AUTOMATION + ANXIETY | ARTIFICIAL INTELLIGENCE, ROBOTICS, LABOR, AND ENVIRONMENT

Advanced Studio 4
Columbia University Graduate School of Architecture, Planning and Preservation
Critic: David Benjamin

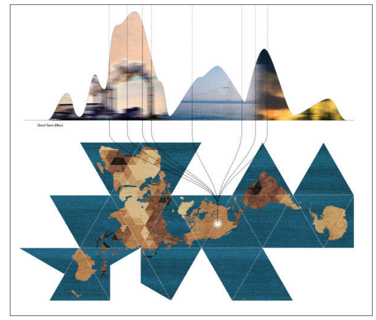
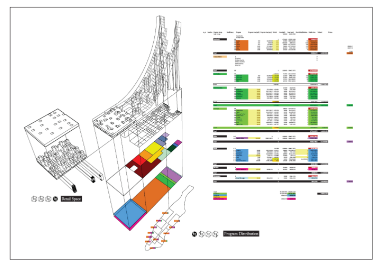
OVERVIEW

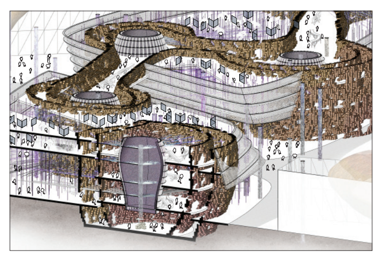
In May of 1997, the world's best human chess player, Garry Kasparov, sat down to play the world's best computer, IBM's Deep Blue. Ten years before, Kasparov had boasted, "No computer can ever beat me." But the recent progress of computation seemed impressive and potentially game-changing. In the lead-up to the competition, the battle had been dubbed Ali-Frazier.

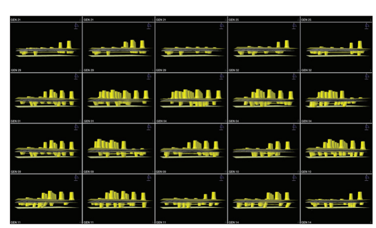
Near the end of the first game, in the forty-fourth move, Deep Blue a made highly unusual play, sacrificing a rook while ahead, which seemed to hint at a sophisticated strategy of preventing countermoves. Kasparov was rattled. He could not comprehend why the computer made the move, and he feared that it demonstrated a superior intelligence. The game ended in a draw, but at the beginning of the next game, Kasparov made an unprecedented error, and Deep Blue went on to win the epic battle. According to a report in Wired Magazine, "The chess world found it devastating. 'It was too much to bear,' said grandmaster Yasser Seirawan. The cover of Inside Chess magazine read 'ARMAGEDDON!'"

In 2012, long after computers asserted their dominance in chess, one of the inventors of Deep Blue revealed that the fateful forty-fourth move had been due to a software bug. According to writer Nate Silver, "Unable to select a move, the program had defaulted to a last-resort fail-safe in which it picked a play completely at random… Kasparov had concluded that the counterintuitive play must be a sign of superior intelligence. He had never considered that it was simply a bug." In the end, the computer won not because of an innovative strategy, but because the human was prone to worry and doubt and self-destruction. The human assumed that machine intelligence worked like human intelligence—and therefore the unusual move must have been a rational strategy. But the computer had a different intelligence altogether, one that was subject to bugs but not subject to weariness or worry. Neurologist Robert Burton elaborates, "The ultimate value added of human thought will lie in our ability to contemplate the non-quantifiable… Machines cannot and will not be able to tell us the best immigration policies, whether or not to proceed with gene therapy, or whether or not gun control is in our best interest." In other words, since machines cannot worry, and since worry and doubt are productive in creating humanistic, fair solutions to the problems of our time, humans will never be replaced by machines.

