Advanced EE Applications & Nanosystems Design

电子工程与纳米系统设计课程

TO：

西安电子科技大学

2019.10.14

CONTENTS

ONE 课程总览

麻省理工学院(Massachusetts Institute of Technology)，简称麻省理工(MIT)，坐落于美国马萨诸塞州波士顿都市区剑桥市，是世界著名私立研究型大学，QS2017-2019排名全球第一。MIT的校友、教授及研究人员包括了93位诺贝尔奖得主，优势学科/领域包括工程技术、自然科学和社会科学等。

关于主题课程

2020寒假麻省理工学院先进电子工程及电路设计课程由麻省理工学院电气工程与计算机科学学部(EECS, MIT)核心实验室-Microsystems Technology Laboratories主办，由麻省理工学院电子工程学科的核心教授担纲课程设计和教学工作。 该课程将重点关注电子工程的最新场景应用、优化设计以及与其他交叉学科的前沿研究方向等内容，以**Project Based Learning** (PBL)教学法展开，教学课程与麻省理工学院同期开设的相关学科课程内容同步。

波士顿(Boston)位于美国东北部大西洋沿岸，创建于1630年，是美国最古老、最具有历史文化价值的城市之一。波士顿大学林立，是美国高等教育的中心，是全美人口受教育程度第二高的城市。包括麻省理工学院、哈佛大学、东北大学、波士顿学院等数十所知名大学。波士顿吸引了大量的高新技术企业，包括计算机及软件、生物工程、高端制造业和金融保险等，吸引了包括GE, Teradyne, Boston Dynamics等知名企业。

