

Undergraduate Curriculum Revision

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Faculty Lunch – March 11, 2008

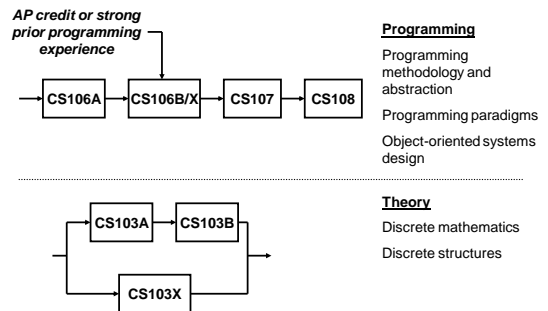
Outline

- Brief review of current curriculum
- Structure of new curriculum
- CS Core courses
- Initial set of tracks
- Vote

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Current Curriculum: Lower Division



Current Curriculum: Upper Division

- Theory Depth
 - CS154: Automata and Complexity Theory
 - CS161: Design and Analysis of Algorithms
- Systems Depth
 - EE108B: Digital Systems II
 - Two Systems Electives (OS, Compilers, Networking, etc.)
- Applications
 - CS121/221: Artificial Intelligence
 - One Applications Elective (Databases, HCI, Graphics, etc.)
- 2-3 Restricted CS Electives
- Senior Project capstone course

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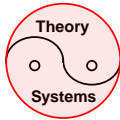
Revised Curricular Structure: *Core*

Theory Core: 3 Courses

- Incorporates portions of current theory sequence
- Eliminates redundancies in cs103 and cs161
- CS-owned probability course with AI applications

Systems Core: 3 Courses

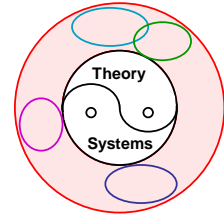
- Incorporates portions of current intro programming sequence
- Incorporates systems concepts in later programming projects
- CS106A considered "funnel" into core (not part of core)



Revised Curricular Structure: *Tracks*

~4 Courses

- Students must complete requirements for any one track
- Developing depth in a specialization
- Provide course/theme options within each track
- Provide multi-disciplinary options
- Modularize curriculum



Why Tracks?

- Explicitly shows available options
 - Allows students to focus on areas in which they have the greatest interest, thus increasing appeal of program
- Helps eliminate image of CS as "just programming"
 - Shows diversity of themes in computer science
 - Provides more context for what is possible with CS degree
- Provides organizational infrastructure
 - Easier to evolve major as the field evolves
 - E.g., add/drop/modify tracks (or programs in them)

Some More Food For Thought

- Tracks already exist:
 - Applied Logic
 - Artificial Intelligence
 - Decision Making and Rationality
 - Human-Computer Interaction
 - Learning
 - Natural Language
 } ...in Symbolic Systems
- Networking
- Robotics and Mechatronics
- Digital Systems
 } ...and CSE

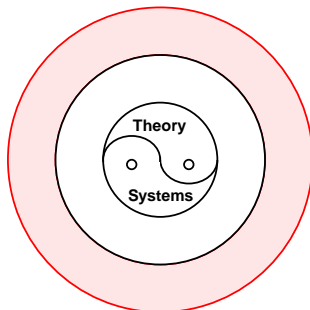
- Biology
- Computational Engineering
 } ...and MCS

- Computer Hardware
- Computer Software
- Communications and Signal Processing
 } ...and EE

Revised Curricular Structure: *Electives*

~2-4 Courses

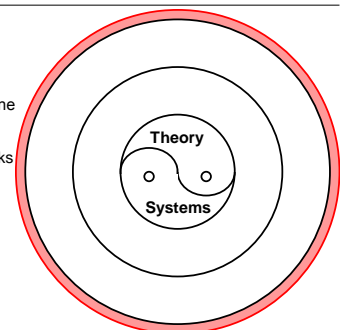
- Restricted electives
- Allow pursuing breadth and/or additional depth
- Track-specific elective options allow for interdisciplinary work



Revised Curricular Structure: *Capstone*

1 Course

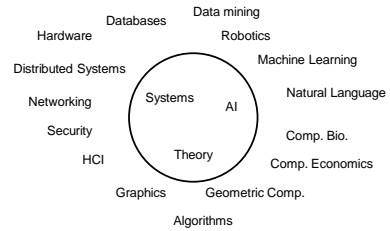
- "Senior project" capstone course
- Developing capstone courses to parallel tracks
- Both application development and research options



