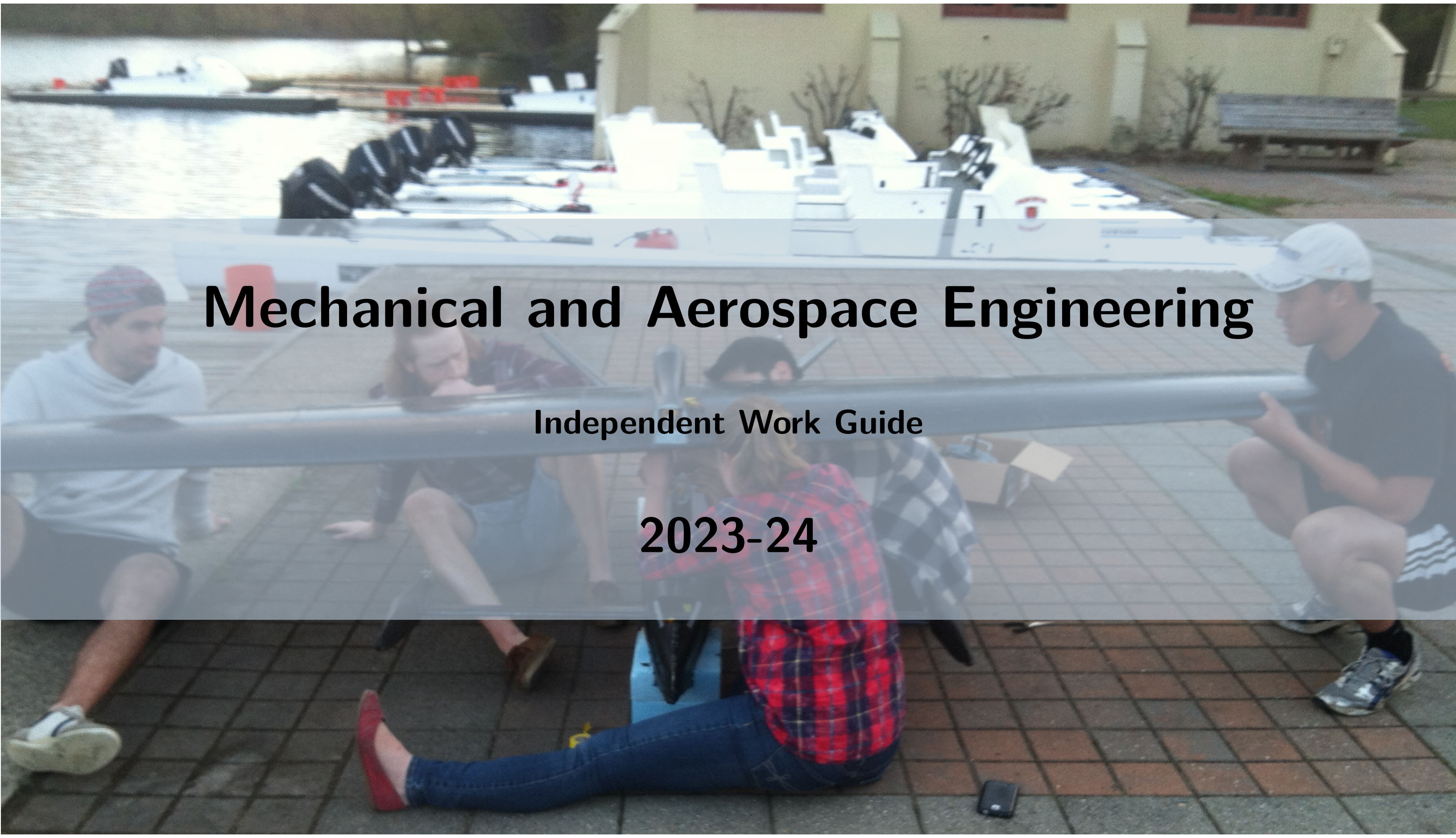

Mechanical and Aerospace Engineering

Independent Work Guide

2023-24

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I Description of the Independent Work Program

1. Independent Work in MAE

1.1 Portrait of the Discipline

Mechanical and aerospace engineering is concerned with the analysis, design, manufacturing, and control of machines components and complete systems that entail motion. It is perhaps the broadest of all engineering branches, is inherently multidisciplinary, and impacts every aspect of modern society: from all forms of transportation to space exploration; from harnessing renewable energy sources to robotics, manufacturing, and biomechanics.

Mechanical and aerospace engineers apply their skills in many different ways: from seeking fundamental advances through scientific research to designing, manufacturing and operating complex systems. Applied and Computational Mathematics, Mechanics (Classical, Continuum, Statistical and Quantum), Thermodynamics, Material Science and Control Theory provide the scientific foundation to the field.