Yet in 2016, almost 20 years after the fateful computer victory in chess, Google's DeepMind defeated a human champion at the game Go, which was once considered a game for uniquely human intelligence. It was thought that Go was impossible for a machine to win due to the nearly infinite number of outcomes and the difficulty of calculating which player is leading at any given moment. Google's computer used a new version of artificial intelligence called machine learning, and this new victory may signal what Maksim Podolyak, a vice-president of the Russian Go Federation, refers to as the birth of a "new age—an age of computers able to resolve specifically humanistic problems." Machine learning is now being applied for financial trading, advertising, language translation, malware detection, computer vision, and countless other applications. And because of





Images (top to bottom): Factory design and visualization (Benjamin Studio 4, Abraham Murrell and Edward Palka); Global production diagram (Benjamin Studio 4, Ruomeng Wang); Generative design program diagram (Benjamin Studio 4, Troy Therrien); Community center and participatory construction (Benjamin Studio 5, Lorenzo Villaggi); Production from waste (Benjamin Studio 4, Troy Lacombe); Physical model of materials designed to change over time (Benjamin Studio 4, Tonia Chi); Generative design to explore mixed-use building (Benjamin Studio 5, John Locke).

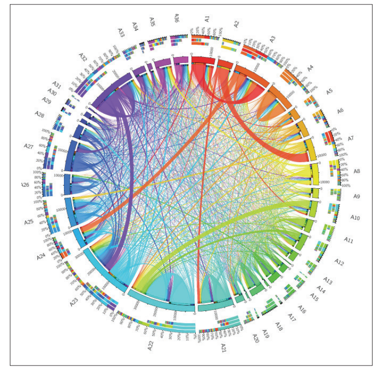
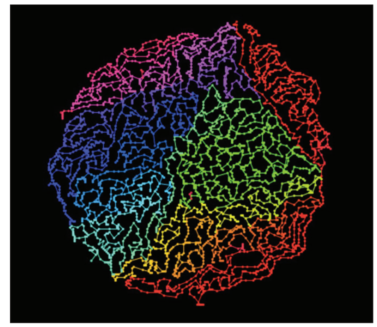
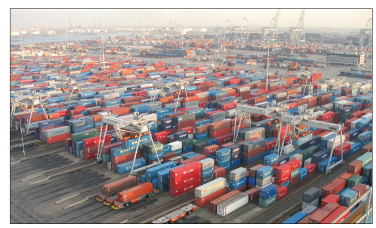
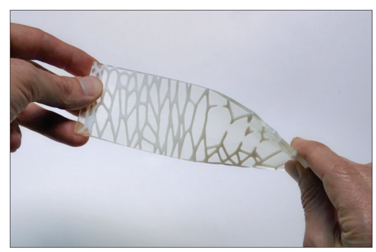
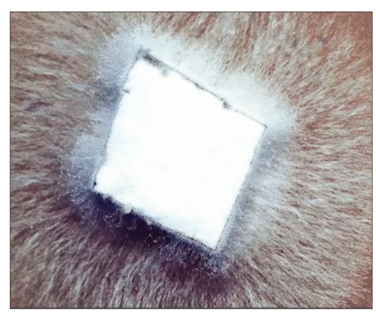
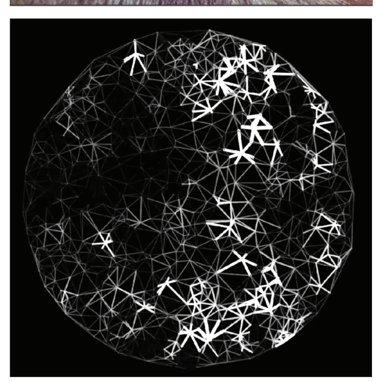
its quiet ubiquity, this brings up questions about its use as well as its effectiveness. As with all technologies, machine learning involves assumptions and biases. But the biases of machine learning may be even more troubling than other biases because they are hidden, sometimes even hidden from their own inventors. This concept has been articulated by recent writing including Cathy O'Neil's "Weapons of Math Destruction" and Kate Crawford's "Artificial Intelligence's White Guy Problem." O'Neil and Crawford show how the biases of these algorithms can lead to racial profiling in policing, sexism in job listings, and uneven distribution of resources in urban neighborhoods. And their arguments imply that understanding algorithms requires understanding the humans who create them, the humans who are displaced by them, and the humans who are affected by their conclusions.

Perhaps the battles of chess and Go—and the growth of machine intelligence that they represent—suggest that it is important to become more fluent in algorithms. It is important to understand what's going on under the hood—including the bugs they contain, the data they are based on, and the rules that lead to their conclusions. This is crucial not just to be able to use the algorithms effectively, but also be able to guide, temper, and respond to their use. In other words, this is a political issue as well as a technical issue. And "automatic" should be a question rather than a conclusion.

