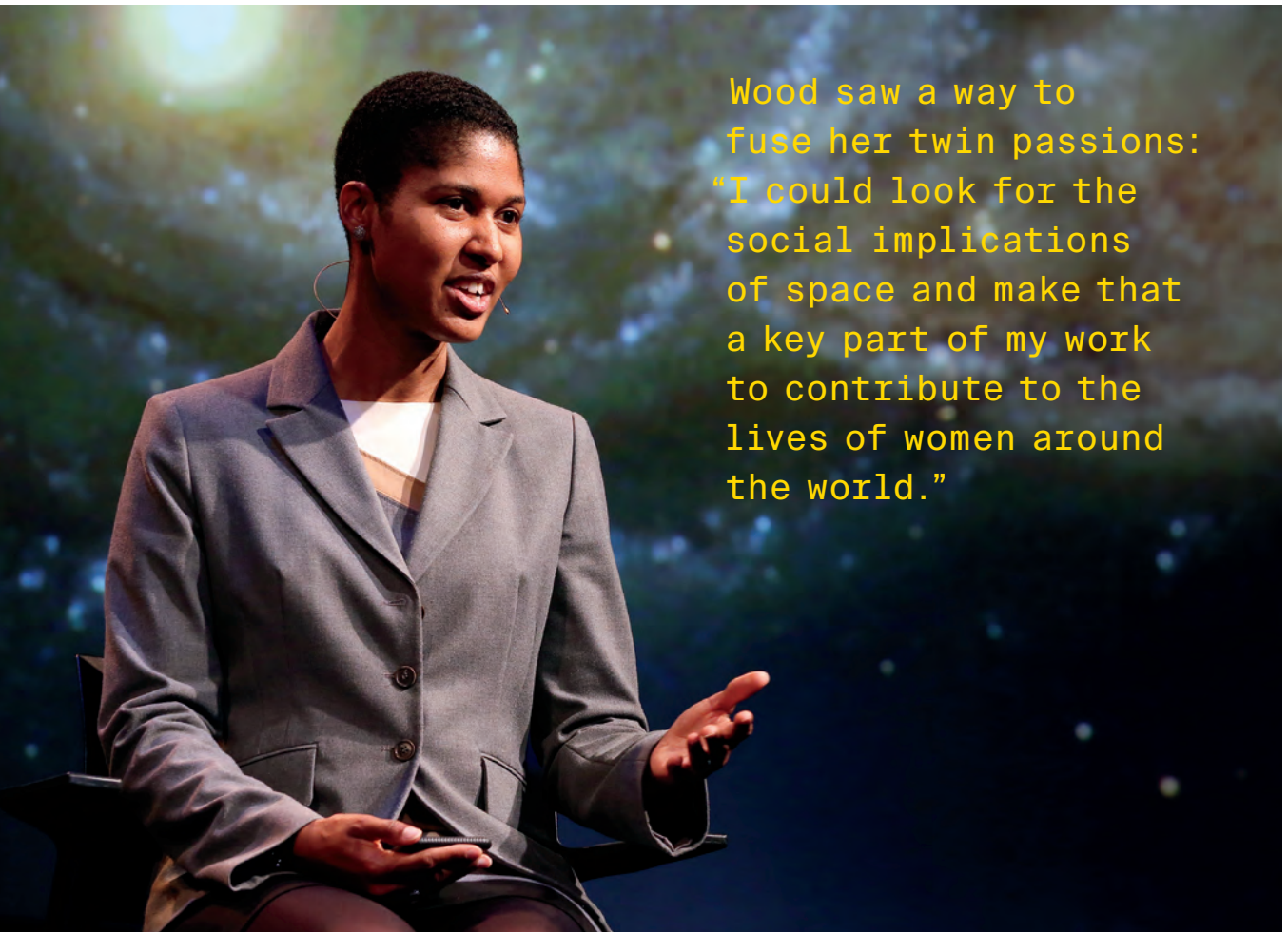
It’s an innovative solution, but there’s a problem: it’s difficult to predict where the water hyacinth will be on any given day. Human behavior and a changing climate are causing it to grow in nonseasonal patterns. So Wood and her team are collaborating with Mouftaou and Green Keeper Africa to design a network of water monitoring sensors and use data from NASA and private satellites to track the plant’s location. They’re also developing computer models that consider environmental data and simulate the potential consequences of various community interactions with the plant.

