

**WORCESTER POLYTECHNIC INSTITUTE**  
**March 14, 2019**

**To:** The WPI Faculty

**From:** Tanja Dominko  
Secretary of the Faculty

The seventh Faculty meeting of the 2018-2019 academic year will be held on **Thursday, March 14, 2019 at 3:15 pm in Olin Hall 107.**

- |  |                      |
|--|----------------------|
| 1. Call to Order   | T. Dominko           |
| • Approval of the Agenda   |                      |
| • Approval of the Consent Agenda and the Minutes from 2-7-19                       |                      |
| 2. Secretary of the Faculty Report   | T. Dominko           |
| 3. President's Report  | L. Leshin            |
| 4. Provost's Report  | W. Soboyejo          |
| 5. Committee Business  |                      |
| • Committee on Academic Policy (CAP) and<br>Committee on Academic Operations (CAO) |                      |
| <b>Motion to approve undergraduate program in<br/>        Data Science (DS)</b>    | D. Olinger/D. Strong |
| • Committee on Academic Operations (CAO)   |                      |
| <b>Motions to modify Data Science (DS) minor</b>                                   | D. Strong            |
| 6. Special Reports   |                      |
| • Accomplishments of the Dean of Arts and Sciences                                 | J. King              |
| • Accomplishments of the Dean of IGSD  | K. Rissmiller        |
| • Research misconduct policy – a refresher   | B. Vernescu          |
| 7. New Business  |                      |
| 8. Adjournment   |                      |

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WORCESTER POLYTECHNIC INSTITUTE  
Faculty Meeting Minutes  
February 7, 2019

**Summary:**

1. Call to Order
2. Faculty Governance Report
3. President's Report
4. Committee Business: COG
5. Special Reports
  - Accomplishments of the Senior VP, K. Tichenor
6. Adjournment

**Detail:**

1. Call to Order

The sixth Faculty meeting of the 2018-2019 academic year was called to order in Olin Hall 107 at 3:30 pm by **Prof. Dominko (BBT)**. The Agenda was approved after modification. The Consent Agenda and Minutes from the January 10, 2019 Faculty meeting were approved as distributed.

2. Faculty Governance Report

**Prof. Dominko** announced that the nomination ballots for COG, CTAF and COAP are being prepared. She was still contacting nominated colleagues that would be able and willing to serve, if elected. She thanked all the faculty colleagues who are currently serving, and those who have agreed to serve, if elected. The election ballots for standing Committee will follow once elections for COG, CTAF and COAP are complete. Prof. Dominko gave a brief update on the Bylaws and Governance Working Group (BGWG) progress. The group is developing a common understanding of goals, expectations, roles and responsibilities of respective constituencies in order to appropriately address everyone's concerns. The Annual Planning and Budget Process is underway and includes institutional commitment to significantly increase tenured and tenure-track faculty to 300; while growing the undergraduate enrollment number to 5,000 in the next five years. She also stated that the Board of Trustees' meeting will be taking place On February 21-22, where she will participate in the Plenary session with the presentation on Faculty Governance.

3. President's Report

**President Leshin** gave a brief update on the meeting of the BGWG, that the conversations have been candid, open, professional, collaborative and informative. She spoke about a level of trust and deeper appreciation for one another, and the care and building of relationships. The President spoke about the plenary session at the BoT meeting, and that approximately 50 faculty members have been invited to attend. She announced that the Celebration of Faculty Achievements would take place on February 21<sup>st</sup> and will serve as an opportunity to celebrate the

faculty's impacts within and beyond the university. The President reported that she had recently attended a meeting for the American Talent Initiative in New York City which affords lower income students an opportunity to attend colleges and universities. President Leshin concluded by announcing that she had been asked by the National Academy to chair a convening on alternative rewards systems and paths to promotion and tenure, and that this is a wonderful opportunity for WPI's innovation in higher education.

#### 4. Committee Business COG

**Prof. Richman** (ME), for the Committee on Governance (COG), moved to approve a new Faculty Conduct Policy. (See Attachment 1 attached to these minutes.) Prof. Richman gave a brief presentation on the changes and improvements from last month's document.

**Prof. Gaudette** (BME) made a motion to amend this policy with inclusion of additional protections for the Faculty:

#### **Proposed Amendment to the PROPOSED POLICY ON FACULTY CONDUCT:**

Proposed Feb. 7, 2019

(with text to be added in **bold underlined italics**)

#### **Section 6. Initial Review of Allegations**

**Subsection h.** The Dean will consider the faculty's recommendation and then decide whether the process under this Policy should continue or whether the Complaint should be dismissed. **When the allegations are within the faculty's area of primary responsibility (i.e. curriculum, subject matter and methods of instruction, research and those aspects of student life which relate to the educational process), the Dean should normally accept the faculty's decision. In rare instances and for compelling reasons, however, the Dean may reject the faculty's determination.** Regardless of the decision, the Dean shall state in writing the basis for the decision and promptly send a copy of both the Dean's report and the report written by the three faculty members to the Complainant and Respondent. **In all cases, the Dean shall also send a copy of the Dean's report to the three faculty members.** If the Dean decides that the process should continue, then the Dean's report will include a sufficiently detailed description of the allegations, the portions of this Policy that are alleged to have been violated, and any interim measures in place about which either party should be made aware. This written notice does not constitute a finding or a determination of responsibility. If the Dean decides that the process should continue, the Dean shall also provide a copy of both reports to the Provost, and the matter shall proceed as described below.

COG accepted this as a friendly amendment.

**Prof. Weekes** (MA) inquired about the involvement of the department heads in the process. Prof. Richman stated that the department heads have no formal role, however the informal process would involve them in the early stages of a complaint.

**Prof. Cocola** (HUA) thanked the committee for their work on this, however is inclined to speak against the motion. He referred to the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings

<https://www.aaup.org/report/statement-procedural-standards-faculty-dismissal-proceedings>.

There are some things to admire about this proposed version of the faculty conduct policy, as articulated in the rationale from COG:

- Greater clarity about the grounds for faculty misconduct
- More guidance concerning the range of sanctions
- Increased grounds for appeal

However, in my recent work on the Bylaws and Governance Working Group, and in my capacity as a new member of the AAUP, I have become more cognizant of the fuller range of AAUP policy documents and reports, and I find it surprising that the proposed version of the faculty conduct policy references the AAUP Statement on Professional Ethics without taking sufficient account of the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings, which is equally germane here.

I will reference that statement in enumerating reasons for voting against this version of the faculty conduct policy.

- IN BRIEF, the proposed version of the faculty conduct policy would further weaken our system of faculty governance and grievously compromise that system as a central component of shared governance. I cannot understand why the faculty itself would endorse the disempowerment of one of its own elected and standing committees, namely the Faculty Review Committee (FRC).

Who does the initial vetting on allegations of misconduct? By the interim policy, "a committee of three tenured faculty members," selected by the dean in consultation with the relevant department chair and others. The proposed policy eliminates language about consultation and tenure in the formation of this committee at 6G, affording the dean even more extraordinary powers of review, and potentially taking the matter out of the voting faculty's hands altogether.

Here we're already in need of reform.

### **According to the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings:**

*"When reasons arise to question the fitness of a college or university faculty member who has tenure or whose term appointment has not expired ... a standing or ad hoc committee elected by the faculty and charged with the function of rendering confidential advice in such situations should informally inquire into the situation, to effect an adjustment, if possible, and, if none is effected, to determine whether in its view formal proceedings to consider the faculty member's dismissal should be instituted."*

We should not make a bad situation worse when it comes to the determination of a rationale for formal proceedings that might entail sanctions up to and including dismissal.

As for the formal proceedings themselves, at present, we rely on "a fact-finding committee (the Committee) of five elected FRC members who are unbiased in the investigation" to formally deliberate on and issue findings on vetted allegations of misconduct. I note that current language last approved in 2017 in the Faculty Handbook deems "faculty members with administrative appointments of 50 percent time or more ... ineligible to serve on the FRC."

Under the proposed policy, we would rely on a "judicial committee" of three faculty members and three senior academic administrators. Here, a tie vote involving a finding of not guilty by all three faculty members is placed into the hand of the president, who transmits an opinion directly to the board for adjudication. While further reporting and review is built into the proposed policy, it would nevertheless become possible under the proposed policy to sanction and even to dismiss a faculty member against the unanimous wishes of the faculty peers who sit in judgment upon her case.

**According to the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings:**

*"A necessary precondition of a strong faculty is that it have first-hand concern with its own membership. This is properly reflected both in appointments to and in separations from the faculty body. .... It seems clear on the American college scene that a close positive relationship exists between the excellence of colleges, the strength of their faculties, and the extent of faculty responsibility in determining faculty membership ... The faculty must be willing to recommend the dismissal of a colleague when necessary. By the same token, presidents and governing boards must be willing to give full weight to a faculty judgment favorable to a colleague."*

At present, we have something much closer to full weight than the proposed policy entails, thanks to the powers invested in the FRC, even though we have some work to do in terms of the preliminary inquiry stage. We should be advocating a restoration of the full weight of faculty opinion, via FRC representation at every stage of the process, rather than reducing ourselves to judicial lightweights who are rather implausibly presented as middleweights.

- This proposed version of the faculty conduct policy also affords undue powers to the deans, at 6E, where suspension can be unilaterally imposed by a dean who "believes the alleged misconduct poses any risk to the community."

**According to the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings:**

*"Suspension of the faculty member during the proceedings is justified only if immediate harm to the faculty member or others is threatened by the faculty member's continuance."*

There is an enormous gap between the perception of "any risk to the community" and the demonstration of "immediate harm to the faculty member or others" as "threatened by the faculty member's continuance."

When it comes to matters of deliberation over misconduct that might involve the sanction of the revocation of tenure, this sanction should be announced, considered, and reviewed up front, through standard mechanisms described in the AAUP's Statement on Procedural Standards in Faculty Dismissal Proceedings. The sanction of the revocation of tenure should not materialize at a stage when the only recourse for appeal is to an appointed rather than elected committee.

In order to continue maturing into a strong university, WPI needs a strong faculty. This proposed policy would compromise protections for faculty of all kinds, allowing irregular deliberations on allegations of misconduct that would further reduce the role of faculty governance and further compromise the faculty's right of peer review in the determination of its own membership. I urge a "no" vote on this item, and I urge further reconsideration of established and interim policies related to faculty conduct.

**Prof. Richman** stated that this policy contains a delicate balance of matters of authority and responsibility, which the committee members have been working on for quite some time now, is not in violation of AAUP. AAUP realizes that, in most of these processes, the Faculty make their recommendations and the Administration and Board of Trustees have the final decision (which could go directly against those recommendations). Professor Richman explained that the members would be 3 Faculty and 3 Administration, selected by both the Secretary of the Faculty and the Provost, in the spirit of shared governance and in good faith. The Secretary of the Faculty would be an elected member, with other tenured members. He stated that he did not share Prof. Cocola's concerns because they have been addressed in different ways. Prof. Richman addressed the idea of suspension with pay being a temporary measure and entrusting the Dean making this decision when risk to community is present. Prof. Cocola stated that we currently have an elected Faculty Review Committee (FRC), and that should not be disempowered. Prof. Richman explained that, at later stages of a case, the Faculty members of the committee would, in fact, be selected from the FRC.

**Prof. Fehribach** (MA) stated that, if this policy was what the General Council thought best for Faculty vs. what AAUP thought best for Faculty, may be the root to the problem. Prof. Richman stated that this was not the case, that there has been much give and take between Faculty and General Council. The committee members feel they have been faithful to AAUP guidelines and have come up with a new model which includes shared decision making.

**Prof. Demetry** (ME) brought up Section 3, and asked if department policies or policies on collegiality existed. Prof. Richman stated that as to date, none exist.

**Prof. Jiusto** (IGSD) thanked the committee for their hard work, thoughtfulness and dedicated hours working on this policy, he supports it, and feels positive moving forward on it.

**Prof. Boudreau** (HUA) stated that although she understands Prof. Cocola's point of view, she believes in the policy even though it may be lacking in some ways. Prof. Cocola (HUA) stated

that the Board of Trustees have already written their own policy and it is in the Faculty Handbook. Prof. Richman stated that the Board of Trustees gave additional time to the Faculty to change and approve the revised policy.

**Prof. Gericke** (CBC) compared AAUP guidelines to “one size fits all” which is unlike our governance system, and urged all to have faith in the system.

**Prof. Dudle** (CEE) called the question. Seconded.

The motion **passed as amended**.

## 5. Special Reports

**Senior VP Tichenor** gave a presentation on her accomplishments and responsibilities. (See **Addendum #1** attached to these minutes).

VP Tichenor came to WPI in 2000 as the Director of Admissions. She is now pursuing her doctorate from the University of Pennsylvania, and is a parent of one WPI alumna and one WPI undergraduate student. She described her various responsibilities with different offices at WPI (Multicultural Affairs, Registrar’s Office, Undergraduate and Graduate Admissions, summing her responsibilities as Recruitment, Revenue and Reputation. VP Tichenor spoke about enrollment goals for the institution, supporting the strategic planning effort and institutional goals, and that Enrollment Management is getting students “to and through” WPI. She spoke of how regional demographics, global politics, competition from peers, and limited resources affect enrollment. She reported that there are over 1800 middle-school through high-school aged students participating in the pre-collegiate Outreach programs at WPI. Currently, the application number for the coming year is 10,806, which proves the demand for WPI remains extremely strong. She thanked the Faculty for being the “secret sauce” at WPI, and stated that her job is to persuade prospective students that a WPI education is worth the high tuition.

**Prof. Gaudette** (BME) asked if there were any areas of professional development or leadership opportunities for faculty within VP Tichenor’s area. VP Tichenor spoke about a wonderful opportunity for Faculty to engage with prospective students and/or parents when they are off-campus. The Admissions division normally hosts approx. 600-700 visits a year.

**Dean McNeill** (Eng.) stated that the “WPI in the Neighborhood” program was well worth the time and effort.

## 6. Adjournment

Meeting was adjourned at 4:40pm by **Prof. Dominko**.

Respectfully submitted,

Tanja Dominko  
Secretary of the Faculty



**Addenda on file with these minutes:**

1. Addendum #1 Senior VP Tichenor Report

## CONSENT AGENDA MOTIONS

CGSR AE Revision AE 5098  
CGSR AE Drop AE 5099  
CGSR AE Revision MS Degree  
CGSR AE Add AE 6999  
CGSR AE Revision PhD Degree  
CGSR BME Add BME 533, BME 593, BME 535  
CGSR BME Revision MS Program  
CGSR CS-Data Science Add DS 541/CS 541  
CGSR CS-Data Science Change Course designation  
CGSR CS-Data Science Change BS/MS Degree Requirements  
CGSR ME Indiv. Designed Interdisciplinary M.S. in Mechanical and Nuclear Engineering

CAO SSPS Change Program name  
CAO SSPS-IDEaS Add Minor in Sci. and Eng. for Development (DEV)  
CAO SSPS-IDEaS Add DEV designation  
CAO SSPS-IDEaS Add DEV 1200  
CAO SSPS-IDEaS Add DEV 2200  
CAO SSPS-IDEaS Add DEV 4400  
CAO MA Add MA 4222  
CAO BUS Add MIS 4084  
CAO AE Revise Distribution Requirements for AE Major  
CAO AE Remove AE 4090  
CAO AE Remove Crosslisting AE/ME 3703, drop AE 3703, Add AE 3717  
CAO AE Remove Crosslisting AE/ME 3602, drop ME 3602  
CAO AE Remove Crosslisting AE/ME 3410, drop ME 3410  
CAO AE Modify AE Course descriptions  
CAO ME Add ME 3411

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to revise a course description. Approved by the AE Program on 1/30/2019.

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the following course description (pg. 34 in the AY 2018-19 Graduate Catalog) be modified in the Graduate Catalog. Additions in underline, deletions in ~~striketrough~~. The proposed course description follows the marked-up version.

**AE 5098. Directed Research**  
(credits TBD)

These courses are offered by aerospace engineering faculty and cover diverse topics that range from 1 to 8 credits and may be completed in one or multiple terms. These courses ~~allow For non-thesis~~ provide M.S. and B.S./M.S. students the opportunity to gain research experience on topics of their interest. ~~for M.S. students wishing to gain research experience peripheral to their thesis topic.~~ The required deliverables for successful completion of Directed Research are defined by the faculty offering the course and take into account the credits and topic involved.  
(Prerequisite: consent of faculty offering the Directed Research supervisor.)

**AE 5098. Directed Research**  
(credits TBD)

These courses are offered by aerospace engineering faculty and cover diverse topics that range from 1 to 8 credits and may be completed in one or multiple terms. These courses provide M.S. and B.S./M.S. students the opportunity to gain research experience on topics of their interest. The required deliverables for successful completion of Directed Research are defined by the faculty offering the course and take into account the credits and topic involved.  
(Prerequisite: consent of faculty offering the Directed Research.)

**Rationale**

The revised course description is aligned with the new MS degree distribution requirements, considered in Motion #3.

**Resources and Anticipated Instructors**

None.

**Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

**Impact on Distribution Requirements and Other Courses**

There is no impact on distribution requirements for the aerospace engineering program or other programs.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to drop a course. Approved by the AE Program on 1/30/2019.

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the following course description be removed from the AE course description in the Graduate Catalog (pg. 34 of the AY 2018-19 Graduate Catalog). This effectively drops the course. Additions in underline, deletions in ~~striketrough~~.

**~~AE 5099. Thesis Research~~**

~~(credits TBD)~~

~~For master's students wishing to obtain research credit toward their thesis. (Prerequisite: Consent of thesis advisor.)~~

**Rationale**

The course is dropped to comply with the new MS degree distribution requirements, considered in Motion #3.

**Resources and Anticipated Instructors**

None.

**Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

**Impact on Distribution Requirements and Other Courses**

There is no impact on distribution requirements for the aerospace engineering program or other programs.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to revise the M.S. Degree. Approved by the AE Program on 1/30/2019.

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the M.S. Thesis option be dropped and the M.S. Degree description in the Graduate Catalog be modified as follows. Additions in underline, deletions in ~~strikethrough~~.

### **M.S. Degree**

~~When applying to the Master of Science degree, students must specify their intention to pursue either the thesis or non-thesis M.S. option. Both the thesis and non-thesis options~~ The Master of Science degree requires the completion of 30 graduate credit hours. Students ~~in the thesis option must complete 12 credits of thesis research (AE 5099), whereas students in the non-thesis option may complete up to 8 credits of directed research (AE 5098). The result of the research credits (AE 5099) in the thesis option must be a completed master's thesis. The number of directed research credits (AE 5098) completed in the non-thesis option can range from 0 to 8.~~

~~In the thesis option, the distribution of credits is as follows:~~

- ~~• 6 graduate credits, with 2 credits in each of the three AE Core Areas of Study~~
- ~~• 12 graduate credits of thesis research (AE 5099)~~
- ~~• 8 graduate credits of free electives in or outside AE~~
- ~~• 3 graduate credits in applied mathematics (any graduate MA course, or any other course with the approval of the AE Graduate Committee)~~
- ~~• 1 graduate credit in the Graduate Colloquium in Aerospace Engineering (AE 5090) TOTAL 30 Credits~~

~~In the non-thesis option, the distribution of credits is as follows:~~

- ~~• 18 graduate credits in AE courses, with a minimum of 2 credits in each of the three AE Core Areas of Study (includes a maximum of 8 credits of directed research – AE 5098)~~
- ~~• 8 graduate credits of free electives in or outside AE~~
- ~~• 3 graduate credits in applied mathematics (any graduate MA course, or any other course with the approval of the AE Graduate Committee) (MA 4551, MA 4733, MA 4631, MA 4632, MA 501, MA 507, MA 511, MA 514, MA 521 or any other course with the approval of AE graduate committee)~~
- ~~• 1 graduate credit in the Graduate Colloquium in Aerospace Engineering (AE 5090) TOTAL 30 Credits~~

Prior to registering for directed research AE 5098, the student must have completed at least 6 graduate credits in AE courses.

### **Academic Advising**

The schedule of academic advising ensures that students are well advised throughout the program.

Temporary Advisor: upon admission to the M.S. program (~~thesis or non-thesis~~), each student is assigned or may select a Temporary Advisor. Arranges an academic plan covering the first 8 credits of prior to the first registration.

Academic Advisor: elected by a student prior to registering for more than 8 credits. Arranges an academic plan covering the remaining course of study.