Contemporary simulation based design and manufacturing as well as the fast paced development of cyber-physical systems whose operations are coordinated, monitored and controlled by a computing core, reinforce the nexus between mechanical and aerospace engineering and scientific computing.

1.1.1 Program Objectives for undergraduate studies in MAE

The stated objectives of the departmental undergraduate programs are:

- Obj 1 - Our graduates will think critically and creatively and excel in applying the fundamentals of mechanical (aerospace) engineering.
- Obj 2 - Our graduates will pursue a life of curiosity with a desire for learning and have the ability and self-confidence to adapt to rapid and major changes.
- Obj 3 - Our graduates will advance toward leadership in shaping the social, intellectual, business and technical worlds and by excelling in diverse careers.

The MAE department uses a hands-on approach to education, with extensive opportunities for laboratory and design work throughout the curriculum. The program is designed to prepare the graduate for an engineering career and give each student the ability to continue to grow professionally. The independent work is designed to support the overall objectives of the departmental undergraduate program. In particular it enables students to undertake realistic design projects, or to conduct challenging scientific research. Thus, the independent work program for MAE concentrators is an important complement to formal coursework and affords students the opportunity to collaborate closely with faculty, staff and graduate students while working on real engineering problems.

1.2 Independent work objectives

In broad terms, the MAE Independent Work program is designed to:

Goal 1	Challenge the student's ability of properly posing real-life engineering problems;
Goal 2	Challenge the student's ability to provide feasible solutions to open-ended problems throughout research and design;
Goal 3	Provide the students with an opportunity for the integration of multiple disciplines and for showcasing depth of technical knowledge in the chosen subject;
Goal 4	Provide a framework to acquire contemporary laboratory and computational skills;
Goal 5	Bridge the undergraduate education to professional practice.

We encourage juniors to use independent work to explore different facets of the field, and to acquire additional empirical and computational skills. For seniors, it is an opportunity to showcase their technical preparation throughout synthesis and research and it is the culminating experience of their undergraduate studies.

A minimum of one semester of independent work with an element of design must be completed in the senior year by all concentrators, and is a graduation requirement for both Mechanical and Aerospace programs. Seniors are encouraged to complete a yearlong project, either individually or as a part of a team; final reports of yearlong individual projects qualify as a Senior Thesis.

By successfully completing their project, MAE concentrators will have honed their ability to

- properly formulate, and solve complex engineering problems by applying foundational principles of engineering, science, and mathematics,
- apply engineering design to produce solutions that meet specified needs, respecting economic, environmental, and societal constraints,

- develop and conduct appropriate simulation and/or experimentation, analyze and interpret data, and use engineering judgment to draw conclusions,
- communicate effectively, in both written and oral form.

1.3 Evaluation

The grading process in place for independent work aims at ensuring equity of evaluation of the student work across the broad range of projects undertaken by MAE concentrators. Each written report is evaluated by the adviser and a second reader selected by the program coordinator. Written reports are graded on technical quality, quality of design, level of effort, creativity, scholarship, and writing quality. Advisers and readers may fill in the evaluation forms by logging in at mae-iw.princeton.edu.

The evaluation of a poster presentation is also factored in the determination of the final grade for all senior independent work; for yearlong project, the evaluation of the preliminary design review (PDR) that takes place at the end of the fall term is also compounded in the calculation of the final letter grade. The rubrics used by the faculty to evaluate these different components are presented next.

1.3.1 Senior Thesis and Independent Work Rubric

The adviser and reader are asked to evaluate the report based on the following rubric (1 is highest, 5 is lowest score), each entry is also used to assess ABET student outcomes, which are listed in Appendix A.

Originality and Creativity

In this report the student:

1. Identified and formulated the problem with exceptional originality, going well beyond the literature or the adviser in several areas.
2. Showed above average originality, demonstrating clear independence, novel thinking in the formulation of the problem.
3. Showed average creativity. It contained one or more good ideas that extended the current thinking.
4. Showed below average creativity. The formulation of the problem stayed within the bounds of current thinking from the literature or the advisor.
5. Showed poor or no originality. It was basically a repeat of other ideas or discussions without modifications.

Completeness (ABET c3: SO4)

This report:

1. Is a complete story and essentially publishable in its own right.
2. Shows above average completeness. It needs just one or two additional experiments or areas to be discussed to get it ready.
3. Shows average completeness. It contains many elements of a nice result or interesting idea/review but would need some additional material or someone to follow up to be complete.
4. Shows below average completeness. It is not complete enough to decide whether there is a result or not. It would need significant fleshing out.
5. Is obviously incomplete.