“We are outsiders—it’s actually not up to us to change this issue,” Wood says. “Our method will be to ask people in the community, ‘What do you think should be done?’” She and her team can then suggest new technology designs in response to that input.

These efforts are just one example of Wood’s work as director of the new Space Enabled research group at MIT’s Media Lab. She uses technology and designs from space (like satellites, life support technology, and information management tools) to empower countries to achieve the United Nations’ 17 Sustainable Development Goals, including ending extreme poverty and providing universal access to food, water, energy, and health care.

For Wood, it’s a matter of advancing justice, helping to correct an unequal distribution of technology and opportunity reinforced by centuries of “racism, colonialism, and imperialism.” In high school, she recognized “it’s hard to be a black woman in the world—something that’s actually been true for most of history.” She cites gaps in performance achievements, salary rates, and health care statistics for black women in the United States. She says, “Although black women throughout history have found clever and resourceful ways to thrive, we continue to overcome a double legacy of racial and gender discrimination.” For a while, Wood separately cultivated her love of space and engineering (by interning, for example, at NASA’s Kennedy Space Center as a 17 year old) and her commitment to social justice (by traveling annually, for instance, to Kenya to volunteer at a school for girls from one of Nairobi’s low-income communities).

Later, when Wood learned about efforts using NASA satellite data to address real-world environmental issues, she saw a way to fuse her twin passions. “I could look for the social implications of space and make that a key part of my work to contribute to the lives of women around the world,” she says. Through Space Enabled, she now has a platform to collaborate with development leaders as they use technology, policy, and design to move their communities forward. —Ari Daniel PhD ’08

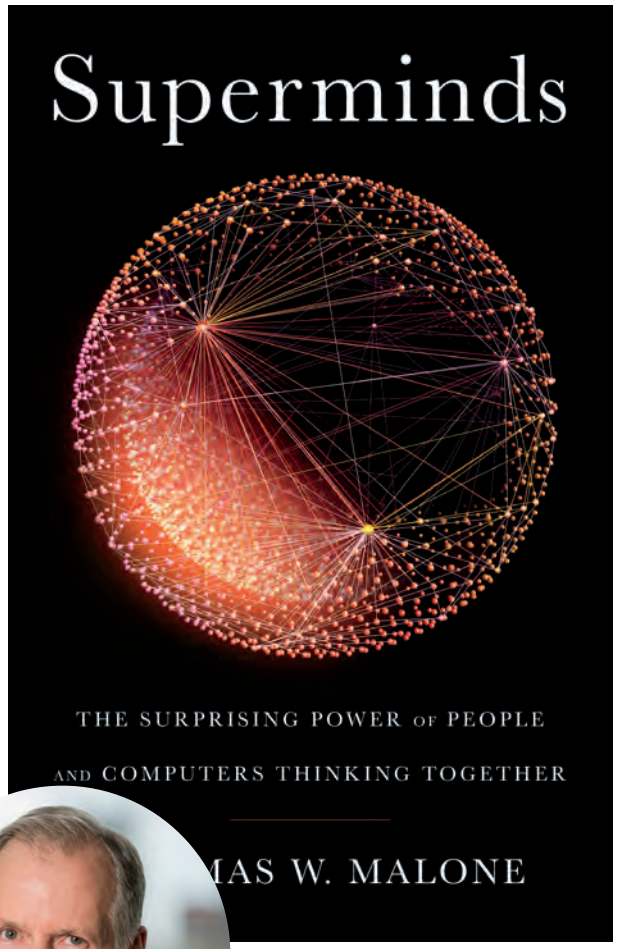


Wood was a panelist at 2017 (pictured) and 2018 MIT Media Lab events titled “Beyond the Cradle: Envisioning a New Space Age.”

PHOTO: DAVID SILVERMAN

Cyber-human Teamwork

An excerpt from Thomas W. Malone's new book *Superminds*



"For most real problems, there aren't perfect answers," writes Thomas W. Malone. "But when they are connected in the right ways, groups of people and computers together can often get closer to perfect intelligence than either could alone." Malone, who is the Patrick J. McGovern Professor of Management at the MIT Sloan School of Management and the founding director of the MIT Center for Collective Intelligence, explores the potential of such connections in his new book, *Superminds: The Surprising Power of People and Computers Thinking Together*, from which this excerpt is taken.

Will general AI be a form of collective intelligence?

We know that the human brain is itself a form of collective intelligence. It is made up of a group of billions of individual neurons that—when working as a group—act in ways that seem intelligent.

