

THE MASTER OF SCIENCE IN DESIGN: ROBOTICS AND AUTONOMOUS SYSTEMS

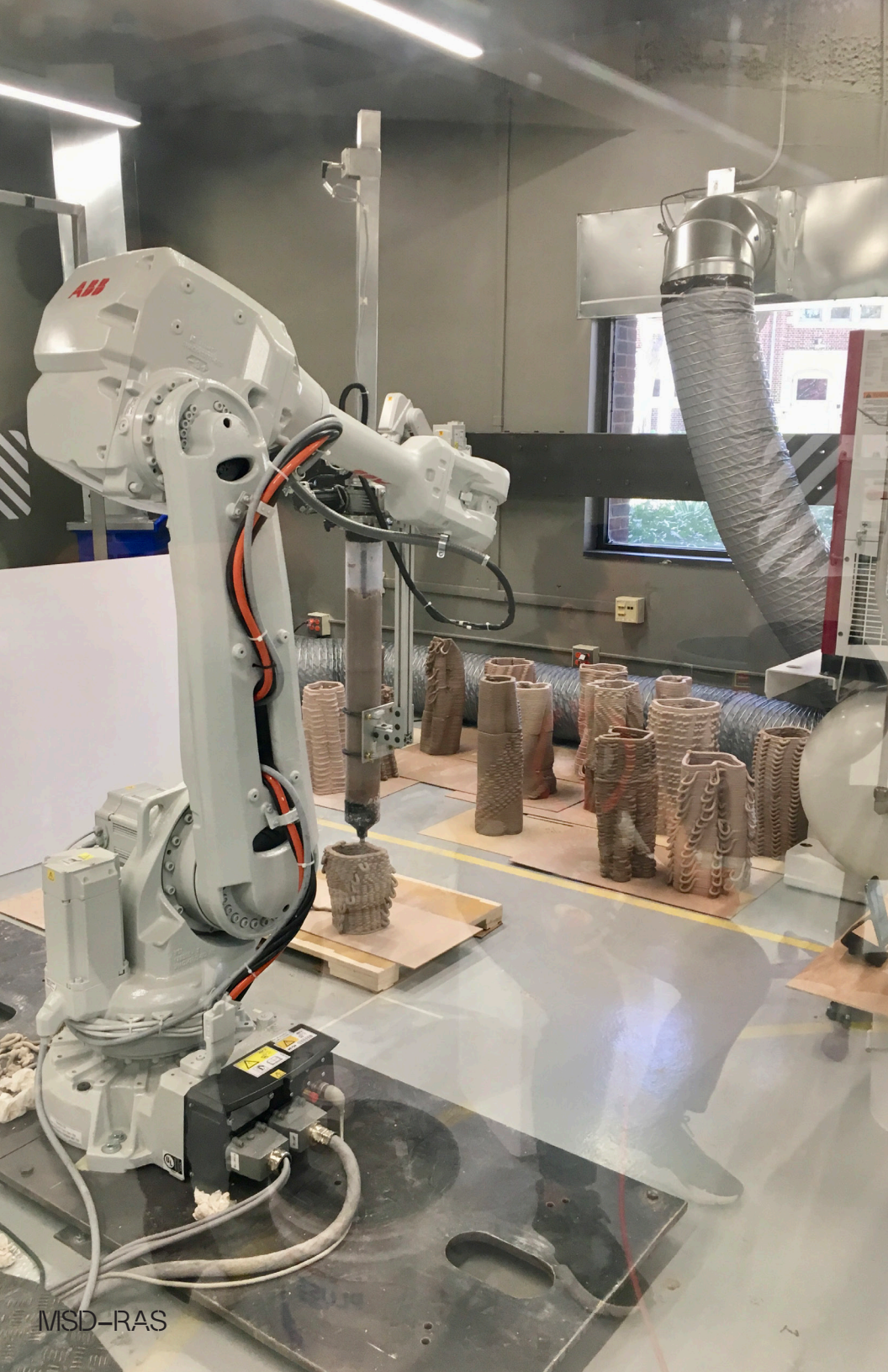
University of Pennsylvania Stuart Weitzman
School of Design Graduate Architecture



READY TO TAKE ON NEW CHALLENGES AND BREAK INTO EXCITING, CUTTING-EDGE FIELDS?