Technical Quality (ABET c3: SO1)

1. Was clearly superior, beautiful, clear-cut application of scientific and mathematical methods, equivalent to that of an excellent graduate student.
2. Was above average. It showed comprehensive mastery of the relevant technical material and few lapses or errors.
3. Was average, with only occasional problems in consistency or reproducibility.
4. Was often sloppy, uncontrolled, or unsubstantiated.
5. Was essentially without merit, not believable, or incorrect.

Analysis Approach (ABET c3: SO6)

This student:

1. Demonstrates a superior ability to collect, analyze, and interpret data to support scientific and engineering conclusions.
2. Indicates a good knowledge of data acquisition techniques and data analysis. The methodology selected is correct, and the analysis of the data supports the conclusions.
3. Indicates only an average analysis ability. There is a recognition of the need for data collection, but there is minimal supporting analysis.
4. Presents limited data with marginal to substandard supporting analysis.
5. Has essentially no data analysis and indicates absolutely no knowledge of design methodology and techniques.

Design Approach (ABET c3: SO2)

This report:

1. Indicates exceptional knowledge of design processes and synthetic thinking, supported by appropriate analysis and optimization; contains a validation of the design, which conforms to applicable industry standards.
2. Indicates a good knowledge of design and an ability of combining several fields. The project design element is significant and clearly stated, the methodology is correct, and the design is supported by some analysis, and appropriate schematics.
3. Indicates only an average design ability. The design element meets the requirements and shows a basic knowledge of design processes. There is minimal supporting analysis.
4. Has little design content with marginal to substandard supporting analysis.
5. Has essentially no design content and indicates absolutely no knowledge of design methodology and techniques.

Scholarship (ABET c3: SO7)

This report:

1. Is a model of impeccable scholarship, very carefully and thoroughly researched and referenced. The author has mastered all the issues and integrated them to make an original and complete intellectual contribution.
2. Shows above average scholarship. The author has mastered most of the material and has integrated it to make an original contribution. However, some subtleties, references or issues may have been missed.
3. Shows average scholarship. The author has made a competent review of the literature. However, the thesis does not go much beyond the existing material, or has left out important issues or references.
4. Shows below average scholarship. The author has mastered only a part of the relevant literature. Significant parts of the thesis are not supported by cited material. Important material has been neglected.
5. Shows poor scholarship. The author knows little or none of the relevant literature.

Writing Quality (ABET c3: SO3)

This report:

1. Is a pleasure to read. It is crisp, clear and concise. It needs no editing to be an excellent review.
2. Is easy to read, needs only minor editing to be a good review. I would give it to students but not a colleague.
3. Is well written, but would still need a fair amount of revision to be an excellent review.
4. Is poorly written. Significant portions are sloppy or unclear. There are many misspellings and grammatical errors.
5. Is very difficult to read. Most sections are unclear, ungrammatical and convoluted.

Level of Effort and Work Ethic (Adviser only)

This student:

1. Worked unusually hard, as much as a good graduate student, accomplishing significantly beyond expectations for the typical independent work project.
2. Worked more than the average student, well beyond the expected level, making substantial progress on her/his project.
3. Put in an average level of effort, accomplishing an acceptable amount level for his/her project.
4. Worked only sporadically on the his/her project or went for long stretches without appearing.
5. Worked rarely or not at all, accomplishing below the minimum expected of an independent work student.

Team Synergies (for group projects only) (ABET c3: SO5)

This student:

1. Excelled in teamwork, cooperation, and demonstrated the ability of setting the project priorities above their own work.
2. Participation was at the expected level, making substantial contribution to the team.
3. Put in an average level of effort in integrating their own tasks with the rest of the team.
4. Worked primarily on their own and went for long stretches without participating.
5. Worked rarely or not at all, accomplishing below the minimum expected and dragging the work for the rest of the team.

1.3.2 PDR evaluation

Faculty and staff present at a PDR presentation are requested to provide their opinion on the following points:

A - The student presented an established configuration, which include all functional components, and verification process.

B - The student presented a clear plan for the completion of the project, which include risk assessment, cost analysis, and a schedule.

C - The student has taken into consideration all relevant standards, and considered the broader impact of the engineering solutions adopted.

They are required to use a scale from 1 to 5 (1 indicating complete agreement with each statement); the form used to record the evaluation provides space for specific feedbacks.

1.3.3 Poster Session evaluation

Faculty and staff participating to the presentations are requested to provide their opinion on the following points:

A - Factual/Conceptual Knowledge:

- 1 - Excellent. This student demonstrated mastery of the larger area of their topic.
- 2 - Above average. The student mastered both the basis of the project as well as areas directly related to it including a thorough review of related work.
- 3 - Average. The student has mastered the basic facts and concepts for the project, showing knowledge of the facts or concepts that are direct extensions of the independent work. There was good evidence of background research.
- 4 - Below average. The student did not know or understand some of the basic material for the project.
- 5 - Poor. The student exhibited serious deficits in understanding/knowledge of the basis of the project.