Structure Aligns With Broader Context

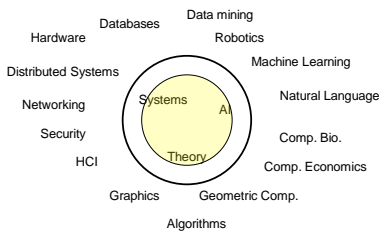
- IEEE-ACM Computing Curricula 2001 Report
 - Supports tracks model
 - Revision committee adopted modular structure to support adaptability
- ICER: Integrative Computing Education & Research
 - Change the popular image of computing
 - Encourage curricular experimentation and innovation
 - Make sure introductory students recognize that the field offers many opportunities
 - Strengthen interdisciplinary connections
- Peer institutions
 - Many peer institutions moving in same direction for similar reasons

Increasing the “Footprint” of CS



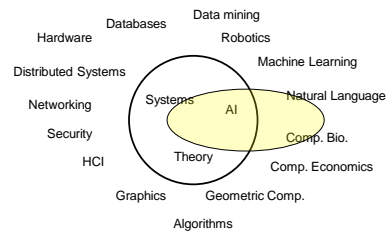
Editor's Note: Two-dimensional projection clearly does not capture the relative importance or organizational nuances of the field. Some topics may be closer to you than they appear on this slide.

“Footprint” of CS Students See Today



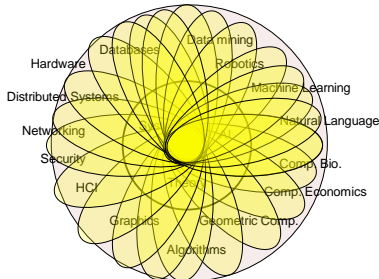
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Tracks Allow More Depth...

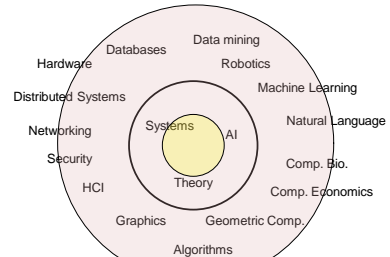


Total amount of material covered must remain the same

...in a More Diverse Set of Areas



Total Potential “Footprint” is Larger



Core material everyone sees is streamlined to accommodate

Curriculum Revision Process

- Curriculum committee met regularly throughout the Fall to discuss and refine core courses
 - Respective subcommittees formed to define Systems and Theory core
 - Proposals for both Systems and Theory core each revised at least 4 times
- Throughout the Winter, various faculty subcommittees met to define Tracks
 - Proposals for eight initial tracks produced (most with multiple revisions)
- Curriculum committee reviewed and approved proposals
 - Still need full faculty approval
 - That's one of the reasons we're all here...

Please Acknowledge Everyone Involved

Curriculum Committee

- Jerry Cain
- Bill Dally
- Vladlen Koltun
- Phil Levis
- John Mitchell
- Andrew Ng
- Nick Parlante
- Eric Roberts
- Mendel Rosenblum
- Mehran Sahami
- Julie Zelenski

Beyond the Committee

- Alex Aiken
- Serafim Batzoglou
- Gill Bejerano
- David Dill
- Ron Fedkiw
- Hector Garcia-Molina
- Leo Guibas
- Pat Hanrahan
- Scott Klemmer
- Daphne Koller
- David Koslow
- Jean-Claude Latombe
- Marc Levoy
- Chris Manning
- David Mazieras
- Rajeev Motwani
- Serge Plotkin
- Bob Plummer
- Vaughan Pratt
- Tim Roughgarden
- Claire Stager
- Sebastian Thrun
- Jennifer Widom
- Terry Winograd
- Patrick Young
- Russ Altman
- Many additional faculty (email/informal meetings)

Shows real dedication to undergraduate education

Outline

- Brief review of current curriculum
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- **CS Core courses**
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Systems I: Programming Abstractions

