MIT Stephen A. Schwarzman College of Computing

MIT Schwarzman College of Computing Task Force

Working Group on Curricula and Degrees

Final Report

Srinivas Devadas and Troy Van Voorhis, Co-Chairs
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OVERVIEW

The hiring of 50 new members of the faculty will bring tremendous intellectual energy to the Institute, energy that has the potential to alter our curriculum in radical ways. Below, we consider a number of proposals for how the Institute might respond in its undergraduate and graduate degree programs. Undergirding these are several proposals that examine how we advise students, develop new curricula, and support new teaching initiatives. We have placed these curriculum and support proposals first to indicate their foundational importance to the success of the graduate and undergraduate programs.

In the compendium below, each proposal is presented with a title along with a short description followed by a bulleted list of discussion points. Within that bulleted list:

- the + bullet indicates a perceived pro
- the – bullet indicates a perceived con
- the • bullet indicates a neutral observation
- the ? bullet indicates an open question

Historically, the administration and conferring of undergraduate degrees at MIT has been the responsibility of corresponding academic departments. For the purposes of this report, our group assumes that this model will continue for any new degree options that we are proposing. Our understanding is that the academic units to be assigned to the Schwarzman College of Computing (SCoC) are yet to be determined. The questions associated with the administration and conferring of any new degrees must be revisited after decisions are made about which academic units are fully or primarily affiliated with the SCoC.

KEY IDEAS

NEW CURRICULUM DEVELOPMENT AND SUPPORT

Teaching Support for Computationally Intensive Subjects

Analogous to the Writing, Rhetoric, and Professional Communication (WRAP) instructors who support communication-intensive subjects, the SCoC would offer Programming, Analytics, Computation, and Data (PACD) instructors for subjects outside of computer science that make substantial use of computation.

+ The model is flexible enough to allow lecturers to be assigned to new subjects or where there are unexpected spikes in enrollments.
+ Lecturers assigned to multiple departments can disseminate good practices and cross-pollinate.
+ Many of the WRAP lecturers have been assigned to departments/subjects for a long enough period that they offer continuity when instructors change. The same benefits could extend to a similarly structured PACD group.
+ Some courses (for example, 4, 6, 11, 16, 18) have dedicated lecturers who also collaborate in developing curricula.

- This model is not inexpensive and grows as the curriculum evolves (new majors, new subjects).
- Retaining qualified and experienced staff can be a challenge.
- While all WRAP lecturers offer communication expertise, not all have discipline-specific expertise. For PACD instructors assigned to interdisciplinary subjects offered within and outside the SCoC, this may also be a concern. For example, a lecturer might have expertise in a certain program language, but not in political science.

• The communication requirement (CR) budget is centrally managed through the Office of the Vice Chancellor. The budget supports staff in communication-intensive subjects in departments. Some lecturers and TAs are hired and appointed by departments, while WRAP is run out of Comparative Media Studies and Writing in SHASS. Experience with the CR can offer lessons about best practices as well as about tensions that can arise over budget, oversight, and expertise.

? Would the SCoC house a centrally administered/managed group?
? Should the SCoC have a faculty director? (Probably.)
? Would departments/subjects need to request or apply for this support?
? Would each department be assigned instructors to work with that group, or might instructors be assigned to multiple departments?

Incubator Grants for Interdisciplinary Subjects

Offer substantial long-term financial support (e.g., five years) for new interdisciplinary subjects to incentivize integration of these subjects into disciplinary curricula. The funding also could be attached to research support (e.g., postdoc support) in the interdisciplinary area.

+ If we want to develop new subjects that run for several years, incubation (as opposed to startup) funding is a must.
- A group of faculty (not just a single faculty member) should be dedicated to sustaining the new subject, which may limit opportunities.
- Dedicated and budgeted staff would be necessary to support faculty in the development and rollout of interdisciplinary subjects.
- Faculty also could benefit from tools to help identify potential collaborators outside their personal networks.
- Truly interdisciplinary subjects are not a simple mixture of A and B disciplines. They are a true A and B alloy.

Summer Program for Incoming First-Year Students with Weak Backgrounds in Computation

Similar to the Interphase EDGE program for new students, this program would target students who are interested in computation but may lack the preparation to perform well in a class like 6.0001/6.0002.

+ This kind of program is very important to ensure that the SCoC presents a broad funnel for students with diverse backgrounds and levels of preparation who are interested in computation.

- Summer and IAP programs detract from students' extracurricular activities, internships, etc. Online offerings with TA support could mitigate this issue, but MIT would have to think carefully about introducing an online program for incoming students.
- Summer programs have a disproportionately negative impact on students of low socioeconomic status who must work during the summer. And such students are likely to be key candidates for this program, given that low-income students often have weaker backgrounds in computation.
- Such a program could have the undesired effect of making incoming students who are less well prepared feel even further behind, particularly where this population overlaps with Interphase students.