B - Technical Quality of Work: The experimental/design/analytical work by this student was:

- 1 - Excellent. It was beautiful, clear-cut, and well-controlled, equivalent to an excellent graduate students.
- 2 - Above average, equivalent to some of the best students.
- 3 - Average, with occasional problems in consistency, or reproducibility.
- 4 - Below Average. It was often sloppy, uncontrolled, or unsubstantiated.
- 5 - Poor. It was essentially without merit, not believable, or incorrect.

C - Interest Enthusiasm and Quality of Presentation:

- 1 - Excellent. The presentation was clear and concise, was superbly organized, with informative and well supported charts.
- 2 - Above Average. The presentation was easy to follow and informative.
- 3 - Average. It needed only minor revisions. It could be better organized or include more supporting information.
- 4 - Below Average. The presentation was poorly organized or hard to follow. The student would have benefited from editing.
- 5 - Poor. The presentation was unacceptable. It was unorganized, unclear, and poorly delivered.

D - Quality of the Responses to Questions:

1 - Excellent. Responses were thoughtful, un-rushed, and well delivered. The student was well prepared and answered carefully and correctly.

2 - Above Average. There were only minor lapses in responses.

3 - Average. The student waited for the question but often rushed the response, didn't answer the question asked, or wasn't able to extend their thinking beyond their work.

4 - Below Average. The student rushed to respond, didn't answer the question asked, or was unable to formulate a clear and cogent answer.

5 - Poor. The student was unable to answer questions, didn't wait to listen to the questions, or was unclear or incorrect in all responses.

In addition, the evaluator has the option to nominate the project for one of the departmental prizes.

1.3.4 Letter grade

The final letter grade for Senior Independent Work and thesis is assigned by the faculty in charge of the program by compounding the evaluations of the adviser, reader, poster session, and of the PDR (for yearlong projects).

In compounding the evaluation of the final reports of thesis the weights summarized in the following table are applied to each entry of the rubric described in Section 1.3.1: The

Criterion	Weight
Technical Quality	1/4
Design	1/4
Level of Effort	1/4
Others (30% Writing, 30% Scholarship, 20% Creativity, 20% Completeness)	1/4

Table 1.1: Weights applied to the evaluation of final reports

evaluations of the written report by the adviser and reader carry the most weight. For one-semester projects 80 % of the final grade is determined from the evaluation of the written work by the adviser (60%) and the reader (20%). For yearlong projects 65% of the final grade stems from the evaluation of the written work by the adviser (50%) and the reader (15%), while 15% of the final grade reflects the evaluation of the Preliminary Design Review (PDR). The remaining 20% of the final letter grade is assigned based on the feedback from attendees of the poster session, for both one term or yearlong projects.

Junior Independent Work

An evaluation process similar to the one described for seniors is implemented for junior independent work. The relevant rubrics and weights are made available electronically to the faculty advisers, readers and students.

Final Grade

For both Junior and Senior Independent Work, an A range grade is awarded for superior work that displays high degree of mastery of the technical subject, and, when required, a well defined and developed design component. In an A range study, all models used are adequate, all approximations are justified, all numerical calculations are correct, and an error analysis is carried out on the experimental data collected. The design process is started from a set of clearly stated requirements, a few variants are considered, and a final verification of the chosen design is carried out. In addition, an A range grade is a reflection of consistent work throughout the term(s), and the compilation of a concise, yet complete and informative final report/thesis.

1.4 Timeline

Date	Deadline
September 8	Mandatory Meeting Senior Class
September 22	Fall proposals due
September 28	Marshall & McKinzie fall funding proposals
December 7	Senior Independent Work Written Report due (MAE 439)
December 11, 12 & 13	Preliminary Design Review Sessions
December 13	Poster Session for fall semester only projects (MAE 439)
January 16	Jr. IW written report due (MAE 339, 339D)
TBD	Mandatory Meeting IW/Thesis
February 9	Spring proposals due February
February 22	Marshall & McKinzie spring funding proposals due
April 24	Senior Independent Work Written Report due (MAE 440, 442 & 444)
April 29	University deadline for Senior Thesis
Aprir 30	Jr. IW written reports due (MAE 340 & 340D)
May 1	Poster Session (MAE 440, 442 & 444) (posters not required for Jr. IW)
May 6	Oral Presentations for Senior Class Awards

NB The dates in red are University deadlines. Absolutely no extensions may be granted beyond these dates without the approval of the student's Residential College Dean or the Dean of the College.