TWO

课程说明

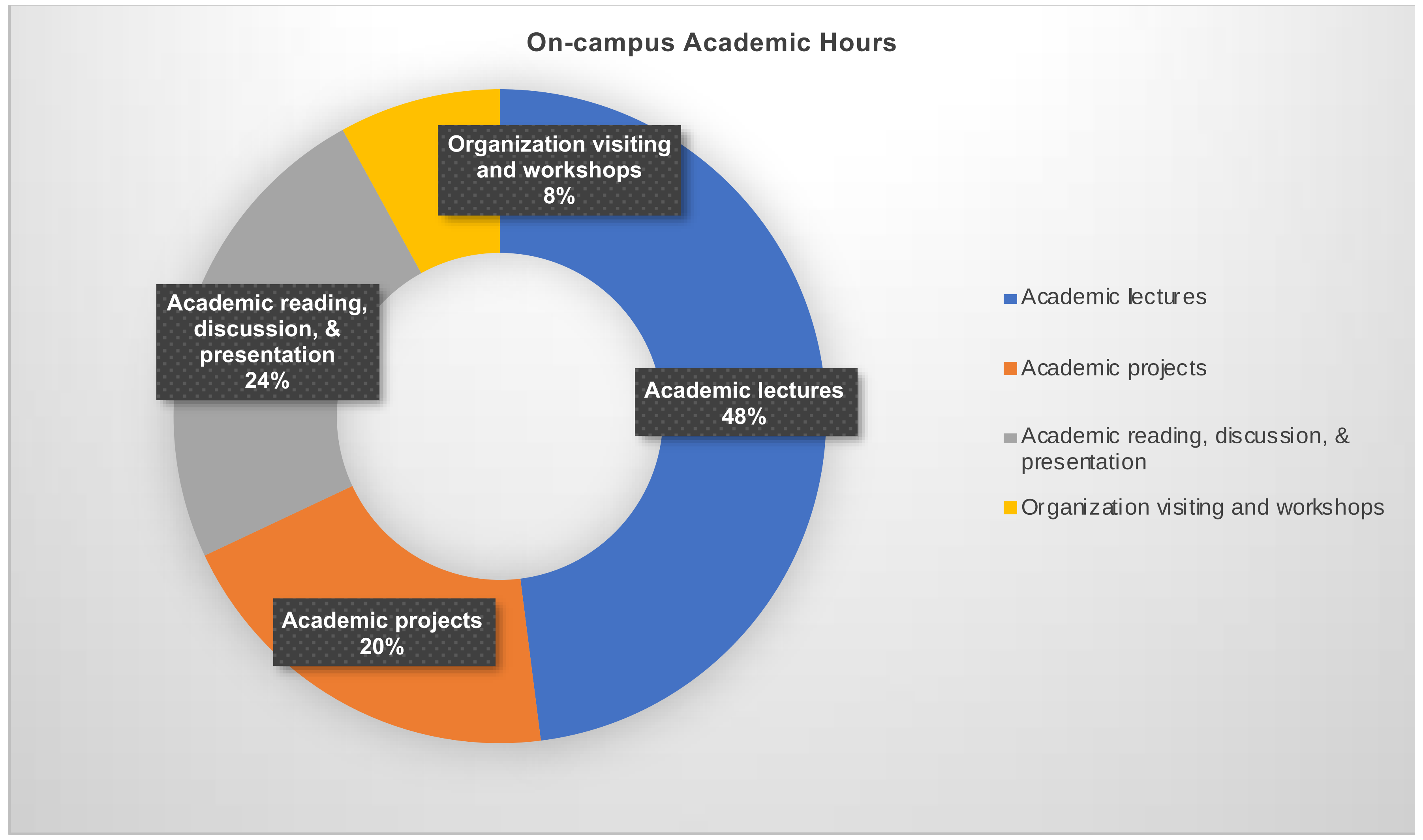
Course Description	Academic Syllabus	Academic Module
The goal of the program is for students to have a robust understanding of the challenges and successes of past and current research on nanotechnologies and its advanced applications in electrical engineering in order to improve chances of success in future research, development and application efforts.	The program will be led by Professor Shulaker and members of his teaching team. The goal of the lectures is to give students a clear understanding of the history, design, and production of nanotechnologies and its advanced applications in electronic engineering. The structure of the first module of the course is historical, by beginning with earlier innovations in electronic engineering and semiconductor technologies students will be led through the various innovations which brought nanotechnologies to their current level. This will prepare students for the second module of the course, which is an analysis of contemporary approaches to the same problems which researchers came across in the past. However, with increased manufacturing accuracy and an improved understanding of materials sciences, solutions involving new materials and design architectures have the potential to provide another revolution in computing. MIT has been a hub of research and practice in all of these disciplines and our program faculty come from areas with a deep focus in Nanosystems. In the third module, this course will dive into the advanced nanotechnologies applications in multiple electronic engineering areas, such as supercomputing, IoT, 5G, and machine learning.	**Module 1: Electronic Engineering: From Vacuum Tubes to Today** Background of electronic engineering, devices, hardware, evolution to solid-state electronics. Going over key metrics by which to analysis electronic systems, which will act as the core of all of the subsequent modules. **Module 2: Nanosystems** Nanoelectronic Systems: Foundations Connect single devices up to complete system-level performance metrics. Understand how computer performance is dictated by the devices and hardware (and calculate key metrics), and how devices parameters can be optimized for different computing applications. Nanoelectronic Systems: State-of-the-Art Today and Next Steps Uderstand the evolution of devices from the first transistors to state-of-the-art devices today, and what has driven these changes. Nanoelectronic Systems: Advanced Concepts Delve deeper into advanced concepts in nanoelectronics, exploring emerging nanotechnologies like one- dimensional and two-dimensional nanomaterials, quantum computing, etc. Nanoelectronic fabrication: Understand nanofabrication techniques and processes for fabricating state-of-the-art electronic systems. Go over new innovations in the field, and what innovations are required to develop the next generation of nanoelectronics systems. Nanoelectronic design: In addition to building systems, we must be able to design them. This module covers the full end-to-end design flow of how hardware is designed: from low-level device compact models up to full system synthesis using industry-standard design flows. **Module 3: Nanosystems Applications in Electronic Engineering** Application I: High-Performance Computing For our first application, apply what we have learnt to the field of high-performance computing. Understand how supercomputers are made, what their requirements are, and what state-of-the-art in supercomputing looks like today and challenges moving ahead. Application II: Internet-of-Everything/ Ultra-Low-Power Embedded Systems: For our second application, apply what we have learnt to the opposite field of supercomputing: ultra-low- power embedded systems. Look at applications ranging from remote sensing nodes to implantable electronics, and compare, contrast, and optimize vs. supercomputers from Module 7. Application III: Telecommunications: For our third application, apply what we have learnt to the broad and rapidly growing field of telecommunications. Covers and integrates topics ranging from antennas and RFIDs to radar systems to next generation 5G. Application IV: Machine Learning For our last application, delve into the exciting world of machine learning. Explore novel hardware for machine learning, including neuromorphic chips, machine learning accelerators, and cutting-edge research at the intersection of hardware and machine learning/ artificial intelligence.