Transform your career by positioning yourself at the forefront of innovation in robotics, fabrication, and design-computation.

Join our new one-year Master of Science in Design: Robotics and Autonomous Systems (MSD-RAS) program at the University of Pennsylvania Stuart Weitzman School of Design, the most recent addition to the Architecture Department's series of advanced MSD programs.



PROGRAM OVERVIEW

The MSD-RAS aims to develop novel approaches to the design, manufacture, use, and life-cycle of architecture through creative engagement with robotics, material systems, and design-computation.

Students will gain skills in advanced forms of robotic fabrication, simulation, and artificial intelligence, in order to develop methods for design that harness production or live adaption as a creative opportunity. Robotically manufactured architectural prototypes (part or whole) will be developed by students and presented and exhibited at the completion of the course.

WHO IS MSD-RAS FOR?

- Students who already hold a first professional degree from an accredited design program in architecture.
- Post-graduate students or those who have completed equivalent programs of study in related professional fields who can demonstrate their ability to complete the required course of study.
- Professionals who have worked for several years and are seeking advanced study and credentials in robotic fabrication and design-computation.



PROGRAM GOALS

The MSD-RAS program will enable graduates to:

GAIN state of the art robotics, material fabrication, and design-computation qualifications.

DEVELOP skills in advanced methods of fabrication, computation, robot programming and multi-modal sensing technologies, and their integration within innovative design methods.

EXPAND career opportunities and options to work in ambitious and diverse fields.

IMPACT the present and future trajectory of architecture through novel forms of production, practice and entrepreneurship.

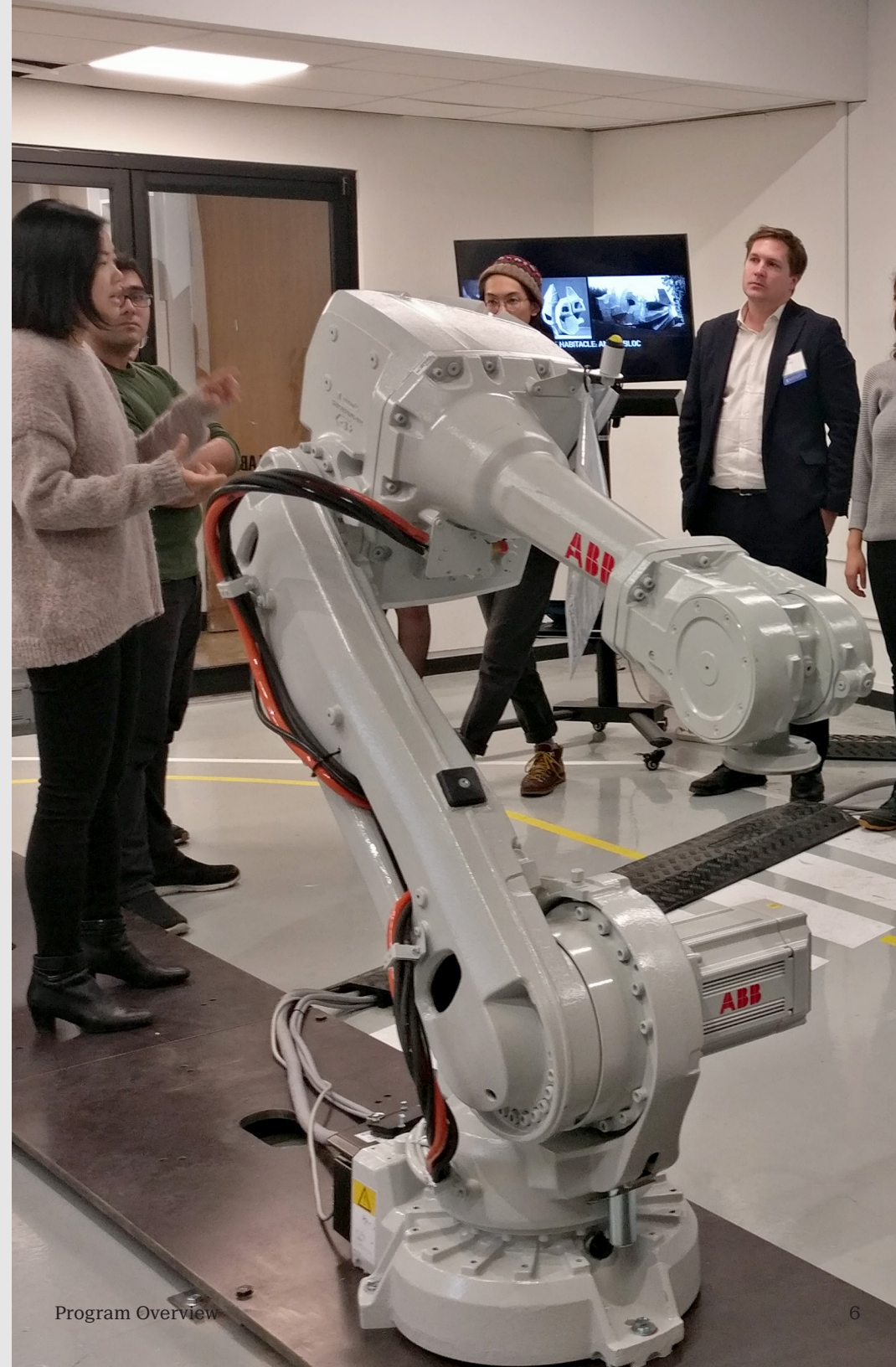
OPERATE at the forefront of industry research and development