1.5 Process

At the beginning of each term, a memo detailing the independent work program and containing all the relevant deadlines is posted on the MAE Independent Work Canvas site. Additionally, the faculty coordinator holds a mandatory meeting with the students to explain the program and answer questions students may have. Students are required to read this guide before the meeting so that they can prepare any additional questions they may have about the program.

1.5.1 Selecting a Topic

"Independence" has been the mantra of the IW in MAE for at least the past four decades. Prof. Enoch Durbin, who shaped and coordinated the program in the 1980's, used to spur the seniors to develop and work on their own ideas, rather than "carry out what your adviser tells you to do". Today, we offer our students several avenues to choose independent work projects: student initiated, faculty inspired research, projects responding to societal needs, and competitions. Hence, students have ample flexibility in choosing a topic, with the only caveat that projects must have a clearly defined mechanical or aerospace engineering content and, when applicable, a specific design component.

Engineering Design

is the creative process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which basic scientific knowledge and mathematics are applied to meet, optimally, a stated objective. Core elements of design are a clear statement of objectives and criteria, synthesis, analysis, realization (construction), testing and evaluation.

Most students have historically developed their projects in conjunction with faculty inspired research, or student initiated ideas. Nevertheless, MAE has an excellent history of participation in national design competitions organized by the professional societies. Group projects are encouraged when the scope of the work is broad enough.

None of the paths available to select a topic is superior as the student will not be evaluated on the topic, but only on the quality of the work performed. However, faculty inspired research projects provide, generally, a more structured framework. No matter what path was chosen, the student must secure a faculty member to serve as an adviser for the project. The program coordinator is the primary resource to helping student in the task of selecting a suitable adviser, but it is the student's responsibility to recruit a faculty member willing to take on the project, before submitting an independent work proposal.

Student Initiated Work

Some students may already have ideas or inventions they wish to pursue. These may be ideas for innovation that the student brought to Princeton, ideas that emerged out of the sophomore or junior lab work, or out of previous research or life experience. The only restriction placed on topics is that it must have a clearly defined mechanical or aerospace engineering content and that the students are able to find a faculty member willing to advise. In past years, there have been many novel and challenging projects of this kind; students interested in pursuing their own ideas are encouraged to review past reports and hold preliminary discussions with the faculty, to develop a feasible proposal. The program coordinator is also available to guide students through this process.

Faculty Inspired Research

The faculty members of the Department have a myriad of interests and research opportunities. This is an excellent way to participate in an exciting project and learn what academic research is like. The faculty members are always thrilled to discuss their research interests with students. A list of faculty interests and sample projects are on the Canvas web site. Students are encouraged to contact faculty in areas of interest and discuss with them the availability of suitable projects. Most students have historically selected their projects this way.

Competitions

There exists numerous student competitions sponsored by professional organizations around the country, which may be of interest to MAE concentrators. The department has an excellent history of supporting student participation in these competitions with many successes. Limited funding may be made available to send successful projects to the national competition in the Spring or Summer. Most competitions involve teams of 3 or 4 students, as the amount of work required is extensive. Many competitions have monetary prizes for the winner.

Students interested in this type of projects are encouraged to explore the web to discover what opportunities are available. For instance, ASME and AIAA have websites devoted to listing various national competitions. The MAE undergraduate administrator emails junior and senior classes the announcements of major competitions as they are received.

NB While these projects can be great fun and rewarding, they are very competitive and often involve a tremendous amount of work. Additionally, the competition deadlines are seldom in sync with the academic calendar; there are multiple deadlines and they approach quickly!

Projects of Benefit to Society

Projects of this kind check are offered throughout individual faculty; the Program for Community-engaged Scholarship ProCES ; and the Office of Sustainability (Campus as Lab).

1.5.2 Proposals

The proposal is due by the third week of the term. It must be signed by the faculty adviser before being submitted. The adviser approval can also be sent directly to the faculty coordinator and Theresa Russo using this google form. The proposal should be a short, one or two-page work plan explaining the objectives of the project and must include a tentative plan/schedule indicating the feasibility of the project. It must be sufficiently detailed to allow the program coordinator to determine whether the project is adequate in scope and content, and it is feasible within the academic term(s). A proposed schedule of student/adviser meetings may also be included.

The proposal should include the title of the project, name and class of the student, the course name and number, and the date. It is particularly important to indicate if the student is enrolled in the one term independent work courses or whether is planning a full year project. It should also specify the adviser for the project; a second reader will be assigned by the coordinator toward the end of the term. Note that it is allowable to select advisers outside the MAE department as long as your proposed work includes adequate mechanical or aerospace content.

The body of the proposal should clearly and concisely describe the project, and be specific about the scope of the proposed work. An Executive Summary format is highly recommended for the body of your proposal. The amount of background material should be limited only to what is pertinent to the proposed project. If the work requires making purchases of material and parts, an estimated budget must be included.