- Philosophy: *Classic CS2 course: problem solving, basic abstract data types, and recursion*
- Basically, our current CS106X/B course
- General Topics
 - Programming methodology (engineering, modularity, documentation)
 - Algorithmic thinking and problem solving
 - Data abstractions
 - Stacks
 - Queues
 - Linked lists
 - Hash tables
 - Binary trees
 - Generics/templates
 - Recursion
 - Procedural recursion
 - Recursive backtracking
 - Searching and sorting
 - Basic algorithm analysis (big-Oh) and comparison

Systems II: Computer Organization and Systems

- Philosophy: *From hardware up to the source code*
- Heavily modified CS107, with material from CS143 & EE108B
- General Topics
 - Machine architecture
 - Registers, ALU, CPU, RAM, I/O, basic assembly language
 - Caching, pipelining
 - Memory model
 - Pointers, Heap management, garbage collection
 - Low-level polymorphism and runtime type identification
 - Data representation
 - Facility with C programming as part of topical coverage
 - Compilation
 - Function call mechanics and stack frames
 - Semantic analysis
 - Simple (intermediate) code generation
 - Basic concurrency usage
 - Threading
 - Synchronization, locks and semaphores

Systems III: Principles of Computer Systems

- Philosophy: *Building larger scale systems using OS and networking abstractions*
- Entirely new course (not replacement for CS140 or CS244A)
- General Topics
 - Processes
 - Concurrency mechanics on a single processor
 - Context switching, interrupts and exceptions
 - Forking processes, process mechanics and management
 - Interprocess communication
 - Threading
 - Storage and file management
 - File systems
 - Virtual memory and paging
 - Networking
 - Sockets
 - Blocking vs. non-blocking strategies
 - Transport layer: TCP/IP
 - Network layer: names, routing
 - Understanding of distributed systems

Theory I: Mathematical Foundations of Computing

- Philosophy: *Mathematical essentials for CS, with proofs*
- New course leveraging CS103/154 (doesn't replace CS154)
- General Topics
 - Logic and proof techniques (9 lectures)
 - Prop. and predicate logic (with quantification), formal proof methods
 - Applications: Satisfiability, SAT solving (Putnam-Davis)
 - Induction (4 lectures)
 - Formal proofs and applications: program proofs, structural induction
 - Sets, functions, and relations (4 lectures)
 - Theory and applications (error-correcting codes, social networks)
 - Intro to formal languages (1 lecture)
 - DFAs, NFAs, and Regular Expressions (4 lectures)
 - Context-free Grammars (2 lectures)
 - Turing machines (3 lectures)
 - TMs, TM program, Undecidability and the Halting problem
 - NP-completeness (3 lectures)
 - P and NP, examples of NP-complete problems and reductions
 - SAT revisited and Cook's theorem

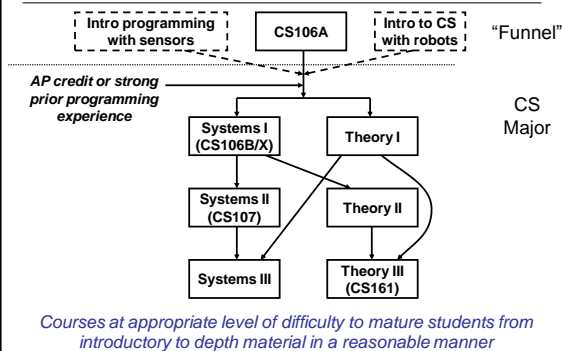
Theory II: Intro. to Probability for Computer Scientists

- Philosophy: *Probability relevant to CS, with applications*
- Entirely new course
 - Replaces Stat116, adds CS applications and machine learning
- General Topics
 - Counting and Combinatorics
 - Combinations, Permutations, Pigeonhole principle
 - Relations, partial orders (concepts, definitions, and proofs)
 - Probability theory
 - Random variables and event spaces
 - Conditional probability, independence, conditional independence
 - Distributions: Uniform, Binomial, Multinomial, Normal, Poisson
 - Point estimation, expectation, variance
 - Bayes' Theorem, Law of large numbers, Central Limit Theorem
 - Hypothesis testing
 - Applications: hashing, PageRank, data analysis, inference
 - Intro. to Machine Learning
 - Hypothesis spaces, learning as search
 - Data fitting, Naive Bayes, Logistic Regression
 - Applications: Email spam filtering, Recommender systems

