PennState College of Engineering | AEROSPACE ENGINEERING

Guide to Graduate Studies

2024-2025

Department of Aerospace Engineering
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Preface

This Guide to Graduate Studies provides information about the graduate degree program in the Penn State Aerospace Engineering Department. It is intended to serve as an introduction to the program for new graduate students and as a reference resource for continuing graduate students, faculty, and staff of the department. It is designed to supplement the Graduate Degree Programs Bulletin (henceforth referred to as "the Bulletin"), issued by the Penn State Graduate School, which is the primary reference document for graduate study at Penn State. Inquiries about the Bulletin and its contents should be addressed to:

The Graduate School
114 Kern Graduate Building
University Park, PA 16802
Phone: 814-865-1795
Fax: 814-863-4627
Email: gswww@psu.edu
http://www.gradschool.psu.edu/

A brief overview of Penn State, the Graduate School, the College of Engineering, and the Department of Aerospace Engineering is provided in the Introduction.

The Aerospace Graduate Program and Academic Requirements and Guidelines are next discussed in Sections II and III, respectively. Section IV presents the faculty and laboratory staff of the department. Any questions regarding the Aerospace Graduate Program should be addressed to:

Harry Bozas
Graduate Program Coordinator
Department of Aerospace Engineering
308M ECoRE
University Park, PA 16802
Fax: 814-865-7092
Email: hqb5322@psu.edu
http://www.aero.psu.edu/

Additional sources of useful information for graduate students may be obtained by contacting:

The University Office of Global Programs
410 Boucke Building
University Park, PA 16802
Phone: 814-865-6348
Fax: 814-865-6480
Email: DISSA-Adviser@psu.edu
https://global.psu.edu/

The Office of Off-Campus Living
230 HUB-Robeson Center
University Park, PA 16802
Phone: 814-865-2346
Fax: 814-863-0812
Email: OffCampus@psu.edu
http://studentaffairs.psu.edu/offcampus/

Student Health Insurance
302 Student Health Center
University Park, PA 16802
Phone: 814-865-7467
Fax: 814-863-1390
Email: uhs-insurance@psu.edu
http://studentaffairs.psu.edu/health/
mailto:studentinsurance@sa.psu.edu

The Office for Disability Services
116 Boucke Building
University Park, PA 16802
Phone: 814-863-1807
Fax: 814-863-3217
http://equity.psu.edu/ods

To the incoming graduate students of the department, I welcome you all on behalf of the Department of Aerospace Engineering and wish you success in your studies.

Joseph Horn
Professor and Director of Graduate Studies
Email: jfh19@psu.edu

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1. Introduction

1.1. The Department of Aerospace Engineering

The department (http://www.aero.psu.edu/) provides undergraduate and graduate educational programs in all the major disciplines of aerospace sciences. It promotes and supports vigorous research by its faculty members with assistance from graduate students and maintains various experimental and computational research facilities.

It is administered by the Department Head (Dr. Amy R. Pritchett), Administrative Assistant (Ms. Lindsay Moist), clerical staff, and faculty directors of undergraduate and graduate program and admission. The Director of Graduate Program (Dr. Joseph Horn) is responsible for the admission of new graduate students into the graduate program, the graduate courses, and Doctoral Qualifying Examination. He is assisted by the Graduate Program Coordinator (Mr. Harry Bozas).

1.2. The College of Engineering

Aerospace Engineering is a department within the College of Engineering (http://www.engr.psu.edu/), which is also home for 12 other departments and a number of specialty programs and research units. The Associate Dean for Graduate Studies and Research provides a liaison between the graduate programs within the College and the Graduate School and external research sponsoring organizations. Several College of Engineering Fellowships are also administered from the Dean's Office.

1.3. The University and Graduate School

The Pennsylvania State University (http://www.psu.edu/) is a land grant university serving the Commonwealth of Pennsylvania from a number of campuses located throughout the state. The central campus, located at University Park, offers undergraduate and graduate education and research through its Colleges of Agricultural Sciences, Arts and Architecture, Business, Communications, Earth and Mineral Sciences, Education, Engineering, Health and Human Development, Information Sciences and Technology, Liberal Arts, and Science.

The Graduate School (http://www.gradschool.psu.edu/) administers for the University all graduate programs in the various colleges and schools. Among other functions, it provides a common admission process for all graduate programs and administers University-level graduate fellowship programs.

2. The Aerospace Engineering Graduate Program

The department provides coursework and research projects in the following areas of emphasis: aeroacoustics, aerospace autonomy and robotics, analytical/computational fluid dynamics, experimental fluid dynamics, flight science and vehicle dynamics, dynamics and control, rotorcraft engineering, structural dynamics/structures and materials, space propulsion, and aircraft propulsion. Graduate students may combine any number of these in a program leading to the M.Eng., M.S. or Ph.D. degrees.

2.1. Supervision and Advising

Students are under the general supervision of their advisors. Consultation or arrangement of the details of the student's semester-by-semester schedule is the function of the academic adviser. The academic adviser may be a member of the doctoral committee or may be another member of the Graduate Faculty designated by the program head or chair of the major program for this specific duty. The academic adviser may be different than the major adviser who supervises the dissertation. All coursework for which the student registers for credit must be approved by the advisor on the Graduate Degree Program Plan Approval form.

The policy for assignment of advisors is as follows:

- Each new student is assigned an advisor prior to arrival.
- If a student is supported by monies from external research support (typically provided by sponsored research contracts), then his/her advisor is ni tended to be permanent (i.e., advisors for Research Assistants and Research Aides are permanent, requiring special exemptions by the Director of Graduate Programs to change, upon confirmation that contractual obligations have been respected by the student’s paid activities to date and that a plan is in place for the advisory and department to continue to meet contractual requirements).
- If a student is supported by non-research monies, i.e., departmental funds or any type of self-support such as private funds or fellowships, then he/she can change advisors, preferably within their first semester in the graduate program, with notification to the past advisor and concurrence of the new advisor in writing to the Graduate Program Coordinator.

2.2. Credit Loads and Academic Status

Graduate Assistants: Graduate assistants must be enrolled at Penn State as graduate students. More specifically, since assistantships are provided as aids to completion of advanced degrees, assistants must be degree-seeking and enrolled in residence for credit loads each semester that fall within the limits indicated in the table below. Maximum limits on permissible credit loads are indicated in order

to assure that the student can give appropriate attention both to academic progress and assistantship responsibilities.

Assistantship level	Credits per semester	Credits per 6-week summer session
	Minimum/maximum	Minimum/maximum
Quarter time	9/14	5/7
Half time	9/12	4/6
Three-quarter time	6/8	3/4

*Credits taken during the Maymester and over both six-week summer sessions must total a minimum of 9 (for 1/4- and 1/2-time assistantships) or 6 (for 3/4-time assistantships) and cannot exceed a maximum of 8 (for 3/4-time assistantships), 12 (for 1/2-time assistantships), or 14 (for 1/4-time assistantships).

To provide for some flexibility, moderate exceptions to the specified limits may be made in certain cases. The credit limits specified above may only be increased or decreased in exceptional cases for a specific semester or summer session by permission of the assistantship supervisor, the student's academic adviser, and the dean of the Graduate School (requests should be submitted for the dean's approval via the Office of Graduate Enrollment Services). The Graduate School expects that an exception made in one semester or summer session will be compensated for by a suitably modified credit load in the subsequent semester or summer session so that, on the average, normal progress is maintained at a rate falling within the limits above. Failure to do so may jeopardize the student's academic status. Maintenance of the established credit loads and responsibility for consequences of a graduate student's change of course load rest with the student and adviser. The course load is a factor in determining whether a graduate student is classified as a full-time or part-time student; has met residence requirements; and is eligible to hold a fellowship, traineeship, assistantship, or departmental or program appointment.

Full-Time Academic Status: Self-supported or fellowship students who register for at least 9 credits are considered engaged in full-time academic work for that semester. If such a student wishes to register for more than allowable maximum credits, an exception to the normal maximum load must be granted through petition (with advisor’s approval) to the Office of Graduate Enrollment Services.