课程结构（4周+2周+4周）

课程结构为：Pre-learning（4周）+ On-campus Course（2周）+ Post-learning（4周）共计10周课程学习计划；包含出发美国前4周Pre-learning，2周在MIT的学习，以及课程结束后4周的Post-learning。

Pre-learning（4周）	On-campus Course（2周）	Post-learning（4周）
▫ 课程概览、预习课件 ▫ 波士顿介绍 ▫ 学术报告阅读、测评 ▫ 出行安全和行动纪律	▫ 共50学术课时 - 结合Project Based Learning (PBL) 教学法 ▪ 24课时 – 专业课 ▪ 10课时 – 实践课 ▪ 12课时 – 学术报告阅读、小组讨论、实践成果汇报 ▪ 4 课时 – 机构探访、研讨会	▫ 实践成果后续跟进 ▫ 助理研究员申请 ▫ 长期项目跟进

On-campus Academic Content	Hours
Academic lectures	24
Academic projects	10
Academic reading, discussion, & presentation	12
Organization visiting and workshops	4
Total	**50**



THREE 〉教学团队

Anantha P. Chandrakasan

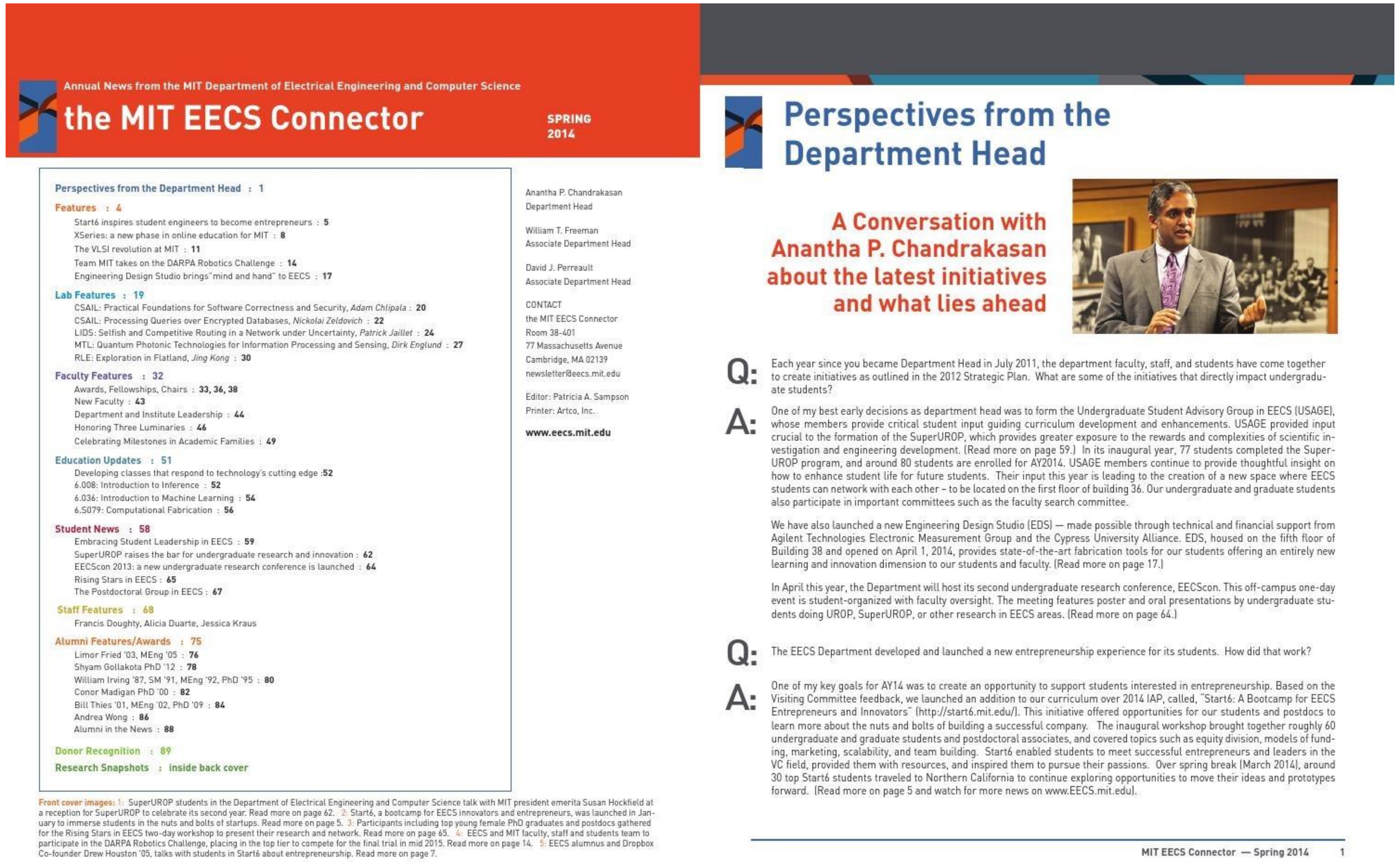
Dean of MIT' s School of Engineering

The Vannevar Bush Professor of Electrical Engineering and Computer Science.

Fellow of National Academy of Engineering

Head of the MIT EECS Department

Co-chairs the MIT–IBM Watson AI Lab and chairs the MIT-SenseTime Alliance on Artificial Intelligence and J-Clinic, the Abdul Latif Jameel Clinic for Machine Learning in Health at MIT



Annual News from the MIT Department of Electrical Engineering and Computer Science

the MIT EECS Connector

SPRING 2014

Anantha P. Chandrakasan
Department Head

William T. Freeman
Associate Department Head

David J. Perreault
Associate Department Head

CONTACT
the MIT EECS Connector
Room 38-401
77 Massachusetts Avenue
Cambridge, MA 02139
newsletter@eecs.mit.edu

Editor: Patricia A. Sampson
Printer: Artco, Inc.

www.eecs.mit.edu

Front cover images: 1: SuperUROP students in the Department of Electrical Engineering and Computer Science talk with MIT president emerita Susan Hockfield at a reception for SuperUROP to celebrate its second year. Read more on page 62. 2: Start6, a bootcamp for EECS innovators and entrepreneurs, was launched in January to immerse students in the nuts and bolts of startups. Read more on page 5. 3: Participants including top young female PhD graduates and postdocs gathered for the Rising Stars in EECS two-day workshop to present their research and network. Read more on page 65. 4: EECS and MIT faculty, staff and students team to participate in the DARPA Robotics Challenge, placing in the top tier to compete for the final trial in mid 2015. Read more on page 14. 5: EECS alumnus and Dropbox Co-founder Drew Houston '05, talks with students in Start6 about entrepreneurship. Read more on page 7.

Perspectives from the Department Head

A Conversation with Anantha P. Chandrakasan about the latest initiatives and what lies ahead

Q: Each year since you became Department Head in July 2011, the department faculty, staff, and students have come together to create initiatives as outlined in the 2012 Strategic Plan. What are some of the initiatives that directly impact undergraduate students?

A: One of my best early decisions as department head was to form the Undergraduate Student Advisory Group in EECS (USAGE), whose members provide critical student input guiding curriculum development and enhancements. USAGE provided input crucial to the formation of the SuperUROP, which provides greater exposure to the rewards and complexities of scientific investigation and engineering development. (Read more on page 59.) In its inaugural year, 77 students completed the SuperUROP program, and around 80 students are enrolled for AY2014. USAGE members continue to provide thoughtful insight on how to enhance student life for future students. Their input this year is leading to the creation of a new space where EECS students can network with each other – to be located on the first floor of building 36. Our undergraduate and graduate students also participate in important committees such as the faculty search committee.

We have also launched a new Engineering Design Studio (EDS) — made possible through technical and financial support from Agilent Technologies Electronic Measurement Group and the Cypress University Alliance. EDS, housed on the fifth floor of Building 38 and opened on April 1, 2014, provides state-of-the-art fabrication tools for our students offering an entirely new learning and innovation dimension to our students and faculty. (Read more on page 17.)

In April this year, the Department will host its second undergraduate research conference, EECScon. This off-campus one-day event is student-organized with faculty oversight. The meeting features poster and oral presentations by undergraduate students doing UROP, SuperUROP, or other research in EECS areas. (Read more on page 64.)

Q: The EECS Department developed and launched a new entrepreneurship experience for its students. How did that work?