~~Thesis Advisor (for thesis option students): elected by a student prior to registering for more than 8 credits. Arranges the thesis topic and the academic plan covering the remaining course of study.~~

### **Thesis Defense**

~~Each student in the thesis option must defend his/her research during an oral defense, which is administered by the Thesis Advisor and a representative of the AE Graduate Committee. The defense is open to public participation and consists of a 30-minute presentation by the student followed by a 30-minute open discussion. At least one week prior to the defense the Thesis Advisor and an AE Graduate Committee Representative must receive a copy of the thesis. Public notification of the defense must be given by the AE program office. The Thesis Advisor will determine the acceptability of the student's thesis and will determine the student's grade.~~

### **Changing M.S. Options**

~~Students in the non-thesis M.S. option may switch into the thesis option at any time by notifying the AE Graduate Committee of the change, provided that they have identified a Thesis Advisor and have worked out a Plan of Study with their thesis advisor. Subject to the Thesis Advisor's approval, directed research credits (AE 5098) earned in the non-thesis option may be transferred to thesis research credits (AE 5099) in the thesis option.~~

~~Any student in the thesis M.S. option may request a switch into the non-thesis option by submitting the request in writing to the AE Graduate Committee. Before acting on such a request, the Graduate Committee will require and seriously consider written input from the student's Thesis Advisor. Financial aid given to the thesis option students who are permitted to switch to the non-thesis option will automatically be withdrawn. Subject to the approval of the AE Graduate Committee, a maximum of 9 credits of thesis research (AE 5099) earned by a student in the thesis option may be transferred to directed research credit (AE 5098) in the non-thesis option.~~

### **The Combined B.S./M.S. Program**

The AE Program offers a combined B.S./M.S. program for currently enrolled WPI undergraduates. ~~When applying to the B.S./M.S. program, students must specify their intention to pursue either the thesis or non-thesis M.S. option. Both the thesis and non-thesis options~~ The M.S. degree requires the completion of 30 graduate credit hours.

For students admitted in the B.S./M.S. program, a maximum of 8 graduate credits may be counted toward both the undergraduate and graduate degrees. Double-counted graduate credits must be in courses, including graduate-level independent study and special topics. A maximum of four (4) credits can be double-counted in courses from Engineering, Basic Science or Mathematics which must be at the 4000- level. A grade of B or better is required for any course to be counted toward both degrees.

Acceptance into the B.S./M.S. program means that the candidate is qualified for graduate school and signifies approval of the graduate courses listed for credit toward both the undergraduate and graduate degrees.

~~Students in the B.S./M.S. program who choose the thesis M.S. option are encouraged to pick a thesis area of research that is closely related to the subject of their major qualifying project. Those students in the B.S./M.S. program who complete their B.S. degrees in May and choose the thesis option are encouraged to begin their thesis research during the summer immediately following graduation.~~

### **Rationale**

The M.S. Thesis has become an obsolete option and this is the main reason for dropping it. The non- Thesis option adopted exclusively for the M.S. degree offers a more flexible research component through Directed Research. Students can complete up to 8 Directed Research credits on a single or multiple areas offered by faculty throughout the academic year. Directed Research provides most of the benefits of the M.S. Thesis research experience but without the rigidity of a Thesis. Students who want to pursue in depth a single topic can do so by registering for up to 8 credits.

An added flexibility with this motion is reflected in the applied mathematics requirement, which is now expanded to include selected undergraduate mathematics course in the 4xxx level and many graduate mathematics courses in the 5xx level.

### **Resources and Anticipated Instructors**

None.

### **Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

### **Impact on Distribution Requirements and Other Courses**

There is no impact on distribution requirements for the aerospace engineering program or other programs.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to add a course for the Ph.D. Degree. Approved by the AE Program on 1/30/2019.

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the following course is added to the AE course description in the Graduate Catalog.

**AE 6999. Ph.D. Qualifying Examination**  
(0 credit)

The written Qualifying Examination is intended to measure the fundamental ability of students admitted in the Ph.D. program in the three Core Areas of Study: fluids and propulsion; dynamics and control; materials and structures. The Qualifying Examination is given in the first week of D term and, if required, a retake of the Qualifying Examination is given in the middle of D Term. For students who enter the Ph.D. program in the fall, the Qualifying Examination must be taken after three terms. For students who enter the Ph.D. program in the spring, the Qualifying Examination must be taken after five terms.

The Qualifying Examination is graded using a Pass/Fail system with Pass/Fail grading in each of the three Core Areas of Study. A student may attempt the retake Qualifying Exam for the Core Areas of Study failed during the Qualifying Examination. A student must earn a Pass in all three Core Areas of Study in order to earn a Pass in the Qualifying Examination. Admission to candidacy is granted when a student has satisfactorily passed the AE 6999. Ph.D. Qualifying Examination.

Requirements: students must be enrolled in the Aerospace Engineering graduate program seeking a Ph.D. degree and must have the appropriate background in the three Core Areas of Study.

**Rationale**

This motion takes advantage of a recently adopted course number for the Qualifying Examination. This allows the Registrar to formally record this important milestone and make it part of a student's record.

**Resource Needs**

None.

**Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

**Impact on Distribution Requirements and Other Courses**

There is no impact on distribution requirements for the aerospace engineering program or other programs.



**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to revise the Ph.D. Degree. Approved by the AE Program on 1/30/2019.

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the Ph.D. Degree description in the Graduate Catalog be modified as follows. Additions in underline, deletions in ~~strikethrough~~.

*Current description* (pp. 29 of the AY 2018-19 Graduate Catalog):

### **Ph.D. Degree**

Students are admitted to the Ph.D. program and must retain a full-time status up to admission to Candidacy granted by successfully passing the AE 6999 Ph.D. Qualifying Examination.

The course of study leading to the Ph.D. degree in aerospace engineering requires the completion of 90 credits beyond the bachelor's degree, or 60 credits beyond the master's degree.

For students proceeding directly from B.S. degree to Ph.D. degree, the 90 credits should be distributed as follows:

- 30 graduate credits in coursework
    - 16 graduate credits in AE courses (incl. Special Topics and ISP)
    - 8 graduate credits in courses in or outside of AE
    - 3 graduate credits in applied mathematics (~~any graduate MA course, or any other course with the approval of the AE Graduate Committee~~) (MA 4551, MA 4733, MA 4631, MA 4632, MA 501, MA 507, MA 511, MA 514, MA 521 or any other course with the approval of AE graduate committee)
    - 3 graduate credits in the Graduate Colloquium in Aerospace Engineering (AE 5090)
  - 30 graduate credits in Dissertation Research (AE 6099)
  - 30 graduate credits in
    - Additional coursework
    - Additional Dissertation Research (AE 6099)
    - Supplemental Research (AE 5098, AE 6098)
  - 0 credits in AE 6999 Ph.D. Qualifying Examination
- TOTAL 90 credits

For students proceeding from Master's to Ph.D. degree, the 60 credits should be distributed as follows:

- 12 graduate credits in AE courses (incl. Special Topics and ISP)
  - 30 graduate credits in Dissertation Research (AE 6099)
  - 16 graduate credits in
    - Courses in or outside of AE
    - Dissertation Research (AE 6099)
    - Supplemental Research (AE 5098 or AE 6098)
  - 2 graduate credits in the Graduate Colloquium in Aerospace Engineering (AE 5090)
  - 0 credits in AE 6999 Ph.D. Qualifying Examination
- TOTAL 60 credits

- Prior to admission to Candidacy, a student may receive up to 18 credits of pre-dissertation research under AE 6098.
- Only after admission to Candidacy with the successful passing the AE 6999 may a student receive credit toward Dissertation Research under AE 6099.
- The result of the dissertation research must be a completed doctoral dissertation.

### **Academic Advising and Schedule**

~~The schedule below ensures that students are well advised and actively engaged in their research at all stages of their programs.~~

- ~~Dissertation Advisor: agreed upon by faculty and student prior to registering for more than 8-10 credits.~~
- ~~Plan of Study and Dissertation Topic: approved by the Dissertation Advisor prior to registering for more than 8-10 credits.~~
- ~~Admission to Candidacy: Admission to candidacy will be granted after the student has satisfactorily passed a written Qualifying Exam.~~
- ~~Dissertation Committee: formed prior to registering for more than 18 credits and after admission to Candidacy. The Dissertation Committee consists of the Dissertation Advisor, at least one core faculty of the Aerospace Engineering Program, and at least one outside member.~~
- ~~Dissertation Proposal: presented by a Doctoral Candidate to the Dissertation Advisor and at least one member of the Dissertation Committee prior to registering for more than 18 credits.~~
- ~~Dissertation Defense: presented orally by the Doctoral Candidate to the Dissertation Committee and an AE Graduate Committee Representative.~~

### **Temporary Advisor**

Upon admission to the Doctoral Program, each student is assigned or may select a temporary advisor to arrange an academic plan covering the first 8-10 credits of study. This plan should be arranged before the first day of registration.

### **Dissertation Advisor and Plan of Study**

A student selects an AE Dissertation Advisor who agrees upon prior to registering for more than 8-10 credits. The Dissertation Advisor will approve the Plan of Study which includes the Dissertation Topic.

### **Ph.D. Qualifying Exam and Admission to Candidacy**

Admission to Candidacy will be granted when the student has satisfactorily passed the written AE 6999 Ph.D. Qualifying Exam. ~~intended to measure fundamental ability in the three Core Areas of Study: fluids and propulsion; dynamics and control; materials and structures. The Qualifying Exam is given in the first week of D term and, if required, a Retake Qualifying Exam is given in the middle of D Term. For fulltime students who enter the program in the fall the exam must be taken after three terms and after five terms if they began in the spring. The Qualifying Exam is graded using a Pass/Fail system with Pass/Fail grading in each of the three Core Areas of Study. A student must earn a Pass in all three Core Areas of Study in order to earn a Pass in the Qualifying Exam. A student may attempt the retake Qualifying Exam for the Core Areas of Study failed during the Ph.D. Qualifying Examination. If a student fails to earn a Pass in all three Core Areas of Study of the Qualifying Examination and the~~

~~retake Qualifying Examination, he/she~~ the student must withdraw from the Ph.D. program by the end of D term of the year of the Qualifying Examination. The details of the examination procedure are arranged ~~can be obtained from~~ by the Aerospace Engineering Office.

### **Dissertation Committee and Dissertation Proposal**

Formed prior to registering for more than 18 credits and after Admission to Candidacy. The Dissertation Committee consists of the Dissertation Advisor, at least one core faculty of the Aerospace Engineering Program, and at least one outside member.

### **Dissertation Proposal**

Each Doctoral Candidate must prepare a brief written proposal and make an oral presentation that demonstrates a sound understanding of the dissertation topic, the relevant literature, the techniques to be employed, the issues to be addressed, and the work done on the topic by the student to date. The Dissertation Proposal must be made within a year after the Qualifying Examination and admission to candidacy. Both the written and oral parts of the Proposals are presented to members of the Dissertation Committee and a representative from the AE Graduate Committee. The prepared portion of the oral presentation should not exceed 40 minutes, and up to 60 minutes should be allowed for discussion. If the members of the Dissertation Committee and the Graduate Committee representative have concerns about either the substance of the proposal or the student's understanding of the topic, then the student will have one month to prepare a second presentation that focuses on the areas of concern. This presentation will last 15 minutes with an additional 35 minutes allowed for discussion. Students can continue their research only if the Dissertation Proposal is approved. If the Dissertation Proposal is not approved, the Doctoral candidate may find a new Dissertation Advisor and proceed with a new Dissertation Proposal.

### **Dissertation Defense**

Each Doctoral Candidate is required to defend the originality, independence and quality of research during an oral dissertation defense that is administered by an examining committee that consists of the Dissertation Committee and a representative of the AE Graduate Committee who is not on the Dissertation Committee. The defense is open to public participation and consists of a one-hour presentation followed by a one-hour open discussion. At least one week prior to the defense, each member of the examining committee must receive a copy of the dissertation. At the same time, an additional copy must be made available for members of the WPI community wishing to read the dissertation prior to the defense, and public notification of the defense must be given by the aerospace engineering graduate program secretary. The examining committee will determine the acceptability of the student's dissertation and oral performance. The dissertation advisor will determine the student's grade.

### **Rationale**

This motion makes clarifications and revisions in the guidelines for the Ph.D. program which was first introduced in 2015. It streamlines and simplifies the academic advising and schedule for Ph.D. students.

The motion clarifies the PhD Qualification Examination with the introduction of the AE 6999 course (in a separate motion).

The motion also adds flexibility in the applied mathematics requirement, which is now expanded to include selected undergraduate mathematics course in the 4xxx level and many graduate mathematics courses in the 5xx level.

**Resources and Anticipated Instructors**

None.

**Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

**Impact on Distribution Requirements and Other Courses**

There is no impact on distribution requirements for the aerospace engineering program or other programs.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to add the following BME courses to the Graduate Catalog

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the following three courses be added to the BME graduate catalog.

**Proposed Course/Catalog Description:**

*All courses are 3 credit hours*

**BME 553: Biomechanics of Orthopaedic Devices**

This course will survey different types of orthopaedic implants and devices, primarily focusing on joint arthroplasty and fracture fixation methods. Topics such as: device design and function, mechanics, materials, validation and testing, failure, use cases, and regulatory requirements will be discussed. Class projects and discussions will cover contemporary topics related to the design, manufacture, and post-implantation measurement and performance evaluation of orthopaedic devices. Students may not receive credit if they previously completed this course as BME 595: Special Topics.

**BME 593: Scientific Communication**

Clear oral, written, and graphical communication of scientific methods and data is an essential skill for success, both in research and in industry. This course will cover aspects of scientific communication including: scientific manuscript preparation and the peer review process, technical report organization, graphical presentation of quantitative data, and oral presentation of scientific information. Organization and clarity will be emphasized in communicating scientific methods, results, and interpretation. Students will complete regular writing and presentation assignments and participate in peer critique sessions. Students will complete an original research article, review article, or technical report as a final project. Students may not receive credit if they previously completed this course as BME 595: Special Topics.

\*Does not fulfil technical depth requirement.

**BME 535: Medical Device Design Controls**

An introduction to the fundamentals of medical device design controls from concept generation to manufacturing. Students work in teams to navigate through the medical device design and development lifecycle on various device types, fulfilling design control requirements while learning what is required to bring a concept to life in industry. Students may not receive credit if they previously completed this course as BME 595: Special Topics.

\*Does not fulfil technical depth requirement.

**Rationale:** These courses have been previously offered as experimental courses. We would like to add them to the catalog because we plan to offer them regularly.

Student Evaluations from Previous offerings:

Biomechanics of Orthopaedic Devices (Fall 2018)

1. My overall rating of the quality of this course is	<b>Very Poor (1)</b>	0	0	0	4	5	<b>(5) Excellent</b>	4.60	9
2. My overall rating of the instructor's teaching is	<b>(1)</b>	0	0	0	3	6	<b>(5)</b>	4.70	9

Scientific Communication (Fall 2017):

1. My overall rating of the quality of this course is	<b>Very Poor (1)</b>	0	0	0	4	4	<b>(5) Excellent</b>	4.50	8
2. My overall rating of the instructor's teaching is	<b>(1)</b>	0	0	0	1	7	<b>(5)</b>	4.88	8

Medical Device Design Controls (Spring 2017 and 2018):

<b>Spring 2017</b>									
1. My overall rating of the quality of this course is	<b>Very Poor (1)</b>	0	0	5	10	3	<b>(5) Excellent</b>	3.89	18
2. My overall rating of the instructor's teaching is	<b>(1)</b>	0	0	5	9	4	<b>(5)</b>	3.94	18
<b>Spring 2018</b>									
1. My overall rating of the quality of this course is	<b>Very Poor (1)</b>	0	0	0	3	7	<b>(5) Excellent</b>	4.70	10
2. My overall rating of the instructor's teaching is	<b>(1)</b>	0	0	0	2	8	<b>(5)</b>	4.80	10

**Impact on Degree Requirements:** These courses will offer graduate students additional options to fulfil their graduate degree requirements.

**Resources and Anticipated Instructors:** Two of the courses are taught by BME Core Faculty (Troy). The other was developed and is currently taught by adjunct Whitney Moore. Should this instructor become unable to offer the course, we will work with her to identify another instructor with the appropriate expertise.

**Implementation Date:** Implementation date for this action is the 2019-2020 academic year.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to amend the BME MS program requirements and modify the catalog description

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the changes described below be made to the MS Program in Biomedical Engineering.

**Proposed Course/Catalog Description or proposed Modifications to Graduate Catalog:**

Summary of changes:

We propose that the BME courses requirement be reduced from 15 credits to 12 credits, with the remaining 3 credits being shifted to electives.

We also make clarifications about how competencies may be met, and more clearly define courses that may count towards Technical Depth.

**Rationale:** Some aspects of this new degree were unclear and confusing to students. For example, whether a BME project or thesis could also fulfil a competency or technical depth requirement was not explicitly defined in the original catalog text. This modification seeks to clarify this. Additionally, one of the original intentions of the new MS program was to allow students the flexibility to pursue a secondary area of interest. The 15-credit BME course requirement made it difficult for students to do this while completing other degree requirements. The intention of the 15-credit BME requirement was to ensure “residency” within the department. We believe this is still the case with 12 credits of BME courses.

Proposed Catalog Edits (changes are highlighted)

**For the M.S.**

A minimum of 30 credit hours is required for the Master of Science degree, which may be met by satisfying the requirements for a Thesis-Based or Project-Based program of study. BME courses include BME 500-level or 4000-level courses (except BME 4300. MQP Capstone Design). Electives may include any WPI graduate-level engineering, physics, math, biomedical engineering, or equivalent course (500- or 4000-level), subject to the approval of the department Graduate Studies Committee. A maximum of 8 credits of coursework at the 4000-level may be applied to meet the requirements for the Master of Science degree.

<b>M.S. (Thesis-Based)</b>	<b>30 credits</b>
BME courses	12 credits
BME 599 (M.S. Thesis)	6 credits minimum
Electives	12 credits

<b>M.S. (Project-Based)</b>	<b>30 credits</b>
BME courses	12 credits
BME 597 (M.S. Project)	6 credits
Electives	12 credits

**BME courses:** BME courses are defined as any course with a BME designator.

### **Thesis (6 credits, Thesis-Based M.S.)**

The Thesis-Based M.S. program requires a minimum of 6 credits of **BME 599. Master's Thesis** and completion of an independent research project under the supervision of a Biomedical Engineering Program Faculty advisor. This option is well-suited for the student seeking to engage in deeper, open-ended inquiry into a research area, in preparation for advanced research training (e.g., Ph.D. degree) or research-focused career opportunities in a medical, academic, government, or industry laboratory setting.

### **Project (6 credits, Project-Based M.S.)**

The Project-Based M.S. program enables students to engage in a focused, credit-based independent project experience that builds on their individual professional and academic experience. The program will facilitate development of experience, skillset, and mindset to contribute and lead in industry as engineers in a variety of biomedical engineering roles. The Project-Based M.S. program requires completion of 6 credits of **BME 597. Professional Project**, and completion of a capstone deliverable representative of their integrated project experience (e.g., poster or platform presentation, department seminar, final presentation, online portfolio). The Project may include one or more integrated project-based experiences:

- 1) **BME 5900. Internship or Co-op.** Students may apply for an industry-based co-op or internship, and earn academic credit while using elements of the co-op or internship as the basis for satisfying the project requirement.
- 2) **BME 5910. Master's Design Project.** Students may work with a faculty advisor to design a device or prototype that meets a specific set of technical objectives.
- 3) **BME 5920. Clinical Preceptorship.** Students may work with faculty advisors in collaboration with clinicians (including medical, dental, veterinary) to design a device, system, or other product that creates value with positive impact on clinical practice.

In addition, the following requirements must be met for both Master of Science degree programs:

- **Technical Depth Requirement (15 credits minimum).** Thematically-related advanced engineering and science coursework in an area of technical focus within a Biomedical Engineering specialization. **No more than one life sciences or regulatory course may be applied towards this requirement, and the course must be relevant to the depth area. Up to 3 credit-hours of a Thesis or Project may be designated as technical depth.**
- **Seminar Requirement.** Students must take BME 591. Graduate Seminar (0 credits) and pass it twice.
- **BME Core Competencies.** In addition to meeting the specified minimum credit requirements for the degree program, all Master of Science candidates must satisfy five (5) BME Core Competencies.
  1. **Mathematics.** Understanding and ability to apply fundamental principles of mathematics (e.g., statistics, numerical methods, or computational modeling).
  2. **Life science.** Understanding and ability to apply fundamental principles of life science (e.g., cell and molecular biology, physiology).
  3. **Clinical needs analysis and design.** Ability to communicate effectively with clinical stakeholders, understanding of healthcare systems, exposure to clinical environments and practice, understanding clinical needs and recognizing opportunities to improve healthcare delivery and practice.
  4. **Regulation and controls.** Understanding of regulations and standards applied to biomedical



engineering design, manufacturing, and research (e.g., medical device design regulations, FDA regulations, engineering standards, QC/QA, GMP/GLP).

- 5. Value creation, innovation, technology commercialization.** Development and practice of innovation mindset and skillset to create value and recognize opportunities for innovation in the design and development of medical technologies; commercial and clinical translation of medical innovations that impact healthcare delivery and practice.

**Core Competencies.** To aid students in developing a Plan of Study, the following example courses that can fulfill each of the five (5) BME Core Competencies are provided. Alternative courses may be applied to fulfill competency requirements. Students need only take one (1) course to fulfill a given competency. Alternatively, waivers may be considered based on documented work experience, advanced degrees, majors, or minors that demonstrate advanced mastery in the core competency area. Course substitutions and waivers must be approved by the department Graduate Studies Committee. **If approved, a Thesis or Project may be used to fulfil up to two (2) Competencies.**

**Impact on Degree Requirements:** The proposed changes add flexibility for students, but do not change the technical rigor or number of credit hours required to earn the degree.