Students holding fellowships, traineeships, or other awards that require full-time summer registration must register for a minimum cumulative total of 9 credits (over all summer sessions), or AERSP 601 (in the case of post-comprehensive doctoral candidates). A graduate assistant whose semester or summer session credit load meets or exceeds the minima in the above credit table and whose assistantship duties are directly related to his or her degree objectives is considered by the

Graduate School to be engaged in full-time academic work for that semester or summer. A post-comprehensive doctoral candidate who is registered for AERSP 601 also is so considered.

Part-Time Academic Status: A student who in any semester or summer session is registered for study but who does not meet the criteria for full-time status is considered engaged in part-time academic work for that semester. This includes students registered for AERSP 601.

Credit Loads for International Students: The Department of Homeland Security requires that international students proceed in a timely fashion toward completion of their degrees, as established by the academic department and (usually) stated on their initial immigration document. Failure to maintain normal progress toward completion of the degree during this period will jeopardize the student's ability to continue academic study, adjust status, or seek future employment in the United States. Because of this, students should not be enrolled less than full-time during fall or spring semester without prior approval of the University Office of Global Programs Directorate of International Student & Scholar Advising (DISSA).

The U.S. Department of Homeland Security requires the DISSA to report violations of status, including failure to maintain full-time enrollment. The following is intended to provide guidance for international graduate students and for DISSA in determining full-time status: A graduate student is considered full-time if registered for a minimum of 9 credits, excluding courses taken for audit, or if a Ph.D. candidate who has successfully completed the comprehensive examination and is registered for AERSP 601.

- On rare occasions, and under exceptional circumstances, international students in master's degree programs who have completed all required course work and, if applicable, research for their degree, may be granted an exception to the need to maintain full-time status as defined above, for a limited period (in no case to exceed two semesters), by special petition to DISSA in advance of the semester in which the exception is needed. This request must be initiated by the student using the DISSA e-Form system. The academic adviser will be asked through this e-Form system to justify the reduced course load.
- Under all circumstances, international students must be enrolled--either full-time or approved by DISSA for a reduced course load.

3. Academic Requirements

The minimum grade-point average for completion of all graduate degrees is 3.0. There are requirements common to all degrees and requirements specific to degrees.

3.1. Common Requirements

3.1.1. Scholarship and Research Integrity: SARI@PSU

SARI@PSU is a responsible conduct of research (RCR) education program for students, postdocs, and faculty at Penn State. SARI (Scholarship and Research Integrity) is designed to create awareness of ethical principles and established professional norms in the performance of all activities related to scholarship and research. Ultimately, our goal is to further foster trust among scientists and to increase the public's support for research.

There are two parts to SARI@PSU for graduate students: Part 1- an online course offered through the Collaborative Institutional Training Initiative (CITI) and Part 2- five hours of discussion-based activities. Each graduate department or program has a specific SARI@PSU plan.

Satisfying the Part 1 Requirement: The CITI Program at Penn State website provides more information about the program, including instructions, FAQs, and access to the Responsible Conduct of Research (RCR) online training that is used to satisfy the Part 1 requirement.

Satisfying the Part 2 Requirement: Five (5) hours of activity is required. Students may attend up to two (2) workshops sponsored by the Office for Research Protections (ORP), see the SARI Workshop Schedule for upcoming events. For aerospace engineering students, at least one (1) workshop attended must be conducted by the Department.

Submit the SARI@PSU checklist with all attachments only when fully completed and a minimum of four weeks before graduation. Failure to complete these requirements on time may delay your graduation.

3.1.2. Core Course Requirements

All graduate students must satisfy the core course requirements. These are listed in Appendix 1. In cases where there is a compelling reason for a student to take another AERSP 5xx course that clearly aligns within discipline, students and their advisors are urged to consult with the Graduate Program Director to petition to substitute a different course from the listed classes within that discipline. Such petitions should articulate the compelling reason for the substitution and describe their current and past course work relative to demonstrating knowledge of fundamentals of the discipline. Petitions must be made before the student takes the course and will need approval of the Graduate Program Director. The Graduate

Program Director will decide on the petition after consulting student's academic advisor and discipline faculty members.

3.2. Master of Engineering

The M.Eng. is a non-thesis professional master's degree. An intensive one-year, 32-credit program, the M.Eng. requires completion of a capstone experience. This is an ideal program for an engineer with a bachelor's degree who wishes to expand his or her set of career possibilities in aerospace-related fields.

Because this program is focused on an intensive set of courses, without an in-depth research component, assistantships (research or teaching) are not normally provided for students working towards an M.Eng. degree.

Degree specific requirements:

A total of at least 32 credits with the following restrictions:

- A maximum of nine credits at 400-level
- A minimum of 21 credits at or above the 500-level
- A minimum of 18 credits of aerospace courses (600-level courses do not count)
- Completion of Core Course Requirements (see Appendix 1)
- Two credits of AERSP 590
- Satisfactory completion of a capstone course or project (for 3 credits of EDSGN 558 or another graduate systems or vehicle design course). AERSP 596, independent study under the supervision of a faculty member, may be used to fulfil this requirement with prior approval of the Graduate Program Director.

TIME LIMITATION: All requirements for a master's degree (including acceptance of a thesis, paper or project report as may be specified), whether satisfied on the University Park campus or elsewhere, must be met within eight years of admission to degree status. Individual programs may set shorter time limits. Extensions may be granted by the Director of Graduate Enrollment Services in appropriate circumstances. (http://www.bulletins.psu.edu/graduate/)

3.3. Master of Science

The M.S. is a thesis-based master's degree having a significant research component and is designed to be completed in two years. This is an ideal program for an engineer with a bachelor's degree who wishes to go deeper into research in specific areas of interest. The M.S. may be a terminal degree for students who intend to pursue research-related careers, or it may be a stepping-stone en-route to a Ph.D. degree.

Students working towards an M.S. will be considered for both research assistantships (provided by sponsored research funds on projects led by faculty) and teaching assistantships (provided by instructional funds). Both have

associated duties that typically mesh well with the research and instructional components of this degree. Because research and instructional funds are limited, assistantships cannot be guaranteed to all interested students. Further, these funds are prioritized towards supporting students who are making reasonable progress within the degree; for M.S. students, this corresponds to a general Department policy to not provide teaching assistantships for students who have been enrolled in the M.S. degree for more than 4 academic-year semesters.

Degree specific requirements:

A total of at least 32 credits with the following restrictions:

- A minimum of 24 course credits
- A maximum of six credits at 400-level
- A minimum of six credits at or above the 500-level
- A minimum of 12 credits of aerospace courses (600-level courses do not count)
- A minimum of six thesis credits (600/610)
- Completion of Core Course Requirements (see Appendix 1)
- Two credits of AERSP 590
- Satisfactory completion of an M.S. thesis
- 3.0 minimum GPA by completion of graduate degree

In addition to any Graduate School or University requirements for electronic submission of the thesis, two bound copies of the MS thesis are required. (One copy for the adviser and one copy for the department).

TIME LIMITATION: All requirements for a master's degree (including acceptance of a thesis, paper, or project report as may be specified), whether satisfied on the University Park campus or elsewhere, must be met within eight years of admission to degree status. Individual programs may set shorter time limits. Extensions may be granted by the Director of Graduate Enrollment Services in appropriate circumstances. (http://www.bulletins.psu.edu/graduate/).

The MS thesis must be approved by a committee comprising of three Graduate faculty members: the student's primary advisor and two Readers. All members of student's thesis committee must be a member of the university's graduate faculty. Student's primary advisor and at least one of the Readers must be a member of the Aerospace Engineering Faculty. The second reader does not need to be a member of the Aerospace Engineering faculty but must be a member of the University's Graduate Faculty. Student must form the committee by the end of their second semester of graduate studies. Students are required to give a presentation on their MS thesis research work at least a week before the Graduate School's MS thesis submission deadline. Students can substitute thesis presentation by a conference or another public presentation of their work by filing a petition to the Director of the Graduate Studies in consultation with their thesis committee members.

In addition to the committee, the department head (or her designee) must also approve the thesis.

Students are encouraged to provide their committee members a copy of their thesis at least two weeks before the Graduate School's submission deadline, allowing sufficient time for them to review and to require revisions to the thesis before its final submission.