A: One of my key goals for AY14 was to create an opportunity to support students interested in entrepreneurship. Based on the Visiting Committee feedback, we launched an addition to our curriculum over 2014 IAP, called, "Start6: A Bootcamp for EECS Entrepreneurs and Innovators" (http://start6.mit.edu/). This initiative offered opportunities for our students and postdocs to learn more about the nuts and bolts of building a successful company. The inaugural workshop brought together roughly 60 undergraduate and graduate students and postdoctoral associates, and covered topics such as equity division, models of funding, marketing, scalability, and team building. Start6 enabled students to meet successful entrepreneurs and leaders in the VC field, provided them with resources, and inspired them to pursue their passions. Over spring break (March 2014), around 30 top Start6 students traveled to Northern California to continue exploring opportunities to move their ideas and prototypes forward. (Read more on page 5 and watch for more news on www.EECS.mit.edu).

Current Research Areas

Security for Internet of Things (IoT)

The sheer number and diversity of IoT devices, along with their limited resources, makes IoT security a challenge quite different from securing traditional computing systems. As a circuits and systems group, we have been working on the design of low-power cryptographic hardware accelerators, wireless authentication tags and energy-efficient security protocols. Apart from the traditional approach, we are also exploring novel applications of security like speech authentication, physical layer security in RF transceivers, and authentication in the analog domain.

教学团队

Max Shulaker

Professor, Department of EECS, MIT
Principal investigator, Microsystems Technology Laboratories
Leader, Novels Group, MIT