WHY ROBOTICS IN ARCHITECTURE?

The fourth industrial revolution (Industry 4.0) describes a recent shift towards autonomous systems, and societal reliance on cyber-physical processes that incorporate digital communications and navigation infrastructure, robotic manufacturing, and artificial intelligence.

The building industry is currently undergoing transformation through the adoption of robotics technologies such as additive manufacturing systems that enable a reduction in the time, cost and complexity of delivering buildings, and have potential humanitarian and socio-economic benefits. Adoption of these technologies also enables greater automation not only in production but also in design, challenging existing modes of architectural practice.

The MSD-RAS program explores avenues for re-situating the role of architectural design within present day autonomous technologies, with the aim of expanding societal and design opportunities by leveraging robotic and material processes within design.



FOSTERING INNOVATIVE CAREER TRAJECTORIES

The MSD-RAS program aims to empower graduates to operate at the forefront of industry research and development, by gaining state of the art robotics, material fabrication, and design-computation qualifications, and to graduate as highly skilled professionals, capable of impacting the present and future trajectory of architecture and industry through novel forms of production, practice and entrepreneurship.



Whether you're looking to advance your career, transition to new industries, start your own company, or pioneer an emerging field, the MSD-RAS program offers hands-on experience with ground-breaking technology and world-class qualifications to help you achieve your goals.



CURRICULUM OVERVIEW

The MSD-RAS program includes the following courses:

SUMMER

Introduction to 3D Programming (2 week course prior to start of Fall Semester)

FALL

ARCH 801 Material Agencies: Robotics & Design Lab I (2 CU)

ARCH 805 Introduction to Micro-controllers, Sensor and Actuator Systems (0.5 CU)

ARCH 803 General Overview of Algorithmic Design and Robotic Fabrication (0.5 CU)

ARCH 807 RAS Theory (1 CU)

Designated Elective (Within Architecture + Engineering)

SPRING

ARCH 802 Material Agencies: Robotics & Design Lab II (2 CU)

ARCH 804 Advanced RAS Programming (1 CU)

ARCH 806 Experimental Matter (1 CU)

ARCH 808 Scientific Research and Writing (1 CU)

Total Course Units: 10

COURSE DESCRIPTIONS

Introduction to 3D Programming

This course introduces 3D modelling and scripting within a 3D software package such as Rhino3D/Grasshopper and aims to build a skill set for 3d design, geometry rationalization/analysis, and bespoke automation. These fundamental skills will be utilized throughout the MSD-RAS program to develop and represent ideas and to drive inputs for other robotic and fabrication methods.

ARCH 801 Material Agencies: Robotics & Design Lab I

The Fall Material Agencies course consists of two half-semester design-fabrication sections, supported by two aligned Core Technical Seminars of half-semester length each. Students will typically work in pairs. Design discourse and subject matter for these sections varies, but is intimately related to a robotic fabrication research such as:

- Example Section: Sculptured Matter investigates the sculptural and manufacturing possibilities of robot hot-wire cutting. An extension of mathematical and artist driven surface production will be explored that leverages robot motion and geometry in order to produce exemplary robotically fabricated works.
- Example Section: Manipulative Matter explores robot manipulation-based manufacture (Eg. Sheet-metal folding) of prototypical building/sculptural parts. Sheet-metal folding requires computational modelling for geometric and fabrication rationalization in order to ensure designs can be realized by manipulating sheet material without it tearing.
- Example Section: Woven Matter aims to unify design and production within one creative process. The course commences with the development of novel programs to control the motion of Penn's industrial robots for robotic weaving. 3D design models will be developed in parallel to fabrication experiments and digital simulations.