New Introductory Offerings in Computation

Target students with weaker backgrounds in programming with more entry-level subjects (e.g., a 6.00L subject analogous to 8.01L)

+ Helpful to students with little or no computational thinking or programming background.
- The load on students increases if these offerings do not satisfy a GIR or major requirement.
- • Harvey Mudd approach: Have two tracks of classes that run at the same time (i.e., 6.00A and 6.00B) so that students end up learning the same foundation; 6.00A, for students with more experience, could offer some interesting extras.

Online Education in Computation

Offer a core set of subjects (e.g., enough to complete a minor in computation) as part of MITx and/or EdX.

+ Online materials are very helpful to residential students.
- Maintaining these offerings in addition to large residential classes—and updating the course materials as the classes evolve—will require appropriate investment from the SCoC and MITx; that includes hiring Digital Learning Lab Fellows as lecturers.
- Evolving these materials and updating them won't be easy.

Online Modules for Programming

Offer a number of short modules as part of MITx and/or EdX to train students in specific programming languages and skills (e.g., SQL, Python, Julia, Matlab, Java).

- \+ We have observed a great demand for this among non-CS disciplines.
- \- Online resources for learning these things already exist. Is there something special about having an MIT-designed course in these languages? Or is it just re-inventing the wheel?

Centralized Infrastructure to Support Education in Computation

In addition to personnel (instructors and TAs), the SCoC could offer a centralized infrastructure for profiling and executing code, grading assignments, and providing student feedback.

- \+ Automatically grading coding assignments and multiple-choice questions would be very helpful to a host of offerings—Stellar for computational classes.
- \+ Could be accomplished in coordination with MITx.
- \- It would be difficult to customize for a class—different classes have different requirements (e.g., languages). In Course 6, this infrastructure keeps changing.

Advising

Dedicate resources to support faculty advising of students affiliated with the SCoC—for example, offer the option of buying out one semester of teaching in exchange for advising X students. See Appendix for a more detailed analysis of advising models.

- \+ Incentives for advising will lead to better advising.
- \+ There exists the potential for advising to inject some element of realism into career planning—specifically, to counter the common misconception that to get a job you must have Course 6 in your degree name.
- \- The MIT community suffers from a shortage of broadly informed advisors, especially for joint majors and interdisciplinary degrees.

- Advisors are needed less for course selection than to help students to determine a path towards a major or make decisions about their careers, etc. Freshman advising is a key pain point here.
- As part of the Committee on the Undergraduate Program's (CUP) experiment on exploration in the first-year experience, the Office of the Vice Chancellor (OVC) is piloting pre-major departmental advising. The new model aims to increase the amount of advising students receive before selecting a major.

? Should the SCoC offer special advising to prepare students in bridge programs for potential graduate programs?

? Should the SCoC offer centralized professional (i.e., non-faculty) advisors?

? Could freshman advisors benefit from a mid-year orientation similar to the pre-Registration Day orientation but focused on resources for choosing a major?

UNDERGRADUATE DEGREES

Undergraduate CS Minor

Enable a large segment of the undergraduate population to complete the flexible CS minor.

\+ A flexible minor provides a useful credential with minimum change to existing degree programs.

\- At most, two courses in the minor can be used toward a major (the double counting rule), and this could place an undue burden on certain students.

Undergraduate "Threads" in Computation

Create an entity much like a minor in scope that can be a deepening or broadening experience (or both). Subjects would be interwoven with major requirements and would pull computation through a major (hence the name "thread"). Would ideally be customized by the major.

\+ Threads can provide depth and breadth.

\- No clear precedent for this exists, so there may be details that our working group did not evaluate.

- Without strong oversight, threads could become meaningless by just double-counting courses that are already part of an existing major.
- Simplest initial implementation would just involve relaxing the double-counting restriction on minors and creating a new category for these relaxed minors, calling them threads.
- Example of a more fully formed thread: scientific computing. This could be built from a number of subjects from physics, biology, EAPS, chemistry, and allied fields. Probably, enough subjects exist across the Institute to populate a program like this, but no one program has enough subjects to create its own thread. But if the general requirements for the thread are fleshed out, it could be combined with any one of the participating majors to enrich the major experience.
- The closest precedent at MIT is the NEET program (New Engineering Education Transformation), which uses similarly conceived threads to interweave areas within majors. In fact, NEET has approved its first communication-intensive subject, offered by Courses 16 and 2, creating a bespoke capstone experience.
- Threads would involve coordination between the SCoC and faculty in different departments.