3.4. Doctor of Philosophy

The Ph.D. is a thesis-based doctoral degree. It is heavily research-oriented and is a terminal degree for students who intend to pursue careers in research and development, research management, or academia. It is an excellent program for an individual with a master's degree in engineering, physical science, or mathematics who wishes to pursue a career in academic, governmental, and/or industry research in the field.

Students can indicate an intention to ultimately seek a PhD degree upon entry into the department's graduate program, and reflect this intention in their application to the Graduate Program and applications for fellowships and scholarships. The academic portion of the Ph.D. program, however, only commences upon satisfactory completion of a master's program in engineering, physical science, or mathematics, and upon passing the Ph.D. qualifying exam. Students may take the qualifying exam while working on the M.S. once they have completed at least 18 course credits beyond the baccalaureate degree.

Students working towards a Ph.D. will be considered for both research assistantships (provided by sponsored research funds on projects led by faculty) and teaching assistantships (provided by instructional funds). Both have associated duties that typically mesh well with the research and instructional components of this degree. Because research and instructional funds are limited, assistantships cannot be guaranteed to all interested students. Further, these funds are prioritized towards supporting students making reasonable progress within the degree; for Ph.D. students, this corresponds to a general department policy to not provide teaching assistantships to students who have not yet passed the qualifying exam after completing a Master's degree in engineering, physical science, or mathematics; similarly, this corresponds to a general department policy to not provide teaching assistantships to students who have not yet passed their comprehensive exam within three years of the latter of passing the qualifying exam and receiving a Master's degree in engineering, physical science, or mathematics.

Restrictions on course credits:

- A maximum of six credits at 400-level
- Completion of Core Course Requirements (see Appendix 1, if the student completed his/her Master of Science in Aerospace Engineering at Penn State then this requirement was completed as part of those studies).

Ph.D. students must demonstrate evidence of experimental experience. This can be done via:

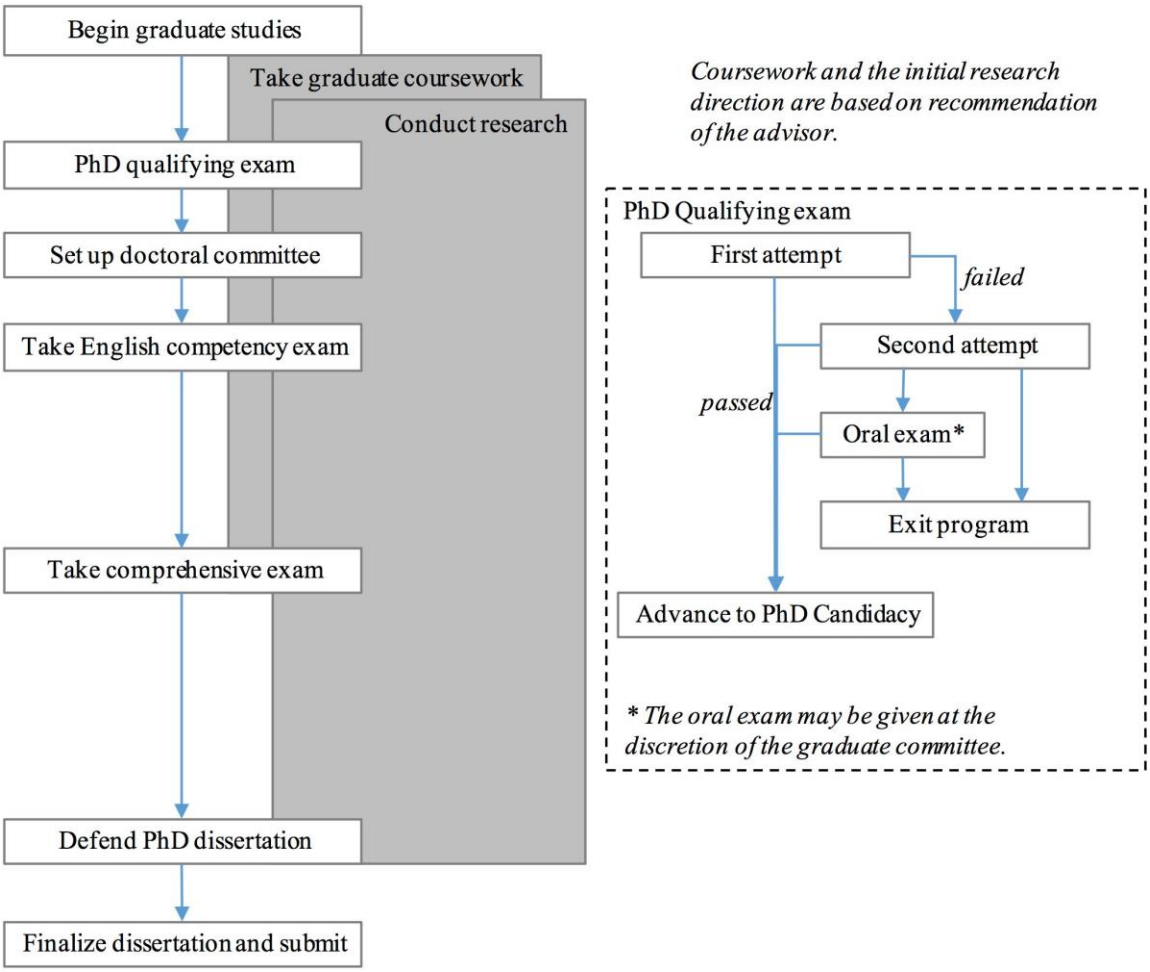
- Perform dissertation research having an experimental component.
- Serve as TA for AERSP 305W.
- Take a course that emphasizes laboratory measurements, and error analysis, such as AERSP 420, AERSP 597* (Advanced Experimental Methods), ME 530, ME 536, ME 544, EMch 506, EMch 528, or ACS 505.
- Perform independent study (1 credit AERSP 596) by arrangement with the student's advisor. This could involve assisting another graduate student with experimental measurements, supervising an undergraduate laboratory project, or another activity.

The Ph.D. requires satisfactory completion of a dissertation.

Graduate course requirements in addition to those specified in the Core Course Requirements are set by the candidate's doctoral committee on an individual basis. In general, there is no specified number of credits for the Ph.D. degree; however, students typically take at least 24 course credits beyond the M.S. degree.

The doctoral dissertation will involve research activity normally exceeding one full year of full-time graduate work equivalent to 30 credits; exact requirements are determined by a student's doctoral committee. In addition to any Graduate School or University requirements for electronic submission of the thesis, two bound copies of the dissertation are required. (One copy for the adviser and one copy for the department).

A flow chart of typical progress through the degree is shown below. Details of each stage are given in the following sub-sections.



TIME LIMITATION: A doctoral student is required to complete the program, including acceptance of the doctoral dissertation or the passing of the final performance, within eight years after the date of successful completion of the qualifying examination. Individual programs may set shorter time limits. Extensions may be granted by the Director of Graduate Enrollment Services in appropriate circumstances. (http://www.bulletins.psu.edu/graduate/).

3.4.1. Qualifying Exam

In Aerospace Engineering, the Qualifying Examination is given each fall and spring semester. Any graduate student seeking to qualify into the doctoral program is required to take the qualifying examination no later than the third semester of entering the Ph.D. program or the fifth semester of entering our graduate program; any student electing a second attempt at the qualifying exam must take it the next semester after the first attempt. The qualifying exam can be taken by students currently enrolled in the M.S. program; indeed, this is recommended so that M.S. students who are considering the Ph.D. program can learn whether they qualify in time to plan to stay for the Ph.D. – or make alternate arrangements – without a delay after completing their M.S.

The qualifying exam covers material that is found in undergraduate courses. However, we expect students to demonstrate a graduate level understanding of the material. While it is not required that a student take the listed recommended graduate level courses to take the qualifying exam, we recommend them given that they illustrate the greater level of depth by which the material will need to be demonstrated, while also satisfying core requirements within our graduate degrees. Students are cautioned to also review the topic lists for the four components of the qualifying exam, as provided in this guide, for the full list of topics on which they may be examined, some of which may be covered only in undergraduate courses and not the recommended graduate level courses.