The ongoing story of humans and machines is a fascinating case study of technology in the 21st Century, and it sets the stage for Automation + Anxiety: an architecture studio that engages technology, environment, buildings, infrastructure, landscapes, ecosystems, numbers, images, stories, values, trade-offs, nature, and climate change. The studio will combine technology with environment. It will explore the latest generation of algorithms, robots, and artificial intelligence—and it will interrogate several emerging frameworks related to themes of environment and technology, including the Circular Economy, Antifragility, and Hyper Nature. The studio will also examine a range of design approaches, including multi-scalar design, new materials, and new software techniques. Within this context, the studio will work on architecture for education, energy, labor, and water bodies. Over the course of the semester, we will generate proposals that are both quantitative and qualitative. We will produce metrics, narratives, and images. We will design rules rather than fixed forms. We will anticipate rapid change. And we will welcome shifting forces, unknowable crises, and uncertainty.

THE CIRCULAR ECONOMY

The Circular Economy is an emerging concept for a new era of design across multiple industries. This concept is based on creating ecosystems with two types of nutrients: biological nutrients that are designed to circulate without unhealthy waste products, and technical nutrients that are designed to circulate at high quality without material impact. The Circular Economy promotes renewable energy and materials with low embodied energy, but it also involves a broader range of open source scientific projects and solutions that are healthy in terms of environment, finance, and society. A recent report by the World Economic Forum explains, "In a world of close to 9 billion—including 3 billion new middle-class consumers—the challenges of expanding supply to meet future demand are unprecedented. Our current 'take-make-dispose' approach results in massive waste, and in the fast-moving consumer goods sector about 80% of its $3.2 trillion value is lost irrecoverably each year. The switch from a linear to a

Images (top to bottom): Diagram of Circular Economy in Portugal (via MM & Random Thought); Data visualization of bacterial colony growth (Columbia Advanced Data Visualization Project, Danil Nagy, Lars Dietrich, David Benjamin); Pre-Circular Economy Global Supply Chain; Multi-material 3D print of new composite sheet (Bio Computation, The Living); Mycelium growth (Ecovative Design); Data visualization of animated hair (Columbia Advanced Data Visualization Project, Danil Nagy, Eitan Grinspun, David Benjamin).

regenerative circular economy provides credible and quantified perspectives to address this generational challenge. Ultimately the circular economy could decouple economic growth from resource consumption—truly a step-change." In this context, could we similarly aim to decouple building construction from resource consumption? How might we design buildings, landscapes, and cities as part of regenerative circular economies? Should the domain of architecture expand over space and time to incorporate global supply chains and recycling/composting of construction material? How should agency and responsibility be shared in this context? What are the social, political, and economic levers that designers might pull?

ANTI-FRAGILITY

In the context of climate change, resilient systems have become appealing as a model for design with shifting forces, unknowable crises, and uncertainty. In response to extreme weather such as Hurricane Sandy, multiple parties—including politicians, community groups, environmental activists, urban planners, architects, engineers, and the general public—are seriously considering resilient design as a strategy for rebuilding and resisting future damage. Yet some people argue that resilient systems are not enough. While resilient systems are defined as recovering quickly from stress, "antifragile" systems are defined as thriving and improving under stress. Nassim Nicholas Taleb, who developed the concept, states: "Antifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better. This property is behind everything that has changed with time: evolution, culture, ideas, revolutions, political systems, technological innovation, cultural and economic success, corporate survival, good recipes . . . the rise of cities, cultures, legal systems, equatorial forests, bacterial resistance . . . even our own existence as a species on this planet." But is the concept of antifragility useful for architecture? Is it possible to design antifragile buildings, landscapes, and cities? How might we design with inherently dynamic ecological processes? How might our design strategies incorporate risk and change?

HYPER NATURE

If the Twentieth Century was the Century of Physics, then the Twenty-First Century is the Century of Biology. Biological technologies are advancing exponentially. In the past ten years, it has become possible observe living systems in new ways through high-resolution imagery, to create computer models of biological cells, to cut and paste DNA, and to combine biological functions such as growth, movement, sensing, deposition, regeneration, and self-healing into new organisms that never existed in nature. These developments allow us to imagine and design a new form of nature—a hyper nature. This concept of nature blurs old distinctions between the artificial and the natural. It involves biology, the environment, engineering, computation, and the problems and technologies of our times. But this concept is not limited to the technical realm. According to the publication Next Nature, "Hyper nature is culture in disguise." So what is new about the concept of hyper nature, and what is simply a rebranding of well-worn ideas? What is the architecture of hyper nature? Can we harness biology for design without fetishizing it? Is it possible to "collaborate" with natural systems and derive hypernatural designs that humans alone—or nature alone—could never create?