Undergraduate Certificate in Computation

The SCoC could offer some kind of competency certification that is less substantial than a minor.

+ Has no official status (both pro and con). MIT already has undergraduate certificates, but these are unofficial.

? Does such a certificate become a de facto GIR or set of GIRs if it becomes an official credential?

? Is credentialing overhyped? Don't students take classes to get jobs?

Continue to Create 6-N and N-6 Degrees

Increase the institutional bandwidth for vetting these types of degrees so that more can be created in parallel in a given year.

+ These degrees appear to be popular with students, and departments are looking to expand their undergraduate majors through these joint degree offerings.

- \+ Works well where there really is an emerging new discipline that needs to be represented in the undergraduate curriculum.
- \- Our group was ambivalent about these joint majors as they currently exist owing to a lack of integrated offerings. Institutional limitation of units beyond the GIRs for SB degrees makes them seem light—the "joint majors are two minors" criticism.
- \- Advising is a concern—overwhelmed and ill-informed advisors are a problem. Students in some programs have two advisors but may only consult one or use the other as a backup (e.g., if parent one says no to you, ask parent two).
- \- 6-N- and N-6-degree students mostly come from Course 6.
- \- Administration of a major, e.g., when anyone needs a report on 6-X, it's one person who handles that for most X.
- \- 18C works because of a number of de facto bridge faculty, while 6-N and N-6 do not have significant numbers of bridge faculty.
- \- There exists a lack of incentive to create interdisciplinary subjects, and MIT needs to think about how to incentivize. The challenge remains getting people to step up to create and sustain these subjects. This issue could be offset by the aforementioned incubator grants.
- Increasing bandwidth for these degrees is complex—more faculty time, more committee time, possibly new standing committee(s), staffing concerns, communication, etc. are all issues.
- ? Some 6-N or N-6 don't have a five-year master's. Would it be possible to develop more of these?

Create Combined 6&N Bi-Majors

Combined 6&N bi-majors would be more substantial than a joint degree (requiring up to 17 subjects) and have a standardized form. This could eventually replace joint degrees. See Appendix for detailed bi-majors proposal.

- \+ Bi-majors address the content concerns of joint majors, including integration across disciplines, and provide depth in two disciplines.

- Students have to take more classes than in a joint major. If a joint 6-N major exists, what is the incentive to be a bi-major? The solution might be to initially offer bi-majors only between departments that do not have joint majors.
- Stanford discontinued a computer science + humanities degree program. One problem was the integration of unit requirements; the other was that faculty didn't want to put work into integrated curriculum. We need to incentivize faculty to create integrated offerings

Encourage and Support More NC Majors

Encourage departments to create majors like 18C that include computation but are managed and advised within one department.

+ 18C works very well and provides an integrated experience partly because of the large number of bridge faculty across math and computer science.
? Can the 18C model work for N ≠ 18?
- Would it be desirable to generate a Master's of Engineering program for 18C and any other NC majors?

Establish a 12- or 18-Unit Computational GIR

This topic, which has been addressed by at least one other committee, considers the importance of an Institute-wide computational thinking requirement.

+ 6.0001/6.0002 is a de facto computational GIR; it makes sense to make this official.
+ 6.0001 (first half of the former 6.00) is not a six-unit class for students with a weak background in programming and computation. 6.0001L, which is 12 units and runs for a semester, would be enormously helpful to such students. Comment from student at Public Forum: "6.00 is NOT an introductory programming class."
+ There exist many flavors of 6.0002—different languages for different disciplines, e.g., materials science, economics. Could be offered as a follow-on six-unit class. This could potentially turn into a requirement for some majors.
+ Students can take an Advanced Standing Exam to bypass 6.0001 as they do now to take advanced programming (6.0002, 6.009) or algorithms classes (6.006).
- GIR changes are difficult to carry out. (An extensive review of GIRs is anticipated next year.)
- Not clear that a one-size-fits-all GIR makes sense for computation.

- Would increase the already burdensome teaching load on CS.

GRADUATE DEGREES

Graduate Certificate in Computation

Offer a small set of subjects (2-4) that graduate students could complete to obtain certification in computation (broadly defined). Some of the subjects could be part of a departmental program.

+ Relatively easy to offer; usually a single department can take charge.
- Lots of diversity in graduate programs across departments may mean that every certificate must be customized.
- Need to be careful about duplication as opposed to coordination.
- MIT does not presently have a "culture" of obtaining certificates in PhD programs.
- Similar to graduate minors in some areas.

? Is there demand for this within PhD programs? These tend to be research-focused, so additional courses might not be welcome.
? Should there be a single umbrella definition of certificates, or is it all discipline-specific?