Theory III: Data Structures and Algorithms

- Philosophy: *Analysis of data structures and algorithms*
- Streamlined version of CS161 with topics from CS103 added
- General Topics
 - Algorithmic complexity and analysis (4 lectures)
 - Asymptotics: Big Oh, Omega, and Theta notation
 - Recurrence relations
 - Master theorem
 - Randomization, divide and conquer (2 lectures)
 - Introduction to randomized algorithms
 - Quicksort, divide and conquer
 - Heaps and counting sort (1 lecture)
 - Hashing (2 lectures)
 - Tree and graph definitions and properties, BSTs (2 lectures)
 - Greedy Algorithms (including min-cost spanning trees) (2 lectures)
 - Dynamic programming (3 lectures)
 - Graph algorithms, shortest paths, and applications (4 lectures)
 - Blind and heuristic search (A*) in graphs (1 lecture)

Prerequisite Structure



Summary of Changes

- CS103 sequence and STAT116 are replaced as Math requirements with Theory I and II
- CS161 incorporated into Theory III (remains CS depth course)
- CS154, CS121/221 (and other application course) not in core
- No change in Math units, 9 net units opened in CS depth
- Systems I considered an Engineering Fundamental
- Systems II and III are CS depth courses
- CS108, EE108B and Systems electives not in core
- 10 net units opened in CS depth
- Existing electives provide 6 additional units of CS depth
- **Net result:** 25 units opened in CS depth

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Track Structure

- Combination of track requirements and electives satisfies:
 - minimum of 7 courses, and
 - minimum of 25 units
- All tracks have at least 4 (possibly more) required courses
 - Students will generally have room for 2 to 4 elective courses
 - Required senior project is not considered part of track
- Elective courses
 - Set of general CS electives that all students may choose from
 - Additionally, each track specifies *track-specific electives* that may count as elective courses only by students in that track
 - Track-specific electives allow for additional depth or related interdisciplinary course options

General CS Electives

- CS108, CS121 or CS221*, CS124, CS140, CS142, CS143, CS144, CS145, CS147, CS148 or CS248*, CS154, CS155, CS156, CS157, CS164, CS205A, CS205B, CS222, CS223A, CS223B, CS224M, CS224N, CS224S, CS224U, CS225A, CS225B, CS226, CS227, CS228, CS229, CS240, CS242, CS243, CS244, CS244B, CS245, CS247, CS249A, CS249B, CS255, CS256, CS257, CS258, CS261, CS262, CS270, CS271, CS272, CS273A, CS274, CS276, CS277, CS295, CME108, EE108B, EE282
- *Students may not count both CS121 and CS221, or both CS148 and CS248 toward their major requirements.
- Very similar to our current set of electives
 - Added courses that are no longer required in major (e.g., CS108, CS121/221)
 - Added some newly proposed undergraduate courses (e.g., CS124, CS142, CS164)

Initial Set of Tracks Areas

- Artificial Intelligence
- Theory
- Systems
- Human-Computer Interaction
- Graphics
- Information
- Biocomputation
- Unspecialized
- *Individually Designed*

AI Track

- Requirements
 - a) CS221
 - b) Any two of: CS223A, CS223B, CS224M, CS224N, CS226, CS227, CS228, CS229
 - c) One additional class from category (b) or from the following:
CS205A, CS222, CS224S, CS224U, CS225A, CS225B, CS227B, CS262, CS276, CS277, CS279, CS321, CS326A, CS327A, CS329, CS374, CS379, EE263, EE376A, Eng205, Eng209A, Ling180, MS&E251, MS&E339, MS&E351, Stat315A, Stat315B
- Track electives
 - Courses in categories (b) and (c) above, as well as:
CS270, CS273A, CS274, CS275, CS278, EE364A, EE364B, Econ286, MS&E252, MS&E352, MS&E355, Phil151*, Phil152, Psych202, Psych204A, Psych204B, Stat200, Stat202, Stat205
- *students may not count both Phil151 and CS157 toward major requirements.