SCALE AND ENVIRONMENT

The studio will operate at multiple scales simultaneously. Over the course of the semester, we will rethink materials, buildings, site plans, and infrastructures. We will

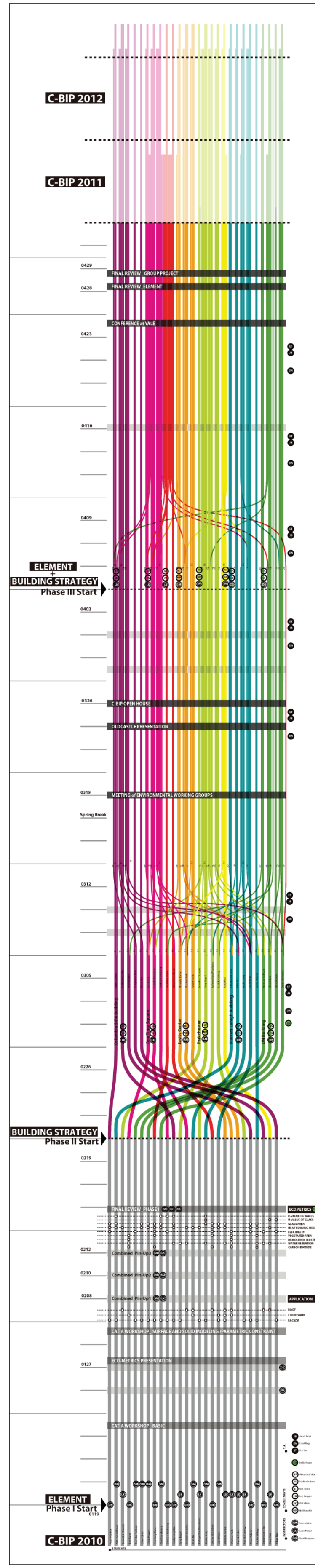


Image: Collaboration diagram (Benjamin Studio 4, Muchan Park).

look at new multi-scalar paradigms that include robust biological and social dynamics, energy generation, and adaptability. We will explore design from the scale of material composition, including molecules with a diameter of about 10^-9 meters, to the scale of global production, including the earth with a diameter of about 10^7 meters—16 powers of ten in the same studio.

ENERGY AND LABOR

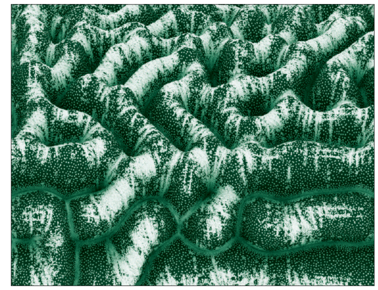
The studio will explore architecture, environment, and technology through the interrelated lenses of energy and labor. It is well known that buildings are major contributors to climate change (about one-third of the world's solid waste, energy consumption, and carbon emissions come from architecture). And energy is fundamentally related to materials as well as systems. (In the past fifty years, operational energy—defined as the energy for things like heating, cooling, and lighting—has in fact declined as a percentage of total energy consumption in buildings. At the same time, embodied energy—typically defined as the sum of all energy required to extract raw materials, and then produce, transport, and assemble the materials of a building—has rapidly increased.)

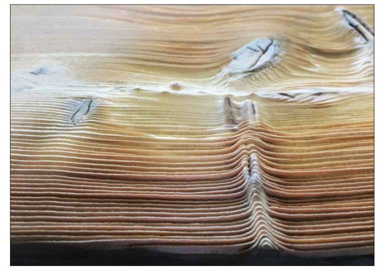
But energy is also fundamentally related to labor. In 1973, a young Swiss architect named Walter Stahel was looking for ways to save large amounts of energy in the construction industry. Instead of looking at technologies such as more efficient lighting or cooling, Stahel turned to behavior patterns and socioeconomic issues. Stahel and his collaborator, Genevieve Reday-Mulvey, eventually reached the conclusion that these problems could be best addressed by substituting manpower for energy. In a report called Jobs for Tomorrow, they wrote, "The creation of new skilled jobs can be achieved in parallel with a considerable reduction of the energy consumption through a prolongation of the useful like of materials and products." Stahel and Reday-Mulvey's line of thinking itself was not new. All accounts of industrialization involve the increase in productivity due to machines taking over the labor of humans, which translates to machines consuming energy (usually fossil fuel) to do work instead of humans consuming food to do work. But it was refreshing for Stahel and Reday-Mulvey to suggest that this trend could be selectively reversed through having humans take back some work from machines.