ARCH 805 Introduction to Micro-controllers, Sensor and Actuator Systems

Supports ARCH 801 Material Agencies I. This introductory seminar covers the design and assembly of electronic circuits using sensors/actuators and micro-controllers, and their use in closed or open reactive systems. The seminar work is intended to support an Arch801 project prototype to drive additional design affects (Eg. morphology/kinetics, lighting, porosity, translucency, etc). The course explores control, feedback, energy and force in relation to interactions of matter, space and perceived activity (human or non-human), and the embedment of Internet of Things (IOT) technologies to drive additional design agencies.

“There is ample room for experimentation is this growing field, and numerous multi-disciplinary career trajectories in high-value industries, where designers can operate as entrepreneurs and specialists, providing substantial societal and environmental impact”.

*–Robert Stuart-Smith,
Assistant Professor of Architecture*

ARCH 803 General Overview of Algorithmic Design and Robotic Fabrication

Supports ARCH 801 Material Agencies I. Topics vary to suit application within the Arch 801 brief. This seminar ties the programming of robot motion to a generative design process, removing conceptual and practical barriers between design conception and project implementation. Computer and robot programming skills will be developed to support both design and robotic fabrication constraints in parallel. Working within a 3d programming environment, participants will aim to program robot production methods that in turn generate design outcomes when deployed in physical processes on Penn's Industrial Robots. Subject matter and software varies, examples include: Java, Python, Grasshopper, etc.

COURSE DESCRIPTIONS

ARCH 807 RAS Theory

This seminar provides a theoretical context to the program, relating autonomous robotics and fabrication research to architectural discourse, philosophy, science and technology. This course critically assesses present and future societal trajectories in relation to technology, exploring socio-political, ethical and philosophical arguments that concern a broader technological shift that has occurred during the last decade which has given rise to our unquestioned reliance on algorithms within our everyday lives (social media, shopping, navigation), and similar impact from Urban OS's, Industry 4 and driverless car technologies. A theoretical written statement related to ARCH 801 Material Agencies I Section 1 or 2 will be produced by participants within this core seminar.

Designated Elective

Students may enroll in available designated electives within the schools of Architecture and Engineering.simulations.

ARCH 802 Material Agencies: Robotics & Design Lab II

The Spring Material Agencies semester-long design course demands a critical and creative response to the role of design within the domain of autonomous manufacturing and Industry 4.0. While the subject matter varies, the course centers on the demonstration of a robotically manufactured prototype that operates as a full-scale part or whole of a design proposal for a building, space, or event. Working in small groups, participants will develop designs for a speculative project-driven scenario explored within computer simulations and other forms of design media in addition to a fabricated prototype. Projects are demonstrated through a comprehensive design-research into material and robotic processes that is supported by ARCH804, ARCH806 and ARCH808 coursework.

ARCH 804 Advanced RAS Programming

II with more advanced robot programming and decision-making methods, enabling student's greater degrees of adaptive control in their engagement with design and production processes. While topics may appear aligned with science and engineering subjects, Arch804 does not engage in development of technologies, rather their strategic application within design, fabrication or end-use scenarios. Topics vary to suit the Arch802 design brief and emerging technologies within industry and academia. Examples include use of machine vision, machine learning, or behavior-based live-adaptation.

ARCH 806 Experimental Matter

This course aims to develop knowledge in state of the art materials, material applications and fabrication methods and to contribute research and experimental results towards ARCH 802 Material Agencies II design projects. Operating predominantly through research and controlled physical experiments, students will develop a material strategy for their ARCH 802 Material Agencies II work, investigating scientific research papers, industry publications and precedent projects in order to develop know-how in materials and material applications. A material application method will be proposed and experimented with in order to evaluate its use within a robotic fabrication process.