Theory Track

- Requirements
 - a) CS154
 - b) Any one of: CS164, CS255, CS258, CS261, CS268, CS361A, CS361B, CS365
Note: CS164: *Computing with Physical Objects* (new course by Leo Guibas)
 - c) Two additional classes from category (b) or from the following:
CS143, CS155, CS156, CS157, CS205A, CS228, CS242, CS256, CS259, CS262, CS354, CS355, CS357, CS358, CS359*, CS364A, CS364B, CS369*, CS374, MS&E310
*requires approval of undergraduate advisor.
- Track electives
 - Courses in categories (b) and (c) above, as well as:
CME302, CME305, Phil151*, Phil152
- *students may not count both Phil151 and CS157 toward major requirements.

Systems Track

- Requirements
 - a) CS140
 - b) One of: CS143 or EE108B
 - c) Two additional courses from category (b) or from the following:
CS144, CS145, CS155, CS240, CS240C, CS240D, CS242, CS243, CS244, CS245, EE271, EE282
- Track electives
 - Courses in category (c) above, as well as:
CS240E, CS240X, CS244C, CS244E, CS315A, CS315B, CS343, CS344, CS344E, CS345, CS346, CS347, CS349*, CS448, EE382A, EE382C, EE384A, EE384B, EE384C, EE384S, EE384X, EE384Y
- *requires approval of undergraduate advisor.

HCI Track

- Requirements
 - CS147, CS247 (*HCI Foundations*)
 - Any one of: CS148, CS248, CS376, CS377, CS378 (*Advanced HCI*)
 - Any one of: CS108, CS140, CS221, CS223B, CS229, CS249A (*Buttressing CS*)
 - Any one of: Psych55, Psych252, MS&E184, ME101, ME115 (*Designing for People*)
 - Track electives
 - Courses in categories (b), (c), and (d) above, as well as:
ArtStudi60, Comm269, CME340, CS447*, CS448B*, Ling180, ME118, MS&E216A, Psych205, Psych221
- *requires approval of undergraduate advisor.

Graphics Track

- Requirements
 - CS248
(*Starting in AY 09-10, CS148 and CS248 will both be required as a two course sequence*)
 - Any one of: CS205A, CME104, CME108, Math52, Math113
(*Of the choices above, CS205A is strongly recommended as a preferred choice*)
 - Any two of: CS164, CS178, CS205B, CS223B, CS268, CS348A, CS348B, CS448
Note: CS164: *Computing with Physical Objects* (new course by Leo Guibas)
CS178: *Digital Photography* (new course by Marc Levoy)
- Track electives
 - Courses in category (c) above, as well as:
ArtStudi 60, ArtStudi 70, ArtStudi 179, CS48N, CS277, CS326A, CME302, CME306, CME324, EE262, EE264, EE278, EE368, ME101, Psych30, Psych221, STS144

Information Track

- Requirements
 - CS124, CS145
Note: CS124: *From Languages to Information*
(new course by Dan Jurafsky and Chris Manning)
 - Two courses, which must be from different areas below:
 - Information-based AI Applications*
CS224N, CS224S, CS229
 - Database and Information Systems*
CS140, CS240D, CS245, CS345A, CS345C, CS346, CS347
 - Information Systems in Biology*
CS262, CS270, CS274
 - Information Systems on the Web*
CS276, CS364B, <<Future course on Internet Algorithmics by Rajeev Motwani>>
- Track electives
 - Courses in category (b) may also be counted as electives

Biocomputation Track

- Requirements (based on BMC Informatics Track)
 - Mathematics: (1 course less than CS)
 - Math 41, Math 42, Theory I, Theory II
 - One of: Stat141, Stat203, Stat205, Stat215, Stat225
 - Science: (3-4 courses more than CS)
 - Physics 41, Chem 31A/B or 31X, Chem 33
 - Bio41, 42, 43 or HumBio2A, 3A, 4A or HumBio Core I, II, III
 - Engineering Fundamentals: (1 course less than CS)
 - CS106B/X (Systems I)
 - Elective
 - Additional CS Core: (same as CS)
 - Theory III, Systems II, Systems III
 - Biocomputation Track: (6-7 units)
 - Any one of: CS121, CS221, CS228, CS229, CS223B
 - Any one of: CS270, CS273A, CS274, CS275, CS278, CS279, CS262
 - Biocomputation Electives: (12-13 units; Different than general CS electives)
 - Two additional BMC Informatics electives
 - One BMC Cell/Mol elective
 - One BMC Organs elective
 - Senior Project, Technology in Society and Writing in Major (same as CS)
 - **Total:** 94-99 units versus 93 units for Standard CS Track