Interdepartmental Master's Degrees

Partner with existing master's programs—for example, the Master of Business Analytics program (MBAn)—to enrich the curriculum of those programs.

+ Students have indicated significant interest in these programs (particularly MBAn students).

- This degree option does not now exist and would require significant effort to develop for appropriate subjects.
- Coordination between departments can be tricky.
- MBA and Master's of Engineering-type programs could both make sense.
- Some joint masters at MIT do already exist. Need to avoid duplication.
- This is the master's equivalent of 6-N and N-6 programs and/or computational "threads" for undergraduate degrees.

- Transportation@MIT and the MIT Department of Urban Studies and Planning are examples of programs that might make use of this.

? What does it mean to own a master's program?

Professional Master's Degree in Computation

Offer a suite of graduate-level classes to train non-CS students to apply computation in their fields. The idea is to have many junior- and senior-level subjects that also can be considered as master's level subjects and are an option for the student who wants to enter the workforce rather than a PhD program.

\+ Would act as a springboard to any profession where computation has a key role.
\+ Would act as a natural extension of the undergraduate curriculum.
\+ This option would create a strong connection to workforce development.
\+ Program could be self-funded since students will pay tuition as they do in other professional master's programs at MIT.
\- These programs require significant effort from development to admissions to delivery to maintenance and evolution.

- This is not for CS undergraduates and not a stepping stone to a PhD. It would represent a contrast to Stanford, where the master's in computation is a segue into Silicon Valley.
- Would require firm differentiation from the MBAn.

? Would a thesis be required?

Micromaster's Credential in Computation

An abridged version of a professional master's leveraged with online education, the idea behind the micromaster's credential is to build a small number (four or five) of online courses that together are about one semester of the professional master's degree. This option would have stand-alone value to people in—or aiming for—a wide range of workplaces. Top students in these classes would be invited to MIT to complete the professional master's.

\+ Could significantly increase the reach of a professional master's and of the SCoC.
\+ Great way to leverage what MIT does with the SCoC and pave our way to teach computation.
\+ Encourages students to take online subjects seriously.

- These programs would require significant investment from MITx and SCoC to maintain and create exams each year and would require a faculty member to be in charge of the hiring of instructors as with 6.0001/2x. Digital Learning Lab fellows would be appointed as lecturers.
- Could select best students for residential master's program.
- ? The professional Master's Degree in Computation (above) is the obvious pathway to MIT credit, but could there be other pathways to MIT credit for micromaster's recipients? Could they enter other master's programs?
- ? If the professional master's degree has "flavors," would there be different micromaster's with corresponding flavors?

Moving Some Interdisciplinary PhD Programs into the SCoC

Shift some existing interdisciplinary PhD programs into the SCoC. Possibilities could include the MIT Institute for Data, Systems, and Society (IDSS), Computational Science and Engineering (CSE), and the Operations Research Center (ORC).

- + Degrees would gain SCoC branding.
- + IDSS-like faculty committee would provide a viable management structure.
- - Programs could lose some independence once merged into the college.
- - Not all IDSS PhD research is computationally focused, so this runs the risk of skewing IDSS toward computation in the future. That may or may not be in accordance with IDSS' own vision.
- Need to maintain access to students for affiliated faculty to participate in admissions, campus visit weekends, advising, etc. One working example of this is the theory of computing area that exists between math and CS.
- This is tied to the organizational structure of the SCoC, which is to be determined. Need to revisit with cognizant units once the structure is defined.

Create New Interdisciplinary PhD Programs within the SCoC

Task the SCoC with creating the next generation of interdisciplinary doctoral programs in computation.

+ The SCoC could act on opportunities for new programs at the interface between computing and other disciplines.
- Securing funding for students is a challenge, as PhD positions are typically fully funded by the Institute through a combination of grants and endowment.
- This option would entail less influence over faculty, who would be weakly affiliated with the SCoC, to advise and financially support students, as compared to, say, a traditional department.
- The time necessary to achieve a PhD is a potential issue here—need to be sure students aren't being expected to earn two PhDs (one from each discipline).

- This appears to be a critical and challenging direction. PhD programs determine the research direction of the Institute. They determine how many PhD students we admit and in what areas. It is those students who perform the bulk of our research enterprise. Thus, strategic development of PhD programs is perhaps the most powerful way the SCoC can influence the direction of research at the Institute.
- The SCoC could create an equivalent program to the Interdisciplinary Doctoral Program in Statistics and Data Science, but focused on computing.
- Need to avoid duplication of sub-disciplines in existing fields. For example, a PhD in computational physics might not be needed if computation within physics is already established enough to offer the same education.
- Two major funding models are worth consideration: one where admits are determined by the number of student fellowships and one where the number of admits is governed by faculty research budgets. Both approaches have pros and cons.