Note, department funds for teaching assistantships are prioritized such that these assistantships will not be offered to students who have been in department graduate programs for more than four semesters, inclusive of the time spent towards an M.S. or M.Eng., without having passed the qualifying exam.

PhD Qualifying Exams for the 2024/2025 Academic Year	
Fall 2024	October 10th, 2024
Spring 2025	TBA

The format and syllabus of the exam are described in Appendix 3.

Students may request a hard copy of Schaum's Outline Series on Basic Equations of Engineering Science and can use this book during the exam. (DO NOT ADD ANYTHING TO THE BOOK). Copies of practice qualifying exams and Schaum's Outline Series are available online: please contact Dr. Horn for access.

Students are permitted to use a calculator that has no ability to communicate to the outside world. Students may also bring two sheets of hand written notes (both sides). The notes sheets must be handed in with the exam.

3.4.2. Doctoral Committee

General guidance of a doctoral candidate is the responsibility of a doctoral committee consisting of four or more active members of the Graduate Faculty, which includes at least two faculty members in the major field. The dissertation/performance adviser must be a member of the doctoral committee. The dissertation/performance adviser usually serves as chair, but this is not required. If the candidate is also pursuing a dual-title field of study, a co-chair representing the dual-title field must be appointed. In most cases, the same individual (e.g., dissertation/performance adviser) is a member of the Graduate

Faculty in both the major and dual-title fields, and in such cases may serve as sole chair.

At least one regular member of the doctoral committee must represent a field outside the candidate's major field of study in order to provide a broader range of disciplinary perspectives and expertise. This committee member is referred to as the "Outside Field Member." In cases where the candidate is also pursuing a dual-title field of study, the dual-title representative to the committee may serve as the Outside Field Member.

Additionally, in order to avoid potential conflicts of interest, the primary appointment of at least one regular member of the doctoral committee must be in an administrative unit that is outside the unit in which the dissertation/performance adviser's primary appointment is held (i.e., the adviser's administrative home; in the case of tenure-line faculty, this is the individual's tenure home). This committee member is referred to as the "Outside Unit Member." In the case of co-advisers, the Outside Unit Member must be from outside the administrative home(s) of both co-advisers. In some cases, an individual may have a primary appointment outside the administrative home of the student's dissertation/performance adviser and also represent a field outside the student's major field of study; in such cases, the same individual may serve as both the Outside Field Member and the Outside Unit Member.

If the candidate has a minor, that field must be represented on the committee by a "Minor Field Member."

The doctoral committee is appointed by the director of Graduate Enrollment Services, upon recommendation of the head of the major program, soon after the student is admitted to candidacy. The dean of the Graduate School may, on occasion, appoint one or more members of the committee in addition to those recommended by the head of the program.

A person who is not a member of the Graduate Faculty (and may not be affiliated with Penn State) who is otherwise qualified and has particular expertise in the candidate's research area may be added as a "Special Member," upon recommendation by the head of the program and approval of the director of Graduate Enrollment Services). A Special Member is expected to participate fully in the functions of the doctoral committee. If the Special Member is asked only to read and approve the doctoral dissertation or to evaluate the final performance, that person is designated a Special Signatory. Occasionally, Special Signatories may be drawn from within the Penn State faculty.

Graduate Faculty officially appointed by the Graduate School to a doctoral committee who then leave Penn State may maintain that committee appointment for up to one year if the student's graduate program and the dean of the Graduate School, through the Office of Graduate Enrollment Services, approve the request for this exception. A retired or emeritus faculty member may serve as a doctoral committee chair if, and only if, that faculty member was officially appointed and

began chairing the committee prior to retirement and has the continuing approval of the program head and the dean of the Graduate School, through the Office of Graduate Enrollment Services. Requests must be sent by the program head to the director of Graduate Enrollment Services. Otherwise, the committee must be revised to either remove the faculty member from the committee or change the individual's appointment to a Special Member.

The membership of doctoral committees should be reviewed periodically by the chair or head of the program to ensure that all members continue to qualify for service on the committee in their designated roles. For example, if type of appointments, employment at the University, etc., have changed since initial appointment to the committee, changes to the committee membership may be necessary. If changes are warranted, they must be made as soon as possible to prevent future problems that may delay academic progress for the student (e.g., ability to conduct the comprehensive examination or final oral examination/final performance).

Chair: The chair or at least one co-chair must be a member of the graduate faculty of the doctoral program in which the candidate is enrolled. A retired or emeritus faculty member may chair a doctoral committee if he/she was officially appointed and began chairing the committee prior to retirement and has the approvals noted above. The primary duties of the chair are to: (1) maintain the academic standards of the doctoral program, Graduate Council, and the Graduate School and assure that all procedures are carried out fairly, (2) ensure that the comprehensive examination and final oral examination/final performance are conducted in a timely fashion, (3) arrange and conduct all meetings, and (4) ensure that requirements set forth by the committee are implemented in the final version of the dissertation (Ph.D./D.Ed.)/final performance (D.M.A.).

Responsibilities of Doctoral Committees: The doctoral committee is responsible for approving the broad outline of the student’s program and should review the program as soon as possible after the student’s admission to candidacy. Moreover, continuing communication among the student, the committee chair, the dissertation/performance adviser, and the members of the committee is strongly recommended, to preclude misunderstandings and to develop a collegial relationship between the candidate and the committee. The Graduate School requires at least annual reviews of progress by the Committee, with a form documenting each review kept in the student’s file.

The “Graduate Student Committee Policies and Procedures and Committee Appointment Signature Page” can be obtained from the Graduate Program Coordinator and, when completed, will need to be approved by the Director of Graduate Studies. This form is necessary to initiate paperwork for formal appointment of the members by the Graduate School.

3.4.3. English Competency

The Graduate School requires a formal assessment of reading, writing, and speaking abilities in English for all Ph.D. students.

The Department of Aerospace Engineering implements the Graduate School English Proficiency Policy by focusing on the attainment of English proficiency as an important component of the development of student research skills. The department's plan requires demonstration of high-level competence in the use of the English language, including reading, writing, and speaking. Please inform the Graduate Program Coordinator, at least one week in advance, of the date, time and place of the exam.

Initial Assessment of English Proficiency: The goal of the initial stage of assessment is to identify those students having serious deficiencies in their command of the English language. Upon entering the Ph.D. program, students normally meet with numerous departmental faculty, including the Department Head, the Director of Graduate Studies, and several potential faculty advisors. Each of these people has ample opportunity to informally assess student competence in English. It is the responsibility of the student's academic adviser to identify serious deficiencies and to recommend an immediate course of action. Recommended courses include ESL 114G-118G. The earlier a student attains English competency, the more effectively he or she can concentrate on developing research capabilities. The adviser will continue monitoring progress in this regard until the student passes the qualifying examination.

Upon passing the qualifying exam, a student's faculty adviser will consult with the Director of Graduate Studies and initiate the constitution of a Doctoral Committee. The committee should be convened as soon as practical (normally within a semester upon passing the qualifying exam) to establish general student research direction and specific coursework requirements. As a natural part of this process, the committee will formally assess the student's English proficiency; this includes native and non-native English-speaking students. The goal at this stage is to identify students having significant deficiencies in their command of English. In addition to informal discussions, the assessment will consist of the following elements:

- **Reading**. In consultation with the faculty adviser and committee, the student will identify several publications pertinent to the contemplated research project. The student will then read and summarize the contents of these publications in both the written dissertation proposal and its oral presentation.
- **Writing**. The student will prepare a preliminary research proposal at least five pages in length, including a tentative plan for Ph.D. coursework, and distribute it to the committee members for advance review. Faculty will evaluate its logical organization, clarity, correct English usage, and technical content. A short expository writing assignment may be required in addition, at the faculty’s discretion.

- **Speaking**. The student will prepare and make a presentation at least 20 minutes in length to the committee, in the subject area of the students proposed research. The student will respond to questions following the presentation. The committee will evaluate the presentation's logical organization, clarity, correct English usage, and technical content.

Upon completion of the first meeting, the committee will report on the student's English competency in three areas: reading, writing, and speaking. If no significant deficiencies are noted, the committee will attest to satisfaction of the Graduate School requirement. (Please inform the Graduate Program Coordinator at least one week in advance of the exam of the date and time. (The student does not need to be registered for classes when this exam is taken.)