**Resources and Anticipated Instructors:** No additional resources are required.

**Implementation Date:** Implementation date for this action is the 2019-2020 academic year.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to add DS 541/ CS 541 Deep Learning course as a core Data Science course

**Motion:** The Committee on Graduate Studies and Research recommends and I move, that the DS 541/CS 541 Deep Learning course be added as a core course under the core area of Data Analytics and Mining

### **Existing core courses under the core area of Data Analytics and Mining**

There are currently three courses under this core area, which include: (1) CS 548 Knowledge Discovery and Data Mining, (2) CS 539 Machine Learning, and (3) DS 504/CS 586 Big Data Analytics. Any of these courses satisfy the requirements of this core area.

### **Proposed change**

The proposed change is to add DS 541/CS 541 Deep learning to the aforementioned list under the core area of Data Analytics and Mining.

**Rationale:** The Deep Learning course offers sufficient content related to analytics and mining, and hence it meets the requirements of the Data Analytics and Mining core area. Currently, students taking this course need to submit a petition to the Data Science program, and we approve all these petitions. This motion removes this unnecessary step.

**Implementation Date:** Fall 2019

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to change the course number of the Data Science Internship

**Motion:** The Committee on Graduate Studies and Research recommends and I move, that the course number of the Data Science Internship course be changed as described below.

**Existing course number from the graduate catalog**

~~DS 594.~~ Data Science Internship

**Proposed new number**

DS 5900. Data Science Internship

**Rationale:** WPI has designated a new course number for the internship course, which is “5900” across departments and programs. The motion proposes changing the old assigned number to match the new WPI designated number.

**Implementation Date:** Fall 2019

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to change the description of the BS/MS degree requirements in Data Science

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the description of the BS/MS degree requirements in Data Science be changed as described below.

### **Existing description from the graduate catalog**

#### **For the B.S./M.S.**

The requirements for the proposed M.S. in Data Science are structured so that undergraduate student would be able to pursue a five-year Bachelors/Masters program, in which the Bachelors degree is awarded in any major offered at WPI and the Masters degree is awarded in Data Science. Students enrolled in the B.S./M.S. program must satisfy all the program requirements of their respective B.S. degree *and* all the program requirements of the M.S. degree in Data Science. WPI allows the double counting of up to 12 credits for students pursuing a 5-year Bachelors-Masters program. This overlap can be achieved through the following mechanisms. They may double-count courses towards both their undergraduate and graduate degrees whose credit hours total no more than *40 percent of the 33 credit hours required for the M.S. degree in Data Science*, and that meet all other requirements for each degree. These courses can include graduate courses as well as certain undergraduate 4000-level course as long as the undergraduate course is acceptable in place of a corresponding graduate course that satisfies a Data Science M.S. requirement. ~~See the individual departmental entries in this catalog for listings of such undergraduate and graduate courses pairs. Students must consult their faculty advisor and the graduate catalog as individual departments have restrictions on which undergraduate courses may be taken for graduate credit, and on which pairs of undergraduate and graduate courses cannot both be taken for credit. Students must register for B.S./M.S. credit prior to taking the courses, as faculty may assign extra work for those taking a 4000-level course as part of both degrees.~~

In consultation with the academic advisor, the student prepares a Plan of Study outlining the selections chosen to satisfy the B.S./M.S. degree requirements, including the courses that will be double-counted. This Plan of Study must then be approved by the DS Program Review Board.

### **Proposed description**

#### **For the B.S./M.S.**

The requirements for the proposed M.S. in Data Science are structured so that undergraduate student would be able to pursue a five-year **Bachelor's/Master's** program, in which the **Bachelor's** degree is awarded in any major offered at WPI and the **Master's** degree is awarded in Data Science. Students enrolled in the B.S./M.S. program must satisfy all the program requirements of their respective B.S. degree *and* all the program requirements of the M.S. degree in Data Science. WPI allows the double counting of up to 12 credits for students pursuing a 5-year **Bachelor's/Master's** program. This overlap can be achieved through the following mechanisms. **Students** may double-count courses towards both their undergraduate and graduate degrees whose credit hours total no more than *40 percent of the 33 credit hours required for the M.S. degree in Data Science*, and that meet all other requirements for each degree. These courses can include graduate courses as well as certain undergraduate 4000-level course as long as

the undergraduate course is acceptable in place of a corresponding graduate course that satisfies a Data Science M.S. requirement.

In consultation with the academic advisor, the student prepares a Plan of Study outlining the selections chosen to satisfy the B.S./M.S. degree requirements, including the courses that will be double-counted. This Plan of Study must then be approved by the Data Science Program.

As a university wide rule, the B.S./M.S. double counting credits can be applied for only while the student is an undergraduate student.

### Double Counting Credits From 4000-Level Courses

The credits from the following list of 4000-level courses can count towards the Data Science M.S. degree:

Courses from Computer Science
CS 4120 Analysis of Algorithms
CS 4341 Introduction to Artificial Intelligence
CS 4432 Database Systems II
CS 4445 Data Mining and Knowledge Discovery
CS 4531 Machine Learning
CS 4802 BioVisualization
CS 4803 Biological and Biomedical Database Mining

Courses from Mathematical Sciences
MA 4235 Mathematical Optimization
MA 4603 Statistical Methods in Genetics and Bioinformatics
MA 4631 Probability and Mathematical Statistics I
MA 4632 Probability and Mathematical Statistics II
MA 4635 Data Analytics and Statistical Learning

Other 4000-level courses not listed above, including 4000-level independent study courses, require a petition and approval from the Data Science Graduate Committee before they can double-count for the B.S./M.S. degree.

### Restricted Undergraduate and Graduate Course Pairs

Some undergraduate and graduate courses have significant overlap in their content. The following table lists these courses. A student can receive credit towards their M.S. degree for at most one of the two courses in any row of this table.

Courses from Computer Science	
Undergraduate Course	Graduate Course
CS 4341 Introduction to Artificial Intelligence	CS 534 Artificial Intelligence
CS 4432 Database Systems II	CS 542 Database Management Systems
CS 4445 Data Mining and Knowledge Discovery	CS 548 Knowledge Discovery and Data Mining
CS 4803 Biological and Biomedical Database Mining	CS 583 Biological and Biomedical Database Mining

CS 4342 Machine Learning	CS 539 Machine Learning
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Courses from Mathematical Sciences	
Undergraduate Course	Graduate Course
MA 4631 Probability and Mathematical Statistics I	MA 540 Probability and Mathematical Statistics I
MA 4632 Probability and Mathematical Statistics II	MA 541 Probability and Mathematical Statistics II
MA 4635 Data Analytics and Statistical Learning	MA 543/DS 502 Statistical Methods for Data Science

**Satisfying Data Science Core Areas**

B.S./M.S. students can use the B.S./M.S. credits to satisfy a core area requirement if any of the following conditions is met: (1) The undergraduate course under consideration must appear in one of the tables above, and the corresponding graduate course must satisfy the core area requirement. (2) The undergraduate course or independent study/project work is not in the tables listed above but it is deemed to satisfy the core area. This requires submitting a petition along with a detailed course description and syllabus to the Data Science Program for final decision.

**Rationale:** The proposed description is more explicit and elaborate compared to the existing description. The Data Science program used to follow all the explicitly added rules but through petitions. The new description would make it easier for students to select their 4000-level courses that can double count towards the B.S./M.S. degree, and would save the unnecessary effort of students submitting petitions and the program approving them at least for the courses listed in the new description.

**Implementation Date:** Fall 2019

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Graduate Studies and Research (Prof. Reeta Rao, Chair)  
**Re:** Motion to Approve Interdisciplinary M.S. in Mechanical and Nuclear Engineering

**Motion:** The Committee on Graduate Studies and Research recommends and I move that the Proposal for Interdisciplinary M.S. in Mechanical and Nuclear Engineering be approved.

### **Program Goal**

The goal of this proposed program is to obtain an interdisciplinary master's degree level education in mechanical and nuclear engineering for personal educational growth and future opportunities in industry or academia.

### **Program Motivation**

The proposed program, reflected in the title, is a fusion of mechanical and nuclear engineering. Mechanical engineering, especially when focused on thermal and energy systems, forms a foundation for the more specific field of nuclear engineering. These work together to allow one to understand both systems and work in the niche between them, specifically nuclear power generation. As nuclear power technology evolves resulting in technologies such as fast neutron fission, inertial confinement fusion, and thermonuclear tokamaks and stellarators, harnessing the power will create new challenges. This will require more engineers in the field with high levels of education to create solutions and educate the next generation of engineers.

### **Comparable Programs**

The proposed program is a combination of two fields that together satisfy the requirements of a single master's degree. Thus their merits will be compared individually to their respective fields and then together to the baseline master's degree requirements.

Mechanical Engineering

Although there are many M.S. programs in mechanical engineering to compare, WPI's M.S. requirements are more pertinent. WPI's non-thesis option for a M.S. requires the following credits (WPI Graduate Catalog 2018-2019, p. 144):

- 18 graduate credits in mechanical engineering
  - Can include a maximum of 9 credits of directed research – ME 598
- 3 graduate credits in mathematics
- 9 graduate credits of electives within or outside of mechanical engineering

The B.S/M.S. program allows students to count 6 to 12 credits of graduate classes towards undergraduate requirements and a maximum of 6 credits of undergraduate 4000 level classes towards graduate requirements.

### **Nuclear Engineering**

WPI does not currently have a nuclear master's degree but the proposed degree does meet similar criteria of WPI's Graduate Nuclear Science and Engineering Certificate. The certificate requires four of the

following NSE courses:

- NSE 510 – Introduction to Nuclear Science and Engineering (3 credits)
- NSE 520 – Applied Nuclear Physics (3 credits)
- NSE 530 – Health Physics (3 credits)
- NSE 540 – Nuclear Materials (3 credits)
- NSE 550 – Reactor Design, Operations, and Safety (3 credits)

Additionally, equivalent credits are permitted upon approval by the NSE Program Committee. The proposed program includes NSE 595 – Dosimetry and Shielding and PH595 – Radiation Biology in lieu of some of the introductory NSE courses to provide a more advanced education. These subjects cover many of the requirements of established NSE master’s programs offered by other institutions including:

- Thermofluid systems
- Nuclear physics
- Radiation Physics – sources, interactions with matter, effects on the human body, measurement
- Reactor theory – reactor design, instrumentation, operations, safety
- Engineering mathematics – linear algebra, partial differential equations, Fourier series, Laplace transforms

A detailed list of requirements for similar programs available at other institutions was included in a previous proposal submitted for review.

### **Mechanical and Nuclear Engineering**

Many topics in mechanical and nuclear engineering overlap resulting in the question: how much can the classes double count? Although most of the proposed classes could count towards either a mechanical or a nuclear engineering degree, they cannot count towards both. Listing a M.S. in Mechanical Engineering and a M.S. in Nuclear Engineering implies more effort than a single M.S. in Mechanical and Nuclear engineering. The latter title implies a rounded education of both mechanical and nuclear engineering that together satisfies the requirement of a M.S. degree.

The proposed program includes 30 credits which satisfies WPI’s base requirement of 30 graduate credits for a master’s degree. Of these, half are mechanical engineering and the remainder are physics (nuclear related), nuclear science and engineering, and mathematics. This is in accordance with the requirements of the interdisciplinary master’s programs in the Graduate catalog:

“Interdisciplinary master’s programs require at least 30 credits beyond the bachelor’s degree. They may also include a thesis or project requirement. Proposals for such programs are initiated by groups of at least two faculty members from different academic departments who share a common interest in a cross-disciplinary field. The sponsoring group submits a proposal for an interdisciplinary degree to the Committee on Graduate Studies & Research (CGSR) that includes the details of a program of study and the credentials of the members of the group. At least one member of the group must be from a department or program currently authorized to award the master’s degree. No more than half of the total academic credit may be taken in any one department. The CGSR may request additional input from the sponsors or appropriate departments. If the CGSR approves the proposal, the sponsoring group serves in place of a department in administration of the approved program.”

### **Planned Coursework Summary**

- ME 5104 – Turbomachinery (2 credits)



- ME 5105 – Renewable Energy (2 credits)
- ME 5441 – Design for Manufacturability (2 credits)
- ME 598 – Directed Research (9 credits)
- MA 501 – Engineering Mathematics (3 credits)
- PH 597 – Radiation Biology (3 credits)
- NSE 530 – Health Physics (3 credits)
- NSE 550 – Reactor Design, Operations, and Safety (3 credits)
- NSE 595 – Dosimetry and Shielding (3 credits)

6 credits of mechanical engineering coursework

9 credits of mechanical engineering directed research 3 credits of mathematics coursework

12 credits of nuclear science, engineering, and physics coursework Total – 30 credits

### **M.S. in Mechanical and Nuclear Engineering Graduate Committee**

I propose the following sponsoring group to advise the program and present it to the Committee on Graduate Studies & Research. This group consists of faculty from both the Mechanical Engineering department and the Physics/NSE department to reflect the hybrid nature of the degree:

Dr. Selcuk Guceri, Professor, Mechanical Engineering

Dr. Jamal Yagoobi, Department Head, Mechanical Engineering

Dr. David Medich, Associate Professor, Department of Physics, Director of the NSE program at WPI.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to change the title of the Environmental and Sustainability Studies Program to International Development, Environment, and Sustainability approved by Program Review Committee on September 26, 2018.

**Motion:** The Committee on Academic Operation recommends and I move, that the Environmental and Sustainability Studies Program be changed as described below.

**Existing title:**  
Environmental and Sustainability Studies

**Proposed title, description, and course offering:**  
International Development, Environment, and Sustainability (IDEaS)

**Explanation of Motion:** This motion changes the program title of Environmental and Sustainability Studies to the new title, International Development, Environment, and Society. The name change only extends to the program and not the major. The major will remain Environmental and Sustainability Studies. The new program, International Development, Environment, and Sustainability will house additional degrees, such as the proposed Minor in Science and Engineering for Development.

**Rationale:** The change in name for the Environmental and Sustainability Studies Program reflects the evolution of this program and its offerings. This is the second name change for this program in its ten years. Originally, the name was Environmental Studies reflecting the original course offerings. In 2012, the name changed to Environmental and Sustainability Studies to reflect the interests of the faculty and a key thrust of sustainability to the curriculum. Now, we seek to change it to International Development, Environment, and Sustainability (IDEaS). The new name reflects the current faculty teaching and scholarly interests along these themes of international development, environment, and society. The program also expects to host the new minor in Development Engineering.

**Impacts on students:** There are no real impacts to this name change. Students and faculty will have to learn the name of a new program. Dean King and Provost Soboyejo have endorsed this program name change.

**Resource Needs:**  
No new resources are required.

**Implementation Date:** 2018/19 academic year.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add Minor in Science and Engineering for Development (DEV)

**Motion:** The Committee on Academic Operation recommends and I move, that Minor in Science and Engineering for Development (DEV) be added to the course catalogue.

**Rationale:** In labs around the world a new generation of thinkers is emerging. They are global citizens who are concerned with the disparity between the rich and the poor, between the global north and south, resource scarcity, and climate change. These ‘development scientists’ and ‘development engineers’ come from within traditional engineering disciplines; they also come from the natural and social sciences and business, too. For students who are interested in combining engineering design principles and the Scientific Method with the social sciences so that development efforts provide culturally appropriate solutions to societal problems the Science and Engineering for Development (DEV) minor provides an exciting opportunity to acquire a solid knowledge in this area.

**Description:**

Successful candidates for the DEV Minor must meet the following requirements:

1. Complete two units of work that meet the requirements below.
2. Complete the following three courses:
  - DEV 1200: International Development and Society
  - DEV 2200: Case Studies in International Development Policy and Engineering
  - DEV 4400: Science, Engineering, and Design in International Development
3. Complete one unit of work in courses thematically related from environmental and sustainability studies, economics, system dynamics, psychology, or international dimensions of science technology policy, Foisie Business School, or an approved combination. Two of the three courses must be at the 2000-level or above. Some combinations could include:
  - ENV 2310, ENV 2600, GOV 2319 (*Governance*)
  - ENV 1100, ENV 2900, ENV 4400 (*Environment and Society*)
  - ECON 1110, ECON 2117, ECON 2125 (*Development Economics*)
  - GOV 2302, SD 1510, GOV 2319 (*International Political Dynamics*)
  - PSY 1400, ENV 2400, PSY 2406 (*Psychological Science*)
  - ETR 1100, ETR 2900, ETR 4930 (*Social Entrepreneurship*)
4. Complete approved courses and/or project work that reflect global experience.

Students seeking a DEV Minor should complete this form and submit it to the SSPS office as early in the program of study as possible. The chair of the DEV curriculum committee will be responsible for review and approval of all DEV Minor requests.

WPI policy requires that no more than one unit of course work can be double counted toward other degree requirements.

## *Application for* Minor in Science and Engineering for Development

Last Name: \_\_\_\_\_ First Name: \_\_\_\_\_

Student ID: \_\_\_\_\_ - \_\_\_\_\_ - \_\_\_\_\_ Major Department: \_\_\_\_\_

Anticipated Graduation Date: \_\_\_\_\_ Email: \_\_\_\_\_ @ wpi.edu

**Instructions:**

- i. In the table below, list the courses for satisfying requirement (1) for two units of work.
- ii. In the shaded cells, list the three courses satisfying requirement (3)
- iii. Check to indicate which courses are being double-counted for other degree requirements. Note that WPI policy requires that no more than one unit of course work can be double counted.
- iv. Verify that you have consulted with your academic advisor regarding the DEV Minor.
- v. Obtain approval from the Chair of the DEV Curriculum Committee

COURSE NUMBER	COURSE TITLE	TERM	GRADE	
DEV 1200	International Development and Society			<input type="checkbox"/>
DEV 2200	Case Studies in International Development Policy and Engineering			<input type="checkbox"/>
DEV 4400	Science, Engineering, and Design in International Development			<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>
				<input type="checkbox"/>

IF DOUBLE COUNTED  ↑

Have you discussed your application for the DEV minor with your academic advisor? Yes \_\_\_\_\_ No \_\_\_\_\_

Minor Approval: \_\_\_\_\_ Date: \_\_\_\_\_  
For DEV Curriculum Committee

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add DEV designation for social science credit. Approved by SSPS Department on 2/11/19.

**Motion:** The Committee on Academic Operation recommends and I move, that the DEV designation be added to the course catalogue as a designation for social science requirement credit.

**Rationale:** This new designation supports the Minor in Science and Engineering for Development. Courses with a DEV designation are approved for social science credit. This matter was voted on favorably by SSPS faculty on February 11, 2019.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:** None

**Impact on Distribution Requirements and Other Courses:** None

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add DEV 1200 approved by IDEaS Program Review on 9/26/2018.

**Motion:** The Committee on Academic Operation recommends and I move, that DEV 1200 as described below, be added.

**Course/Catalog Description:** DEV 1200, International Development and Society (Cat. I).

What is development? How has international development been understood and what has been done about it? How do development scholars explain why some countries are rich while others are poor? How can students understand and incorporate development studies in the contexts of their own global engagements? This course addresses these questions by looking at theories, ideologies, and processes that have influenced and embodied development thinking and practice over the past five decades. We will examine the role of colonization, modernization, dependency, globalization, democratization, industrialization, and urbanization in processes of development in countries across the globe. The course encourages students to think critically about what development is, about how it is carried out and, most importantly of all, about what it can achieve. DEV 1200 provides excellent preparation for international projects and careers.

**Recommended background:** No recommended background.

**Anticipated Instructor:** Professor Lauren Elgert

**Rationale:** This is a core course in the proposed Minor in Science and Engineering for Development. The course will provide an introduction to issues around international development. The course will be beneficial for students who seek to complete their IQP at a developing world project center. We expect 50-60 students per offering.

**Implementation Date:** It is expected that this course will be offered in B term 2019.

**Resource Needs:**

Please summarize basic resources needed to deliver this course, including the following:

- Information on the instructor. This will be a new course for Professor Elgert and will be part of her normal load.
- Classroom for 60 people
- Laboratory: N/A
- Library resources: N/A
- Information Technology: N/A

**Impact on Distribution Requirements and Other Courses:** In addition to being a core course in the new Minor in Science and Engineering for Development this course will bear social science requirement credit. This course could draw away from ENV 1100 Introduction to Environmental Studies. As such, we will reduce the number of ENV 1100 to two a year, down from the current offering of three.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add DEV 2200 approved by IDEaS Program Review on 9/26/2018.

**Motion:** The Committee on Academic Operation recommends and I move, that DEV 2200 as described below, be added.

**Course/Catalog Description:** DEV 2200, Case Studies in International Development Policy and Engineering (Cat. II).

The engineers and scientists of tomorrow have a crucial role to play in discovering and implementing solutions to daunting international challenges related to food, water, energy, sanitation and infrastructure. The urgency of such challenges grows alongside and increasingly globalized workplace, where a growing number of graduates find themselves working outside the US, and invited to engage cultures, worldviews, value systems and physical environments that are very unlike their own. This course prepares students with ‘global competency’, to enable them to more effectively and ethically tackle problems in the context of starkly different socioeconomic, political, social and physical realities. Students will develop the knowledge, skills and understanding required to consider, accommodate and effectively integrate contextual difference into engineering practice by exploring the complexity of project design, the potential for unintended consequences, and how technologies are transformed in different contexts. This course will prepare students for a broad range of international IQP and MQPs.

**Recommended background:** none.

**Anticipated Instructor:** Professor Lauren Elgert or Professor Robert Krueger

**Rationale:** This is a core course in the proposed Minor in Science and Engineering for Development. The course will provide an introduction to issues around international development. The course will be beneficial for students who seek to complete their IQP at a developing world project center. We expect 40 students per offering.