1.5.3 Action Items - Juniors

Students planning on completing junior independent work should be enrolled in one of the following courses:

- MAE 339 Independent Work or MAE 339D Independent Work with Design (Fall)
- MAE 340 Independent Work or MAE 340D Independent Work with Design (Spring)

NB These courses do not satisfy the departments Independent Work/Senior Thesis/Senior Project requirement.

Each of these courses will have the following requirements:

- a proposal approved by the adviser, and
- a written report to the adviser and reader and an electronic copy to the Undergraduate Office (Theresa Russo) at the end of the term.

Although you have enrolled in one of two class sessions, there will not be a required bi-weekly class. Rather, there may be meetings scheduled if needed.

NB For juniors and sophomores: If you wish to extend your one semester Independent Work project (MAE 339/339D) from fall into spring, you should enroll in MAE 340/340D in the Spring. Since these are separate courses, you will need to prepare and submit a written report for each term. You will receive a final grade for the Fall semester and a final grade for the Spring semester. It is perfectly acceptable to structure the first report as a progress report. For instance, an analysis of the scientific literature relevant to your overall project, the initial design of your experiment or gadget, may be included in the first report together with your plans for future work, even without having obtained any concrete results yet.

1.5.4 Action Items - Seniors

Students planning on doing only one term of independent work should enroll in one of the following courses:

- MAE 439 Independent Work (Fall)
- MAE 440 Independent Work (Spring)

Each of these courses will have the following requirements:

- a proposal approved by a faculty adviser,
- a written report to the adviser and reader and a copy to the Undergraduate Office (Theresa Russo) at the end of the term,
- a poster presentation to the faculty at the end of the term.

These courses are open to seniors only and should be used exclusively for one semester of independent work.

NB Note that some seniors will enroll in 439 in the fall with the intent of doing only a single semester project. However, they may find that the scope is more than expected and they want to extend it to a full year. In that event, it is possible to drop 439 (within the drop period), complete the PDR, and enroll in the spring in one of the full year courses either 442 or 444.

Senior planning on doing a full year thesis or project will not enroll in a course in the Fall and are allowed to take 3 courses.

NB If you are a senior enrolled in three courses only in the Fall semester you must enroll in a year-long senior thesis or senior project course in Spring semester. You will not be allowed to drop down to a one semester project in Spring without incurring a failure for the Fall semester. In other words, you are committed. In Spring you must enroll in three courses plus Senior Thesis or Senior Project (which count as two courses). Therefore your senior year course load will be 3 in the Fall, 5 in the Spring as opposed to 4 in the Fall and 4 in and Spring. **For seniors that opt for 3 courses only in the fall: there are NO exceptions to this rule even if your total number of courses will exceed 36**.

In the Spring seniors completing a full year of IW/Thesis must enroll in one of the following courses:

- MAE 442 Senior Thesis (individual effort)
- MAE 444 Senior Project (team or group effort)

Each of these courses will have the following requirements:

- a proposal approved by your adviser due in the Fall,
- a preliminary design review (PDR) presentation to the faculty in December,
- a final written report to your adviser and reader and a copy uploaded to Thesis Central at the end of Spring term, and
- a poster presentation at the end of Spring term.

Group projects are encouraged when the scope of work is broad enough. This is particularly true of the many student design competitions available. Students interested in doing a team project should enroll in Senior Project in the Spring. Team efforts may be graded either individually, with separate reports on independent aspects of the project from each member, or collectively, with one group report and a single grade assigned to each member. To avoid confusion, students must decide early in the term in consultation with their adviser and their teammate on how the group wishes to be graded.

Only single authorship may qualify as a Senior Thesis, which is normally completed at the end of individual projects. One term independent work may be done either individually or in teams.

NB Although you have enrolled in one of two class sessions, there will not be a required bi-weekly class. Rather, there will be meetings scheduled if needed.

1.6 Advising

A faculty member must serve as project adviser, and it is up to the students, in consultation with the faculty coordinating the independent work courses, to enlist a faculty member as a project adviser before submitting for approval an independent work proposal. Any member of the Princeton faculty may serve as principal adviser.

The Canvas site contains a list of research interests of the MAE faculty, which is updated yearly; but the faculty may have newer ideas in mind, that have not made it on the Canvas site. Hence, MAE concentrators are encouraged to approach faculty members (via email, or after a class) and set up an appointment to discuss their interests on a particular topic. It is extremely important to start this process early, so that the selection of a project is timely and informed.