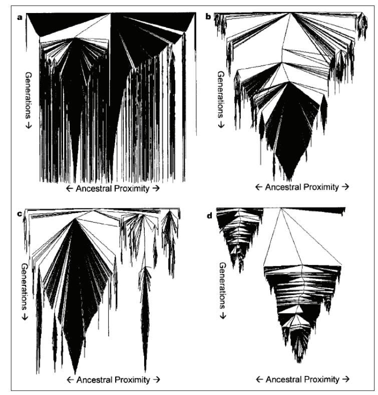
Of course much has changed since 1973, but Stahel and Reday-Mulvey's original argument about the need to look simultaneously at fossil fuel consumption and fulfilling employment is as relevant as ever—especially in light of the current wave of anti-globalization populism in Europe and the United States. Labor and environment should not be considered separate agendas. This studio will consider how architects might design jobs, machines, and materials as well as buildings, energy, and environmental impact. It will explore how labor and equality are necessary factors when considering urgent environmental issues.

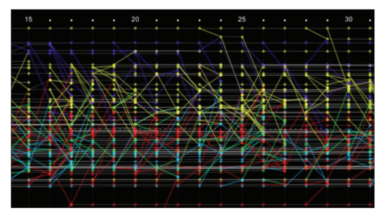
PHYSICAL EXPERIMENTS: NEW MATERIALS, A.I., AND ROBOTICS

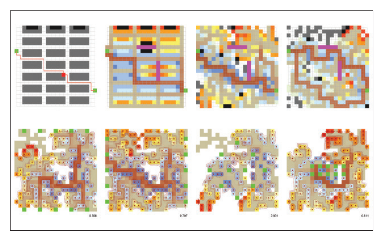
This is a hands-on studio, and we will apply our concepts to physical and digital designs and prototypes. Our physical experiments will combine our thinking about embodied energy, raw materials, re-use, and waste with old and new technologies for making. More specifically, this studio will work with physical automation through a new "friendly robot" at GSAPP that points to a new era of human-machine collaboration. Students will develop systems to use robotics not just for top-down precision fabrication, but also

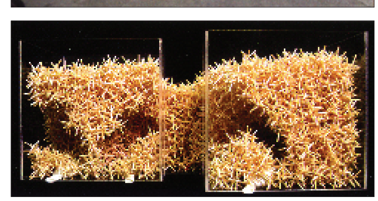












Images (top to bottom): Material ecologies (Neri Oxman, MIT Media Lab); Robotic processing of salvaged New York City scaffolding boards (Princeton Laboratory for Embodied Computation, by The Living); Evolutionary computation through generative design (Hod Lipson, Creative Machines Lab, Columbia University); Visualization of design space of 10,000 designs (The Living); Using generative design for program layout and robotic circulation (Benjamin Studio 5; Thomas Wegener).

for bottom-up feedback-based assembly. We will learn to program the Universal Robots UR3 and design systems for processing and constructing prototypes with salvaged materials. We will program the robot with rules rather than forms. We will rely on the robot's sensors to capture real-time information, and we will experiment with its ability to adapt and learn over time as a new form of artificial intelligence. We will create novel design ecosystems that combine high-tech and low-tech, digital and physical, control and emergence. We will engage advanced robotics as well as messy found materials. We will explore the next generation of robotics in architecture, as it tackles complexity, feedback, and machine learning. And at the same time, we will engage a return to craft and multi-material physical prototypes.