ARCH 808 Scientific Research & Writing

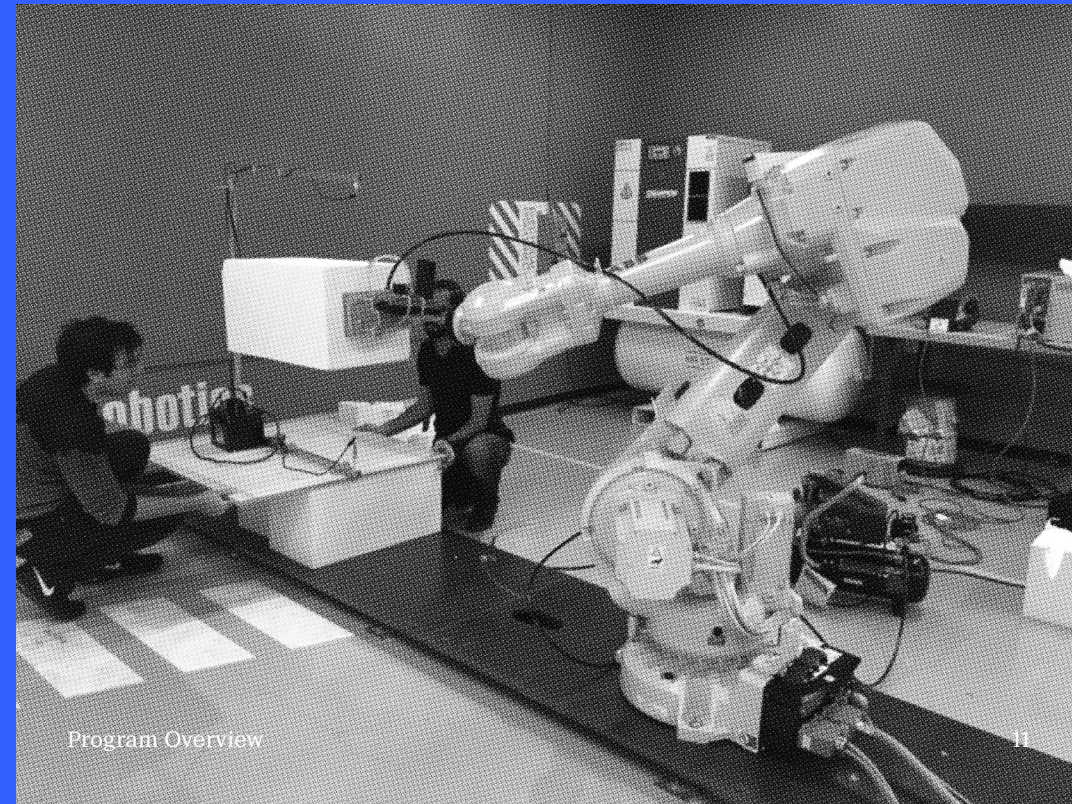
This course aims to provide students with knowledge in state-of-the-art robotics and design taking place in the research community and to introduce methods to evaluate and demonstrate academic research that encompasses both creative and technical work. Submissions will include literature review of precedent research and a technical written statement related to ARCH 802,804,806 work. The course will help raise the level of technical and research discourse within the MSD-RAS and train students in a necessary skill required for many potential academic and industry career opportunities.

AN INNOVATIVE NEW PROGRAM — WHAT MAKES THE WEITZMAN SCHOOL MSD-RAS UNIQUE?

The MSD-RAS at the Stuart Weitzman School of Design, a global leader in architectural design, offers a unique education in architectural design and robotic fabrication. While other courses might focus on fabrication or computation, the MSD-RAS offers opportunities for hands-on experimentation, design speculation, team-based collaboration, and access to world-leading facilities, with learning supported primarily through project-based work rather than through a written thesis alone.

The program's emphasis on project-based work provides practical learning opportunities, also supported by technical and theoretical courses that run in parallel and are directly related to design projects, ensuring participants learn how to approach design from multiple creative and technical aspects holistically, while learning how to communicate design-research to industry and academia. As the MSD-RAS operates within the context of a large, Ivy League, research institution, there are also overlapping interests with the departments of mechanical engineering, computation science, material science, biology, and medicine that enable opportunities for interdisciplinary collaboration, or participation in seminal interdisciplinary research and symposia.