Perhaps one of the best ways to create a real general AI, therefore, is to create a collective intelligence that combines, inside a single system, many different kinds of artificial intelligence. In fact, Marvin Minsky, one of the fathers of AI, suggested as much in his writings about a "society of mind." In Minsky's view, a society of mind emerges from the interactions of many smaller "agents," none of which is very intelligent as an individual but all of which, together, create an overall system that *is* intelligent.

A hint of what this might look like comes from IBM's Watson system. When Watson plays *Jeopardy*, the system makes use of thousands of smaller agents, many of which work in parallel on different processors. Each of these agents is more complex than a single human neuron, but none of them alone is nearly smart enough to be a competitive *Jeopardy* player.

For instance, one of the questions Watson answered was "President under whom the US gave full recognition to Communist China." To answer this question, some of Watson's agents went to work proposing the names of US presidents as possible answers. Other agents started looking in encyclopedias and similar resources for information about "US," "recognition," and "Communist China." Using a special encoding of this reference information together with commonsense knowledge, these agents proposed more answers to the question, probably including the names of Chinese and American officials involved in the announcement. Eventually, based on many different agents evaluating many different kinds of evidence, and each "voting" for the answers it thought were most plausible, Watson's society of agents concluded that the answer with the highest confidence level was "Jimmy Carter," which was, in fact, correct.

How can AI help make groups smarter?

In the long run, it seems to me very likely that—whenever it happens—real general AI will include something like Minsky's society of mind: a combination of many different specialized forms of reasoning and intelligence that, together, produce general intelligence.

But what can we do in the meantime? Here's the surprisingly important idea that many people still don't really appreciate: *Long before we have general AI, we can create more and more collectively intelligent systems by building societies of mind that include both human and machine agents.* In other words, instead of having computer agents like those in Watson try to solve a whole problem by themselves, we can create cyber-human systems where human and machine agents work together on the same problem. In some cases, the human agents may not even know—or care—whether they are interacting with another human or another machine.

In this way, humans can supply the general intelligence and other specialized skills that machines don't have. The machines can supply the knowledge and other specialized capabilities that people don't have. And the groups of people and computers together can act more intelligently than any person, group, or computer has ever done before.

How is this different from the ways people are thinking about AI today? Many people assume that computers will eventually do most things by themselves and that we should put "humans in the loop" in situations where they're still needed. But I think it's more useful to realize that most things now are done by groups of people, and we should put computers into these groups in situations where that's helpful. In other words, we should move from thinking about *putting humans in the loop* to *putting computers in the group.*

PHOTO: JASON GROW

A Transformative Future for the Met Warehouse

The Metropolitan Storage Warehouse is on track to become MIT's newest interdisciplinary hub. Constructed in the late 19th and early 20th centuries, this iconic Cambridge landmark, already owned by MIT, is slated to serve as the new home for the School of Architecture and Planning (SA+P), boosting the school's capacity and enhancing the impact of its faculty, students, and researchers at MIT and in the world. The proposed renovations (subject to city approval, given the structure's historic status), with generous support from the Victor and William Fung Foundation and the Dar Group, would preserve its distinctive external features and create 200,000 square feet of state-of-the-art interior spaces. These will include classrooms, studios, galleries, and a theater. The building will also contain a new makerspace for the entire Institute community, in a location convenient to student residences on West Campus.

SA+P is consistently ranked as one of the world's top schools of architecture, planning, and design. It is the home of the first department of architecture in the United States—which this year is celebrating the 150th anniversary of its first graduating class—as well as the oldest continuously running department of urban studies and planning. In recent years, SA+P has become increasingly involved in cross-disciplinary collaborations, reflecting the growing incorporation of design principles in engineering, greater use of data in urban studies, and new connections between architecture, planning, climate science, and engineering. In 2016, MIT created

a design minor for students of all majors, and in 2018, the Institute approved a new urban science major for undergraduates. The new space would play a significant role in such areas of study, especially when it comes to hosting studio-based classes.

Bringing the Met Warehouse project to fruition will rely on the generosity of many donors. Two gifts have already been announced that have made launching the project possible.

Earlier this year, MIT and SA+P announced a collaboration with the Dar Group—an international planning, design, and architectural firm led by SA+P Advisory Council member Talal Shair—that will support the Met Warehouse project. Dar and SA+P will also come together to engage in research on the future of cities and urban areas.