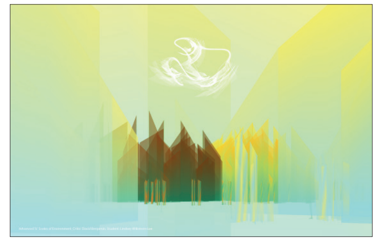
DIGITAL EXPERIMENTS: NEW SOFTWARE AND GENERATIVE DESIGN

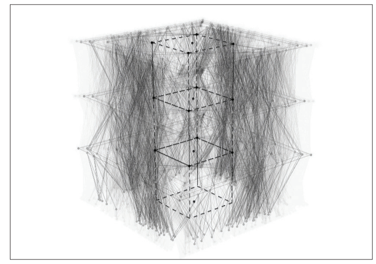
Our digital experiments will build off of our physical experiments and explore the emerging framework of generative design. This framework relies on recent advances in cloud computing, digital simulation, and data science. It involves designing goals and constraints (as opposed to designing formal solutions), and using automation to generate, evaluate, and evolve thousands or tens of thousands of designs. With this framework, we will use software to investigate data, to explore a very wide potential design space, to minimize our preconceptions, to avoid relying on old rules of thumb, to derive unexpected high-performing results, and to negotiate between competing architectural values. For our purposes, computation and optimization will not be about achieving cold-blooded efficiency—but rather it will be about enhancing our creativity. It will be about discovering possibilities that a human alone—or a computer alone—could never produce. Yet while this studio will explore new frontiers of design and computing, no prior experience with software is necessary.

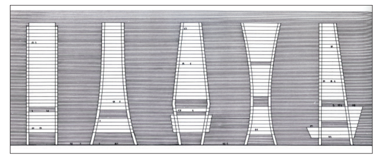
METRICS + NARRATIVES + IMAGES

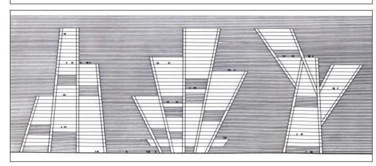
Metrics are inextricably related to climate change and our understanding of the natural environment. They are also entwined with almost everything about our current world. Metrics drive public health, personal health, election polling, global supply chains, search engines, social networks, and computer simulations of everything from airplane flights to hurricane paths to crowd behavior. Writers Michael Blastland and Andrew Dilnot declare, "For good or ill, numbers are today's preeminent public language—and those who speak it rule." But while numbers are more available and more important than ever, in many ways our understanding and use of them is confused and unimaginative.

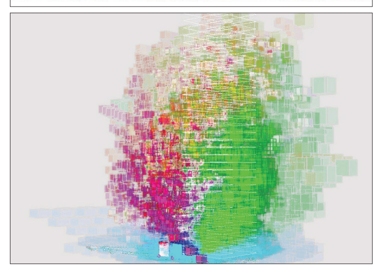
In this studio, we will consider how architecture might be defined by an ecology of numbers—an ebb and flood of input numbers and output numbers. But we will also explore aspects of architecture and the environment that are difficult to quantify. We will engage theory, culture, and aesthetics. We will recognize that dealing with complex and urgent issues requires qualitative approaches as well as quantitative approaches. In a recent New York Times essay called "Are We Missing the Big Picture on Climate Change?" Rebecca Solnit explores the complexity of ecosystems, and she argues, "Addressing climate [change] means fixing the way we produce energy. But maybe it also means addressing the problems with the way we produce stories." As architects, we might add that addressing climate change means addressing problems with the way we produce images. With this in mind, our studio will explore a nuanced combination of designing with metrics, designing with narratives, and designing with images.

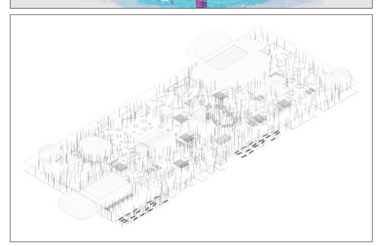


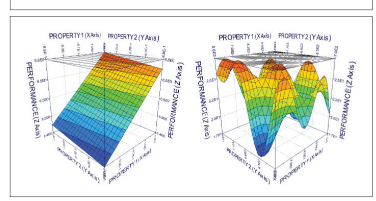


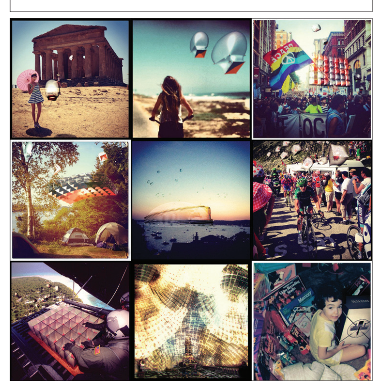












Images (top to bottom): Metric drawing (Benjamin Studio 4, Lindsey Wikstrom); Metric drawing (Benjamin Studio 5, Nathan Smith); Tower typologies; Generative design options (Benjamin Studio 5, Nathan Smith); Flexible space for education on Governors Island (Benjamin Studio 4, Xiaoyu Wang); Response surface as visualization of complexity of design space (The Living); Decentralized, self-organizing living pods for adaptive architecture (Benjamin Studio 5, Ray Wang and Jim Stoddart).