Research Interests: Nanosystems exploiting emerging nanotechnologies

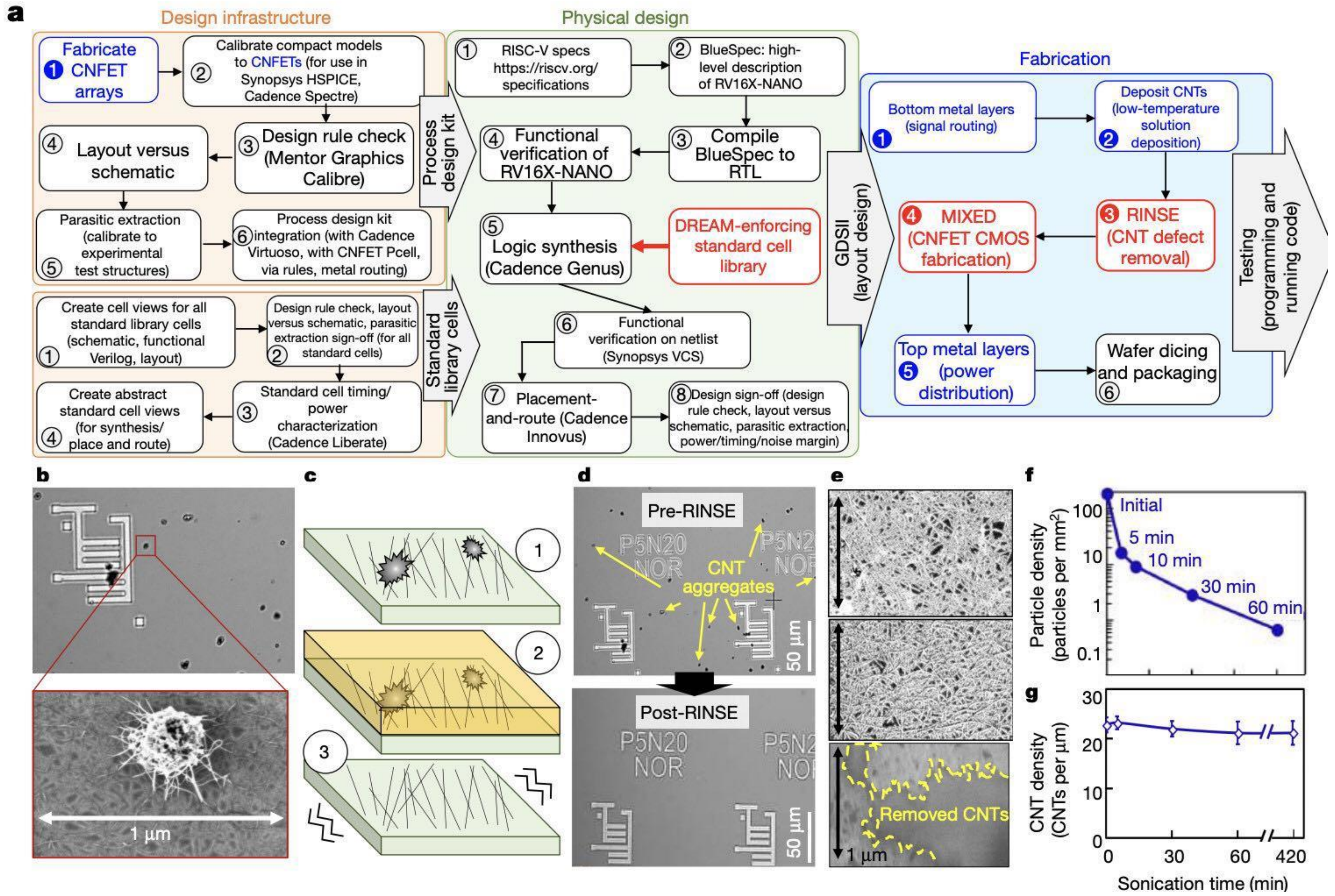
nature
International journal of science

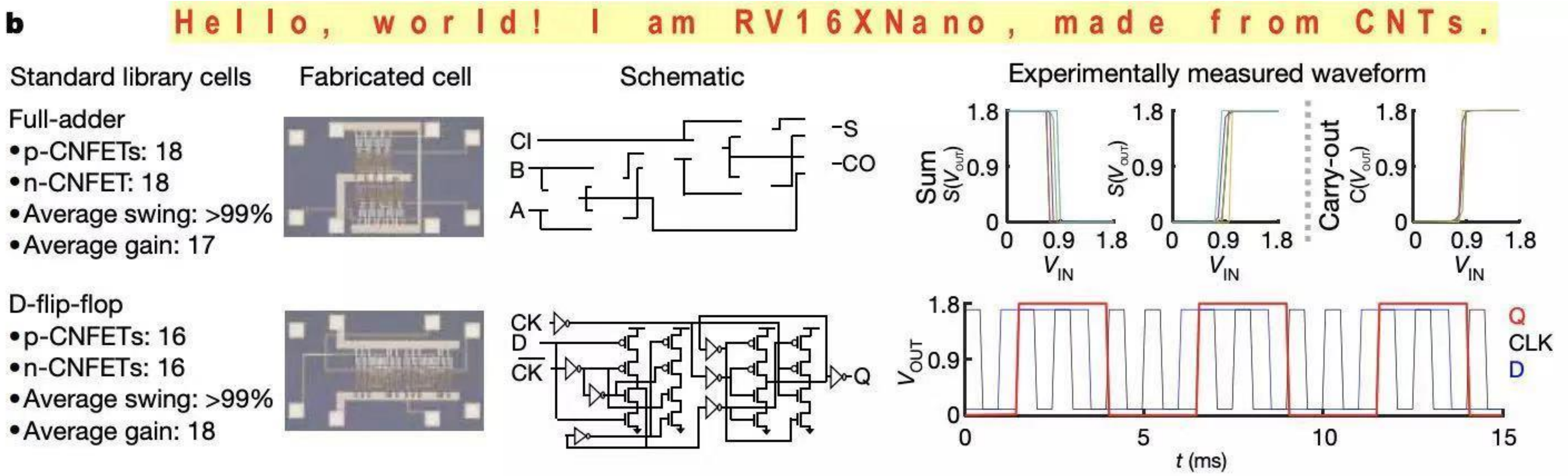