**Implementation Date:** Implementation date for this action is the 2020-2021 Academic year.

**Resource Needs:**

Please summarize basic resources needed to deliver this course, including the following:

- Information on the instructor. This will be a new course for Professor Elgert and will be part of her normal load. Elgert was recently awarded Tenure and we expect her teaching load to increase from 3-4 courses per year. Similarly, we have reduced the number of sections of ENV 1100 to accommodate this change.
- Classroom for 40 people
- Laboratory: N/A
- Library resources: N/A
- Information Technology: N/A

**Impact on Distribution Requirements and Other Courses:** In addition to being a core course in the

new Minor in Science and Engineering for Development. This course will bear social science requirement credit. We expect the course to be popular among students seeking an IQP in a developing world context.



**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add DEV 4400 approved by IDEaS Program Review on 9/26/2018.

**Motion:** On behalf of the Committee on Academic Operation recommends and I move, that DEV 4400 as described below, be added.

**Course/Catalog Description:** DEV 4400, Science, Engineering and Design in International Development (Cat. II).

This course provides students with a set of skills that will allow them to address complex problems and design challenges in development engineering. Students will learn to participate in and lead innovation and creativity in collaborative settings. This course includes design projects and case studies, many related to projects at WPI. Student teams will work with preliminary data to define the problem. They will then collect and analyze interview and survey data to learn about user needs. Students will explore how to understand end-user needs. Students will use a variety of tools to analyze their data, ideate potential solutions, and prototype. The teams will use their projects to develop plans for rapid improvement, scaling, continuous improvement and a rigorous impact evaluation.

**Recommended background:** None.

**Anticipated Instructor:** Professors Paul Mathisen (CEE) and Robert Krueger (SSPS)

**Rationale:** This is a core course in the proposed Minor in Science and Engineering for Development. The course will provide an introduction to issues around international development. We expect 40 students per offering.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:**

Please summarize basic resources needed to deliver this course, including the following:

- Information on the instructor.  
This will be a new course for Professors Mathisen and Krueger and will be part of their normal load.
- Classroom for 40 people
- Laboratory: N/A
- Library resources: N/A
- Information Technology: N/A

**Impact on Distribution Requirements and Other Courses:** In addition to being a core course in the new Minor in Science and Engineering for Development this course will bear social science credit. We expect the course to be popular among students seeking an IQP in a developing world context.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add MA 4222 approved by the Department of Mathematical Sciences on 12/11/18.

**Motion:** On behalf of the Department of Mathematical Sciences, the Committee on Academic Operation recommends and I move, that MA 4222 as described below, be added.

**Course/Catalog Description: MA 4222, Top Algorithms in Applied Mathematics (Cat. II)**

This course will introduce students to the top algorithms in applied mathematics. These algorithms have tremendous impact on the development and practice of modern science and engineering. Class discussions will focus on introducing students to the mathematical theory behind the algorithms as well as their applications. In particular, the course will address issues of computational efficiency, implementation, and error analysis. Algorithms to be considered may include the Krylov Subspace Methods, Fast Multipole Method, Monte Carlo Methods, Fast Fourier Transform, Kalman Filters and Singular Value Decomposition. Students will be expected to apply these algorithms to real-world problems; e.g., image processing and audio compression (Fast Fourier Transform), recommendation systems (Singular Value Decomposition), electromagnetics or fluid dynamics (Fast Multipole Method, Krylov Subspace Methods, and Fast Fourier Transform), and the tracking and prediction of an object's position (Kalman Filters). In addition to studying these algorithms, students will learn about high performance computing and will have access to a machine with parallel and GPU capabilities to run code for applications with large data sets.

Recommended background: Familiarity with matrix algebra and systems of equations (MA 2071, MA 2072, or equivalent), numerical methods for the solution of linear systems or differential equations (MA 3257, MA 3457, or equivalent), and concepts from probability (MA 2621, MA 2631, or equivalent). The ability to write computer programs in a scientific language is assumed.

**Anticipated Instructor:** Profs. Arnold, Olson, Sarkis, Weekes, M. Wu, or other qualified Mathematical Sciences faculty.

**Rationale:**

Opportunities for mathematically trained students expand every year in business, industry, and government. Accordingly, the National Academies report “Mathematical Sciences in 2025” calls for an increasing number of mathematical scientists who are knowledgeable across a broad range of the discipline; understand the role of the mathematical sciences in the wider world of science and engineering; and have some experience with computation.

With this in mind, we have designed this 1/3 unit course to highlight several influential numerical algorithms over the past century. Some of the top algorithms are already taught in other classes (e.g. Newton and Quasi-Newton methods in Numerical Methods for Linear and Nonlinear Systems - MA 3257, Matrix Factorizations in MA 3257, Simplex Algorithm in MA 3231 – Linear Programming). We will focus on those algorithms that are not highlighted in other courses. Through class lectures and homework, students will learn the details of these algorithms, including hands on experience with high performance computing to see in real time how these algorithms were designed to be fast on different

computer architectures. Through class lectures and mini projects, students will gain exposure to the importance and utility of these algorithms in several application areas. This course extends methods learned in other courses and focuses on the computational aspects of these methods commonly used in industry. A familiarity with these algorithms will make our students more attractive on the job market, and prepare them to do interesting MQP research.

In addition, currently, there is a single Cat. II 4000 level numerical analysis focused course. We are proposing that this course alternate with MA 4411, Numerical Analysis of Differential Equations, to ensure that the Department of Mathematical Sciences is offering a numerical or computational algorithms course every year. In the past, some undergraduate students have chosen to take MA 510, a graduate level numerical analysis course. Since MA 510 consistently has over 20 students, this course will provide an additional 4000 level course for the students to choose from as an alternative to a graduate level course.

These fast algorithms have broad applicability, including but not limited to classical problems related to computational fluid dynamics, as well as modern applications in the data sciences. This class will be of general interest to students with an interest in computation and algorithms. This course is already a proposed elective for the Data Sciences undergraduate major and minor. It will also be broadly applicable for Computer Science, Physics, and Mathematical Sciences majors. As an experimental course, the students registered for the course had majors in: Mathematical Sciences, Computer Science, Physics, Mechanical Engineering, and Electrical and Computer Engineering.

This course had 8 students in B-2016 and 7 students in B-2017 and was offered in B term. We are proposing an A term every other year offering. First, in B term of 2016 and 2017, there was competition with other 3000 and 4000 level courses (e.g., Probabilistic Methods in Operation Research - MA 4237 met at exactly the same time). We have identified time slots not in conflict with competing courses for A term. In addition, in terms of algorithmic and computational background, this course will be useful as additional background material for computational and/or numerical analysis related MQPs and as such, would be more beneficial to students to be offered in A term. This course was offered two years in a row and we are proposing a Cat. II offering in order to rotate with MA 4411, Numerical Analysis of Differential Equations, which is also being moved to A term. This would allow a computational or numerical analysis 4000 level course every year. We will also seek cross listing with the Computer Science department. The enrollment should increase up to the anticipated enrollment of 15 students as a result of the following: this course may now be taken as a Data Sciences elective, this course provides a 4000 level numerical class option (instead of graduate Numerical Analysis – MA 510), and the A term offering will have decreased course conflicts and better timing to get additional computational experience relevant for MQPs.

The proposed course number has not been used previously.

### **Metrics for Student Evaluations**

This course was taught two times as an experimental course, MA 422X, in B-term of 2016 and 2017. Weekly homework was assigned, accounting for a large portion of the grade, and was a combination of mathematical concepts and coding the methods to look at an application specific question. There were also two mini projects where students delved deeper into applications to further understand how these algorithms were applied to solve scientific problems. In the first offering of the course, exams were

given. In the second offering of the course, no exams were given and the grade was based solely on the homework and projects.

In the two offerings, students were highly engaged and were able to easily follow the quick introduction to high performance computing and remote access of Ace, one of the clusters on campus. Homework involved mathematical analysis of the algorithms as well as writing code to test the timings of different algorithms, comparing CPU and GPU implementations. The students were able to write code, test algorithms, and in the projects, use the algorithms on applications such as image compression and solving scientific problems.

### Evaluation of the Experimental Course

To illustrate the effectiveness of this course, Table 1 summarizes student responses on the standard course evaluations. The answers are on a 1-5 Scale. The responses are for the following questions: Q1- My overall rating of the quality of this course is; Q2- My overall rating of the instructor’s teaching is; Q4- The educational value of the assigned work was; Q9- The amount I learned from the course was. In Table 2, the response to Q26b on the student evaluations is summarized, corresponding to the number of hours students spent on the course outside of the classroom.

Table 1: Average Student Evaluations

Year	# Students Enrolled	# Responses	Q1	Q2	Q4	Q9
B-2016	8	6	4.5	4.67	4.67	4.17
B-2017	7	6	4.67	4.67	4.83	4

Table 2: Average Number of Hours Spent Outside of Class. (Q26b)

Year	1-5	6-10	11-15	16-20	>20
B-2016	17%	50%	33%	0%	0%
B-2017	17%	66%	0%	17%	0%

In the first offering, students specifically requested not to have exams. In order for the algorithms to be implemented and understood, the student’s commented that this was only occurring through hands on coding usage of the cluster for different applications. In the second year, this suggestion was addressed with slightly longer homework assignments. In addition, students in the first iteration of this course emphasized that in the lengthy derivations, the overall goal or application was lost. In the second offering, this was reworked so that more motivating applications were presented and reemphasized during the algorithm derivation. Comments from the second year are provided below:

Responses to the question, What did you particularly LIKE about this course?

- “Homework was well designed; after completing the assignment, I felt I understood the lecture much better.”
- “The practicality and the challenges of different algorithms.”
- “I liked the cloud computing.”
- “A wide variety of algorithms that were covered well.”

Responses to the question, Was this a useful course?

- “Yes, interesting and very applicable.”
- “Yes, I learned much more than most courses.”

During the preparation of the experimental course, the course content was discussed with several mathematical sciences faculty to ensure that students taking the course were appropriately prepared. Additionally, there was a discussion to ensure that the content did not overlap with other courses. In the newly approved course, MA 4635 – Data Analytics and Statistical Learning, there is overlap with the introduction of Singular Value Decomposition. However, MA 4635 does not focus on the numerical implementation and mathematical details of this algorithm whereas that is the focus of this class. In addition, MA 4237 – Probabilistic Methods of Operations Research, teaches Monte Carlo methods, but in MA 4222 differs in that the focus is on fast computation of these methods with the use of GPUs.

**Implementation Date:**

Implementation date for this action is the 2019-2020 Academic year.  
The preferred term is A term.

**Resource Needs:**

This course has already been taught twice as an experimental course by Prof. Olson and teaching resources have already been given by the department. Prof. Olson, or other qualified Mathematical Sciences faculty, will teach this Cat. II course as part of their teaching load. At present, Profs. Arnold, Olson, Sarkis, Weekes, and M. Wu have expressed an interest in teaching this course. A classroom suitable for 30 students with normal AV equipment is required. No other resources are required.

**Impact on Distribution Requirements and Other Courses:**

MA 4222 can be used as one of the required MA courses at the 3000 level or higher in the Mathematical Sciences degree requirement. On p. 93 of the current course catalog, we would add MA 4222 to the list of courses of interest in the Computational and Applied Analysis area. We would also add MA 4222\* to the computational math category in the chart on p. 94. Since this is an approved elective for the Data Science major and minor, this should be appropriately noted in the course catalog in the Data Science section.

**Appendix A – proposal for experimental course**

**To:** Chair, Committee on Academic Operations

**From:** Department of Mathematical Sciences

**Re:** Motion to add *Top Algorithms of the Century MA 422X* approved by the Department of Mathematical Sciences on 09/29/2015

**Date:** 10/02/2015

The Department of Mathematical Sciences requests the approval of the following experimental course (*MA 422X, Top Algorithms of the Century*) in Academic Years: A or B term of 2016 and A or B term of 2017.

Note: Experimental courses are approved for two offerings.

**Contact:** Prof. Sarah Olson, Prof. Suzanne Weekes

**Preferred term:** A or B

**Expected enrollment:** 15

**Course type:** Category I. Junior / Senior level course.

**Intended audience:** If the course becomes permanent, this course will be of interest to all Mathematical Sciences undergraduate students in their Junior or Senior year. Additionally, Computer Science, Physics, and Engineering students with sufficient mathematics background would also benefit from this course.

**Anticipated Instructors:** Prof. Sarah Olson and Prof. Suzanne Weekes

**Course/Catalog Description:**

*MA 422X, Top Algorithms of the Century* (Cat. I)

Cat. I. This course will highlight top algorithms that have tremendous impact on the development and practice of modern science and engineering. Class discussions will focus on introducing students to the mathematical theory behind the algorithms, and their applications. In particular, the course will address issues of computational efficiency, implementation, and error analysis. Algorithms to be considered may include the Fast Multipole Method, Metropolis Algorithm for the Monte Carlo Method, Fast Fourier Transform, Kalman filters and Singular Value Decomposition. Students will be expected to apply these algorithms to real-world problems. For example, we will look at image processing and audio compression (Fast Fourier Transform), recommendation systems (Singular Value Decomposition), and the tracking and prediction of an object's position (Kalman Filters). In addition to studying these algorithms, students will learn about high performance computing and will have access to a machine with parallel and gpu capabilities to run code for applications with large data sets.

**Recommended background:**

MA2071 (Linear Algebra), MA2621 or MA2631 (Probability), MA3257 (Numerical Methods for Calculus and Differential Equations), MA3457 (Numerical Methods for Linear and Nonlinear Systems), at least one course in Computer Science. The ability to write computer programs in a scientific language is assumed.

**Rationale:** The purpose of this course is to highlight influential algorithms of the past century. See <https://www.siam.org/news/news.php?id=637> and <http://galton.uchicago.edu/~lekheng/courses/309/top10/>.

Mathematical Sciences students will benefit from a high level survey course that introduces them to these algorithms. They will understand the various application areas and learn the value that these algorithms have on science and computing. This course will extend methods learned in other courses and focus on methods commonly used in industry. It is believed that even an introductory familiarity with these algorithms will make our students even more marketable, as well as prepare them to do interesting MQP research.

**Course Learning Objectives and Outcomes:**

For each algorithm introduced, students will be able to:

- Understand the precise steps and assumptions of the algorithm
- Describe computational run time
- Analyze accuracy and efficiency of the algorithm
- Describe scientific impact of the algorithm

### Resource Needs:

Please summarize basic resources needed to deliver this course, including the following:

- Information on the instructor – Prof. Olson and Weekes are available to teach this course when it is offered. A post-doc or adjunct will be assigned to teach a calculus course in place of the professor of MA 442X.
- Classroom – A room with seating of 30 students will be requested. The classroom will need to be technology enabled allowing for demos on the computer and for course capturing. The classroom will be needed for 4 hours a week.
- Laboratory – The course will have a conference which will take place in a computer lab to allow interactive learning.
- Library resources – N/A
- Information Technology – N/A

**Assessment:** Students will be assessed through two exams, homework, and a project that focuses on a new algorithm or applies an algorithm from class on a bigger real world application. Student feedback will be determined via course evaluations as well as a set of questions to evaluate the project portion of the class and the use of high performance computing. The outcomes of questions 1, 2, 9, and 26 of student course evaluations will be utilized to help design the second running of the course. The number of students who enrolled in the courses will also be considered.

This course is not a required course. This course will not have any impact on the distribution requirements of any mathematical sciences majors, or any other major.

## DISCUSSION

### HOW THE ALGORITHMS FIT IN AT WPI

**TOP 10 ALGORITHMS**      <http://galton.uchicago.edu/~lekheng/courses/309/top10/>

1. Integer Relation Detection
  - Not covered in any course
2. The Simplex Method for Linear Programming
  - Covered enough in MA3231
3. Krylov Subspace Iteration
  - Not taught at undergrad level
  - See <https://vimeo.com/bcmedia/review/123232219/3cd1e59f2b>  
<https://www.youtube.com/watch?v=TwHiZvLz1mA>
4. The QR Algorithm
  - See MA 514 course description below
5. Quicksort
  - See CS 2223 and CS 4120 course descriptions below
6. Decompositional Approach to Matrix Computation
  - i) Cholesky, ii) Pivoted LU Decomposition, iii) QR Decomposition, iv) Spectral Decomposition, v) Schur Decomposition, vi) SVD.
  - See MA 514 course description below
7. Fast Fourier Transforms

- Not taught anywhere
- 8. The Metropolis Algorithm
  - Not taught at the undergraduate level
- 9. The Fortran I Compiler
  - Not an option to teach
- 10. The Fast Multipole Algorithm
  - Not covered anywhere

### **MA 514. Numerical Linear Algebra**

This course provides students with the skills necessary to develop, analyze and implement computational methods in linear algebra. The central topics include vector and matrix algebra, vector and matrix norms, the singular value decomposition, the LU and QR decompositions, Householder transformations and Givens rotations, and iterative methods for solving linear systems including Jacobi, Gauss-Seidel, SOR and conjugate gradient methods; and eigenvalue problems. Applications to such problem areas as least squares and optimization will be discussed. Other topics might include: special linear systems, such as symmetric, positive definite, banded or sparse systems; preconditioning; the Cholesky decomposition; sparse tableau and other least-square methods; or algorithms for parallel architectures. (Prerequisite: basic knowledge of linear algebra or equivalent background. Knowledge of a higher level programming language is assumed.)

### **CS 2223. Algorithms**

Cat. I Building on a fundamental knowledge of data structures, data abstraction techniques, and mathematical tools, a number of examples of algorithm design and analysis, worst case and average case, will be developed. Topics include greedy algorithms, divide-and-conquer, dynamic programming, heuristics, and probabilistic algorithms. Problems will be drawn from areas such as sorting, graph theory, and string processing. The influence of the computational model on algorithm design will be discussed. Students will be expected to perform analysis on a variety of algorithms. Undergraduate credit may not be earned both for this course and for CS 507. Recommended background: CS 2102 and CS 2022.

### **CS 4120 Analysis of Algorithms**

This course develops the skill of analyzing the behavior of algorithms. Topics include the analysis, with respect to average and worst case behavior and correctness, of algorithms for internal sorting, pattern matching on strings, graph algorithms, and methods such as recursion elimination, dynamic programming, and program profiling. Students will be expected to write and analyze programs. Undergraduate credit may not be earned both for this course and for CS 504. Recommended background: CS 2223 and some knowledge of probability.

### **NOTES ON ALGORITHMS SELECTED FOR THE PROPOSED WPI COURSE**

- Fast Multipole Method
  - Common application: Electromagnetics, Fluid dynamics
  - N body problem – want to reduce the number of calculations when you have N bodies that are interacting with each of the other N bodies
  - Idea is to break into a near field and a far field. Use an approximation to describe the far field
  - Reduces complexity of matrix vector multiplication with dense matrices
- Metropolis Algorithm for Monte Carlo Method



- Idea - Creating a sequence of samples from a distribution that are hard to create
- Samples could be gene expression, topology, particles/molecules, etc. Many applications in statistical mechanics
- Closely related to Bayesian Statistics
- Can start with estimation of  $\pi$ , volume of  $m$ -dimensional hyper sphere, integration, and then move to creating sequence of samples from a distribution
- FFTs
  - discrete transform of a signal from time or space domain to frequency domain
  - applications in digital signal processing, image processing, audio compression, seismic data processing, medical imaging, ...
- Kalman filter
  - estimate internal state of system from noisy measurements
  - <http://www.mathworks.com/discovery/kalman-filter.html>
  - aircraft guidance/navigation/control
  - bio applications – optimal schedule of medicine
- Singular Value Decomposition
  - Dimension reduction for information retrieval
  - Netflix movie – each dimension is a movie, each point is a person that watched the movie, can we group users together that like the same movies?

## **SIMILAR COURSES AT OTHER UNIVERSITIES**

*University of Illinois at Urbana-Champaign:* <http://www.math.uiuc.edu/~hirani/teaching/595fa14/>

In January 2000, Computing in Science and Engineering magazine published a list of 10 algorithms which (in their words) had the "greatest influence on the development and practice of science and engineering in the 20th century". With an eye towards the future we have prepared a slightly modified list of Top 10 algorithms which we will study in this class.

There will be approximately 2-3 sessions (lecture/discussion) on each algorithm. The first session for each algorithm will be a lecture by the instructors. In it we will give an overview of the algorithm and its applications and provide the relevant reading list and programming suggestions. Later sessions on that algorithm will largely be student-led and moderated by the instructors. For each algorithm there will be a team of 3 students working with the instructors : a **historian**, a **programmer** and a **scribe**.

The historian will have primary responsibility for leading the survey of the literature, the programmer will do the computer experiments, and scribe will record the material collected and presented by that team.