Enhancement of English Competency: If the majority of the committee deems that significant deficiencies exist in any of the areas, the student will be required to enroll in appropriate remedial courses from the following list:

- Reading: ESL 116G
- Writing: ESL 116G, ENGL 202C, ENGL 198G, ENGL 418
- Speaking: ESL 114G, ESL 115G (Presenting: ESL 100A, ESL 312)

Attainment of a grade of "B" or better will be taken to constitute satisfactory completion of the corresponding requirement.

3.4.4. Comprehensive Exam

When a candidate for a doctoral degree has substantially completed their coursework, a comprehensive examination is given. The examination is intended to evaluate the candidate's mastery of the major, and if appropriate, the minor field and whether the candidate is prepared to embark upon his/her dissertation research (Ph.D.). Before taking the "comps", a student must have satisfied the English competency requirement, must have a minimum GPA of 3.0 and must be registered. If the exam will be taken during the summer, the student should apply for the Summer Tuition Assistance Program early in the preceding spring semester. For a student making reasonable progress within the Ph.D., the comprehensive exam should be taken within three years of the latter of passing the qualifying exam and receiving a master's degree in engineering, physical science, or mathematics.

The student's doctoral committee administers the exam. In aerospace engineering, the doctoral committee may, at its discretion, require the candidate to complete one or more written problems in advance of the oral exam. During the oral part of the comprehensive exam, the candidate typically presents a proposal for Ph.D. dissertation research, including a literature review (if that was not covered as part of the English proficiency exam), objectives, approach, preliminary results, and a plan for completion. A nominal duration for the presentation is 30-40 minutes. Following that presentation, the committee may pose questions regarding

written problems (if any), the proposed research topic and the general preparation of the candidate to pursue Ph.D. research. A favorable vote of at least two-thirds of the members of the committee is required for passing. In case of failure, it is the responsibility of the doctoral committee to determine whether the candidate may take another examination. Once the comprehensive exam has been passed, the student may register for AERSP 601 (reduced tuition) in subsequent semesters.

Please inform the Graduate Program Coordinator **at least two weeks in advance** of the date, time, and place of the exam. Materials need to be processed by Graduate Enrollment Services and returned in time for the exam.

After a Ph.D. candidate has passed the comprehensive examination and met the two-semester full-time residence requirement, the student must register continuously for each fall and spring semester, until the dissertation is accepted and approved by the doctoral committee.

When a period of more than six years has elapsed between the passing of the comprehensive examination and the completion of the program, the student is required to pass a second comprehensive examination before the final oral examination will be scheduled.

3.4.5. Final Oral Examination (Defense) and Acceptance of Dissertation

The final examination of the doctoral candidate is an oral examination administered and evaluated by the entire doctoral committee. It consists of an oral presentation of the dissertation by the candidate and a period of questions and responses. Questions will relate in large part to the dissertation, but may cover the candidate's entire program of study, because a major purpose of the examination is also to assess the general scholarly attainments of the candidate. The portion of the examination in which the dissertation is presented is open to the public.

The final defense may not be scheduled until at least three months have elapsed after the comprehensive examination was passed; a more typical time is in excess of a year. A student must be registered in the semester during which the exam is taken. (If the exam will be taken during the summer, the student should apply for the Summer Tuition Assistance Program early in the preceding Spring semester.)

Both the dissertation adviser and the student are responsible for ensuring the completion of a draft of the dissertation **and for adequate consultation with members of the dissertation committee well in advance of the oral examination. Major revisions to the dissertation should be completed before this examination.** It is the responsibility of the doctoral candidate to provide a copy of the dissertation to each member of the doctoral committee at least two weeks before the date of the defense. The dissertation should be in its final draft at the time of the oral examination; both the content and style should be correct and polished. A favorable vote of at least two-thirds of the members of the committee is required for passing. If a candidate fails, it is the responsibility of the doctoral committee to determine whether another examination may be taken.

Please inform the Graduate Program Coordinator **at least two weeks in advance** of the date, time, and place of the defense. Materials need to be processed by Graduate Enrollment Services and returned in time for the exam.

Completion of the requirements of a Ph.D. degree program entails acceptance of the dissertation, as indicated by the signatures of at least two-thirds of the doctoral committee, as well as the head of the graduate program, on the doctoral signatory page, and by its acceptance as meeting the editorial standards of the Graduate School, so that it constitutes a suitable archival document for inclusion in the University Libraries. Thus, it is to be noted that passage of the final oral examination is necessary but not sufficient for award of the degree; the dissertation must be accepted as the ultimate step for the Ph.D. and is to be made available to the public through inclusion in the University Libraries.

3.4.6. Registration and Residency Requirements

There is no required minimum number of credits or semesters of study, but over some twelve-month period during the interval between admission to the Ph.D. program and completion of the Ph.D. program, the candidate must spend at least two semesters (summer sessions are not included) as a registered full-time student engaged in academic work at the University Park campus. Full-time University employees must be certified by the department as devoting half-time or more to graduate studies and/or thesis research to meet the degree requirements. Students should note that 601 cannot be used to meet the full-time residence requirement.

It is expected that all graduate students will be properly registered at a credit level appropriate to their degree of activity. (See Registration.) After a Ph.D. candidate has passed the comprehensive examination and met the two-semester full-time residence requirement, the student must register continuously for each fall and spring semester (beginning with the first semester after both of the above requirements have been met) until the final oral examination is passed. Students who are in residence during summers must also register for summer sessions if they are using University facilities and/or faculty resources, except for Graduate Lecturers/Researchers, who are not required to enroll for any credits unless they are first-semester graduate students, or are required to be enrolled by their graduate program.

Post-comprehensive Ph.D. students can maintain registration by registering for credits in the usual way, or by registering for noncredit 601 or 611, depending upon whether they are devoting full time or part time to thesis preparation. Students may take 601 plus up to 3 additional credits of course work for audit by paying only the dissertation fee. Students wishing to take up to 3 additional credits of course work for credit, i.e., 590, 602, etc., with 601 may do so by paying the dissertation fee and an additional flat fee. Enrolling for either 3 credits for audit or credit will be the maximum a student may take with AERSP 601 without special approval by the Graduate School. NOTE: Registration for additional credits above this will incur an

additional charge at the appropriate tuition per-credit rate (in state or out of state). Students wishing to take more than 3 additional credits of course work must register for 600 or 611 (i.e., not for 601, which is full-time thesis preparation).

Note that the least expensive way for a student to maintain full-time status while working on research and thesis preparation is to register for 601. This clearly is the procedure of choice for international students who need to maintain status as full-time students for visa purposes.

If a Ph.D. student will not be in residence for an extended period for compelling reasons, the director of Graduate Enrollment Services will consider a petition for a waiver of the continuous registration requirement. The petition must come from the doctoral committee chair and carry the endorsement of the department or program chair.

4. Research in the Department of Aerospace Engineering

Detailed information covering research can be found on our department website at www.aero.psu.edu/research and on faculty web pages. A brief description of faculty research is given here.

4.1. Faculty Research Interests

Sven Bilen, Ph.D., University of Michigan

Professor, SEDI
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Engineering Design, Remote Sensing & Space Systems, Space Propulsion & Physics: Research interests focus on electrodynamic-tethers, measurements of space plasmas and environments, spacecraft-plasma interactions, plasma diagnostics, engineering design and entrepreneurship, innovative design, software-defined radio, systems.

Kenneth S. Brentner, Ph.D., University of Cambridge, U.K.

Professor
ksbrentner@psu.edu

Aeroacoustics, Computational & Experimental Fluid Dynamics, Rotorcraft Engineering: Research interests focus on rotorcraft and aircraft aeroacoustics, computational aeroacoustics, fluid mechanics, computational fluid dynamics, and high-performance computing. Specific areas of research include rotor source noise prediction, prediction and characterization of rotorcraft noise in maneuvering flight, prediction of landing gear noise and other types of airframe noise. Recent research activities include the development of the rotorcraft noise prediction code PSU-WOPWOP which is able to predict noise from a rotorcraft with multiple rotors in both steady and maneuvering flight; prediction of noise generation and propagation from wind turbines; acoustic scattering for aircraft noise, including ducted rotors; and the development of a component based landing gear noise prediction system.