The MSD-RAS operates in state-of-the-art facilities, including the newly launched Weitzman School ARI Robotics Lab, and has close ties to the building industry. The program's STEM status, renowned faculty, and proximity to prospective employers in Philadelphia and New York City also ensure it offers the best industry and employment opportunities for graduates.



WORLD-LEADING, INTER-DISCIPLINARY FACULTY

The MSD-RAS program is taught by some of the Weitzman School's most inter-disciplinary and internationally-experienced architecture faculty, while drawing on expertise from Penn Engineering and Computer Science departments to contribute expert knowledge in robotics, computer vision, electrical engineering, and more.

Penn's faculty are actively working on research and practice projects related to the core topics of the MSD-RAS, such as a full-scale precast concrete house prototype in collaboration with Cemex that leverages robot hot-wire cutting for the production of formwork molds, a robot curve-folded sheet-metal installation undertaken in collaboration with Robofold, or an advanced environmentally performative cooling-oculus skylight, fabricated using thermo-adaptive robot sheet metal-forming.



Winka Dubbeldam

Chair and Miller Professor Architecture

Winka Dubbeldam is a seasoned academic and design leader, serving as Chair and Miller Professor of Architecture at the University of Pennsylvania Stuart Weitzman School of Design, where she has gathered an international network of innovative research and design professionals. Previously, Professor Dubbeldam oversaw the Post-Professional Degree program for 10 years (2003-2013), providing students with innovative design skills, cutting-edge theoretical and technological knowledge, and the analytic, interpretive, and writing skills necessary for a productive and innovative career in the field of architecture. She also taught advanced architectural design studios at Columbia University and Harvard University, among other prestigious institutions. Dubbeldam gave a TED talk at TEDGLOBAL 2013, in Edinburgh, Scotland, "Bottom-up Design for Bogota". Dubbeldam was the External examiner at the Architectural Association London (2006-2009), and is currently the External Examiner at the Bartlett School of Architecture in London (2019-present). Professor Dubbeldam was named one of the DesignIntelligence 30 Most Admired Educators 2015. She has been a juror at the Prix de Rome, several AIA juries, and at the Bogota Architecture Biennale in 2010.

As the founder/principal of the WBE certified New York firm Archi-Tectonics, Dubbeldam is widely known for her award-winning work, recognized as much for its use of hybrid sustainable materials and smart building systems as for its elegance and innovative structures. Publications include published in numerous international architecture and design periodicals, as well as in three monographs Winka Dubbeldam, Architect (O10 Publishers, Rotterdam, 1996), AT-INDEX (Princeton Press, NYC, 2006), and Archi-Tectonics (DAAB publishers, 2010); a new book is planned for 2019 with Actar Spain. Recently Archi-Tectonics won the Asian Games Sports Park Invited Design Competition (2018), with a mile long park, a shopping mall and 2 stadiums, currently under construction in Hangzhou, China.

WORLD-LEADING, INTER-DISCIPLINARY FACULTY



Robert Stuart-Smith

MSD-RAS Program Director,
Assistant Professor of Architecture

Robert Stuart-Smith is an Architect and Designer who operates at the intersection of architecture, generative design and robotics. He directs the Autonomous Manufacturing lab(AML) in the Weitzman School of Design where he teaches design studios in the MSD-RAS and M.Arch programs, and the M.Arch core technology course Material-Formations, which integrates robotic and material processes within design. Operating in the fields of architecture and computer science, Robert's research involves inter-disciplinary collaborations, and sponsorships from world-leading industry partners Cemex, Skanska, Kuka, Burohappold, Arup, Ultimaker and others, alongside multi-million dollar government funding on pioneering research into Autonomous Multi-Robot Construction, and Aerial Additive-Manufacturing. Stuart-Smith has been at the forefront of generative design since 2001, co-founding Kokkugia, who pioneered the development of multi-agent systems for building design.sustainable materials and smart building systems as for its elegance and innovative structures.



Ezio Blazetti

Senior Lecturer in Architecture

Ezio Blazetti, is registered Architect (TEE-TCG), and holds a Masters of Science in Advanced Architectural Design from Columbia University, having previously studied in Athens and Paris. His academic and professional research focuses on the application of advanced technologies in all phases of architectural design, from initial composition to digital and robotic fabrication. He is a founding partner at Maeta Design, an architectural design and research firm based in Brooklyn NY, Philadelphia PA, and Athens Greece. In 2009 he co-founded Ahylo, an architectural design and construction practice as well as "Apomechanes", an annual intensive design lab on algorithmic processes and fabrication.