APPENDIX

THOUGHTS ON ADVISING FOR THE SCoC

The best academic advising strategy for students will depend heavily on the structure of the SCoC. If every student at MIT is still associated with a single department, for example, it may make sense to keep advising at the departmental level. If students are associated only with the SCoC and/or with new departments within the SCoC, or with multiple departments or other entities, then new alternate advising options must be developed.

Here, we present the concerns that an advising program should aim to address, along with some possible approaches and their pros and cons. Not all the options considered here pivot on the existence of bridge majors, bridge programs, and so on.

Concerns for Advising

- Will students studying topics that span computing and other entities be able to get adequate advising support from each area? Note that the answer to this question as well as the needs of the students depend very much on the nature of specific programs. Are these programs joint majors? Bridge majors? Are the programs managed by new entities? By multiple entities (e.g., departments)?
- What are the advising issues specific to the SCoC? This will depend on the exact programs it offers and the exact structure of the SCoC. If advising support is offered, it may make sense to have advisors that are dedicated to the SCoC.
- Could the advising program be scaled to meet the potentially large population that it will be serving?

Possible Approaches

<u>Structure-Based Issues</u>

- Departmental advising—At present, each student is advised by an advisor from the department in which their major originates. Joint majors have a few different approaches but ultimately their advising also comes from the department. If each SCoC student is still associated with at least one department, advising could conceivably be left to departments.

- A centralized advising office for the SCoC—Such an office could employ professional academic advisors or have dedicated faculty to advise SCoC students. Students who are part of the SCoC but not any department could be assigned an SCoC advisor as their primary advisor. For other students, it may be useful to have SCoC-specific advisors on hand for issues that arise. Note that such an office could exist even if each student remains associated with a department. Extensive and thoughtful coordination between a central advising office and the traditional department advisors would be necessary.

<u>For Students in Bridge Programs</u>

Many of the issues surrounding student advising in bridge programs, whatever that may look like, are similar to the issues surrounding advising in joint majors (i.e., majors between two existing departments).

- Multiple advisors—Students in bridge programs could have two advisors: one in computing and one from the entity that is being bridged; this approach is similar to how advising in Course 6-7 works. This would allow students to get support from both sides of the bridge but could possibly lead to conflicts if the two advisors disagree. This may also put an untenable strain on computing advisors.
- Single advisor—Students in bridge programs could choose to have an advisor in computing or in the bridge program. This would prevent any conflicts that might arise from having two advisors, but potentially leave students with support from only one side. Depending on how students select advisors, this may put strain on the SCoC or on the bridge program.
- Bridge advisors—Faculty hired as multi-community faculty could be expected to serve as advisors for students in associated bridge programs. Students would have the logistical ease of a single advisor and get support from someone in their chosen field. The advising load on these advisors would be in direct proportion to how many majors were in the bridge program; as such, it could potentially strain the advising resources of multi-community faculty.

If programs are built between existing entities (e.g., departments), advisors for students in these programs should be carefully trained in the advising needs of the existing entities.

Note that virtually any method for bridge-program advising could be supplemented with dedicated professional advising staff associated with the SCoC, an approach that is used in many STEM-heavy schools.

BI-MAJORS—A PROPOSAL FOR A NEW TYPE OF COMBINED MAJOR AT MIT

This section outlines a new way in which students can major in two different disciplines. We propose a new category called a bi-major. It is motivated by the desire of faculty and students at MIT to create new majors that are joint with computer science. We refer to the bi-majors that are joint with computer science as CS + X. We are proposing bi-majors in a more general context that would be appropriate for combining majors from discipline X and from discipline Y. We refer to the resulting bi-major as X + Y.

In creating the structure of bi-majors, we have tried to adhere to the following design principles.

1. Transparency. It should be easy for students to understand how to combine two majors into a single bi-major.
2. Consistency. The rules should be consistent between bi-majors. The number of required subjects should be equal (or nearly equal) for different bi-majors.
3. Simplicity. The rules under which a student declares a bi-major should also be simple.
4. Streamlined creation. The process for creating bi-majors and getting them approved by MIT should be straightforward and efficient.
5. Ease of management. The bi-majors should be easy for departments to manage.
6. Flexibility for students. Bi-majors should provide undergraduates with useful alternatives and additional flexibility to existing options.
7. Incentives for the creation of interdisciplinary subjects. The rules for bi- majors should be designed so as to encourage new interdisciplinary subjects.

We first briefly describe our proposal, then answer key questions we believe might arise.