Article | Published: 28 August 2019

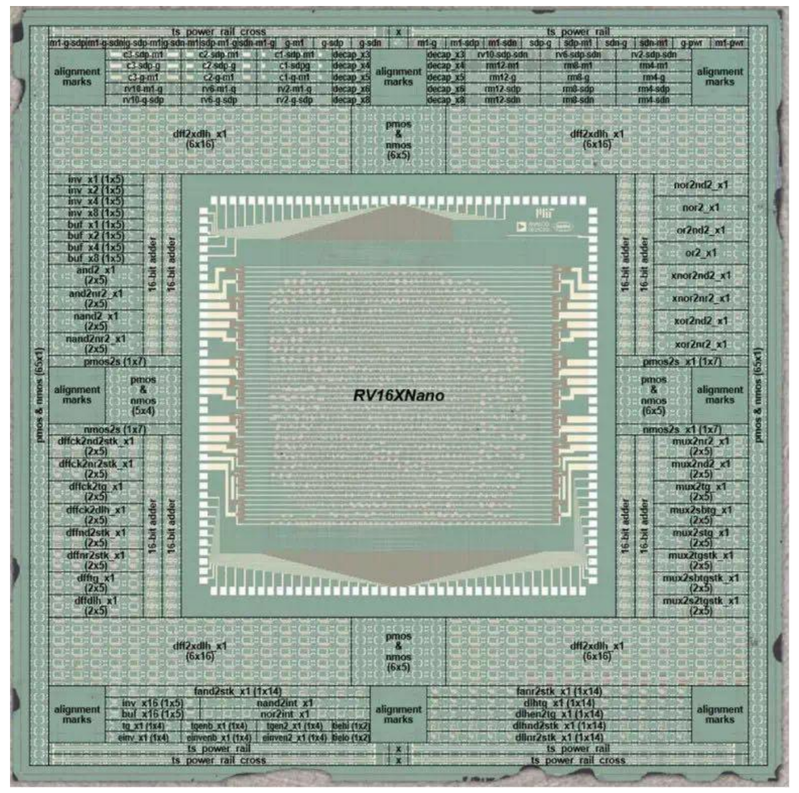
Modern microprocessor built from complementary carbon nanotube transistors