Andrew Saunders

Associate Professor of Architecture

Prof. Andrew Saunders has undertaken research into robot sheet metal bending, and 3D scanning of historic buildings; publishing in building technology, mathematics, and architectural journals. He is an Associate Professor of Architecture at Weitzman School of Design and founding principal of Andrew Saunders Architecture + Design, an internationally published, award-winning architecture, design and research practice committed to the tailoring of innovative digital methodologies to provoke novel exchange and reassessment of the broader cultural context. The practice innovates at a number of scales ranging from product design, exhibition design, and residential and large-scale civic and cultural institutional design. His current practice and research interests lie in computational geometry as it relates to aesthetics, emerging technology, fabrication, and performance.



Dorit Aviv

Assistant Professor of Architecture

Dorit Aviv is a designer and researcher specializing in the fields of energy and ecology. Her work investigates the relationships between thermodynamics, architectural geometry and material science. Prior to Penn, Aviv taught at The Cooper Union, Pratt Institute, and Princeton University and has practiced in design roles at Tod Williams Billie Tsien Architects, Kohn Pedersen Fox, and Atelier Raimund Abraham. Her research projects include a prototype for combined evaporative and radiative cooling roof device for desert climate, being built in full scale at Tuscon, Arizona in collaboration with Aletheia Ida, an experimental pavilion built in Singapore to allow radiant cooling below the dew point and the curation of the energy pavilion in the 2017 Seoul Biennale for Architecture and Urbanism with Forrest Meggers.

FACILITIES — THE ADVANCED RESEARCH AND INNOVATION ROBOTICS LAB

MSD-RAS students will utilize Penn's new Advanced Research and Innovation Robotics Lab facility that houses state of the art industrial robots and experienced staff. The new facility includes 2 x ABB IRB4600-60 robots that provides a flexible production space for individual and team-based robot production. Considerable investment in auto-tool changing capabilities enables an extensive range of production activities to be undertaken with minimal set-up time such as robotic milling, additive manufacturing, sheet-metal bending or robot hot-wire cutting. ARI facilities also include other industrial robots, 3d printers, pre and post-production work spaces and equipment for supporting fabrication and robot tooling development. Students in the MSD-RAS will be trained to utilize the ARI industrial robots, and it is expected that a considerable amount of their design-research is developed through robotically fabricated prototypes and the development of robot programs and/or end-effector tools.



ADMISSIONS + NEXT STEPS

For specific information regarding admissions, please [click here](#). Applicants must submit three letters of recommendation, official transcripts from each US college or university attended for credit and/or a BASIC course-by-course evaluation from World Education Services (<http://www.wes.org/>) or Educational Perspectives (<https://www.edperspective.org/>) from institutions outside of the United States, GRE scores, a résumé, a digital portfolio of design work, one writing sample, a description of computing skills and software proficiency, and a personal statement describing his/her educational goals in taking the program. International applicants must submit official IELTS Academic, PTE Academic, or TOEFL scores if English is not their first language.

Applicants to the Master of Science in Design must also submit official GRE scores. International applicants must submit official IELTS Academic, PTE Academic, or TOEFL scores if English is not their first language. All applications are reviewed by the Admissions Committee of the graduate program.



Program Director:

Robert Stuart-Smith, rsmith@design.upenn.edu

Program Faculty:

Andrew Saunders, Dorit Aviv, Ezio Blazetti, Robert Stuart-Smith, among others.

Department of Architecture Chair:

Winka Dubbeldam, Assoc. AIA



“The MSD-RAS will be a unique opportunity to learn and combine the most advanced design techniques with the most innovative robotic manufacturing technologies. As professionals of the architecture industry, I consider that the knowledge acquired in this Masters will be crucial to giving us agency in the professional or academic universe of today and tomorrow.

Furthermore, Robert Stuart Smith as director of the program, accompanied by the faculty of the Weitzman School of Design guarantee the professionalism, dedication and high academic level of the program”

–Mariana Righi, Current Master of Architecture Student

COURSE DESCRIPTIONS

How much of the Program involves groupwork versus individual work?