Proposal Description

Semi-Majors and the Bridge Subject

A bi-major consists of two "semi-majors" plus an interdisciplinary subject that we refer to as a "bridge subject." A semi-major is an abbreviated form of a major consisting of, at most, 96 units of requirements. These requirements will usually contain some units that are in the GIRs, such as subjects that fulfill a REST lab requirement. The courses available for the semi-major must include at least one CI-M subject.

Later in this document, we offer three illustrations of possible semi-majors: (i) computer science (CS), (ii) physics, and (iii) mechanical engineering (ME). The semi-majors in ME and physics are excerpted from the requirements for 2A and from the flex major in Course 8. The semi-major in CS is an attempt to synthesize requirements for 6-7, 6-14, and 11-6. In all three cases, the description is not a proposed semi-major, but is offered for illustrative purposes only.

The bridge subject should be an interdisciplinary subject that crosses the two disciplines of the bi-major. For example, if the bi-major was CS + biology, then one of the bridge subjects would be 6.047, Computational Biology: Genomes, Networks, Evolution.

Requirements for a Bi-Major in X and Y

Consider the situation in which a student declares a bi-major in X and Y. To satisfy the requirements of the bi-major, the student would have to satisfy the requirements for each of the semi-majors X and Y and also take at least one bridge subject for X + Y. In addition, students would have to satisfy every other MIT graduation requirement, including the communication and GIR requirements. The requirements of each of the semi-majors plus a bridge subject would bring the maximum number of required units for the bi-major to 204. Of these, 24 to 36 units would satisfy requirements in the GIRs.

Refinement 1. For a bi-major in X and Y, the departments X and Y may create semi- majors that are specific to the bi-major X + Y.

Refinement 2. Cases likely will arise in which the same subject fulfills requirements in X and Y. For example, a subject in probability may satisfy requirements of several semi-majors. If a student takes a subject that satisfies requirements in both X and Y, the student would be required to take an additional elective in either X or Y. This refinement helps to ensure the consistent level of course requirements of the bi- majors.

Development of Semi-Majors and the Approval Process

Departments would develop one or more semi-majors and submit them to MIT committees for approval. (Actually, departments would not be required to create any semi-major.)

The MIT committee process for the approval of semi-majors would be the same (or nearly the same) as for the approval of majors. Each semi-major proposed by a department would require approval by CUP, SCoC[1], FPC, and the faculty as a whole. Because the semi-majors are typically a subset of the requirements of the major, the approval process with MIT committees could be streamlined.

The bridge subject requires approval from both departments of the bi-major. It would have to be approved by SCoC[1] as a bridge subject.

A bi-major in X and Y would be approved as an MIT bi-major provided that (1) there exists an approved semi-major in X, (2) there exists an approved semi-major in Y, and (3) there exists a subject approved as a bridge for X and Y.

Petitioning for a Bi-Major

We expect there will arise situations in which a student is interested in having a bi-major in X and Y, but no approved subject exists that is a bridge for X and Y; thus, there is no approved bi-major in X + Y. In this case, a student could petition for taking the bi-major in X and Y. (MIT would have

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1 Those not involving computation would require approval by the Committee on Curricula rather than the SCoC.

to set up a process for handling these petitions.) The petition must include a way in which the student proposes to satisfy a "bridge requirement." Some potential ways for a student to satisfy the bridge requirement are: (1) taking a subject at MIT or elsewhere that bridges the two disciplines (2) completing a set of directed readings, or (3) carrying out a UROP project or thesis, or (4) having a summer internship.

Advising of Students in Bi-Majors.

Each student taking a bi-major in X and Y would select a primary department and a secondary department for the purposes of advising. The student would be assigned an advisor from the primary department and a secondary advisor from the other department. The role of the secondary advisor is to offer advice concerning subjects in the semi-major of their department.

Questions and Answers Concerning Bi-Majors

Question. What does this proposal about bi-majors have to do with the SCoC?
Answer. One key aspect of the charge of the SCoC Curriculum and Degrees committee is the following:

> Knowing that it normally has taken about one year to develop each dual degree program at MIT and that many units have expressed an interest in creating new ones, how can we create the bandwidth to develop several new programs in parallel without sacrificing a careful and thorough review process for each one? What templates can be synthesized from the current dual degree programs approved by CUP and SCoC? What is the best way to design/manage dual degree programs and courses, particularly courses that are developed within the SCoC but are broader ranging?

We have developed bi-majors for creation of majors that are joint with CS. However, bi-majors apply much more broadly. Rather than create a structure for joint majors that is specific to the SCoC, we developed a framework that could be used by all of MIT.

Question. How did you come up with the maximum number of requirements at 96 units per bi-major and 204 units in total for a bi-major?