NB Rising seniors, should be thinking about what they might want to pursue and who would be a good adviser for their project in the spring of junior year. They should feel free to contact as many professors as needed to explore any and all areas of interest; the doors of the faculty offices are always open to discuss exciting projects they wish to share with undergraduates, whether or not they have listed some in the handout.

NB Students planing to complete one-term of IW in the Spring semester, should secure a faculty adviser by Dean's date of the preceding Fall term.

Once a faculty member has agreed to advise your project they will need to fill out this google form.

Faculty have their individual advising style. Some requires regular advising meeting, others will make time available upon request. In both cases students should be proactive in reaching out and ask their adviser how often they would like to meet and how best to get in touch throughout the completion of the project.

One member of the MAE technical staff will also be assigned to those projects that do not leverage faculty research facilities to facilitate the allocation of work space and provide technical support for the project.

The program coordinator organizes a mandatory meeting at the beginning of each term, and remains available through the academic year for consultation and general advising on the IW program.

1.7 Structure and Style of the reports

This section summarizes the principal elements of style and structure for all Independent Work reports. All reports should be typed and adhere to a common format outlined below. Each report is expected to be neat, clear and professional in appearance and style. Additional information is available on the Canvas site which also provides a LaTex template for the final report and a powerpoint template for the poster.

1.7.1 Preliminary Design Review

All seniors who are completing a year-long Senior Thesis (MAE 442) or year-long Senior Project (MAE 444) must prepare a 15 minute presentation for the Preliminary Design Review; students in a group will present together. The presentations will take place on December 11, 12, 13, 2023. Students are only required to attend their assigned session, but are welcome to stay for as many presentations as they wish. The PDR is also an opportunity for the faculty to provide early feedbacks. The advisers are required to attend their student presentations, and invited to participate and evaluate other projects in their area of interest and expertise.

The purpose of a Preliminary Design Review (PDR) is to assess the level of maturity of **the design component of a project** , and its readiness to progress forward. Upon successfully passing a PDR, the students will have:

a) Created an established configuration baseline of the design containing all items making up the system, which include all functional components, and the required verification to demonstrate the achievement of stated performance.
b) Taken into account all relevant industry standards, when applicable.
c) Provided an updated risk assessment for the realization phase.
d) Provided an updated cost analysis when appropriate.
e) Developed an updated schedule and milestones for completion.

NB The 15 min presentation should address all four elements, students should refrain to present other aspects of project. Focus is on the design component only!

1.7.2 Final report - Thesis

The purpose of technical reports is to present the results of fundamental or applied research and support decision-making based on said results; it must include all information needed for interpreting, applying, and replicating the results or techniques of an investigation. Although there is not a generally accepted standard for producing technical reports, the ANSI/NISO 239.18-2005, Scientific and Technical Reports - Preparation, Presentation, and Preservation, published by the National Information Standards Organization (NISO) can be used as a guideline.

The ANSI/NISO 239.18-2005 is intentionally brief and general in nature; therefore, it does not address the specific requirements of all scientific and technical reports. There are two prevailing styles currently in use, which require either a content-based or a reader-centric organization of the subject. Both styles are acceptable, but the following content-based organization is best suited for most projects.

Technical and Scientific Reporting: content-based organization

- Front matter
  i) Title page
  ii) Table of Contents (includes list of the subject of the Appendix)
  iii) List of Illustrations/Figures/Tables
  iv) List of Symbols (and acronyms if used extensively)
  v) Abstract or Executive Summary.
- Body of the report
  i) Problem/background
  ii) Methodology
  iii) Results
  iv) Discussion Conclusion/Summary/Recommendations
- Back matter
  i) References
  ii) Index
  iii) Appendix material

All senior projects need to include a design component, which must be reported (even in a content based technical report) using the following structure.

Problem Definition

This section deals with the scope of the design including a short paragraph explicitly stating the problem to be solved. A technical review of the problem may be included before stating the most important part of a design project, that is the **design requirements**.

NB Without requirements there is no design!

Design Description

This section describes the solution proposed and how it works. The design needs to be summarized at a high level, but a complete description of the final product, including how to use it needs to be included.

Evaluation

This section describes the verification of the design. The evaluation may be carried out throughout experimental testing of a physical prototype, throughout testing of a virtual prototype (computer model and simulation) or by analysis.

The design component may be inserted as a chapter in the body of the report (methodology) or as an Appendix, depending on the content of the design.

NB All figures and tables included in the report should be referenced in the text; they should convey important information and not be just page-fillers. All Engineering drawing should conform to ANSI/ISO standards.

1.7.3 Design Report

For projects that are purely design based, the final report should be structured as follows:

Design Report: content-based organization

- Front matter
  i) Title page
  ii) Table of Contents (includes list of appendix materials)
  iii) List of Illustrations/Figures
  iv) Abstract or Executive Summary.
- Body of report
  i) Problem Definition
  ii) Design Description
  iii) Design Evaluation
- Back matter
  i) References
  ii) Index
  iii) Appendix materials (explanation of the design process - a novel computer code developed to enable the design - etc.)