James Coder, Ph.D., Pennsylvania State University

Associate Professor
jcoder@psu.edu

Computational Aerodynamics, Fluid Mechanics: Research interests include turbulence and transition modeling, computational methods development, and aerodynamic design. The research is driven by a need for improved modeling of complex, nonlinear flow phenomena to support the design of new flight vehicle systems with enhanced performance and expanded operating envelopes. Three major thrusts are pursued: High-fidelity numerical simulations (LES and DNS) that offer detailed knowledge of key flow physics; Development

of new mathematical and theoretical frameworks that overcome existing technical barriers; and Application of data- and theory-driven tools (such as modal decompositions) to dominant flow behaviors. Application areas include rotorcraft, urban air mobility, ultra-efficient commercial aircraft, and hypersonic vehicles.

Roshan Eapen, Ph.D., Texas A&M University
Assistant Professor
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Astrodynamics, Dynamical Systems Theory & Computational Vision: Research interests include multi-body dynamical environments applied to spaceflight, image generation, computer vision, differential rendering, dynamical astronomy, satellite tracking, space domain awareness, and rendezvous and proximity operations. The core research stems from the convergence of (i) developing semi-analytic methods for modeling, analysis & control, (ii) designing data-driven approaches through dynamic sensing, and (iii) performing loop closure through verification and validation for dynamical systems.

Junyi Geng, Ph.D., Pennsylvania State University
Assistant Professor
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The research is guided by the desire to develop next-generation aerial robotics, characterized by the growing demands for the robotic systems that behave smartly, efficiently, and robustly at low cost. Research interests lie at the junction of aerospace engineering and robotic science, and include aerial robotics (i.e., unmanned aerial vehicles, UAVs), cooperative control, aerial manipulation, learning-based perception. Specific research topics include cooperative transportation of a slung load, vision-based object pose and shape estimation, control of a tilt-rotor UAV in the presence of actuator failure, aerial manipulation with fully-actuated aerial robots, robotic perception for smart manufacture. Current research includes visual servo control, learning physics for aerial manipulation, differentiable model predictive control, and design optimization. See more at the website https://aerogjy.github.io/

Eric Greenwood, Ph.D., University of Maryland
Assistant Professor
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Aeroacoustics, Rotorcraft Engineering: Research interests include theoretical and experimental aerodynamics and acoustics, with a particular focus on application to vertical takeoff and landing aircraft. Ongoing research includes the development and of fast and accurate aeroacoustic models for complex rotorcraft using semianalytical and

empirical methods. Novel applications are being explored, including the use of real-time aeroacoustic models to provide piloted, semi-, and fully-autonomous systems with an intuitive "acoustic awareness" to enable low noise operations, taking advantage of recent advances in flight dynamics and control, human-machine interfaces, and autonomy.

David Hall, Ph.D., Massachusetts Institute of Technology

Assistant Professor

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Air-breathing Propulsion, Computational & Experimental Fluid Dynamics, Vehicle Systems Engineering: Research interests focus on advancing aircraft and propulsion technologies and concepts for improved performance and reduced environmental impact. Specific areas of research include propulsion-airframe integration, including boundary layer ingesting (BLI) propulsion; aerodynamics and aeromechanics of turbomachinery subject to inlet distortion; electrified aircraft propulsion; application of numerical optimization to vehicle, propulsion, and power system design; technologies for sustainable aviation.

Joseph F. Horn, Ph.D., Georgia Institute of Technology

Professor and Director of Graduate Studies

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Flight, Science, Rotocraft Engineering, Vehicle Dynamics & Controls: General research interests are in the areas of flight dynamics, automatic flight control systems, guidance and navigation, handling qualities, and flight simulation and modeling. Current research activities have focused on control system design and flight simulation for rotorcraft and rotorcraft UAV applications. Specific research topics include envelope protection systems, damage mitigating control, nonlinear adaptive control, integration of flight controls and health and usage monitoring systems, control design for compound helicopters, simulation and control of HELICOPTER shipboard operations, autonomous control of UAV's, and coupled flight dynamics and acoustics simulation of rotorcraft.

Daning Huang, Ph.D., University of Michigan

Assistant Professor

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The research activities in the APUS lab are motivated by the desire to expand the last frontier of aerospace engineering, represented by hypersonic vehicles and high-speed VTOL aircraft. The development of these advanced aerospace systems has been constrained by their inherent complex multi-physics nature and the adverse uncertain working environment. We tackle these multi-

physics problems by integrating the multi-disciplinary tools for the modeling, testing, and robust design of future unconventional aircraft. Specifically, we develop (1) coupled high-fidelity modeling tools to capture and understand the multi-physics interactions involving differing spatial and temporal scales; (2) faster yet accurate data-driven reduced-order models with quantifiable uncertainty to enable the rapid and robust design of new concept vehicles; (3) computer-aided design of multi-physics experiments that help understand new physics and identify the limitations of the modeling tools. See more at our website sites.psu.edu/daning.

Eric N. Johnson, Ph.D., Georgia Institute of Technology
Professor
enj4@psu.edu

Autonomous Flight & UAVs, Vehicle Dynamics & Controls: Professor Johnson performs research in unmanned aircraft fault-tolerant guidance/control, aided inertial navigation, and autonomy. This work has included the first air-launch of a hovering aircraft, automatic flight of helicopters/airplanes with simulated frozen actuators, and vision-based air-to-air tracking. His most recent work has included automatic low altitude high speed flight of helicopters, indoor and outdoor vision-aided inertial navigation, and methods for sensing and avoiding other aircraft. The mission of this work is to enable unmanned aircraft systems to contribute to society.

Jack W. Langelaan, Ph.D., Stanford University
Professor
jlangelaan@psu.edu

Autonomous Flight & UAVs, Vehicle Dynamics & Controls: Research interests include state estimation, data fusion, path planning, and control for small uninhabited aerial vehicles (UAVS). The drivers of this research have been two areas critical to improving vehicle capabilities: perception (transforming sensor data into knowledge of the vehicle state and surroundings by developing novel state estimation and data fusion algorithms) and persistence (exploiting energy available in the environment to improve range and endurance). Controls work focuses on developing coordination algorithms for flocks of cooperating vehicles. Motivating examples driving these research themes include autonomous soaring, cooperative transport of a slung load, and (more recently) planetary exploration. A key goal of research has always been to implement all algorithms required for flight on-board the aircraft.

Sara Lego, M.S., University of Colorado at Boulder
Associate Teaching Professor

Conceptual Design, Systems Engineering, and Trade Space Exploration: Research interests include systems engineering, system-of-systems modeling, and trade space exploration, especially as these topics apply to conceptual design and decision-making, both at the individual level and within design teams. Additional research includes the investigation into innovative pedagogical approaches for applying these topics at both the undergraduate and graduate levels to capstone design settings that mirror a professional industry design experience.

George A. Lesieutre, Ph.D., University of California, Los Angeles
Professor
g-lesieutre@psu.edu
Structural dynamics and active structures: General research interests are motivated by aerospace vehicle applications, and include materials and controls for precision structures, vehicle dynamics and control, and systems engineering. Present activities address concepts for morphing aircraft structures, the dynamic behavior of elastomeric components in rotorcraft applications, piezoelectric actuators for structural control, energy harvesting using piezoelectric materials, and the nonlinear dynamics of particle dampers. Other research addresses the dynamic analysis of damped structures, structural composite materials with improved intrinsic damping, semi-active vibration control using tunable transducers and shunted piezoelectrics, shape determination for gossamer space structures, structural condition monitoring, and bioinspired control. Experiments are an important part of much work, and improved measurement methods are also of concern.

Mark D. Maughmer, Ph.D., University of Illinois
Professor
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Flight Science, Vehicle Systems Engineering: Research interests are in the areas of aerodynamics, aircraft design, and stability and control. Current activities deal with the design and analysis of airfoils, low Reynolds number aerodynamics, wing planform optimization, uninhabited air vehicles, wind turbines, and experimental aerodynamics.