Answer. The 96 units (and the 204 units) overlap with the GIRs. We chose 96 units (typically, eight 12-unit classes) as the maximum load because it seems to strike the right balance between depth of knowledge in each of the semi-majors and flexibility for students to pursue bi-majors. And there is an MIT precedent for this value—96 units of Mech E subjects are required in 2A and 96 units of physics subjects are required in the flex major for Course 8. These requirements are listed as sample semi-majors below.

A bi-major of the form CS + X (including a bridge) would require as many as 204 units. Each bi-major would satisfy at least 24 units of GIRs and typically satisfy 36 units or more. Therefore, each bi-major would require, at most, 180 units beyond GIRs. The number of units required by a bi-major in CS + X is comparable to the number of units a student would take if they majored in CS and minored in X or if they majored in X and minored in CS.

Question. Why is a "bridge course" required for bi-majors?

*Answer***.** Faculty involved in SCoC discussions have been very enthusiastic about the creation of bridge subjects, believing that they are of value to a student's overall education. However, bridge subjects are challenging to create and challenging to sustain on a long-term basis. By requiring a bridge subject as part of the approval process, MIT would be clearly communicating the importance of bridge subjects while providing a strong incentive for their creation.

At the same time, we want students to have the flexibility to take bi-majors even if a bridge subject has not yet been approved. For this reason, we provide ways in which the student can petition to take a bi-major, provided that the student includes a method for satisfying the bridge requirement.

*Question***.** If a bi-major is permitted to have 204 total units, won't this be more than current joint majors such as 5-7, 6-7, 6-14, and 11-6?

*Answer***.** Yes. That would be the case when existing joint majors have been created using MIT rules regarding limits on units for majors. These rules ensure that each student has at least 48 units remaining after completing the GIRs and the major (assuming that the student takes 180 units beyond GIRs[2]). The 48 units are valuable to students for several reasons. In particular, MIT students need the flexibility to be able to switch from one major to another after taking three or four courses in the first major.

With bi-majors, the students still have that flexibility. If a student starts in major X and wants to switch to bi-major X + Y, fewer additional subjects are required than if that student switched to Y. Moreover, if the student starts in the bi-major X + Y, it is easy for the student to switch to a single major in X or Y. We also observe that the creation of bi-majors does not remove any option for a student that currently exists.

Question. What would happen to the current joint majors 5-7, 6-7, 6-14, and 11-6 if bi-majors are approved?
Answer. Our proposal does not address existing joint majors. Under this proposal, the joint majors would continue in their present forms.

Question. Would students be permitted to have tri-majors?
Answer. If the category of bi-majors is approved by MIT, it is possible (perhaps likely) that there would be interest in creating a category of tri-majors, where a student would satisfy the requirements of a bi-major plus a different semi-major. But this is a proposal for bi-majors and not for tri-majors.

Question. Would students still be permitted to double major? If so, won't it be confusing that we have distinct categories of bi-majors and double majors?
Answer. Under this proposal, students still would be permitted to double major. As for the second question, it will be important to provide clarity and avoid confusion in communicating to students the various options for majoring, bi-majoring, and double-majoring.

Question. Do sufficient incentives exist at MIT for the creation of and sustenance of bridge subjects?

[2] Exceptions to the requirement of 180 units beyond GIRs do exist for some majors.

*Answer***.** While this proposal provides an incentive for the creation of bridge subjects, we believe that much more is needed to incentivize their creation and sustenance. This proposal for bi-majors was motivated by a desire to create CS + X subjects. The SCoC should actively explore various approaches for incentivizing the development of bridge subjects that involve computing. The SCoC also should develop incentives to ensure a commitment to the maintenance and continued teaching of these bridge courses in subsequent years. We are aware of several proposals to the SCoC concerning the development and maintenance of bridge courses.

*Question***.** Is there a danger that too many bi-majors will be created? Won't this be too unwieldy? How can it be managed?
*Answer***.** We would view the creation of a great many bi-majors as a success of this proposal. We believe that the system could be managed primarily with existing resources. Each department would be in charge of managing its own semi-major(s). This would be comparable to the current system of managing majors, except that we would have an additional category of semi-major. The MIT catalogue would list the semi-majors and explain how students can get credit for a bi-major. It also would list all the approved bi-majors, i.e., those with an approved bridge subject.

*Question***.** Do other universities offer bi-majors or something similar?
*Answer***.** Northeastern offers "combined majors." We have structured bi-majors here in a way that is similar to the construction of combined majors at Northeastern. One difference between bi-majors in this proposal and combined majors at Northeastern is that the combined majors at Northeastern (called "threads") can require as many as nine subjects each, which is more than in our proposal. Northeastern has additional requirements for majors, in part, because they have fewer GIR requirements.