"At Dar, we believe that with sufficient imagination, commitment, and determination, our most ambitious goals are within reach," Shair said in the June 2018 announcement. "This project enables us to join with MIT in that spirit and make a lasting contribution to our field, and to the world."

"More than ever before, innovation will define tomorrow's business world," said Victor K. Fung '66 during the 2016 signing ceremony celebrating plans for the new makerspace within the Met Warehouse. "Supporting the construction of makerspaces at MIT will contribute to pushing the frontier of innovation by more rapidly moving ideas from laboratory to market."

The design and fabrication facility will be headed by Martin Culpepper SM '97, PhD '00, professor of mechanical engineering, MIT's first "maker czar," and director of Project Manus, an Institute-wide program to create a gold standard for next-generation maker systems. The space will facilitate connections between the MIT campus and the global community—allowing Institute researchers to collaborate physically and virtually with the MIT Hong Kong Innovation Node, which opened in 2017—and meet the increasing demand for hands-on learning opportunities at MIT.

> The proposed renovations would create state-of-the-art classrooms, studios, galleries, a theater, and a makerspace.

"Everybody's looking at it as an opportunity," says SA+P Dean Hashim Sarkis of the renovations. "We can think about how we can do things better together, how we can create new opportunities for teaching and research, and technology and resources and workspaces—together we can reimagine everything."

In the words of MIT President L. Rafael Reif, "Who better to revive a grand old building and reknit the streetscape along Massachusetts Avenue than those who love and understand buildings and cities the most? SA+P already has a wonderful spirit and sense of identity; uniting so many elements of the school in a single building will amplify that strength and create a central resource for the whole MIT community."

Portions of this story were adapted from a June 14, 2018, article by Peter Dizikes for MIT News.

Opposite, below: Located at the corner of Massachusetts Avenue and Vassar Street, the Metropolitan Warehouse opened in 1895 as a storage facility and was added to the National Registry of Historic Places in 1986.

PHOTO: JOSE-LUIS OLIVARES/ MIT NEWS

Opposite, above: Students prepare to present architectural models in an SA+P lab. From left, Martin Elliott MArch '18 and James Addison MArch '18.

PHOTO: JOSE MANDOJANA

Better World Events in China and California

The MIT Campaign for a Better World continues its global tour with upcoming stops in Beijing and several cities in California. Attended by MIT's alumni and friends, these regional events showcase the Institute's work to build a better world. Hear from MIT leadership, faculty, alumni, and students in these and other locations still to be announced.

NOVEMBER 12, 2018
Beijing

FEBRUARY 2019
Palo Alto
San Francisco

MARCH 2019
San Diego
Los Angeles

LEARN MORE AND REGISTER TO ATTEND
betterworld.mit.edu/events-spectrum

The May 2018 Better World event in Chicago brought members of the MIT community together for a discussion on the world-changing possibilities of human and machine intelligence through the powerful lens of MIT. Panelists (above, from left) included Avrim Blum '87, SM '89, PhD '91; Leyla Isik PhD '15; Panasonic Professor of Computer Science and Engineering Leslie Pack Kaelbling; and School of Engineering Dean Anantha P. Chandrakasan.

PHOTOS: MATTHEW KAPLAN

ROBERT ’63, SM ’64 AND EVA RATONYI

Encouragement at a Pivotal Moment

For Robert Ratonyi ’63, SM ’64, MIT is a pivotal chapter in an extraordinary life story that has spanned the struggle to survive the Holocaust as a young child in 1940s Budapest all the way to a highly successful career in the American business world. At age 18, in the aftermath of the Revolution of 1956, Ratonyi escaped communist Hungary for the West and ended up in Montreal, where he met his future wife Eva Vero, also a Jewish Hungarian refugee.