Gage Hills, Christian Lau, Andrew Wright, Samuel Fuller, Mindy D. Bishop, Tathagata Srimani, Pritpal Kanhaiya, Rebecca Ho, Aya Amer, Yosi Stein, Denis Murphy, Arvind, Anantha Chandrakasan & Max M. Shulaker

Nature **572**, 595–602 (2019) | Download Citation







FOUR > 在美生活

1. 入住公寓，住宿标准为两人一间；项目期间自由使用MIT校园餐厅、图书馆、自习室等公共设施；
2. 两周当地公共交通卡，探索波士顿作为教育之都、历史之都、体育之都、艺术之都的重要印记；
3. 按照授课要求完成规定学习及考核内容将获得课程官方证书和成绩单；项目中表现优异者将有机会获得授课教授的推荐信。
4. Fellowship，由当地学生组成Fellow团队，全程与学生一起，使学生们更加全面客观地了解在美留学生活状况及当地文化。

FIVE 暑期针对Max团队授课部分（总计8学时）的学生反馈

Q. 反馈1

对于纳米材料的课程，真的非常惊喜，主讲教授MAX给我们都留下了很深刻的印象：他幽默风趣，平易近人，讲课非常清晰和生动，并且英语口音真的很好听。能让我们感受到他对于课程的用心，他带着我们将半导体器件材料的整个发展过程，以及遇到的问题，下一步的解决等知识梳理了一遍，本来以为是关于材料结构的知识，但实际上将芯片设计，工艺制程等知识都涉及到，最后再介绍了碳纳米工艺的现状。虽然听上去似乎是我已经学习过的知识，但是跟着他的脚步重温，从不同的角度看待问题，真的让我对知识有了新的认识。听课之余，也在不断定位自己在半导体行业中的位置和将要如何发展的方向。

Q. 反馈2

微电子相关的专业课程，是由MIT年轻的教授Max来授课，这次的微电子课程使我受益匪浅。第一节课，Max教授从一个最小的晶体管讲起，从理想情况出发，逐步延伸，加入非理想因素，得到了最简单的也是最基本的最小单位：非门，紧接着将非门进行组合逻辑排布，得到了一些简单的逻辑电路，他不循循善诱，让我们不断考虑需要加入的非理想因素和其他的条件，最终得到了一个数字逻辑电路和几个基本公式，这种全新的授课模式，以及授课思维，让刚学完数字集成电路的我大为震惊，原来数字集成电路可以这样学，原来从纵向以及横向不同的角度来思考问题竟然这样有趣，同时又如此整合和综合。在课堂Max教授是学识渊博的讲师，而在答疑时间，又是耐心的人生导师，同学们在下课后都对Max教授赞不绝口，同时也感叹MIT师资的雄厚。第二节课我们按照时间线梳理了半导体器件的发展史，从一个单纯的MOSFET到SOI 再到FinFET,使我真正的理解了人类在半导体发展史上智慧，以及创新思维。