### **List of algorithms:**

- Metropolis algorithm for Monte Carlo (with Gibbs sampler)
- Integer relation detection (PSLQ, LLL and related algorithms)
- Simplex method for linear programming (with interior point methods)
- Matrix factorization algorithms for solving linear systems and least squares
- Quicksort
- Conjugate gradients and Krylov subspace methods for solving linear systems

- Bloom filter
- QR algorithm for eigen computations
- Fast Fourier transform
- Fast multipole method

*Florida State University* <http://www.cs.fsu.edu/~lacher/courses/CIS49301/spring14/syllabus.html>

This course will explore the Top Ten Algorithms of the last 100 years. This collection of algorithms will be obtained from official listings of the Top Ten Algorithms from the 20th Century, modified slightly by considering 21st century achievements, and modified again to keep the overlap between this course and the typical coverage of COP 4531 (Analysis of Algorithms) acceptably small. While subject to these influences, the top ten list is certain to contain 10 interesting and influential algorithms representing a broadly diverse collection of applications. **Pre-Requisite:** COP 4530 or equivalent

Note that this class is suitable for students in the BS program prior to OR after taking COP 4531 (Algorithms) as well as students in the BA program who want to know more about what is arguably the most central core subject of Computer Science.

For each algorithm in our list, we will proceed along this exploratory path:

1. Background - overview of the scientific/engineering environment in which the algorithm is applied
2. Core
  - i. Precise description of algorithm body or recipe for computation
  - ii. Assumptions
  - iii. Conclusions
  - iv. Runtime and Runspace
3. Variations and Spinoffs
4. Impact - scientific and economic
5. History - discovery and subsequent development of the algorithm and its principal applications

*Stanford University:* <https://explorecourses.stanford.edu/search?view=catalog&filter-coursestatusActive=on&page=0&catalog=&q=MATH+310%3A+Top+Ten+Algorithms+of+the+20th+Century&collapse=>

MATH 310: Top Ten Algorithms of the 20th Century (CME 329)

A high-level survey course covering one algorithm per week: metropolis, simplex method, conjugate gradient, QR, quicksort, fast fourier transform, maxcut, fast multipole method, integer relation detection, and convex/semi-definite programming.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to add MIS 4084 Business Intelligence approved by Foisie Business School on 12/05/18.

**Motion:** The Committee on Academic Operations recommends and I move, that MIS 4084 Business Intelligence as described below, be added.

**Course/Catalog Description:** MIS 4084 Business Intelligence, Category I.

This course provides an introduction to the technologies and techniques for organizing, analyzing, visualizing, and presenting data about business operations in a way that creates business value, and prepares students to be knowledgeable producers and consumers of business intelligence. During the course, students will study a variety of business decisions that can be improved by analyzing large volumes of data about customers, sales, operations, and business performance. Students will employ commercially available business intelligence software to organize, summarize, visualize, and analyze data sets and make recommendations to decision makers based on the results. The course explores the technical challenges of conducting analytics on various forms of data including social media data and the managerial challenges of creating value from business intelligence expertise deployed in organizations. The course includes business cases, in-class discussion, hands-on analyses of business data, and methods for presenting results to decision makers. It is designed for any student interested in analyzing data to support business decision-making, including students whose primary focus is Management Information Systems, Marketing, Operations and Industrial Engineering, Business, Management Engineering, Data Science, or Computer Science.

Recommended background: Previous knowledge in data management, such as that provided by MIS 3720 Business Data Management or CS 3431 Database Systems I.

**Anticipated Instructor:** Nima Kordzadeh

**Rationale:** As the availability and use of large volumes of data increases in organizations, there is increasing demand for employees who can both conduct analyses of value to organizations and to explain the results to those who are making organizational decisions. This course addresses that need to provide practical value for businesses from large volumes of data. This course will be an elective in the MIS major and minor, the Data Science minor, and the new BS in Data Science. We anticipate offering this course once each year with enrollment of 20-30 students.

MIS 470X Business Intelligence currently has 8 students registered for D '19. A similar course at the graduate level (MIS 584) has been highly successful, with sections in both fall and spring, as an elective in the MS in Information Technology and the MS in Data Science.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:** Professor Nima Kordzadeh will teach this as part of his regular load, and is scheduled to teach an experimental version of this course in D '19. He regularly teaches the graduate version of this course. A classroom to seat 30 students is needed. No additional laboratory, library or information technology support is needed.

**Impact on Distribution Requirements:** This course will add flexibility to students by providing another elective in the MIS major, MIS minor and DS minor and by providing a business elective in the proposed new data science major.

**Catalog Changes:**

- MIS major, Note 4:  
Current: Complete two of the following courses: MIS 4741, MIS 4781, ...  
New: MIS 4084, MIS 4741, MIS 4781, ...
- MIS minor,  
Current: Item 2. Two (2) courses from the group of courses: ...  
New: Add MIS 4084 Business Intelligence to this list
- The addition of MIS 4084 to the Data Science major and minor are included in those motions

**Also include original experimental course proposal if applicable.**

Note: An experimental course, MIS 470X Business Intelligence, was approved, but has not been offered due to a lack of resources. We now have resources to offer it, and it will be offered for the first time in D '19. Because Business Intelligence is important to the proposed new Data Science major, we propose adding MIS 4084 Business Intelligence as a permanent course now.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to revise the Distribution Requirements for the Aerospace Engineering Major, approved by the Aerospace Program on 12/4/2018

**Motion:** The Committee on Academic Operations recommends, and I move that the sections of the undergraduate catalog listing the program distribution requirements for the Aerospace Engineering Major be modified as follows. Additions are indicated with an underline. Deletions with ~~strikethrough~~:

Requirements	Minimum Units
1. Mathematics and Basic Sciences (Notes 1, 2, 3, 4, <del>5</del> )	10/3
2. Engineering <del>Science and Design</del> <u>Topics</u> (Notes 5, 7, <del>9</del> )	16/3
3. <u>Major Engineering Design Experience (including the MQP)</u> (Notes <del>6, 8</del> )	4/3
4. <del>Aerospace Engineering Colloquium</del>	<del>0</del>

Notes

1. Must include a minimum of 6/3 units of mathematics (prefix MA) with topics in: differential, integral, vector, multivariable calculus, differential equations, and linear algebra.
2. Must include a minimum of ~~3/3~~ 2/3 units of physics (prefix PH) with topics in: ~~introductory~~ mechanics, electricity and magnetism. ~~and intermediate mechanics~~
3. Must include 1/3 unit of space environments (fulfilled by PH/AE 2550 Atmospheric and Space Environments as a Math and Basic Science course or other equivalent course with approval of the AE Program Undergraduate Committee).
4. ~~Must include 1/3 unit in dynamics (fulfilled by PH 2201 Intermediate Mechanics I or other equivalent course with approval of the AE Undergraduate Committee).~~
4. Must include 1/3 unit of chemistry (prefix CH). ~~with topics in: molecularity or forces and bonding.~~
6. ~~Must include 1/3 units in thermodynamics (fulfilled by PH 2101 Principles of Thermodynamics, CH 3510 Chemical Thermodynamics as a Math and Basic Science or ES 3001 Intro to Thermodynamics as a Free Elective or other equivalent course with approval of the AE Undergraduate Committee)~~
5. Must include ~~47~~ 16/3 units of Engineering Topics ~~Science and Design~~, distributed as follows:
  - a. ~~12/3~~ 14/3 units of Aeronautical Engineering
    - i. 2/3 units of Aerodynamics, with topics in: compressible fluid dynamics, subsonic and supersonic aerodynamics.
    - ii. 2/3 units of Aerospace Materials, with topics in: introductory materials science, and advanced materials.
    - iii. 3/3 units of Structures, with topics in: stress analysis, aerospace structures, and structural dynamics.
    - iv. ~~2~~ 3/3 units of Propulsion, with topics in: thermodynamics, incompressible fluid

- dynamics, and ~~gas turbine~~ air breathing propulsion.
- v. 3/3 units of Flight Mechanics, and Stability and Control, with topics in: dynamics, control theory, and aircraft dynamics and control.
- vi. ~~1/3 units in Major Design of a system, component, or process to meet desired needs incorporating appropriate engineering standards and multiple realistic constraints, including the integration of aeronautical topics (fulfilled by AE 4770 Aircraft Design).~~
- vii. ~~e). 1/3 units of Experimentation (fulfilled by ME 3901 Engineering Experimentation).~~
- b. 2/3 units in Astronautical Engineering
  - i. 1/3 units of Orbital Mechanics (fulfilled by AE 2713 Astronautics).
  - ii. 1/3 units of Telecommunications (fulfilled by AE 4733 Guidance, Navigation and Communication).
- e. ~~4/3~~ 1/3 units in Aeronautical and Astronautical Engineering
  - i. ~~i. 1/3 unit in Experimentation (fulfilled by ME 3901 Engineering Experimentation).~~
  - ii. ~~ii. 3/3 units in Aerospace Design that involves the design of a system, component, or process to meet desired needs that includes integration of aeronautical and/or astronautical topics (fulfilled by the MQP).~~
- 6. Must include 4/3 Units of Major Engineering Design Experience devising an aerospace system, component, or process to meet desired needs that incorporates appropriate engineering standards and multiple constraints, is based on the knowledge and skills acquired in earlier course work, and includes integration of aeronautical or astronautical topics (fulfilled by 1/3 Unit in AE 4770 Aircraft Design and 3/3 Units in MQP).

**or**

- 5. Must include 16/3 units of Engineering Topics Science and Design, distributed as follows:
  - d. ~~12/3~~ 14/3 units of Astronautical Engineering
    - i. 2/3 units of Orbital Mechanics, with topics in: dynamics and space flight mechanics.
    - ii. 2/3 units of Attitude Determination and Control, with topics in: control theory, and spacecraft dynamics and controls.
    - iii. 1/3 units of Telecommunications, with topics in: guidance, navigation and communication.
    - iv. 4/3 units of Space Structures, with topics in: introductory material science, stress analysis, aerospace structures, and structural dynamics.
    - v. 4/3 units of Rocket Propulsion, with topics in: thermodynamics, incompressible fluid dynamics, compressible fluid dynamics, and rocket propulsion.
  - ~~4/3 Units in Aeronautical and Astronautical Engineering~~
  - vi. ~~e). 1/3 units of Experimentation (fulfilled by ME 3901 Engineering Experimentation).~~
  - vii. ~~1/3 unit in Major Design of a system, component, or process to meet desired needs incorporating appropriate engineering standards and multiple realistic constraints,~~

~~including the integration of aeronautical topics (fulfilled by AE 4771 Spacecraft and Mission Design).~~

b. 2/3 units in Aeronautical Engineering

i. 1/3 units of Aerodynamics (fulfilled by AE 3711 Aerodynamics).

ii. 1/3 units of Flight Mechanics, and Stability and Control (fulfilled by AE 4723 Aircraft Dynamics and Control).

~~iii. ii. 3/3 units in Aerospace Design that involves the design of a system, component, or process to meet desired needs that includes integration of aeronautical and/or astronomical topics (fulfilled by the MQP).~~

6. Must include 4/3 units of Major Engineering Design experience devising an aerospace system, component, or process to meet desired needs that incorporates appropriate engineering standards and multiple constraints, is based on the knowledge and skills acquired in earlier course work, and includes integration of aeronautical or astronomical topics (fulfilled by 1/3 Unit in 4771 Spacecraft and Mission Design and 3/3/ Units in the MQP).

~~7. 10. Must include a 1/3 Capstone design activity (fulfilled by AE 4770, AE 4771 or MQP).~~

~~9. 11. Must include an activity in professional and ethical responsibility, and communication (fulfilled by a minimum of two terms of the zero-unit Aerospace Engineering Colloquium AE 4090).~~

~~7.-8. . Great Problem Seminar (GPS) courses can only be used to fulfill the HUA, SSPS or the Free Elective requirement.~~

### **Rationale**

The revisions in the Distribution Requirements and Notes address ABET's EAC "Criterion 5. Curriculum", the "Program Criteria Aerospace and Similarly Named Engineering Programs" and "Criterion 3. Student Outcomes" applicable to the 2019-20 cycle.

There is no impact on students.

### **Resources**

No additional resources are required.

### **Implementation Timeline**

Implementation date for this action is the 2019-2020 Academic year.

**Date:** March 14, 2019  
**To:** WPI Faculty  
**From:** Committee on Academic Operations (Prof. Mattson, Chair)  
**Re:** Motion to remove an AE course from the AE section of the undergraduate catalog course descriptions, approved by the AE Program on 12/4/2018.

**Motion:** The Committee on Academic Operations recommends that the following course be removed from under the “Aerospace Engineering” heading in Section 3 (Course Descriptions) of the Undergraduate Catalog as noted below.

**AE 4090. AEROSPACE ENGINEERING COLLOQUIUM. Cat. I (0 credit)**

This pass/fail graduation requirement is intended for students with ongoing or completed project experience (ISP, IQP, MQP) and is offered under the supervision of an Aerospace Engineering faculty. The Aerospace Engineering Colloquium convenes once per week, every A, B, C, and D term. Students are required to register for a minimum of two terms during which they are expected to make presentations on their ongoing or previously completed project experience (ISP, IQP, or MQP). Students are also required to attend Colloquium seminars by experts on subjects such as engineering ethics, professionalism, career guidance, and library research skills. Recommended Background: students majoring in Aerospace Engineering with ongoing or completed project experience (ISP, IQP, or MQP).

**Rationale:**

The zero credit colloquium was introduced in 2018-19 AY in an effort to address ABET related outcomes. The new ABET criteria and distribution requirements make this colloquium obsolete.

**Implementation Date:**

Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:**

No additional resources are needed.

**Impact on Distribution Requirements:**

Removing the zero-credit, AE 4090 colloquium has no impact on the AE distribution requirements. In addition, the colloquium requirement appeared for the first time in the 2018-19 undergraduate catalog. Because this course was to be taken by seniors, the first cohort for which it was to be a requirement would not have taken it until the 2021-2022 AY. Most students follow the most updated set of requirements. For any students who opt to follow the requirements in the 2018-19 or 2019-20 catalog, the AE program will allow for the MQP to serve as a substitution for this zero-credit activity.



**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to remove cross-listing of an AE/ME course, remove it from the AE and ME section of the undergraduate catalog course descriptions, and add a replacement AE course, approved by the AE Program on 12/04/2018 and the ME Program on 2/12/2019.

### **Motion 1**

The Committee on Academic Operations recommends and I move that the following course, currently cross-listed with the prefix “AE/ME” in the Undergraduate Catalog, have the cross-listing removed and instead be designated with the prefix “AE” under the “Aerospace Engineering” and “ME” under the “Mechanical Engineering,” heading in Section 3 of the Undergraduate Catalog .

#### **AEROSPACE ENGINEERING**

##### **~~AE/ME~~ 3703 INTRODUCTION TO CONTROL OF DYNAMICAL SYSTEMS**

Cat. I The course introduces the mathematical modeling and control of dynamical systems found in aerospace and mechanical engineering applications. Topics include: introduction to feedback control analysis and synthesis of linear dynamic systems; transient response analysis of first and second order systems (thermal, pneumatic, hydraulic, and mechanical); introduction to state-space modeling and representation of control systems; linearization of nonlinear systems; stability analysis using Routh’s criterion and Lyapunov methods; system analysis using frequency response methods; introduction to the design of controllers in time and frequency domain. The analysis and design will be accomplished with Matlab/Simulink software.

Recommended background: ordinary differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201, PH 2202 or equivalent), fluid dynamics (ES3004, AE/ME 3602 or equivalent), electricity and magnetism (PH 1120 or PH 1121 or equivalent)

#### **MECHANICAL ENGINEERING**

##### **~~AE/ME~~ 3703 INTRODUCTION TO CONTROL OF DYNAMICAL SYSTEMS**

Cat. I The course introduces the mathematical modeling and control of dynamical systems found in aerospace and mechanical engineering applications. Topics include: introduction to feedback control analysis and synthesis of linear dynamic systems; transient response analysis of first and second order systems (thermal, pneumatic, hydraulic, and mechanical); introduction to state-space modeling and representation of control systems; linearization of nonlinear systems; stability analysis using Routh’s criterion and Lyapunov methods; system analysis using frequency response methods; introduction to the design of controllers in time and frequency domain. The analysis and design will be accomplished with Matlab/Simulink? software.

Recommended background: ordinary differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201, PH 2202 or equivalent), fluid dynamics (ES3004, AE/ME 3602 or equivalent), electricity and magnetism (PH 1120 or PH 1121 or equivalent)

### **Motion 2**

The Committee on Academic Operations recommends and I move that the following course be removed from under the “Aerospace Engineering” heading in Section 3 (Course Descriptions) of the Undergraduate Catalog as noted below. This effectively drops the AE version of the course.

## AEROSPACE ENGINEERING

### AE 3703 INTRODUCTION TO CONTROL OF DYNAMICAL SYSTEMS

Cat. I The course introduces the mathematical modeling and control of dynamical systems found in aerospace and mechanical engineering applications. Topics include: introduction to feedback control analysis and synthesis of linear dynamic systems; transient response analysis of first and second order systems (thermal, pneumatic, hydraulic, and mechanical); introduction to state-space modeling and representation of control systems; linearization of nonlinear systems; stability analysis using Routh's criterion and Lyapunov methods; system analysis using frequency response methods; introduction to the design of controllers in time and frequency domain. The analysis and design will be accomplished with Matlab/Simulink? software.

Recommended background: ordinary differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201, PH 2202 or equivalent), fluid dynamics (ES3004, AE/ME 3602 or equivalent), electricity and magnetism (PH 1120 or PH 1121 or equivalent)

#### **Rationale:**

The AE 3703 course will be replaced by AE 3713 INTRODUCTION TO AEROSPACE CONTROL SYSTEMS.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

#### **Resource Needs:**

No additional resources are needed.

#### **Impact on Distribution Requirements:**

Removing the "AE" cross-listing from the AE/ME 3703 course and dropping AE 3703 has no impact on the AE distribution requirements, because it will be replaced by AE 3713.

#### **Motion 3**

The Committee on Academic Operations recommends and I move that the following course be removed from under the "Mechanical Engineering" heading in Section 3 (Course Descriptions) of the Undergraduate Catalog as noted below. This effectively drops the ME version of the course.

## MECHANICAL ENGINEERING

### ME 3703 INTRODUCTION TO CONTROL OF DYNAMICAL SYSTEMS

Cat. I The course introduces the mathematical modeling and control of dynamical systems found in aerospace and mechanical engineering applications. Topics include: introduction to feedback control analysis and synthesis of linear dynamic systems; transient response analysis of first and second order systems (thermal, pneumatic, hydraulic, and mechanical); introduction to state-space modeling and representation of control systems; linearization of nonlinear systems; stability analysis using Routh's criterion and Lyapunov methods; system analysis using frequency response methods; introduction to the design of controllers in time and frequency domain. The analysis and design will be accomplished with Matlab/Simulink? software.

Recommended background: ordinary differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201, PH 2202 or equivalent), fluid dynamics (ES3004, AE/ME 3602 or equivalent), electricity and magnetism (PH 1120 or PH 1121 or equivalent)

**Rationale:**

The ME 3703 course will be replaced by ES3011 CONTROL ENGINEERING I which has and will continue to be offered by the ME Program.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:**

Dropping the course represents resource savings. The ME Program was covering once a year ME/AE3703 and ES 3011 and from now and it will only offer ES 3011.

**Impact on Distribution Requirements:**

Removing the “ME” cross-listing from the ME/AE 3703 course and dropping ME 3703 has no impact on the ME distribution requirements. Controls is not a required course for ME Majors and the topic of Controls will continue to be available through the ES 3011 course.

**Motion 4**

The Committee on Academic Operation recommends and I move, that AE 3713. INTRODUCTION TO AEROSPACE CONTROL SYSTEMS be added to the undergraduate catalog.

**Course/Catalog Description:**

AE 3713. INTRODUCTION TO AEROSPACE CONTROL SYSTEMS.

Cat I. This course introduces feedback control systems analysis and design for applications to aircraft and spacecraft. Topics include: linear dynamical systems modeling of aircraft and spacecraft motion, including linearization; identification and transient response analysis of typical modes of motion; time- and frequency domain analysis; Bode plots; criteria for stability; design of stability augmentation and, attitude and orbital control systems using linear state feedback or PID control; numerical simulation of controlled and uncontrolled aircraft and spacecraft motion.

Recommended background: ordinary differential equations (MA 2051 or equivalent), introductory dynamics (ES 2503, PH 2201 or equivalent), and linear algebra (MA 2071 or equivalent).

Students may not receive credit for both AE/ME 3703 and AE 3713.

**Rationale:**

The new course AE 3713. INTRODUCTION TO AEROSPACE CONTROL SYSTEMS better meets ABET requirements in the dynamics and controls areas for Aerospace Engineering and replaces the existing AE 3703 INTRODUCTION TO CONTROL OF DYNAMICAL SYSTEMS. In the new course we introduced topics specific to aerospace systems, such as aircraft and spacecraft (attitude and orbital) motion, stability and control design.

**Implementation Date:**

Implementation date for this action is the 2019-2020 academic year.

**Resource Needs:**

No additional resources are needed for this motion. The crosslisted AE/ME 3703 was offered once a year by an AE faculty and once by an ME faculty. After the motions are approved, AE will offer the

AE3713 once a year so no additional resources are needed. The Aerospace Engineering Program has instructors available for this course; Prof. Cowlagi (primary), Prof. Demetriou (secondary).

**Impact on Distribution Requirements and Other Courses:**

There is no impact on distribution requirements for the aerospace engineering program or other programs.

**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to remove cross-listing of an ME/AE course 3602, remove it from the ME section of the undergraduate catalog course descriptions, approved by the ME Program and the AE Program, 2/19/2019.