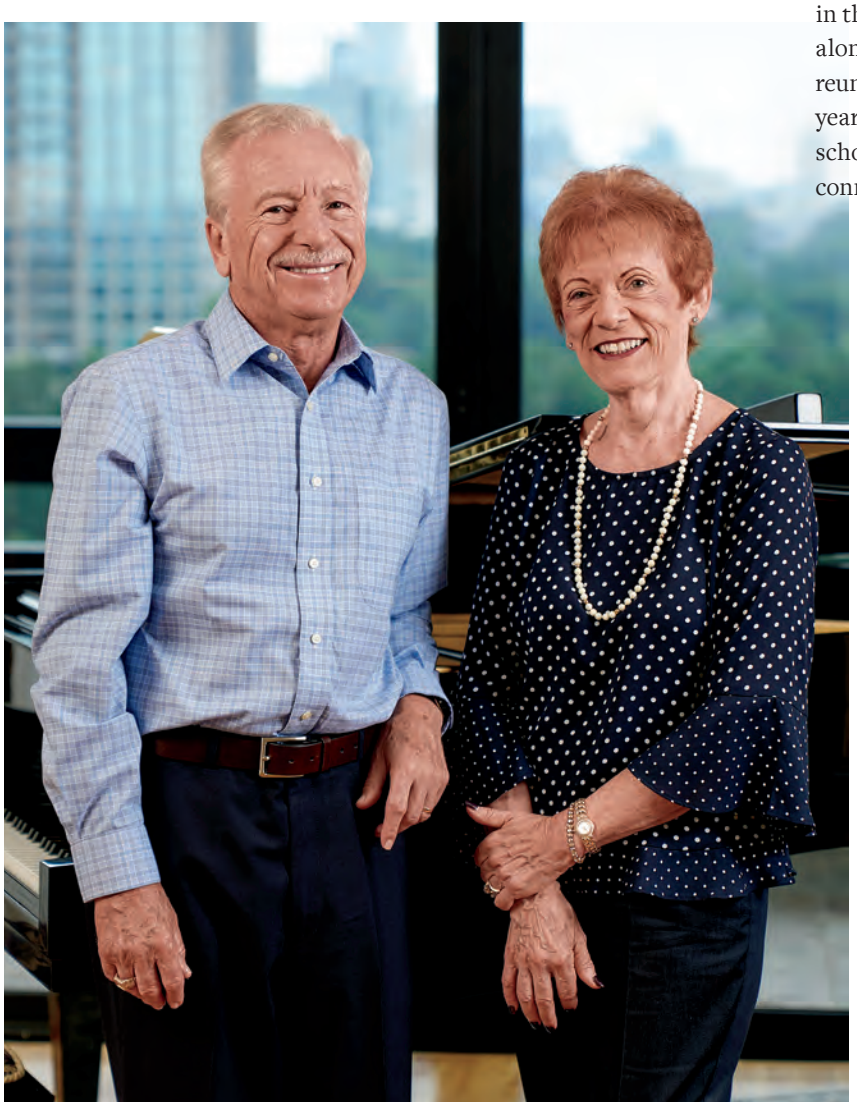
Robert, who has worked in mergers and acquisitions and investment management as a senior executive in large corporations and with his own firm, credits much of his success to his MIT education and subsequent business degree from Drexel University. “I would have never been able to accomplish as much as I did in my business career without my engineering education,” says Robert. “MIT taught me how to solve problems analytically and helped me develop an approach to business that is very organized, methodical, and logical.” But Robert’s time at MIT almost didn’t happen. He credits his father-in-law, Andrew Vero, with giving him the inspiration and encouragement to pursue the idea when it seemed impossible. The Ratonyis recently endowed a scholarship fund to honor Andrew Vero’s memory and legacy and provide much-needed support to MIT students.

As a young immigrant with immense talent but modest means, Robert was working as a mechanical draftsman and taking night classes toward an engineering degree from McGill University when he says he applied to MIT as an act of “bravado.” When his acceptance letter arrived, Robert felt validated intellectually but brushed off the prospect of actually attending MIT, believing he could not afford it. His future father-in-law happened to be visiting from New York City, and was “more excited than I was to hear about the acceptance letter,” remembers Robert. “He dismissed all my objections to the cost of attending MIT, and he wanted me to pursue the invitation.” As an incentive, Vero offered to drop Robert off in Cambridge on his way back to New York City. He insisted that the very least Robert could do was to visit MIT and meet with admissions officials. Robert did so and was promised loans and scholarships if his grades met the requirements. He began his studies at the Institute in the fall of 1961.

“Not until I learned a lot more during the ensuing years about my father-in-law’s past did I understand his feelings,” explains Robert. Vero, a fellow Holocaust survivor, was denied the opportunity to attend college because of the anti-Semitic laws passed in Hungary in 1920. In Robert, Vero saw the chance to succeed that he never had.

“Education is extremely important to us,” says Eva, who earned a bachelor of science in math and physics from Temple University and a master’s degree in management science at the University of Texas at Dallas. “Without MIT, we would not have progressed from just having the clothes on our back and loans to pay off to all we have accomplished in this world.”