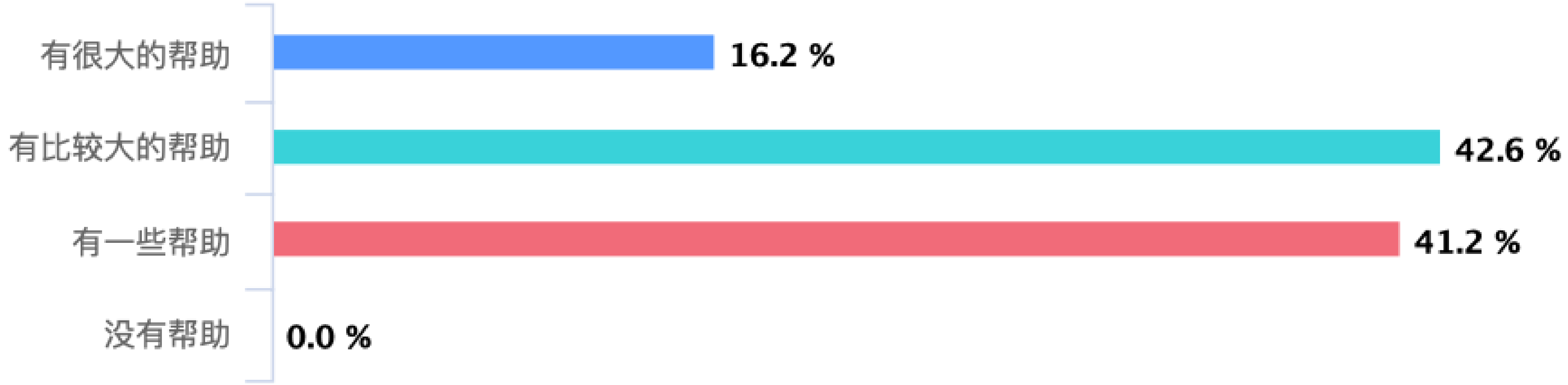
Q. 反馈3

在MIT给我们讲课的是Max Shulaker教授和他的团队，包括Gage Hills教授和Mindy Bishop。Max教授一共给我们上了两节课，第一节课就让我们感觉非常过瘾，以计算机的结构为主线，给我们讲为什么计算机会有速度上的限制，贯穿了从半导体材料到MOS管到大型集成电路的方方面面，给我们讲了如何成百倍，千倍地提升运算速度，受益匪浅。第二节课上以半导体器件为线索，从SOI到FinFET和未来有可能的碳纳米管CNFET，以及未来可能的纳米系统（3D集成电路）并提出了各自的优势与劣势。而且还问了我们未来的可能的方向，提出了许多建议。仅仅两节课就让我们感觉到这个教授很不一般。

FIVE 核心收获

Q. 通过本次课程，对你在学术方面是否有帮助？

100%的学生认为学术课程对自身有不同程度的帮助，学生对于暑期课程的整体打分平均分为8.04/10



Q. 通过本次课程，你的收获主要体现在哪些方面（最多选择三项）？

除了开拓视野外，60%左右的学生认为通过此次暑期学术课程，不但学习到很多新知识、新技能，对后续的学习或研究方法有所启发，同时对机器学习这门学科有更深的了解，其中有27.9%的学生坚定了出国留学的方向。

核心收获

- Teaching Methodology
- Hands-on Project
- Research Methodology
- Long-term Study Abroad Opportunity

SIX 日程安排

Week 1

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
08:00-09:00	Arrival & Check-in	Breakfast (Included)					
09:30-11:30		Boston Exploration - Education: MIT Campus Visiting	Lecture	Lecture	Lecture	Lecture	Lecture
11:30-13:00		Lunch time					
13:00-15:00		Opening Ceremony	Lecture	Project	Lecture	Project	Presentation 1
15:00-17:00			Academic Reading	Organization Visiting & Workshop	Project	Group Discussion	Academic Reading
17:00-19:00		Dinner time					
19:00-21:00		Ice Breaking: Self-introduction	Self-study	Assignment 1	Self-study	Self-study	Self-study

Week 2

Time	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15
08:00-09:00	Breakfast (Included)							Back to China
09:30-11:30	Boston Exploration - Education: Harvard Campus Visiting	Boston Exploration - Arts: Harvard Museums	Lecture	Lecture	Lecture	Presentation 2	Check-out & Drop off	
11:30-13:00	Lunch time							
13:00-15:00	Boston Exploration - Arts: The Institute of Contemporary Art	Boston Exploration - History: Freedom Trail	Lecture	Project	Lecture	Closing Ceremony		
15:00-17:00			Organization Visiting & Workshop	Group Discussion	Project		Departure	
17:00-19:00	Dinner time					Lobster Farewell Dinner (Included)		
19:00-21:00	Boston Exploration - Sports: NBA Game	Boston Exploration - Arts: Museum of Fine Arts	Assignment 2	Self-study	Self-study			

*The schedule may be affected by the weather, event space, and other emergency situation.