*Question***.** Which bi-majors do you predict will be popular?
Answer. As Yogi Berra said, "It's tough to make predictions, especially about the future." Nevertheless, we'll try:

- Several CS + X bi-majors promise to become popular.
- Many students, who would usually take 2A will instead take a 2+X bi-major.

- Many students who would usually take the flex major in Course 8 will take an 8+X bi-major.
- Many students in science and engineering will select a bi-major in which the second semi-major is in analytics or data science.
- Many students in engineering will select a bi-major in which the second semi-major is in management or entrepreneurship. We note that entrepreneurship is currently offered as an interdepartmental minor and not as a major. However, it is plausible that the minor in entrepreneurship could be extended into a semi-major.

Three Sample Semi-Majors

<u>Physics [3]</u>

Required subjects

18.03	Differential Equations 1
8.03	Physics III
8.04	Quantum Physics I
8.044	Statistical Physics I

At least one of the following two subjects

8.21	Physics of Energy
8.223	Classical Mechanics II

At least one of the following three subjects

8.05	Quantum Physics II
8.20	Introduction to Special Relativity
8.033	Relativity

At least one of the following experimental experiences

8.13	Experimental Physics I (CI-M)

A laboratory subject of similar intensity in another department

An experimental research project or senior thesis 2

[3] These are requirements of the flexible option in Course 8.

An experimentally oriented summer externship

At least one additional subject in the Department of Physics

Mechanical Engineering[4]

Required subjects

2.00	Introduction to Design (half course)
2.001	Mechanics and Materials I
2.003[J]	Dynamics and Control I
2.005	Thermal-Fluids Engineering I
2.009	The Product Engineering Process (CI-M)
2.086	Numerical Computation for Mechanical Engineers
2.671	Measurement and Instrumentation (CI-M)
18.03	Differential Equations

At least one of the following two subjects

2.678	Electronics for Mechanical Systems (half course)
2.674	Introduction to Micro/Nano Engineering Laboratory (half course)

[4] These are requirements within 2A.

Computer Science [5]

Required subjects

6.00	Introduction to Computer Science and Programming
6.006	Introduction to Algorithms
6.009	Fundamentals of Programming

At least one of the following three subjects:

6.042[J]	Mathematics for Computer Science
6.046[J]	Design and Analysis of Algorithms
18.06	Linear Algebra

At least one of the following two subjects

6.034	Artificial intelligence
6.036	Machine learning

At least one of the following two subjects

6.UAR	Seminar in Undergraduate Advanced Research
6.UAT	Oral Communication

At least two additional subjects in Course 6

5 These requirements are our attempt to synthesize requirements in 6-7, 6-14, and 11-6. Any semi-major created for computer science is likely to be different.

CURRICULA AND DEGREES WORKING GROUP MEMBERS

Srinivas Devadas (Co-Chair)
Edwin Sibley Webster Professor, Department of Electrical Engineering and Computer Science

Troy Van Voorhis (Co-Chair)
Associate Head and Robert T. Haslam and Bradley Dewey Professor, Department of Chemistry

W. Craig Carter
Professor, Department of Materials Science and Engineering

Jen Donath
Assistant Registrar

Mary Fuller
Head and Professor, Literature Section

Michel Goemans
Head and Professor of Applied Mathematics, Department of Mathematics

Tami Kaplan
Faculty Governance Administrator

Katrina LaCurts
Senior Lecturer, Department of Electrical Engineering and Computer Science

Kathleen MacArthur
Associate Dean for Curriculum and Faculty, Registrar's Office

Caitlin Mueller
Associate Professor, Departments of Architecture and Civil and Environmental Engineering

James Orlin
E. Pennell Brooks (1917) Professor in Management and Professor of Operations Research, Sloan School of Management

Georgia Perakis
William F. Pounds Professor of Management and Professor of Operations Research and Operations Management, Sloan School of Management

Krishna Rajagopal
Dean of Digital Learning and William A.M. Burden Professor of Physics

Janet Rankin
Director, Teaching and Learning Laboratory

Stephanie Ren
Undergraduate Student, Department of Electrical Engineering and Computer Science

Mitchell Resnick
LEGO Professor of Learning Research, Program in Media Arts and Sciences

Devavrat Shah
Associate Director, Institute for Data, Systems, and Society; Professor of Electrical Engineering and Computer Science, Department of Electrical Engineering and Computer Science

Ishan Shah
Graduate student, Sloan School of Management

Kai Von Fintel
Andrew E. Mellon Professor in the Humanities and Professor of Linguistics, Department of Linguistics and Philosophy

P. Christopher Zegras
Associate Professor, Department of Urban Studies and Planning