Unspecialized Track

- Requirements
 - CS154
 - Any one of: CS140, CS143
 - One additional class from category (b) or from the following: EE108B, CS144, CS155, CS240D, CS242, CS244
 - Any one of: CS121 or CS221, CS223A, CS223B, CS228, CS229
 - Any one of: CS145, CS147, CS148 or CS248, CS262
- This is basically our current curriculum
 - Adapted to fit into new track structure
 - Some additional options for AI courses

Individually Designed Track

- Students may propose Individually Designed Track
- Must be an intellectually coherent program of study
 - Proposal should justify program and why it cannot be satisfied via an existing track
- Must specify equivalent of track and electives
 - Minimum of 7 courses; at least 4 must be CS courses numbered 100 or above
 - Each course must be taken for a minimum of 3 units
 - Minimum of 25 total units for track + electives
- Proposal must be approved by undergraduate advisor and Associate Chair
 - Approvals must be obtained at least 2 quarters prior to completion of program
- Proposal cannot modify any non-track/elective requirements
 - E.g., SoE requirements (Math, Science, Eng Fundamentals) cannot be modified
 - Must take all CS Core courses

Preliminary Unit Calculations

- Core (30 units)
 - Theory: 3 courses @ 5 units = 15 units
 - Systems: 3 courses @ 5 units = 15 units
 - Upper division (28 units)
 - Track: 4-5 courses
 - Electives: 2-4 courses
 - Capstone: 3 units
- } Minimum of 7 courses
(at least 25 units)
- Total related units = 58 units (same as now)
 - 10 units are classified as Math
 - 5 units are classified as Engineering Fundamentals
 - Total CS depth units = 43 units (same as now)

Curriculum Comparison

| Current | Proposed |
|----------------------------------|----------------------------|
| Programming: 3 courses | Systems core: 3 courses |
| Theory: (2 + 2 depth): 4 courses | Theory core: 3 courses |
| Systems depth: 3 courses | Track (depth): 4-5 courses |
| Applications: 2 courses | Electives: 2-4 courses |
| Electives: 2 courses | Capstone: 1 course |
| Capstone: 1 course | |
| TOTAL: 15 courses | TOTAL: 14-15 courses |

Same number of units in both cases

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Timeline

- ✓ Spring 2006/07 Preliminary agreement on structure.
- ✓ Fall 2007/08 Complete definition of core.
- ☐ Winter 2007/08 Define initial set of tracks.
Vote to adopt new curriculum.
Start transition plan for new courses.
- ☐ Spring 2007/08 Complete transition plan.
Publicize new program to students.
- ☐ Fall 2008/09 New curriculum requirements in place.
Begin shift in core course content.
- ☐ Winter 2008/09+ Continued development of course contents and new courses.

Thank you for your attention

Questions before voting

Vote!

(early and often)

Additional Material

Issues We've Considered

- *Undergrad program isn't broken, why fix it?*
 - Field has evolved more significantly than curriculum in last 15 years, and will continue to do so
 - Modularity allows for easier evolution of curriculum with the field
 - "Footprint" of CS has potential to be much larger by explicitly providing more options and inter-disciplinary ties
- *Students won't know what to take*
 - They don't need to know right away (common core)
 - Can provide effective advising from faculty and staff
- *What if very few students take a particular track?*
 - Some MS concentrations are small, but still available
 - Provides useful feedback for future revisions

More Issues We've Considered

- *Students will take fewer systems courses and potentially have weaker programming skills*
 - There is still a substantial amount of programming in curriculum
 - Students will still be well prepared for a broad array of work
 - Not all students want to take high-intensity programming jobs
 - For students who do, the Systems track is likely to be popular
 - Note: Currently, 47% of MS students take Systems specialization

Current Curriculum: Additional SoE Reqs.

- **Mathematics**
 - Two quarters Calculus (many students receive AP credit)
 - One quarter Probability
 - Two restricted Math electives
- **Science**
 - Two quarters Physics (Mechanics, Elec. & Magnetism)
 - One restricted Science elective
- **Engineering Fundamentals**
 - E40: Introductory Electronics
 - One Engineering Fundamental Elective
- **Technology in Society** (One restricted elective course)