### **Motion 1**

The Committee on Academic Operations recommends and I move that the following course, currently cross-listed with the prefix “AE/ME” in the Undergraduate Catalog, have the cross-listing removed and instead be designated with either the prefix “AE” under the “Aerospace Engineering,” and “ME” under the “Mechanical Engineering,” heading in Section 3 of the Undergraduate Catalog.

#### **AEROSPACE ENGINEERING**

##### **~~AE/ME~~ 3602. INCOMPRESSIBLE FLUIDS**

Cat. I This course covers inviscid and viscous incompressible fluid dynamics. Fundamental topics presented include: fluid kinematics and deformation; integral conservation laws of mass, momentum and energy for finite systems and control volumes; differential conservation laws of mass, momentum and energy; the Navier-Stokes equations. Applications will be considered from the following topics: hydrostatics; Bernoulli’s equation; the streamfunction and the velocity potential; incompressible, inviscid, irrotational (potential) flows; incompressible boundary layer flows; viscous incompressible steady internal and external flows; and dimensional analysis. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent)

#### **MECHANICAL ENGINEERING**

##### **~~AE/ME~~ 3602. INCOMPRESSIBLE FLUIDS**

Cat. I This course covers inviscid and viscous incompressible fluid dynamics. Fundamental topics presented include: fluid kinematics and deformation; integral conservation laws of mass, momentum and energy for finite systems and control volumes; differential conservation laws of mass, momentum and energy; the Navier-Stokes equations. Applications will be considered from the following topics: hydrostatics; Bernoulli’s equation; the streamfunction and the velocity potential; incompressible, inviscid, irrotational (potential) flows; incompressible boundary layer flows; viscous incompressible steady internal and external flows; and dimensional analysis. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent)

### **Motion 2**

The Committee on Academic Operations recommends and I move that the following course be removed from under the “Mechanical Engineering” heading in Section 3 (Course Descriptions) of the Undergraduate Catalog as noted below. This effectively drops the ME version of the course.

#### **MECHANICAL ENGINEERING**

##### **ME 3602. INCOMPRESSIBLE FLUIDS**

Cat. I This course covers inviscid and viscous incompressible fluid dynamics. Fundamental topics presented include: fluid kinematics and deformation; integral conservation laws of mass, momentum and energy for finite systems and control volumes; differential conservation laws of mass, momentum and energy; the Navier-Stokes equations. Applications will be considered from the following topics:

hydrostatics; Bernoulli's equation; the streamfunction and the velocity potential; incompressible, inviscid, irrotational (potential) flows; incompressible boundary layer flows; viscous incompressible steady internal and external flows; and dimensional analysis. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent)

**Rationale:**

The course was taken by very few ME majors over the years. ES 3004 is more appropriate as a first course for ME majors.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:**

No additional resources are needed.

**Impact on Distribution Requirements:**

Removing the "ME" cross-listing from the AE/ME 3602 course and dropping ME 3602 has no impact on the ME distribution requirements.

**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to remove cross-listing of the ME/AE course, remove it from the ME section of the undergraduate catalog course descriptions, approved by the ME Program and the AE Program, 2/19/2019.

### **Motion 1**

The Committee on Academic Operations recommends and I move that the following course, currently cross-listed with the prefix “AE/ME” in the Undergraduate Catalog, have the cross-listing removed and instead be designated with either the prefix “AE” under the “Aerospace Engineering,” and “ME” under the “Mechanical Engineering,” heading in Section 3 of the Undergraduate Catalog.

#### **AEROSPACE ENGINEERING**

**ME/AE 3410. COMPRESSIBLE FLUID DYNAMICS.**

Cat. I

In this course, students are introduced to various compressibility phenomena such as compression (shock) and expansion waves. Conservation laws and thermodynamic principles are applied to the description of flows in which compressibility effects are significant. One-dimensional models are applied to analysis of flow in variable area ducts, normal and oblique shock waves, expansion waves, and flows with friction and heat addition. Numerous applications from engineering are investigated including supersonic inlets, rocket nozzles, supersonic wind tunnels, gas delivery systems, and afterburning jet engines. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent), fluid dynamics (ES 3004 or equivalent).

#### **MECHANICAL ENGINEERING**

**ME/~~AE~~-3410. COMPRESSIBLE FLUID DYNAMICS.**

Cat. I

In this course, students are introduced to various compressibility phenomena such as compression (shock) and expansion waves. Conservation laws and thermodynamic principles are applied to the description of flows in which compressibility effects are significant. One-dimensional models are applied to analysis of flow in variable area ducts, normal and oblique shock waves, expansion waves, and flows with friction and heat addition. Numerous applications from engineering are investigated including supersonic inlets, rocket nozzles, supersonic wind tunnels, gas delivery systems, and afterburning jet engines. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent), fluid dynamics (ES 3004 or equivalent).

### **Motion 2**

The Committee on Academic Operations recommends and I move that the following course be removed from under the “Mechanical Engineering” heading in Section 3 (Course Descriptions) of the Undergraduate Catalog as noted below. This effectively drops the ME version of the course.

#### **MECHANICAL ENGINEERING**

**ME 3410. COMPRESSIBLE FLUID DYNAMICS.**

Cat. I

In this course, students are introduced to various compressibility phenomena such as compression (shock) and expansion waves. Conservation laws and thermodynamic principles are applied to the description of flows in which compressibility effects are significant. One-dimensional models are applied to analysis of flow in variable area ducts, normal and oblique shock waves, expansion waves, and flows with friction and heat addition. Numerous applications from engineering are investigated including supersonic inlets, rocket nozzles, supersonic wind tunnels, gas delivery systems, and afterburning jet engines. Recommended background: thermodynamics (ES 3001, CH 3510 or equivalent), fluid dynamics (ES 3004 or equivalent).

**Rationale:**

The course was taken by very few ME majors over the years. The material is directed more toward aerospace majors. A new course is proposed which covers elements of this course.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

**Resource Needs:**

No additional resources are needed.

**Impact on Distribution Requirements:**

Removing the “ME” cross-listing from the AE/ME 3410 course and dropping ME 3410 has no impact on the ME distribution requirements.



**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to revise the course descriptions in the Aerospace Engineering section of the catalog.  
Approved by the Aerospace Program on October 30, 2018.

### **Motion 1**

The Committee on Academic Operations recommends, and I move, that the course descriptions be modified as follows. Additions are indicated with an underline. Deletions with overstrike. The proposed course description follows the marked-up version.

#### **AE 2713. ASTRONAUTICS. *Cat. I***

An introductory course that covers the fundamentals of space flight., ~~spacecraft trajectory analysis and mission design.~~ Topics studied: two-body orbital mechanics; dynamics and classification of orbits; geocentric orbits and impulsive maneuvers: orbit shaping, escape trajectories, Hohmann and non-Hohmann transfers; time of flight analysis; orbital elements in 3D; ambient space environments for geocentric orbits and interplanetary Hohmann and generalized transfers, intercepts, flybys. ~~introduction to spacecraft and mission design.~~

Recommended background: multivariable calculus (MA 1024 or equivalent), differential equations (MA2051 or equivalent), dynamics (ES 2503, PH 2201 or equivalent).

#### **AE 2713. ASTRONAUTICS. *Cat. I***

An introductory course that covers the fundamentals of space flight. Topics studied include: two-body orbital dynamics, classification of orbits, and time of flight analysis; geocentric orbits and impulsive maneuvers: orbit shaping, escape trajectories, Hohmann and non-Hohmann transfers; orbital elements in 3D; interplanetary Hohmann and generalized transfers, intercepts, flybys.

Recommended background: multivariable calculus (MA 1024 or equivalent), differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201 or equivalent).

#### **AE 2712. INTRODUCTION TO AEROSPACE STRUCTURES. *Cat. I***

This course ~~introduces the basic concepts of stress analysis and extensively covers mechanics of aerospace structures under bending loads~~ provides a concise overview of statics and then focuses on basic stress analysis applied to simple aerospace structures. Topics in stress analysis include: Three-dimensional stress and strain, stress transformation and Mohr's circle, basic constitutive relationships, statically determinate and indeterminate one-dimensional problems, thermal stresses, and stress distributions and deflections of structural elements under bending loads. The laboratory component of this course will introduce the students to basic constitutive behavior of isotropic and anisotropic composites materials concepts of stress and strain; basic constitutive relations; one-dimensional response to axial loading; thermal stresses; statically determinate and indeterminate problems; shear forces, bending moments, bending stresses and deflections in beams with symmetric cross sections; two-dimensional stress transformation and Mohr's circle; and an introduction to energy methods in structural analysis.

Recommended background: ~~differential (MA 1021, or equivalent) and integral (MA 1022, or equivalent) calculus; vector algebra (MA 1023, or equivalent); and double and triple integration (MA 1024, or equivalent); and basic mechanics (PH 1110, PH 1111, or equivalent).~~ differential, integral, multivariable calculus (MA 1021, MA 1022, MA 1024 or equivalent), mechanics (PH 1110, PH 1111, or equivalent).

### **AE 2712. INTRODUCTION TO AEROSPACE STRUCTURES. *Cat. I***

This course provides a concise overview of statics and then focuses on basic stress analysis applied to simple aerospace structures. Topics in stress analysis include: concepts of stress and strain; basic constitutive relations; one-dimensional response to axial loading; thermal stresses; statically determinate and indeterminate problems; shear forces, bending moments, bending stresses and deflections in beams with symmetric cross sections; two-dimensional stress transformation and Mohr's circle; and an introduction to energy methods in structural analysis.

Recommended background: differential, integral, multivariable calculus (MA 1021, MA 1022, MA 1024 or equivalent), mechanics (PH 1110, PH 1111, or equivalent).

### **AE/ME 3410. COMPRESSIBLE FLUID DYNAMICS. *Cat. I***

In this course, students are introduced to various compressibility phenomena such as compression (shock) and expansion waves. Conservation laws and thermodynamic principles are applied to the description of flows in which compressibility effects are significant. One-dimensional models are applied to analysis of flow in variable area ducts, normal and oblique shock waves, expansion waves, and flows with friction and heat addition. Numerous applications from engineering are investigated including supersonic inlets, rocket nozzles, supersonic wind tunnels, gas delivery systems, and afterburning jet engines.

Recommended background: thermodynamics (ES 3001, PH 2101, CH 3510 or equivalent), incompressible fluid dynamics (AE/ME 3602 or equivalent).

### **AE 3410. COMPRESSIBLE FLUID DYNAMICS. *Cat. I***

In this course, students are introduced to various compressibility phenomena such as compression (shock) and expansion waves. Conservation laws and thermodynamic principles are applied to the description of flows in which compressibility effects are significant. One-dimensional models are applied to analysis of flow in variable area ducts, normal and oblique shock waves, expansion waves, and flows with friction and heat addition. Numerous applications from engineering are investigated including supersonic inlets, rocket nozzles, supersonic wind tunnels, gas delivery systems, and afterburning jet engines.

Recommended background: thermodynamics (ES 3001, PH 2101, CH 3510 or equivalent), incompressible fluid dynamics (AE/ME 3602 or equivalent).

### **AE/ME 3602. INCOMPRESSIBLE FLUIDS. *Cat. I***

This course covers the fundamentals of inviscid and viscous incompressible fluid dynamics. ~~Fundamental~~ Topics presented will be considered from the following include: fluid kinematics and deformation; integral conservation laws of mass, momentum and energy for finite systems and control volumes; differential conservation laws of mass, momentum and energy; the Navier-Stokes equations; the streamfunction and the velocity potential. Applications will be considered from the following topics: hydrostatics; ~~Bernoulli's equation~~; incompressible, inviscid, irrotational (potential) flows; incompressible boundary layer flows; viscous incompressible steady internal and external flows; and dimensional analysis.

Recommended background: differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201 or equivalent), thermodynamics (ES 3001, PH 2101, CH 3510 or equivalent).

### **AE 3602. INCOMPRESSIBLE FLUIDS. *Cat. I***

This course covers the fundamentals of inviscid and viscous incompressible fluid dynamics. Topics presented will be considered from the following: fluid kinematics and deformation; integral conservation laws of mass, momentum and energy for finite systems and control volumes; differential conservation

laws of mass, momentum and energy; the Navier-Stokes equations; the streamfunction and the velocity potential. Applications will be considered from the following topics: hydrostatics; incompressible, inviscid, irrotational (potential) flows; incompressible boundary layer flows; viscous incompressible steady internal and external flows; and dimensional analysis.

Recommended background: differential equations (MA2051 or equivalent), dynamics (ES 2503, PH 2101 or equivalent), thermodynamics (ES 3001, PH 2101, CH 3510 or equivalent).

### **AE 3711. AERODYNAMICS. *Cat. I***

This course introduces students to the aerodynamics of airfoils, wings, and aircraft in the subsonic and supersonic regimes. Topics covered include: prediction of aerodynamic forces (lift, drag) and moments, dynamic similarity, experimental techniques in aerodynamics, Kutta-Joukowski theorem, circulation, thin airfoil theory, panel methods, finite wing theory, subsonic compressible flow over airfoils, linearized supersonic flow, and viscous flow over airfoils.

Recommended background: incompressible and compressible fluid dynamics (AE/~~ME~~ 3602, AE/ME 3410 or equivalent).

### **AE 3711. AERODYNAMICS. *Cat. I***

This course introduces students to the aerodynamics of airfoils, wings, and aircraft in the subsonic and supersonic regimes. Topics covered include: prediction of aerodynamic forces (lift, drag) and moments, dynamic similarity, experimental techniques in aerodynamics, Kutta-Joukowski theorem, circulation, thin airfoil theory, panel methods, finite wing theory, subsonic compressible flow over airfoils, linearized supersonic flow, and viscous flow over airfoils.

Recommended background: incompressible and compressible fluid dynamics (AE 3602, AE 3410 or equivalent).

### **AE 3712. AEROSPACE STRUCTURES. *Cat. I***

This course provides an overview of theoretical and practical aspects of mechanics of structures relevant to aerospace applications under different loading conditions. focuses on intermediate-level topics in stress analysis relevant to aerospace structures. It begins with an overview of energy methods used in mechanics of aerospace structures. Applied topics include general torsion of solid circular and noncircular cross sections, torsion of thin-walled multi-celled members, flexural shear flow in and shear center of thin walled multi-celled members, buckling and stability of columns, and aerospace structures under combined loading. Topics include: buckling under centric and eccentric loadings with and without lateral loads applied; torsion of solid circular and noncircular cross sections; torsion of thin-walled multi-celled members; flexural shear flow in and shear center of thin walled multi-celled members; bending stresses in beams with unsymmetric cross sections; stresses under combined loadings; and three-dimensional states of stress. The laboratory component of this course will provide students with provides testing and measurement experience related to buckling of columns under a variety of loadings and support conditions; and to the determination of shear center and the behavior of structures undergoing buckling. bending response of beams with unsymmetric cross sections.

Recommended background: differential equations (MA2051 or equivalent), introductory level aerospace structures (AE 2712 or equivalent.)

### **AE 3712. AEROSPACE STRUCTURES. *Cat. I***

This course focuses on intermediate-level topics in stress analysis relevant to aerospace structures. Topics include: buckling under centric and eccentric loadings with and without lateral loads applied; torsion of

solid circular and noncircular cross sections; torsion of thin-walled multi-celled members; flexural shear flow in and shear center of thin walled multi-celled members; bending stresses in beams with unsymmetric cross sections; stresses under combined loadings; and three-dimensional states of stress. The laboratory component of this course provides testing and measurement experience related to buckling of columns under a variety of loadings and support conditions; and to the determination of the shear center and bending response of beams with unsymmetric cross sections.

Recommended background: differential equations (MA 2051 or equivalent), introductory aerospace structures (AE 2712 or equivalent.)

#### **AE 4712. STRUCTURAL DYNAMICS. *Cat. I***

This course introduces the analysis of vibrations of flexible bodies encountered as elements of aircraft and space structures. Topics include: ~~modal analysis for determining structural response to forced vibrations; vibrations of strings and rods; free and forced vibrations of beams and plates~~ modeling of aerospace structures with lumped parameters using Newton's Law and Lagrange's equations, free- and forced-vibration response of single degree of freedom systems and multi-degree of freedom systems, design of simplified vibration absorption systems, dynamic testing, modal analysis for determining structural response of lumped and continuous systems.

Recommended background: ~~Recommended background: ordinary differential equations (MA 2051 or equivalent),~~ dynamics (ES2503, PH 2201, PH2202 or equivalent), control (AE 3713 or equivalent), aerospace structures (AE/ME 3712 or equivalent)

#### **AE 4712. STRUCTURAL DYNAMICS. *Cat. I***

This course introduces the analysis of vibrations of flexible bodies encountered as elements of aircraft and space structures. Topics include: modeling of aerospace structures with lumped parameters using Newton's Law and Lagrange's equations, free- and forced- vibration response of single degree of freedom systems and multi-degree of freedom systems, design of simplified vibration absorption systems, dynamic testing, modal analysis for determining structural response of lumped and continuous systems.

Recommended background: dynamics (ES2503, PH 2201, PH2202 or equivalent), control (AE 3713 or equivalent), aerospace structures (AE 3712 or equivalent).

#### **AE 4713. SPACECRAFT DYNAMICS AND CONTROL. *Cat. I***

The course covers broad topics in spacecraft attitude dynamics, stability and control. The course includes a review of particle and two-body dynamics and introduction to rigid body dynamics. Orbital and attitude maneuvers are presented. Attitude control devices and momentum exchange techniques such as spinners, dual spinners, gravity gradient, and geomagnetic torques are presented. Attitude sensors/actuators are presented and the attitude control problem is introduced. ~~Gyroscopic instruments are introduced and demonstrated in the laboratory.~~ Open-loop stability analysis for a variety of equilibrium conditions is discussed. Control using momentum exchange and mass expulsion (thrusters) devices is discussed. The analyses and designs will be implemented using scientific computing software such as MATLAB®.

Recommended background: astronautics (~~MAE~~ AE 2713 or equivalent), dynamics (ES 2503, PH 2201 or equivalent), control (AE 3713 or equivalent).

#### **AE 4713. SPACECRAFT DYNAMICS AND CONTROL. *Cat. I***

The course covers broad topics in spacecraft attitude dynamics, stability and control. The course includes a review of particle and two-body dynamics and introduction to rigid body dynamics. Orbital and attitude maneuvers are presented. Attitude control devices and momentum exchange techniques such as spinners,

dual spinners, gravity gradient, and geomagnetic torques are presented. Attitude sensors/actuators are presented and the attitude control problem is introduced. Open-loop stability analysis for a variety of equilibrium conditions is discussed. Control using momentum exchange and mass expulsion (thrusters) devices is discussed. The analyses and designs will be implemented using scientific computing software such as MATLAB®.

Recommended background: astronautics (AE 2713 or equivalent), dynamics (ES 2503, PH 2201 or equivalent), control (AE 3713 or equivalent).

#### **AE 4717. FUNDAMENTALS OF COMPOSITE MATERIALS. *Cat. I***

This course provides an overview of the processing techniques and mechanical behavior of composite materials relevant to aerospace applications. Topics in this course may include: classification of composites; elasticity of composite materials; the effect of reinforcements on strength and toughness; bonding mechanisms of interfaces in composite; fabrication methods for polymer-matrix composite materials; viscoelasticity and creep of composites; advanced composites materials (bio-composites, nano-composites).

Recommended background: Introductory level material science (ES 2001), and introductory level stress analysis (AE 2712, ~~ES 2502~~ or equivalent).

#### **AE 4717. FUNDAMENTALS OF COMPOSITE MATERIALS. *Cat. I***

This course provides an overview of the processing techniques and mechanical behavior of composite materials relevant to aerospace applications. Topics in this course may include: classification of composites; elasticity of composite materials; the effect of reinforcements on strength and toughness; bonding mechanisms of interfaces in composite; fabrication methods for polymer-matrix composite materials; viscoelasticity and creep of composites; advanced composites materials (bio-composites, nano-composites).

Recommended background: introductory material science (ES 2001), and introductory stress analysis (AE 2712 or equivalent).

#### **AE 4719. ROCKET PROPULSION. *Cat. I***

This course provides a study of rocket propulsion systems for launch vehicles and spacecraft. Dynamics, performance, and optimization of rocket-propelled vehicles are presented. Performance and component analysis of chemical ~~and electric~~ propulsion systems are covered including flight dynamics, vehicle staging, nozzle design, and thermochemistry of bipropellant and monopropellant thrusters. Different classes of electric thrusters are introduced along with the concept of optimal specific impulse. Additional topics may include advanced propulsion concepts and propellant storage and feed systems.

Recommended background: compressible fluid dynamics (AE/~~ME~~ 3410 or equivalent).

#### **AE 4719. ROCKET PROPULSION. *Cat. I***

This course provides a study of rocket propulsion systems for launch vehicles and spacecraft. Dynamics, performance, and optimization of rocket-propelled vehicles are presented. Performance and component analysis of chemical propulsion systems are covered including flight dynamics, vehicle staging, nozzle design, and thermochemistry of bipropellant and monopropellant thrusters. Different classes of electric thrusters are introduced along with the concept of optimal specific impulse.

Recommended background: compressible fluid dynamics (AE 3410 or equivalent).