Now living in Atlanta, Robert and Eva are committed donors to the arts, Jewish organizations, and education, and Robert remains active in the MIT community. He founded the Atlanta MIT Enterprise Forum along with several other alumni and for many years organized the reunion of his Sigma Alpha Mu fraternity brothers. And for the last several years, he has been working as an educational counselor with high school students who have applied to MIT. “I still treasure the MIT connection,” he says. —Katy Downey



“I would have never been able to accomplish as much as I did in my business career without my engineering education,” says Robert. But his time at MIT almost didn’t happen.

PHOTO: JASON HALE

At left: On a visit to MIT, Miguel Alemán Velasco (center), followed by daughters Claudia (in blue) and Monica, walks with AeroAstro faculty member Jaime Peraire. Below: Alemán Velasco and his wife, Christiane, with Paulo Lozano, inaugural holder of the new professorship.

PHOTOS: JAKE BELCHER

THE ALEMÁN FAMILY

Core Values

For Miguel Alemán Velasco, air and space travel have always been sources of inspiration: "All my life I have been interested in the wonders of flight." He is the founder of the Mexican airline Interjet and has had a long and varied career in Mexican industry and government, including six years as the governor of the state of Veracruz. His father, Miguel Alemán Valdés, served as President of Mexico from 1946 to 1952.

Since 2014, Miguel Alemán Velasco has been honored to serve on the Visiting Committee for the MIT Department of Aeronautics and Astronautics, which offers advice and insight on that academic program to the MIT Corporation. Along with his wife, Christiane, and their four children, he has made several significant philanthropic investments in MIT. Most recently, the family created the Miguel Alemán Velasco Professorship in Aeronautics and Astronautics. The chair was endowed by a gift from Alemán's children in celebration of his 85th birthday—a gesture he describes as "a very emotional moment." Paulo Lozano SM '98, PhD '03, a leading figure in aerospace research and native of Mexico City, is the inaugural holder of the Alemán Velasco Professorship. Lozano directs the MIT Space Propulsion Lab and is the newly appointed faculty director of the MIT-Mexico program within the MIT International Science and Technology Initiatives.

Supporting MIT research is an opportunity to "see beyond our time and invest in the best minds to develop scientific and technological advances," says Miguel Alemán Velasco. Philanthropy also reflects deeply held family values: "We have been taught by our parents to be generous and to invest in what really changes the destiny of a country and society. The best way to do this is to invest in knowledge, education, and scientific research," he says. He is particularly gratified to see the growth of the MIT community in Mexico and Latin America and believes that an MIT education will help to develop a new generation of inspired leaders in Mexico and around the world.

A gift to MIT was a natural way to commemorate her father's birthday, says Claudia Alemán Magnani: "Creating the Miguel Alemán Velasco Professorship was one of the best gifts we could give to our father, because we have seen his determination every day to work in favor of what he believes." She adds, "He is our best example." She joined her parents on a recent visit to MIT to see the newly renovated Building 31, home of the aero/astro department—including a lobby newly named for the Alemán family in honor of its support—and was inspired "to see MIT students from every part of the world living [and learning] together."

> Supporting MIT research is an opportunity to "see beyond our time and invest in the best minds to develop scientific and technological advances," says Miguel Alemán Velasco.

Like her father, Claudia Alemán Magnani is a dedicated philanthropist, and plays an active role in the Fundación Miguel Alemán, established in honor of her grandfather, the former Mexican president. The foundation's priorities include research in health and the environment, gender equality, and the development of agricultural innovation, tourism, and the humanities in Mexican society. The foundation's accomplishments, she says, are "the deepest pride in our family."

As he looks to the future of MIT, and his own growing family, Miguel Alemán Velasco is full of optimism: "We feel very proud of all of them—my daughters, my son, my grandchildren, and now my great-grandchildren who are joining this heritage of generosity and love for our country."

—Kris Willcox

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WE GET TOGETHER AND SPARKS FLY.

The first annual “Maker Break,” hosted by Project Manus, invited students, faculty, and staff to unwind with hands-on activities ranging from origami and jewelry making to welding together 350 digits of Pi (pictured). Work on the collaborative steel sculpture, which involved 70 participants over the course of the day, will continue at future maker events before the final product is displayed on campus.

MIT CAMPAIGN FOR A BETTER WORLD