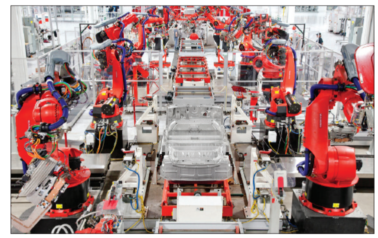
EDUCATION + JOBS + AUTOMATION

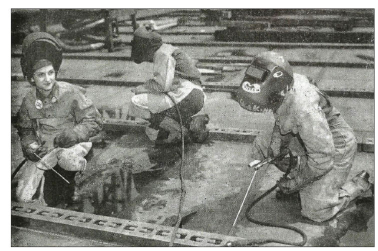
Automation involves more than technology. It is clearly affecting economics and employment. Many economists have noted that the loss of jobs in the Midwestern United States—clearly a major factor in the 2016 United States Presidential election—was caused more by automation than by trade deals. The same robots and algorithms that are exciting for designers can be devastating for workers who are displaced by them. But perhaps energy offers a clue to a new direction. According to a recent report by the U.S. Department of Labor, wind-farm technician is projected to be the fastest-growing occupation in America over the next decade.

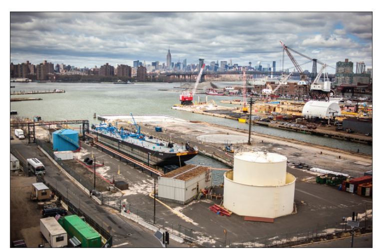
This studio will address climate change through the architecture of education, energy, labor, and water bodies. Students will design a new mixed-use building for education and job training in the Brooklyn Navy Yard. The Navy Yard is currently playing out a complex and ambitious private-public partnership that aims to become a hub for entrepreneurship and to bring manufacturing back to New York City. The Navy Yard is also one of the waterfront sites in the city that is most susceptible to the rising sea levels and flooding that will come with climate change. In a sense, this site is ground zero for a new integration of technology and environment. Yet this is also a contested site, and our job training center will address the friction between the advancement of the people who program robots and the transformation of the people who have been upended by them.

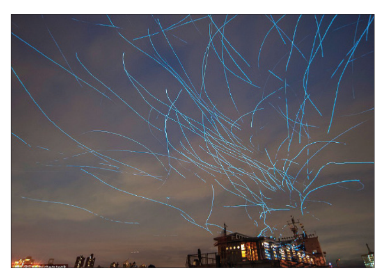
This friction reminds us that "sustainability" has to be framed in social as well as environmental terms. As Jodi Dean has recently put it, "Just as a class politics without ecology can support extractivism, so can an ecology without class struggle continue the assault on working people that has resulted in deindustrialization in parts of the North and West and hyperindustrialization in parts of the South and East (we might call such an ecology without class struggle 'green neoliberalism')."

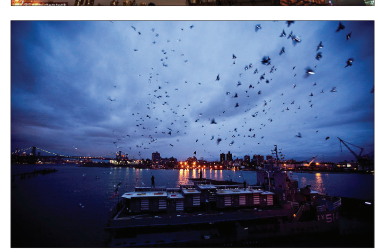
In this studio, we will engage both a new form of technical education and an expanded waterfront as classroom. We will engage both the traditional campus and an expanded city as campus. We will think about the future, and design for the present, encompassing new models of environment and technology into our projects, and producing visionary and viable buildings.











Images (top to bottom): Brooklyn Navy Yard; Same; Tesla factory with reconfigurable robots; Labor in Brooklyn Navy Yard; Future food building in Brooklyn Navy Yard; Brooklyn Navy Yard; Fly By Night art performance in Brooklyn Navy Yard; Same.