#### **AE 4723. AIRCRAFT DYNAMICS AND CONTROL. *Cat. I***

~~The goal of this course is for students to develop, analyze, and utilize~~ This course covers models of fixed-wing aircraft dynamics, and to study various the design of aircraft control systems. Topics include: ~~review of linear systems, aircraft performance,~~ longitudinal and lateral flight dynamics, simulation methodologies, natural modes of motion, static and dynamic ~~aircraft stability,~~ and aircraft control systems (such as autopilot design, flight path control, and automatic landing). ~~Other topics may include: vertical take-off and landing (VTOL) vehicles and rotorcraft.~~

Recommended background: dynamics (ES 2503, PH 2201 or equivalent), controls (AE 3713 or equivalent), attitude and position kinematics (AE 4733 or equivalent),.

### **AE 4723. AIRCRAFT DYNAMICS AND CONTROL. *Cat. I***

This course covers models of fixed-wing aircraft dynamics, and the design of aircraft control systems. Topics include: aircraft performance, longitudinal and lateral flight dynamics, simulation methodologies, natural modes of motion, static and dynamic stability, and aircraft control systems (such as autopilot design, flight path control, and automatic landing).

Recommended background: controls (AE 3713 or equivalent), attitude and position kinematics (AE 4733 or equivalent),

### **AE 4733. GUIDANCE, NAVIGATION AND COMMUNICATION. *Cat. I***

This course ~~broadly~~ covers methods and current enabling technologies in the analysis, synthesis, and practice of aerospace guidance, navigation, and communications ~~and information~~ systems. Topics covered include: ~~position fixing and celestial navigation with redundant measurements, recursive navigation, and Kalman filtering;~~ attitude- and position kinematics, inertial navigation systems, global positioning satellite navigation systems, and ~~Doppler navigation; orbit determination; atmospheric re-entry;~~ communication architectures for satellite navigation, data rates, and communication link design; and tropospheric and ionospheric effects on radio-wave propagation, least squares estimation, the Kalman filter, and pursuit guidance and ballistic flight.

Recommended background: controls (~~AE/ME 3703, ES 3011~~ AE 3713 or equivalent), linear algebra (MA 2071 or equivalent), dynamics (ES 2503, PH 2201 or equivalent).

### **AE 4733. GUIDANCE, NAVIGATION AND COMMUNICATION. *Cat. I***

This course covers methods and current enabling technologies in the analysis, synthesis, and practice of aerospace guidance, navigation, and communications systems. Topics covered include: attitude- and position kinematics, inertial navigation systems, global satellite navigation systems, communication architectures for satellite navigation, tropospheric and ionospheric effects on radio-wave propagation, least squares estimation, the Kalman filter, and pursuit guidance.

Recommended background: linear algebra (MA 2071 or equivalent), dynamics (ES 2503, PH 2201 or equivalent), and controls (AE 3713 or equivalent).

### **AE 4770. AIRCRAFT DESIGN. *Cat. I***

This course introduces students to design of aircraft systems. Students complete a conceptual design of an aircraft in a term-long project. Students are exposed to the aircraft design process, and must establish design specifications, develop and analyze alternative designs, and optimize their designs to meet mission requirements. Students work together in teams to apply material learned in the areas of aerodynamics, structures and materials, propulsion, stability and control, and flight mechanics and maneuvers to the preliminary design of an aircraft. The project requirements are selected to reflect real-life aircraft mission requirements, and teams are required to design systems which incorporate appropriate engineering

standards and multiple realistic constraints. The teams present their design in a final report and oral presentation.

Recommended background: ~~fluid dynamics (ME/AE 3410, ME 3602 or equivalent), subsonic aerodynamics (ME AE 3711 or equivalent), aerospace structures (AE 3712 or equivalent), airbreathing propulsion (AE 4711 or equivalent), aircraft dynamics and control (AE 4723 or equivalent).~~

#### **AE 4770. AIRCRAFT DESIGN. *Cat. I***

This course introduces students to design of aircraft systems. Students complete a conceptual design of an aircraft in a term-long project. Students are exposed to the aircraft design process, and must establish design specifications, develop and analyze alternative designs, and optimize their designs to meet mission requirements. Students work together in teams to apply material learned in the areas of aerodynamics, structures and materials, propulsion, stability and control, and flight mechanics and maneuvers to the preliminary design of an aircraft. The project requirements are selected to reflect real-life aircraft mission requirements, and teams are required to design systems which incorporate appropriate engineering standards and multiple realistic constraints. The teams present their design in a final report and oral presentation.

Recommended background: aerodynamics (AE 3711 or equivalent), aerospace structures (AE 3712 or equivalent), air breathing propulsion (AE 4711 or equivalent), aircraft dynamics and control (AE 4723 or equivalent).

#### **AE 4771. SPACECRAFT AND MISSION DESIGN. *Cat. I***

This course introduces students to design of spacecraft and missions. Students are introduced to the process of designing a spacecraft and major subsystems to meet a specific set of objectives or needs. In addition, students will learn about different spacecraft subsystems and what factors drive their design. Particular emphasis is given to propulsion, power, attitude control, structural, and thermal control subsystems. Students work together in teams to apply material learned in the areas of orbital mechanics, ~~space environments~~, attitude determination and control, space structures, and propulsion to the preliminary design of a spacecraft and mission. The project requirements are selected to reflect real-life missions, and teams are required to design systems which incorporate appropriate engineering standards and multiple realistic constraints. The teams present their design in a final report and oral presentation.

Recommended background: astronautics (AE 2713 or equivalent), rocket propulsion (AE 4719 or equivalent), spacecraft dynamics and control (AE 4713 or equivalent).

#### **AE 4771. SPACECRAFT AND MISSION DESIGN. *Cat. I***

This course introduces students to design of spacecraft and missions. Students are introduced to the process of designing a spacecraft and major subsystems to meet a specific set of objectives or needs. In addition, students will learn about different spacecraft subsystems and what factors drive their design. Particular emphasis is given to propulsion, power, attitude control, structural, and thermal control subsystems. Students work together in teams to apply material learned in the areas of orbital mechanics, attitude determination and control, space structures, and propulsion to the preliminary design of a spacecraft and mission. The project requirements are selected to reflect real-life missions, and teams are required to design systems which incorporate appropriate engineering standards and multiple realistic constraints. The teams present their design in a final report and oral presentation.

Recommended background: astronautics (AE 2713 or equivalent), rocket propulsion (AE 4719 or equivalent), spacecraft dynamics and control (AE 4713 or equivalent).

**Rationale:**

These revisions in course descriptions are undertaken in preparation for the upcoming ABET review and reflect the current coverage. The revised course descriptions are aligned with the revised distribution requirements for AE majors.

There is no impact on students due to the revisions in the recommended background of courses. These revisions include: additions that reflect the current coverage of material in a course; course renumbering; addition of courses that can be used as alternatives in order to increase flexibility in scheduling; removal of courses that are not aligned with current material coverage. For 2000- and 3000-level courses we list all recommended background needed. This will help first-year and sophomores who due to AP credits take courses earlier than they used to do. For 4000-level courses we deleted reference to math and basic science courses that either are required for AE majors or they are recommended background of 2000- or 3000-level courses. Course scheduling becomes easier with these clarifying revisions.

The specific revisions in the recommended background of courses are as follows:

**AE 2713. ASTRONAUTICS. *Cat. I***

Added multivariable calculus (MA 1024 or equivalent), differential equations (MA2051 or equivalent). These are required math courses by AE majors.

**AE 2712. INTRODUCTION TO AEROSPACE STRUCTURES. *Cat. I***

Revisions are editorial.

**AE/~~ME~~ 3602. INCOMPRESSIBLE FLUIDS. *Cat. I* :**

Added differential equations (MA 2051 or equivalent), dynamics (ES 2503, PH 2201 or equivalent). Both MA2051 and ES 2503 (or PH 2201) are required by AE majors. Added PH 2101 as another option for thermodynamics.

**AE/~~ME~~ 3410. COMPRESSIBLE FLUID DYNAMICS. *Cat. I***

Added PH 2101 as another option for thermodynamics.

**AE 3711. AERODYNAMICS. *Cat. I***

We added compressible fluid dynamics AE/~~ME~~ 3410 which is required by AE majors.

**AE 3712. AEROSPACE STRUCTURES. *Cat. I***

Added differential equations (MA2051 or equivalent) which is required by AE majors.

**AE 4712. STRUCTURAL DYNAMICS. *Cat. I***

Removed recommended background: ordinary differential equations (MA 2051 or equivalent). This is a basic math course taken by AE majors and need not be listed in a 4000-level course.

**AE 4713. SPACECRAFT DYNAMICS AND CONTROL. *Cat. I***

Added controls (AE 3713 or equivalent) which is required by AE majors.

**AE 4717. FUNDAMENTALS OF COMPOSITE MATERIALS. *Cat. I***

Removed ES 2502 which is no longer required by AE majors.



**AE 4723. AIRCRAFT DYNAMICS AND CONTROL. Cat. I**

We added controls (AE 3713 or equivalent), attitude and position kinematics (AE 4733 or equivalent). These courses are required by AE majors.

**AE 4733. GUIDANCE, NAVIGATION AND COMMUNICATION. Cat. I**

Replace AE/ME3703 with AE 3713; added linear algebra (MA 2071 or equivalent), dynamics (ES 2503, PH 2201 or equivalent). MA 2071 and ES 2503 are required by AE majors.

**AE 4770. AIRCRAFT DESIGN. Cat. I**

Removed fluid dynamics (~~ME~~ AE 3410, ~~ME~~ AE 3602 or equivalent).

**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to add ME 3411 Intermediate Fluid Mechanics, approved by the ME Program 02/12/19.

**Motion:** The Committee on Academic Operations recommends and I move that the following course, as described below, be added.

## MECHANICAL ENGINEERING

### ME 3411 INTERMEDIATE FLUID MECHANICS.

Cat. I

This course provides a mixture of theory and applications and covers topics not found in the introductory course in fluid mechanics. Topics include kinematics of fluid flow, potential flow, Navier-Stokes and the theory of viscous flow, basic turbulence, boundary layer theory, and introduction to compressible flow. Recommended background: Introductory fluid mechanics (ES 3004, or equivalent).

**Anticipated instructor:** Any of the thermal fluid faculty could teach this.

**Rationale:** In prior motions, ME requested to de-list ME from two courses: AE/ME 3602 and 3410 since these have developed into specialized aero courses. This leave a gap for students to bridge the undergraduate and graduate programs in fluid mechanics with mechanical engineering focus. We have several key topics uncovered, in particular, the fundamentals of compressible flow and advanced fluid analysis.

We anticipate this having an enrollment of 30.

**Implementation Date:** Implementation date for this action is the 2019-2020 Academic year.

#### **Resource Needs:**

We currently have sufficient teaching load to cover this for one section a year.

#### **Impact on Distribution Requirements:**

None. It fills a gap in the Thermal-fluid Concentration.

2. Committee Business:	Page
• Committee on Academic Policy (CAP) and Committee on Academic Operations (CAO) <b>Motion to approve undergraduate program in Data Science (DS)</b>	76
• Committee on Academic Operations (CAO) <b>Motions to modify Data Science (DS) minor</b>	91

**To:** WPI Faculty  
**Date:** March 14, 2019  
**From:** Committee on Academic Policy (Prof. Olinger, Chair)  
Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to approve an undergraduate B.S. program in Data Science

**Motion:** The Committee on Academic Policy and the Committee on Academic Operations jointly recommend and we move that an interdisciplinary undergraduate program in Data Science (DS) as described below be established at WPI and implemented through the coordinated efforts of faculty members from the Computer Science (CS), Foisie Business School (FBS), and Mathematical Sciences (MA) units.

Motions below have been approved and/or endorsed by the Data Science Steering Committee faculty on Oct 9, 2018; the Robert A. Foisie School of Business faculty on November 7th, 2018; the Department of Computer Science faculty on November 20th, 2018; and the Department of Mathematical Sciences faculty on Nov 27<sup>th</sup>, 2018.

### **Proposed Program Overview**

The undergraduate major in Data Science at WPI will take advantage of existing courses at WPI offered by CS, MA, and FBS. A few additional interdisciplinary courses will be created and additional faculty and other resources will be required. The choice of course requirements for the major was informed by surveys of students (to determine interest), discussion with Data Science Executive Advisory Board members, review of job statistics (to determine job market requirements), and analysis of existing undergraduate Data Science programs across the country (to determine program requirements) and examination of already available WPI curriculum in the affiliated programs (to understand available resources). Most importantly, we incorporate the recommendations by the group of experts convened for National Academies' 2017 Interim Report "*Envisioning The Data Science Discipline: The Undergraduate Perspective*" (National Academies 2017).

### **WPI Faculty Contacts**

Elke Rundensteiner, Computer Science, and DS Program Director.  
Diane Strong, Foisie School of Business.  
Jian Zou, Mathematical Sciences.

These three faculty represent the 26 faculty with formal Data Science collaborative appointments; with 14 of them currently serving on the Data Science Steering Committee.

### **Student Outcomes**

Students graduating with a Bachelor of Science degree in Data Science:

- Have mastered foundational studies in business, computer science, and mathematical sciences
- Have mastered advanced principles and techniques in at least one of the three disciplines
- Can apply computational and mathematical knowledge to the solution of big data problems

- Can communicate effectively across disciplines both verbally and in writing
- Can locate, read, and interpret primary literature in data science
- Can function effectively as members of an interdisciplinary team
- Have an understanding of accepted standards of ethical and professional behavior
- Have the ability to be a life-long independent learner

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### **Program Distribution Requirements for the Data Science Major**

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The distribution requirements for the BS degree in Data Science consists a series of interdisciplinary courses in Data Science, fundamental courses in Computer Science, Mathematical Sciences, and Business, and a set of more advanced courses selected primarily from the three supporting disciplines: Computer Science, Mathematical Sciences, and/or Business.

<b>REQUIREMENTS</b>	<b>MINIMUM UNITS</b>
1. Data Science Core Courses (Note 1)	3/3
2. Business (Note 2)	2/3
3. Computer Science (Note 3)	3/3
4. Mathematical Sciences (Note 4)	5/3
5. Data Privacy and Ethics (Note 5)	1/3
6. Natural or Engineering Sciences (Note 6)	2/3
7. Disciplinary Elective Courses (Note 7)	11/3
8. MQP (Note 8)	3/3

#### **NOTES:**

1. Students must complete the series of three DS core courses (DS 1010, DS 2010, and DS 3010)
2. Business foundation courses must include 1/3 unit in entrepreneurship and innovation, and 1/3 unit in business analysis:
 

One of BUS 1010, ETR 1100, BUS 3010, ETR 3633  
One of BUS 2080
3. Computer science foundation courses must include 2/3 units of introductory computer science (with no more than 1/3 unit at the 1000 level) and 1/3 unit of algorithms. CS elective courses at level of 3000 and above as defined in Note 7 may substitute for introductory computer science credits.
 

Two of CS 1004, 1101, 1102, CS 2102, CS 2103, CS 2119, or CS elective courses below.  
One of CS 2223
4. Mathematics foundation courses must include 2/3 units calculus, 2/3 units applied statistics, and 1/3 unit linear algebra. Mathematics disciplinary elective courses as defined in Note 7 may substitute for introductory calculus credits.

Two of MA 1020, MA 1021<sup>1</sup>, MA 1022, MA 1120<sup>2</sup>, or disciplinary elective courses in MA as per Note 7.

Both MA 2611, MA 2612

One of MA 2071, MA 2072

5. Data Privacy and Ethics. Choose 1/3 unit from among the following:

CS 3043

GOV 2313, GOV 2314, GOV 2315, GOV 2320

PY 2713, PY/RE 2731

RBE 3100

6. 2/3 units of work chosen in Natural or Engineering Science (courses with prefixes AE, AREN, BB, BME, CHE, CE, CH, ECE, ES, GE, ME, PH or RBE count).

7. Chosen from disciplinary elective courses in CS, MA, or BUS listed below.

At least one course must be selected from each of the following categories:

- Data access and management (CS 3431, MIS 3720, CS 4432, CS4433/DS4433)
- Data mining/machine learning (CS 4445, CS 4342)
- Business modeling and prediction (MIS 4084, OIE 4420)

Disciplinary electives must include at least 4/3 units at the 4000 level or above.

8. Data Science <sub>MQP</sub> projects must have a MQP faculty advisor that has a formal collaborative appointment in the Data Science program.

#### **Disciplinary elective courses in CS:**

CS 2022 Discrete Mathematics

CS 2301 Systems Programming For Non-Majors

CS 2303 Systems Programming Concepts

CS 3133 Foundations of Computer Science

CS 3733 Software Engineering

+CS 3431 Database Systems I

CS 3041 Human-Computer Interaction

CS 4120 Analysis of Algorithms

+CS 4341 Introduction to Artificial Intelligence

+CS 4432 Database Systems II

+CS 4445 Data Mining and Knowledge Discovery in Databases

CS 4803/BCB4003 Biological and Biomedical Database Mining

+CS 4342/DS4342 Machine Learning

+CS 4804 Data Visualization

CS 4802/BCB4002 Bio Visualization

+CS 4433/DS4433 Big Data Management & Analytics

CS 4233 Object-Oriented Analysis and Design

CS 4241 Webware: Computational Technology for Network Information Systems

Students are encouraged to take elective courses with a (+) prefix.

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<sup>1</sup> Students cannot take both MA 1020 and MA 1021 for credits.

<sup>2</sup> Students cannot take both MA 1022 and MA 1120 for credits.

**Disciplinary elective courses in MA:**

MA 1023 Calculus III  
MA 1024 Calculus IV  
MA 1033 ~~Introduction to Analysis~~ Theoretical Calculus III  
MA 1034 ~~Introduction to Analysis~~ Theoretical Calculus IV  
MA 2201 Discrete Mathematics  
MA 2051 Ordinary Differential Equations  
MA 2073 Matrices and Linear Algebra II  
MA 2210 Mathematical Methods in Decision Making  
MA 2431 Mathematical Modeling with Ordinary Differential Equations  
+MA 2621 Probability for Applications  
+MA 2631 Probability<sup>3</sup>  
MA 3231 Linear Programming  
MA 3233 Discrete Optimization  
MA 3257 Numerical Methods for Linear and Nonlinear Systems  
+MA 3627 Introduction to the Design and Analysis of Experiments  
+MA 3631 Mathematical Statistics  
MA 4213 Loss Models I - Risk Theory  
MA 4214 Loss Models II - Survival Models  
MA 4235 Mathematical Optimization  
MA 4237 Probabilistic Methods of Operations Research  
+MA 4603 Statistical Methods in Genetics and Bioinformatics  
MA 4631 Probability and Mathematical Statistics I  
MA 4632 Probability and Mathematical Statistics II  
+MA 4635/DS4635 Data Analytics and Statistical Learning

Students are encouraged to take elective courses with a (+) prefix.

**Disciplinary elective courses in BUS:**

+MIS 3720 Business Data Management  
MKT 3650 Consumer Behavior  
OIE 3460 Simulation Modeling and Analysis  
+MIS 4084 Business Intelligence  
MIS 4720 Systems Analysis and Design  
MIS 4741 User Experience and Design  
+OIE 4420 Practical Optimization: Methods and Applications

Students are encouraged to take elective courses with a (+) prefix.

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<sup>3</sup> Students cannot take both MA 2621 and MA 2631 for credits

## New Course Descriptions

### **DS 1010 Data Science I: Introduction to Data Science**

#### *Cat. I*

This course provides an introduction to the core concepts in Data Science. It covers a broad range of methodologies for working with and making informed decisions based on real-world data. Core topics introduced in this course include basic statistics, data exploration, data cleaning, data visualization, business intelligence, and data analysis. Students will utilize various techniques and tools to explore, understand and visualize real-world data sets from various domains and learn how to communicate data results to decision makers.

Recommended background: None

### **DS 2010 Data Science II: Modeling and Data Analysis**

#### *Cat. I*

This course focuses on model- and data-driven approaches in Data Science. It covers methods from applied statistics (regression), optimization, and machine learning to analyze and make predictions and inferences from real-world data sets. Topics introduced in this course include basic statistics (regression), analytics (explanatory and predictive), basics of machine learning (classification and clustering), eigen values and singular matrices, data exploration, data cleaning, data visualization, and business intelligence. Students will utilize various techniques and tools to explore and understand real-world data sets from various domains.

Recommended background: Data science basics equivalent to DS 1010, applied statistics and regression equivalent to MA2611 and MA 2612, and the ability to write computer programs in a scientific language equivalent to a CS programming course at the CS 1000 or CS 2000 level are assumed.

### **DS 3010 Data Science III: Computational Data Intelligence**

#### *Cat. I*

This course introduces core methods in Data Science. It covers a broad range of methodologies for working with large and/or high-dimensional data sets to making informed decisions based on real-world data. Core topics introduced in this course include data collection through use cycle, data management of large-scale data, cloud computing, machine learning and deep learning. Students will acquire experience with big data problems through hands-on projects using real-world data sets.

Recommended background: Data science basics equivalent to DS 1010, and data analysis principles and modeling equivalent to DS 2010, knowledge of basic statistics equivalent to (MA2611 and MA 2612), and the ability to program equivalent to (CS 1004 or CS 1101 or CS 1102) and (CS 2102, CS2103 or CS 2119), as well as understanding of databases equivalent to (CS3431 or MIS3720) are assumed.