Material Agencies: Robotics & Design Lab I & II involve group projects while the majority of the other courses involve individual submissions. There is ample opportunity to demonstrate individual knowledge whilst benefiting from the empowering capabilities of collaborative group work!

How Long is the MSD-RAS Program?

The MSD-RAS involves a 2-Week introductory course and two semesters. The program is full-time and can be completed in approximately 9 months.

Can I do the MSD-RAS part-time while working?

The MSD-RAS is a full-time program due to the fact that all course-work is inter-related to project-based assignments.

Is Financial Aid Available for the MSD-RAS?

Yes, the Weitzman School of Design awards scholarships to master's degree students based on merit and/or need. Need is determined for consideration for these awards, as well as for Federal loans and work-study, from the Free Application for Federal Student Aid (FAFSA) form for US citizens and permanent residents. Need is determined for international students from our International Student Application (www.design.upenn.edu/sites/default/files/uploads/International_Financial_Aid_Application_2020.pdf).

Are there elective studios in the MSD-RAS?

All MSD-RAS students undertake the same courses with the same professors with the exception of an elective course in the Fall Semester.

What qualifications will I have when I complete the course?

The course is a Master of Science in Design in Robotics and Autonomous Systems. It is offered in the University of Pennsylvania Stuart Weitzman School of Design's Department of Architecture and is a STEM certified course.

Is this an architectural design Masters degree?

The MSD-RAS is both a design and science degree. The MSD-RAS is open to anyone with a degree in architecture, the coursework is focused on design operating through material experimentation and robotically manufactured prototypes, with parallel support and training in computer programming and generative design methods. The Program is both speculative and hands-on! The department also offers Post-Professional degrees in Advanced Architectural Design (MSD-AAD) and in Environmental Building Design (MSD-EBD)

I don't have a degree in Architecture.

Am I eligible to apply?

The MSD-RAS is primarily geared towards architectural graduates however, candidates from other fields whose prior experience and future career interests align with the course and who can fulfill the application requirements will be considered. If you believe this applies to you, we strongly encourage you to contact us so that we can help you determine whether your application would be considered.

I have a Masters degree in Architecture however, my Bachelor degree was in another field.

Am I eligible to apply?

Yes.

COURSE DESCRIPTIONS

What skills can I expect to learn during the Program?

Participants will gain state of the art knowledge and experience in industrial robot fabrication and programming, design and computer programming skills, material research and application methods, academic writing skills and more.

Does Penn also offer a certificate similar to MSD-RAS?

No, if you are interested, you would need to undertake the MSD-RAS!

I don't have prior experience in robots or computer programming, can I apply?

The MSD-RAS program has been structured in such a way as to not require applicants to have prior knowledge or experience in computer programming or robotics however, prior knowledge and experience is helpful.

What software will be utilized and do I need to know these before starting the MSD-RAS?

Use of software programs varies with continual updates to the curricula. Where use of a specific software is required, training in the software will be provided. Commonly used software in the fields of design and robotic fabrication include: Rhino3D, Grasshopper, ABB RobotStudio, HAL, Visose Robots, ROS, Arduino, Processing, and others, in addition to Adobe Creative Suite and MS Office. Prior experience in these is helpful but not required.

What programming languages will classes utilize, and will I be taught these?

Programming languages vary with continual updates to the curricula. A MSD-RAS student can expect to be taught and to utilize at least two programming languages from the most common languages in use (python, java, C++, C#). Python is perhaps the most versatile language for daily use at present due to its easy adoption and broad support across many OS and software frameworks. Note that programming is taught for the purposes of the MSD-RAS applications in design and robot programming, and does not provide a comprehensive education into these languages suitable for other purposes such as web or software development. For those not accustomed to writing software, code can be learned by anyone in a short amount of time, and is far simpler than learning a second language.

Am I required to bring my own computer?

Yes. While the School has lab facilities, the MSD-RAS requires all students to have their own computer. If you are accepted into the program, we can provide you with minimum computer performance recommendations.

What Operating Systems am I able to use in the Program?

All students will be required to have Microsoft Windows 10 installed on their computer. Some courses may utilize Linux for specific tasks, but no pre-installation is required.

HAVE QUESTIONS?

Drop us a line. We'd be happy to answer any remaining questions you might have about the MSD-RAS program.

Architecture Department

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Monday through Friday 9:00-5:00

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