Dennis K. McLaughlin, Ph.D., Massachusetts Institute of Technology
Professor Emeritus
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Aeroacoustics, Experimental & Computational Fluid Dynamics: Research interests include experiments on a variety of fluid dynamic and aero-acoustic problems. Experiments are being conducted in the anechoic chamber with forward flight capability on a number of

aeronautical applications. Most prominent are the experiments on high speed (transonic and supersonic) jets of various geometries. In these flows helium/air mixtures are used to simulate the high temperature exhausts of the jets. In addition, wind tunnel experiments and flight tests are being conducted as part of the development project for vertical takeoff aircraft using ducted lift fans.

Robert G. Melton, Ph.D., University of Virginia

Professor and Director of Undergraduate Studies

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Astrodynamics, Vehicle Dynamics & Controls: Astrodynamics, spacecraft dynamics and control; trajectory optimization, perturbation analysis of low-thrust orbital motion, orbit determination, dynamics and control of multi-body spacecraft.

Mark Miller, Ph.D., Princeton University

Assistant Professor

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Rotating and Unsteady Fluid Systems: Ongoing research focuses on exploring unsteady and rotating fluid systems by using a multifaceted experimental approach with the goal of attaining a more fundamental understanding of the flow physics present in these systems. Considering the entire flow regime, instead of a simplified two-dimensional mechanism, can facilitate better models and more efficient designs which take into account or even take advantage of the rotational and unsteady nature of the flow. Current work primarily focuses on experimental characterization of the rotational augmentation behavior observed on wind turbine blades utilizing a new, compressed air tow-tank facility. Additional projects cover a wide range of unsteady and rotating flows including unmanned aerial vehicle (UAV) flight profile characterization, turbulence modifications due to unsteady forcing, rotation and stall on rotorcraft, and development of innovative sensor systems which are tailored to these specific flow regimes.

Philip J. Morris, Ph.D., University of Southampton

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Aeroacoustics, Computational & Experimental Fluid Dynamics: Dr. Morris' research centers on the modeling and prediction of unsteady incompressible and compressible flows. The work is primarily analytical and computational. Current research projects include: the prediction of noise from high-speed jet flows; the prediction of airframe noise; the simulation of blast loading of complex structures; the prediction of contaminant dispersion in urban environments; wind turbine noise prediction; the simulation of aeroelastic phenomena; prediction of the nonlinear propagation of identification using near

and far field arrays. Each of these analytical or computational studies is linked closely with experimental studies at Penn State, NASA Langley and Glenn Research Centers, The Boeing Company, GE Aviation and GE Energy, Sandia Laboratories, and the National Renewable Energy Laboratory.

Jose L. Palacios, Ph.D., The Pennsylvania State University
Associate Professor
jlp324@psu.edu
Computational & Experimental Fluid Dynamics, Multifunctional & Nano-Materials, Structural Dynamics & Adaptive Structures: Research interests focus on aircraft and wind turbine icing, as well as experimental test and evaluation of active rotor blades. Specific areas of on-going research related to aircraft icing are engine ice crystal melting and accretion, experimental ice shape acquisition for model validation and aerodynamic performance degradation quantification, optimization and testing of low-power ice protection systems, and experimental evaluation of ice protective coatings. Research related to active structures includes design and centrifugal testing of active rotor systems instrumented with trailing edge flaps, micro trailing edge effectors, centrifugal power generation prototypes, and mechanical de-icing systems.

Amy R. Pritchett, Sc.D., Massachusetts Institute of Technology
Professor and Head
apritchett@psu.edu
Safety, Aerospace Autonomy, Human-Autonomy Teaming, Multi-Agent Systems: Research interests include aviation and spaceflight safety, particularly around the intersection of intelligent systems / machine autonomy with expert human performance. Computational and human-in-the-loop simulation of complex aerospace operations involving multiple agents, particularly towards identifying and preventing safety concerns. Design of avionics systems, flightdecks, and procedures for flight operations, spaceflight operations, and air traffic control and management.

Ashwin Renganathan, Ph.D., Georgia Institute of Technology
Assistant Professor
Computational complex engineered Systems Design: Primary research goals are to develop scalable computational methods toward the design of multidisciplinary complex engineered systems such as aircraft, gas turbine engines, and wind turbines. In this regard, we develop novel methods and algorithms in approximation theory, numerical optimization, and uncertainty quantification. Our long-term vision is to gain leadership in computational design that

would make the design of engineered systems reliable, efficient, and cost-effective.

Sven Schmitz, Ph.D., University of California, Davis

Boeing/A.D. Welliver Professor

sus52@psu.edu

Computational & Experimental Fluid Dynamics, Wind Energy: Research interest includes basic and applied Research in Computational Fluid Dynamics (CFD). Development of Hybrid RANS/Vortex methodologies for wind turbines and helicopters. Prediction of unsteady aerodynamic loads on wind turbine blades, effects of surface contaminations on blade performance. Designs and optimization of wind turbines and blades.

Puneet Singla, Ph.D., Texas A&M University

Professor

pxs433@psu.edu

Astrodynamics, Autonomous Flight & UAVs, Vehicle Dynamics & Control: Research interests include orbital dynamics, multi-body dynamics, data driven modeling, optimal estimation, and control under uncertainty. The interplay between dynamic system analysis, estimation and control lay the scientific groundwork for diverse range of problems such as tracking resident space objects, conjunction analysis, close-proximity operations, spacecraft attitude estimation, navigation and control of hypersonic vehicles, modeling of large space structures, and control of robotic systems.

Edward C. Smith, Ph.D., University of Maryland

Professor and Director of the Vertical Lift Research Center of Excellence

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Rotorcraft Engineering, Structural Dynamics & Adaptive Structures: Research interests include analytical modeling and experimentation focused on innovative applications of advanced composite structures to aerospace vehicles. Recent research has concentrated on the development of improved methods for the analysis of composite box-beams and rotor blade spars, and the aeroelastic and aeromechanical tailoring of helicopters with composite rotor blades. Research interests related to helicopter and tilt-rotor dynamics also include blade and airframe vibration reduction, gust response suppression, rotor and rotor-body stability augmentation, modeling of bearingless rotors, and helicopter flight simulation. Material damping of advanced composites and elastomerics is also of particular interest.

Susan Stewart, Ph.D., Georgia Institute of Technology

Teaching Professor

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Wind energy: Research interest include the intersection of renewable energy system design for improved performance and economics, evaluating effects of changing policies, design standards and/or the resulting impacts on society. Thermal fluid system design optimization for improved energy system performance. Renewable energy resource assessment and impacts to technology performance and financial analyses.

Alan R. Wagner, Ph.D., Georgia Institute of Technology
Associate Professor
azw78@psu.edu

Autonomous flight, UAVs, and human-robot interaction: Research interests include UAV control, social robotics, human-machine interaction, game theory, trust and ethics. His work has focused on the development of a framework for social action selection by robots and UAVs based on social psychological theories and behavioral modeling of human partners. Application areas include search and rescue, humanitarian missions, and healthcare. Recent research activities include examinations of the factors that cause people to over-trust robots and UAVs, trust repair by these systems, the use of deep learning to generate experiential representations of the visual environment, and the creation and use of behavioral models by systems to predict the needs and behavior of a human teammate.

Namiko Yamamoto, Ph.D., Massachusetts Institute of Technology
Associate Professor
nuy12@psu.edu

Multifunctional and nano-materials: Research interests include experimental studies of materials and structures engineered at the nano and micro level, mostly nano-composites, for aerospace applications. Nanocomposites consist of nanoparticles (carbon, ceramic, metal, etc.) embedded within matrices (polymers, metals, ceramics, etc.). Organization of these nanoparticles within matrices can be tailored for optimized performance (mechanical, electrical, thermal, etc.), and/or for effectively interdisciplinary coupling (thermomechanical, electromechanical, thermoelectrical, etc.). These novel materials can provide solutions to the tight requirement for the next-generation aerospace vehicles and rotorcrafts, energy and power devices, and biomedical applications. Research goals will be to obtain knowledge on multi-scale structure-property relationship and to establish scalable manufacturing methods.

4.2. Research Centers and Institutes

4.2.1. Center for Acoustics and Vibration

Research in acoustics and vibration is one of Penn State's enduring strengths. The steady growth of research in acoustics and vibration in recent years establishes the Penn State program as the largest and most respected of its kind at a major research university. The Center for Acoustics and Vibration (CAV), housed in the Penn State College of Engineering, ensures the continued excellence of acoustics and vibration research in the 1990's.