### **DS 4433/CS4433 Big Data Management and Analytics**

#### *Cat. I*

This course introduces the emerging techniques and infrastructures for big data management and analytics including parallel and distributed database systems, map-reduce, Spark, and NO-SQL infrastructures, data stream processing systems, scalable analytics and mining, and cloud-based computing. Query processing and optimization, access methods, and storage layouts developed on these infrastructures will be covered. Students are expected to engage in hands-on projects using one or more of these technologies.



Recommended background: Knowledge in database systems at the level of CS4432, and programming experience are assumed.

**Impact on Distribution Requirements:** No impact on distribution requirements. The courses are part of the new DS Major being proposed. They are currently not cross-listed with other majors. The courses do not fulfill Mathematics, Basic Science or Engineering Science/Design credits, unless they are correspondingly cross-listed by other departments.

**Anticipated Instructors:** Faculty in the Data Science program would be able to teach the proposed courses. We expect to hire at least two additional faculty members to help cover the load imposed by the new courses.

Sample of Student Pathways Focused on Elective Choices:

We list some, among many possible, pathways below to facilitate planning of course sequencing and resources.

**Sample pathway for Mathematics-oriented students (11/3 electives):**

MA 1023 Calculus III  
MA 1024 Calculus IV  
MA 2073 Matrices and Linear Algebra II  
MA 2631 Probability  
MA 3627 Introduction to the Design and Analysis of Experiments  
MA 3631 Mathematical Statistics  
MA 4603 Statistical Methods in Genetics and Bioinformatics  
MA 4635 Data Analytics and Statistical Learning  
CS 3431 Database Systems I  
CS 4445 Data Mining and Knowledge Discovery in Databases  
MIS 4084 Business Intelligence

**Sample pathway for Computing-Centric students (11/3 electives):**

CS 3733 Software Engineering  
CS 3431 Database Systems I  
CS 4445 Data Mining and Knowledge Discovery in Databases  
CS 4342 Machine Learning  
CS 4804 Data Visualization  
CS 4432 Database Systems II  
CS 4433 Big Data Management & Analytics  
CS 4341 Introduction to Artificial Intelligence  
MA 1024 Calculus IV  
MA 2072 Accelerated Matrices and Linear Algebra  
MIS 4084 Business Modeling and Prediction

**It is anticipated that students will take a much richer diversity of courses between the two extreme pathways listed above.**

## **Double Majors**

Currently, we allow all combinations of double majors with respect to the data science program.

## **Rationale**

### **The Data Science Industry**

Technological advances in devices, software, networking, and other technologies give rise to digital data, rich in variety, volume, velocity and complexity. These data, ranging from business transactions, social media, health and fitness monitoring, to scientific data sets represent an exceptional opportunity to harvest and extract insights important for competitive businesses and innovation, health, science, engineering, and societal well-being. The knowledge and skills for analyzing large data sets—so called “big data”—is being referred to as the field of Data Science. This data science program thus educates professionals, namely Data Scientists, with interdisciplinary skills in analytics, computing, statistics, and business intelligence. Key skills include the ability to recognize problems that can be solved with data analytics, apply the appropriate technologies on a given data problem, and communicate those solutions effectively to relevant stakeholders.

To bring about transformative solutions to important real-world problems, the program will educate the students to collect, organize, and analyze big data using state-of-the-art data analytic technologies. The skills used with these technologies include computational thinking, data mining, statistics, data management, and visualization. Students will be educated to have a deep understanding of the foundations underlying these technologies.

Professional skills, such as communication, presentation, and storytelling with data, will also be fostered. The students will emerge as future leaders in data analytics, with the technical and professional skills needed for the career demands of data scientists of the future. Due to their increased interdisciplinary perspective, our graduates will have a competitive advantage over professionals who are trained in a single discipline (e.g., business administration, statistics, or computer science for example) and are seeking to work in the data analytic industry.

According Glassdoor's 2018 Rankings [Glassdoor2018], Data Scientist has been named the best job in America for three years running, with a median base salary of \$110,000 and 4,524 job openings. Six analytics and data science jobs are included in Glassdoor's 50 best jobs in America for 2018, namely, Data Scientist, Analytics Manager, Database Administrator, Data Engineer, Data Analyst and Business Intelligence Developer. These six analytics and data science jobs, in total, represent 16,702 openings as of July 2018 according to Glassdoor. See the detailed table extracted from Glassdoor in the appendix. LinkedIn's 2017 U.S. Emerging Jobs Report found that there are 9.8 times more Machine Learning Engineers working today than five years ago with 1,829 open positions listed on their site as of last month. Data science and machine learning are generating more jobs than candidates right now, making these two areas the fastest growing tech employment areas today.

## **Program Opportunities**

Our WPI faculty, who have been offering Data Science degree programs at the graduate level since 2014, along with WPI's strong relationships with industrial partners provide students with the resources and opportunities to engage in practical purpose-driven projects, formal course work, teaming engagements with cohorts, and mentored interdisciplinary research work. This data science program requires advanced, in-depth course work in several core areas that include business and innovation, data analytics and computing, and statistical foundations. At the same time, the data science program provides flexibility for purpose-driven plans of study focusing on an area of concentration of interest to the student, ranging from general data analytics and computing, mathematical analytics, business analytics, to specialized concentrations in financial analytics, healthcare analytics, biomedical analytics, and so on. Last but not least, the data science program has strong active collaborations with companies and organizations sponsoring Graduate Qualifying Projects (GQPs). We expect that our industrial partners will equally be eager to work with our undergraduate majors on MQP projects in Data Science.

## **Program Educational Objectives**

The B.S. Degree program in Data Science (DS) strives to produce the future generation of data scientists who are able to:

- Assess the suitability of, apply, and advance state-of-art data analytics tools and methods from data analysis, statistics, data mining, data management, computational thinking, big data algorithms, and visualization to bring about transformative solutions to important real-world problems across a number of domains.
- Bring to bear their integrative, interdisciplinary knowledge and skills in the core disciplines central to Data Science (Computing, Statistics, and Business) to understand and then to explain analytics results and their applicability and validity to those responsible for solving real-world problems.
- Serve as visionary leaders and project managers in data analytics, with the technical, and professional knowledge and skills needed for the current and future career demands of data scientists working on impactful projects.

## **Business Accreditation**

We require that the number of business course credits that can be applied to the data science student's program must be less than 25 percent that is, no more than 3 and 2/3 units (11 courses) of a 15 units program. This in part is based on the fact that an accreditation rule from the Association to Advance Collegiate Schools of Business (AACSB) says that if 25 percent or more of an undergraduate degree involves business courses then that program will be reviewed by AACSB as part of business school accreditation.

## **Competing Programs**

There are 75 degree-granting Data Science programs or other similar programs with different names at colleges across the US. Mostly offered by only one department/unit (CS, Stat, or Business), typically as a variation on their existing curriculum.

Currently, to the best of our knowledge, there are only 5 truly interdisciplinary BS program in Data Science degree programs in the nation (Ohio State University, Pennsylvania State University, University of Rochester, Valparaiso University, and University of Rhode Island). These interdisciplinary programs combine computer science, statistics and usually a student's choice of advanced coursework in an application area of data science, such as business, biology, health sciences, among others.

Four colleges in New England offer a BS degree related to Data Science (Northeastern University, UMass-Dartmouth, University of Rhode Island, Yale University), and 2 offer undergraduate concentrations (Becker College, Smith College). This leaves plenty of room for WPI to distinguish itself from the local competition. Our DS program at WPI is one of a kind in the New England area in the sense that it encompasses WPI's strength and resources in interdisciplinary data science research and interdepartmental data science academic programs.

### **Growth and Assessment**

We expect this to be a popular major; conservatively we expect at least 25 students in the first year, and a growth to 50 students per year by the end of year 5.

Success of a program at WPI will be measured, among other metrics, by the growth of the majors in the program, the quality of the students in the program, and the rate and quality of professional employment secured by our graduates.

### **Discussion**

There has been robust interest in the graduate data science program at WPI since its inception in 2014; with over 450 applications a year. There currently are well over 130 students in the graduate program. We have observed a near 100% employment for our Data Science graduates with salaries in many cases in the 6 digits. Furthermore, industrial partners have expressed difficulty in attracting strong Data Science talent given the global demand for qualified workers in this discipline.

Similarly, prior offerings of the DS minor at WPI, in particular, the currently active capstone course DS3001 in place since 2016/2017 for the DS minor, has had a strong demand by WPI students. This course DS3001 will now be phased out to be replaced by the full data science core series DS1010, DS2010, and DS3010. The attendance of DS3001 has been:

- in Spring 2017 (d term, Kong), Population: 35 (capped);
- in Spring 2018 (d term, Lee), Population : 49 (capped);
- in Spring 2019 (d term, Lee), current Population : 39 and 7 on waitlist. (capped).

The graduate version of the course "Big Data Management" (DS503/CS585) has been popular in the Data Science program, as shown by the enrollment numbers below. We propose to add the equivalent course at the undergraduate level to teach the students big data management knowledge fundamental to data science jobs. For the graduate version of this course, we have seen a robust demand by WPI students. Namely:

- in Spring 2015 (Eltabakh), Population: 29
- in Spring 2017 (Eltabakh) , Population : 82
- in Fall 2017 (Rundensteiner), Population : 36

- In Spring 2018 (Singh), Population: 9
- In Fall 2018 (Eltabakh), Population: 24
- In Spring 2018 (Rundensteiner), projected Population: 30 with 28 currently on waitlist (as of Oct, 1, 2018)

## **Implementation**

The undergraduate program will begin during the 2020-2021 academic year when all the new core DS courses will be offered. The timeline for implementation is as follows:

### Academic Year 2018-2019.

- Develop the DS major and revised DS minor curriculum.
- Approval of proposal by the Data Science Steering Committee and the BUS, CS, and MA Departments' committees and faculty.
- Dean's Offices and Provost's Office commit to the resource requirements, including additional faculty.
- Approval of the proposal, including the new core courses, by CAP and CAO. Also CAO approval of converting several existing experimental courses in the associated disciplines to permanent courses.

### Summer 2019.

- Develop web presence program description.
- Design marketing material.
- Preparation for allowing existing students to declare as DS students.
- Development of the new DS4433 course in "big data management and analytics"
- Preparation of the new course DS 1010 "Data Science I".

### Academic Year 2019 – 2020.

- Recruitment of new faculty members for AY2020-2021.
- Marketing of new program.
- Existing students may start taking existing courses toward the new degree
- Offer DS4433 course in "big data management and analytics"
- Offer the first core data science DS 1010 course, if resources are available.

### Summer 2020.

- Develop program forms and materials.
- Preparation of initial offerings of DS 2010 and DS 3010.
- Additional administrative staff in place

### Academic Year 2020 – 2021.

- Official start of the program.
- First DS majors arrive at WPI
- Two new tenure-track faculty members arrive at WPI.
- Offering of all DS core courses as regular courses.

## Resources Required

To assure the design and delivery of the newly proposed courses, administer the program, mentor, advise and manage the students given the expected growth of students in the major, (conservatively we expect at least 25 students in the first year, and a growth to 50 students per year within the first five years), both majors and minors, and engage the students in data science specific MQP projects, the initial launching of the program requires significant resources both within the program as well as in each of the disciplinary units associated with the Data Science program in terms of TT faculty and TA support and administrative support to keep up with the load imposed on these units with the growth of the program.

In particular, for the launch itself, the Data Science program requires the addition of at least two new Data Science TT faculty, 2 TAs, and appropriate staff and faculty support for the administrative management of the program. Similarly, TT faculty positions and associated resources are also required for the supporting disciplinary departments and units based on the size of the Data Science cohort and load imposed on the respective units in steady state.

The WPI leadership has committed to make the needed resources available to assure the successful launch of the program. Plus, the administration commits to providing future investment in the program and associated units commensurate with student interest and growth of the program.

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(DS Community Colleges 2018) <http://datascience.community/colleges>

### Glassdoor 50 Best Jobs In America, 2018

Ranking	Job	Median Base Salary	Job Score (5.0 scale)	Job Satisfaction (5.0 scale)	Job Openings
1	Data Scientist	\$ 110,000	4.8	4.2	4,524
2	DevOps Engineer	\$ 105,000	4.6	4	3,369
3	Marketing Manager	\$ 85,000	4.6	4	6,436
4	Occupational Therapist	\$ 74,000	4.5	4	11,903
5	HR Manager	\$ 85,000	4.5	3.9	4,458
6	Electrical Engineer	\$ 76,000	4.5	3.9	5,839
7	Strategy Manager	\$ 135,000	4.5	4.2	1,195
8	Mobile Developer	\$ 90,000	4.5	4.1	1,809
9	Product Manager	\$ 113,000	4.4	3.7	7,531
10	Manufacturing Engineer	\$ 72,000	4.4	4	4,241
11	Compliance Manager	\$ 96,000	4.4	4.3	1,222
12	Finance Manager	\$ 116,000	4.4	3.8	2,998
13	Risk Manager	\$ 97,000	4.4	4.2	1,209
14	Business Development Manager	\$ 75,000	4.4	3.9	4,060
15	Front End Engineer	\$ 100,000	4.4	4.2	1,222
16	Site Reliability Engineer	\$ 120,000	4.4	4.1	1,064
17	Mechanical Engineer	\$ 75,000	4.4	3.8	5,079
18	Analytics Manager	\$ 115,000	4.4	3.9	1,381
19	Tax Manager	\$ 110,000	4.4	3.7	3,309
20	Creative Manager	\$ 110,000	4.3	4.3	824
21	Software Engineer	\$ 102,500	4.3	3.6	29,187
22	Hardware Engineer	\$ 115,000	4.3	4.2	806
23	Corporate Recruiter	\$ 65,000	4.3	4.3	2,330
24	QA Manager	\$ 92,000	4.3	3.8	1,741
25	Physician Assistant	\$ 104,000	4.3	3.6	5,517
26	Database Administrator	\$ 94,000	4.3	3.8	2,370
27	UX Designer	\$ 90,000	4.3	3.8	1,963
28	Nursing Manager	\$ 84,660	4.3	3.7	4,209
29	Engagement Manager	\$ 115,000	4.3	3.7	2,169
30	Solutions Architect	\$ 125,000	4.2	3.6	3,325
31	Process Engineer	\$ 78,000	4.2	3.8	3,033
32	Reliability Engineer	\$ 92,000	4.2	4.3	747
33	Data Engineer	\$ 100,000	4.2	3.7	2,816
34	Operations Manager	\$ 65,000	4.2	3.8	13,706
35	Speech Language Pathologist	\$ 72,000	4.2	3.7	11,573
36	Communications Manager	\$ 80,000	4.2	3.9	1,380
37	Audit Manager	\$ 100,000	4.2	3.7	1,951
38	Data Analyst	\$ 60,000	4.2	3.9	4,729
39	Systems Analyst	\$ 75,000	4.2	3.7	2,710
40	Facilities Manager	\$ 75,000	4.2	3.8	2,139
41	Strategic Account Manager	\$ 85,000	4.2	4.1	808
42	Business Intelligence Developer	\$ 86,000	4.1	3.9	882
43	Business Analyst	\$ 71,000	4.1	3.6	9,603
44	Accounting Manager	\$ 82,000	4.1	3.6	3,273
45	UI Developer	\$ 95,000	4.1	3.8	1,004
46	Executive Assistant	\$ 55,000	4.1	3.9	4,684
47	Management Consultant	\$ 110,000	4.1	3.8	1,024
48	Project Manager	\$ 80,000	4.1	3.5	23,274
49	Nurse Practitioner	\$ 100,000	4.1	3.5	8,510
50	HR Generalist	\$ 57,210	4.1	3.9	2,705



## DATA SCIENCE MAJOR PROGRAM CHART

UNIVERSITY REQUIREMENTS	
Minimum Academic Credit	15 Units
Residency	8 Units
Humanities and Arts	2 Units
Interactive Qualifying Project	1 Unit
Social Science	2/3 Unit
Physical Education	1/3 Unit
Free Electives	1 Unit

MAJOR-SPECIFIC REQUIREMENTS (10 UNITS)	
DS Core Courses*	1 Unit
Disciplinary Foundation Courses	10/3 Units
Disciplinary Electives	11/3 Units
DS MQP	1 Unit

(\*). DS core courses include DS 1010, DS 2010, DS 3010.

### DISCIPLINARY FOUNDATION COURSES (10/3 UNITS)

COMPUTER SCIENCE COURSES (3/3 Unit Required)	MATHEMATICS COURSES (5/3 Unit Required)	BUSINESS COURSES (2/3 Unit Required)
Two of CS 1004, CS 1101, CS 1102, CS 2102, CS 2103, CS 2119, or from CS electives below (**)  One of CS 2223	Two of MA 1020, MA 1021, MA 1022, MA 1120, or from MA electives below  Both MA 2611, MA 2612 One of MA 2071, MA 2072	One of BUS 1010, ETR1100, BUS 3010, ETR 3633  One of BUS 2080

(\*\*) At most 1/3 CS unit at the 1000 level.

**DISCIPLINARY ELECTIVE COURSES (11/3 UNITS)**

COMPUTER SCIENCE COURSES	MATHEMATICS COURSES	BUSINESS COURSES
CS 2301    CS 4120	MA 1023    MA 3257	+MIS 3720
CS 2303    +CS 4432	MA 1024    +MA 3627	MKT 3650
CS 3733    +CS 4445	MA 1033    +MA 3631	OIE 3460
Cs 3041    +CS 4342/DS4342	MA 1034    MA 4213	+MIS 4084
+CS 3431    +CS 4804	MA 2051    MA 4214	MIS 4720
CS 4233    +CS 4433/DS4433	MA 2073    MA 4235	MIS 4741
	MA 2201    MA 4237	

Electives must include at least one course in each of the categories below:

- Databases (CS 3431, CS 4432, MIS 3720, DS 4433)
- Data mining/machine learning (CS 4445, CS 4342/DS4342)
- Business modeling and prediction (MIS 4084, OIE 4420)

Electives must include at least 4/3 at the 4000 level or above. Students are encouraged to take electives with a prefix (+)

**To:** WPI Faculty

**Date:** March 14, 2019

**From:** Committee on Academic Operations (Prof. Mattson, Chair)

**Re:** Motion to change the existing minor in Data Science to align it with as well as leverage the courses to be offered as part of the newly proposed Data Science major program, including to drop one DS course.

Motions below have been approved and/or endorsed by the Data Science Steering Committee faculty on Oct 9, 2018; the Robert A. Foisie School of Business faculty on November 7th, 2018; the Department of Computer Science faculty on November 20th, 2018; and the Department of Mathematical Sciences faculty on Nov 27<sup>th</sup>, 2018.

**Motion 1:** The Committee on Academic Operations recommends, and I move, that the changes to the DS Minor, as described below, be approved.

**Proposed Changes to the Minor in Data Science:**

The **Minor in Data Science** will consist of 2 units, all of which must be selected from the list of approved Data Science major courses. These 2 units must be selected to include the following:

- Three courses, one from each of the three areas (Business, Computer Science, Mathematical Sciences) at the 2000 level or above from the list of disciplinary courses approved for the Data Science major
- At least two courses out of the DS series DS 1010, DS 2010, and DS 3010.
- At least one course at the 3000 level or above selected from the list of disciplinary courses approved for the Data Science major.

The Minor in Data Science is open to all undergraduate majors at WPI. Students majoring in Business, Computer Science, or Mathematical Sciences should consult WPI rules on minors for double-counting courses.

**This replaces the current guidelines of the DS minor, as listed below.**

The **Minor in Data Science** consist of 2 units, all of which must be selected from the list of approved Data Science minor courses. These 2 units must be selected to include the following:

- Three courses, one from each of the three areas (Business, Computer Science, Mathematical Sciences) at the 2000 level or above from the list of approved Data Science minor courses
- Two courses at the 3000 level or above, as follows:
  - DS 3001 *Foundations of Data Science*
  - Any other 3000 level or above course from the list of approved Data Science minor courses
- One course at any level selected from the list of approved Data Science minor courses

The Minor in Data Science is open to all undergraduate majors at WPI. Students majoring in Business, Computer Science, or Mathematical Sciences should consult WPI rules on minors for double-counting courses.

**Rationale:**

The change is to line up the DS minor with the newly proposed DS courses and DS major degree.

**Implementation Date:** Implementation date for this action is the 2020-2021 academic year.

**Resource Needs:**

No additional resources are needed beyond what is needed to offer the DS major.

**Impact on Distribution Requirements:** No impact on distribution requirements.

## **Motion 2**

The Committee on Academic Operations recommends, and I move, that DS 3001 *Foundations of Data Science*, as described below, be removed.

### **Course/Catalog Description:**

DS 3001 *Foundations of Data Science*

Cat. I

This course provides an introduction to the core ideas in Data Science. It covers a broad range of methodologies for working with and making informed decisions based on real-world data. Core topics introduced in this course include data collection, data management, statistical learning, data mining, data visualization, cloud computing, and business intelligence. Students will acquire experience with big data problems through hands-on projects using real-world data sets.

Recommended background for this course includes statistics knowledge equivalent to MA2611 and MA 2612, linear algebra equivalent to MA2071, and the ability to program equivalent to (CS 1004 or CS 1101 or CS 1102) and (CS 2102 or CS 2119).

### **Rationale.**

We propose to remove the current Data Science course DS 3001, as it is replaced by a series of core Data Science courses DS 1010, DS 2010, and DS 3010 designed for the newly proposed data science major.