Problem Definition

This section deals with the scope of the design including a short paragraph explicitly stating the problem to be solved. A technical review of the problem may be included before stating the most important part of a design project, that is the **design requirements**.

NB Without requirements there is no design!

Design Description

This section describes the solution proposed and how it works. The design needs to be summarized at a high level, but a complete description of the final product, including how to use it needs to be included.

Evaluation

This section describes the verification of the design. The evaluation may be carried out throughout experimental testing of a physical prototype, throughout testing of a virtual prototype (computer model and simulation) or by analysis. Elements to be included are

- Description of the prototype
- Testing and Results
- Assessment (brutally honest)
- Recommendations

The suggested structure for a design report is consistent with the one required by US Patent office. (Background of the Invention, Brief Summary of the Invention, Brief Description of the Several Views of the Drawing, Detailed Description of the Invention)

1.8 Funding

The MAE department has made available $200 for each student per semester to spend on independent work. Thus, a group of 4 will have $800 available for the semester. Note that there are two restrictions on spending this money:

1. The department will not pay for any travel expenses, regardless of distance.
2. Students are responsible for all materials & services relating to production of their report (we do not require binding and will not pay for binding). Posters can be printed for free at the Engineering Library.

These independent work funds may be used to cover computing charges.

For projects requiring funds above the departmental allotment, there are other sources available. For projects in established research programs, the faculty may choose to support the work through their own funding. The Department also offers the John Marshall II Memorial Prize fund and the McKinzie prize fund in the fall and spring. The award provides financial support for senior independent work only. Allocation of these funds is competitive, and students are required to submit an application following the deadlines announced early in the fall term. Supplemental funding will be considered upon request.

There are also a variety of other funds available both within and outside the Department (these are generally available to both seniors and juniors). For example, in the past, the Princeton Environmental Institute has offered thesis support and the School of Engineering through Dean Boguckis office and the Keller Center.

NB Each source of funding has a set of rules of allowable expenditures. The John Marshall II Memorial Prize and the McKinzie funds cannot be used for capital equipment, computer charges, and travel.

1.9 Additional Resources

There are several resources available in MAE to support independent work projects. Rooms C131 and a portion of J209 have been outfitted as an undergraduate design center and independent work lab. They are equipped with workstations, PCs, audio visual capability, and lab benches. Most software packages needed are installed (Matlab, Pro-E, Lab View, etc) Students are expected to use these facilities for lab work unless they have made other arrangements with the adviser. The other undergraduate lab facilities are not available for independent work unless an explicit permission from the responsible faculty or staff (Prof. Littman, Prof. Martinelli, Mike Vocaturo, Glenn Northey, or Jon Prevost) is granted.

MAE also maintains one license of ANSYS and several licenses of NX/NASTRAN to support independent projects that may require industrial strength simulation software. Access to these shared resources can be obtained by contacting the program coordinator.

One professional technical staff member is assigned to each project. He will be the primary point of contact for technical issues relating to equipment, testing etc. Students working in a faculty members research laboratory will follow the all established protocols and will be supported by personnel in the research lab.

The Engineering Library, and the The Princeton Writing Center are additional institutional resources supporting undergraduate research and Senior Thesis.

1.10 Other Information and Materials

MAE maintains and regularly updates a Canvas site dedicated to independent work. Students enrolled in the program have automatic access to the site. Faculty access to the site is granted upon request. The site contains updated information on relevant regulations that may impact planing and realization of a project such as the use of common space in Equad for testing, policies and regulations regarding the operation of Unmanned Aerial Vehicles (UAVs), etc.

1.10.1 Safety Training

Princeton University and the School of Engineering and Applied Science place great importance on protecting the safety of their students, faculty and staff. It is key to our safety mission that anyone who engages in experimental work is provided with professional training in safe working practices and procedures. We take safety VERY seriously, in order to be authorized to conduct research and/or work in the laboratories, MAE concentrators need to complete Mandatory Laboratory Safety Training.

The Laboratory Safety Training Course is composed of both on-line components and instructor-led session which are both accessible through the Employee Learning Center.

II Appendices

A. ABET Students Outcomes

The outcomes of both mechanical and aerospace programs offered in the MAE department align with the ABET Criterion 3 students outcomes, which prepares graduates to enter the professional practice of engineering. These are:

- SO1 an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics;
- SO2 an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors;
- SO3 an ability to communicate effectively with a range of audiences;
- SO4 an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions;
- SO5 an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives;
- SO6 an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions;
- SO7 an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.