The CAV has three missions:

- to strengthen basic and applied research in related engineering areas;
- to foster graduate education in acoustics and vibration engineering; and
- to provide a base for technology transfer to industry.

The center consists of faculty, graduate students, and staff in nine laboratories throughout the College of Engineering and ARL. These laboratories perform both disciplinary and cross-disciplinary research in areas related to acoustics and vibration. Areas of research activity include:

Active control, adaptive structures, flow-induced noise, machinery prognostics and condition monitoring, propagation and radiation, rotorcraft acoustics and dynamics, and structural vibration and acoustics.

Contact Person:

Dr. Steve Hambric
Director, Center for Acoustics and Vibration
The Pennsylvania State University
3220B Garfield Thomas Water Tunnel
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4.2.2. Penn State Vertical Lift Research Center of Excellence

The Penn State Vertical Lift Research Center of Excellence (VLRCOE) is one of only three university research centers in the country focused on technical problems specific to rotary-wing and vertical flight aircraft. Funded by the US Army, US Navy and NASA, the Penn State Vertical Lift Research Center involves facilities, faculty and students from the Departments of Aerospace Engineering, Mechanical Engineering, and Engineering Science and Mechanics. Research thrust areas include rotor and vehicle dynamics, composite and smart structures, flight simulation and controls, cabin noise, rotor noise, rotor and airframe aerodynamics, drivetrain technologies, unmanned air vehicles, and condition-based maintenance. In addition to core Army and Navy support, many VLRCOE research

projects are supported directly by the rotorcraft industry (e.g. Bell, Boeing, Sikorsky, Kaman, Lord Corp, Timken Corp, Goodrich, etc.), as well as NASA and other federal agencies. More than 40 full-time graduate students are centrally located within our laboratories in brand new office space in Engineering Unit C. Our VLRCOE faculty and students are also actively involved in a wide range of educational programs, educating students from pre-school to graduate school and beyond. Vertical Lift Fellowships are available to provide additional financial support for outstanding graduate students. Undergraduate research assistantship positions are also available for highly qualified undergraduate engineering students.

Website: http://www.vlrcoe.psu.edu/

Contact Person

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4.2.3. Center for Autonomous Air Mobility and Sensing

The aviation industry is moving beyond remotely-piloted aircraft toward future autonomous air mobility and sensing concepts, from urban air mobility systems that transport goods and people to autonomous aircraft performing adaptive sensing of complex environments. The Center for Autonomous Air Mobility and Sensing (CAAMS) is is a National Science Foundation-funded Industry/University Collaborative Research Center (IUCRC) that includes the University of Colorado Boulder (lead), Brigham Young University, Penn State University, Sinclair Community College, Texas A&M University, the University of Michigan, and Virginia Tech to address the unmet, precompetitive research needs of the aviation industry as it moves toward the design and deployment of increasingly autonomous systems.

Contact person

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The Pennsylvania State University
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5. Expenses and Financial Aid

5.1. General Expenses

For the latest information concerning tuition rates, room and board rates, bill due dates, payment plan, refund policy, residency policy, retroactive registration, tuition bill instructions, tax credits, and tuition adjustments please go to http://www.bursar.psu.edu/.

5.2. Medical Insurance

The Penn State Student Health Insurance plan (SHIP) is offered through First Student College Health Insurance, underwritten by United Healthcare Student Resources. Most Penn State graduate students are eligible to purchase the Penn State SHIP even if coverage is not required.

Graduate students eligible for SHIP include:

- All graduate students registered for 1 or more credit hours
- **Graduate Assistants**: graduate students who have been appointed to a graduate assistantship. All graduate assistants receive a monthly stipend check, a tuition grant-in-aid, and have signed a "Terms of Offer and General Conditions of a Graduate Assistantship Appointment" with Penn State.
- **Graduate Fellows**: graduate students who have received a fellowship award for which they receive a monthly stipend check from Penn State, and for whom a tuition grant-in-aid is provided.

Students who meet eligibility requirements for the Penn State SHIP must actively attend classes for at least the first 31 days after the date when coverage becomes effective.

Please contact Student Health Insurance by email at uhs-insurance@psu.edu or by phone at 814-865-7467. Information is also available on their website at https://studentaffairs.psu.edu/health-wellness/health-insurance.

Graduate Assistants and Graduate Fellows are eligible to receive subsidies in the amount of 80% of the annual premium cost for the Penn State SHIP for graduate students. The University will pay this amount directly to the insurance company and will deduct your 20% contribution to premium expense from your monthly stipend.

The insurance subsidy for your eligible spouse/domestic partner or child is 75% of the annual premium expense. As with the subsidy for your individual insurances, the university will pay 75% of the premium expense directly to the insurance companies and you will pay your 25% of the premium costs through a deduction from your stipend.

The term "family" consists of a student and 2 or more dependents, i.e. a student, spouse and one child, a student and 2 or more children, or a student, spouse and 2 or more children. The insurance subsidy for your eligible family is 76% of the annual premium expense. As with the subsidy for your individual insurances, the university will pay 76% of the premium expense directly to the insurance companies and you will pay your 24% of the premium costs through a deduction from your stipend.

The deadline to submit Graduate Assistant or Graduate Fellow enrollment/waive information is September 3, 2019 for the Fall 2019 semester and January 22, 2020 for the Spring 2020 semester. This process needs to be completed every fall semester since the GA/GF benefits are reset to Single Student Coverage each fall semester.

Health insurance is *mandatory* at Penn State for international students and their accompanying dependents (spouse and/or children).

The mandatory health insurance requirement may be fulfilled in one of two ways:

- Purchase Penn State SHIP
- Demonstrate proof of insurance by submitting a waiver application.

For yourself: An online waiver must be completed through First Student. A copy of your current health insurance ID card and your health insurance brochure or plan description is required.

For dependents: A Fall Dependent Waiver Application Form and/or a Spring Dependent Waiver Application Form must be completed through the Student Health Insurance office.

There is a late fee for students who fail to fulfill the mandatory health insurance requirement by August 30, 2023, for the Fall 2023 semester and January 17, 2024, for the Spring 2024 semester.

5.3. Financial Aid

Financing graduate education is an important topic all students. There are numerous sources of support from inside the University and from external agencies that afford funding for graduate students. The most likely source of support is through an assistantship, fellowship or scholarship offered by the college or department. The Graduate School also offers a number of funding programs coordinated by the Office of Graduate Fellowships and Awards Administration. Government agencies, foundations, professional associations and other private entities offer support of graduate education. A database of outside awards is available online at http://www.gradschool.psu.edu/graduate-funding/types-of-graduate-support/external/. The Office of Student Aid administers the Federal Direct Loan program and Federal Work-Study program and maintains a listing of some on-and-off-campus employment opportunities. Information on these

opportunities is available online at http://studentaid.psu.edu/types-of-aid/employment.

5.4. TAs, RAs and TAides

There are two main types of graduate assistantships at Penn State providing both stipend and tuition support: Teaching Assistantships (TA) and Research Assistantships (RA). The student on a half-time assistantship normally schedules 12 credits per semester and performs tasks that, on average, occupy approximately 20 hours per week.

RA activities typically include literature review, problem definition, analysis, experiments, report writing, and presentations. A report of this research work and its results will likely constitute the bulk of a graduate thesis. The financial support for RAs is usually provided by external grants made to individual faculty members; students should coordinate explicitly with the faculty member providing them with an RA to confirm expectations for expected workload and duties, contractual deadlines depending on these RA duties, and expectations for whether the RA duties will provide summer support (and expect the student to stay on campus to conduct research over the summer). *To inquire about the possibility of an RA, contact faculty members who are performing research relevant to the intended graduate thesis topic.*

TA positions also provide stipend and tuition support but typically do not provide summer support. Teaching Aide positions instead only provide a stipend commensurate with the hours required and does not include tuition remission or insurance coverage; TAides will be paid via wage payroll, on a bi-weekly pay schedule, and will be responsible for their tuition and health insurance expenses. The allocation of these teaching positions is controlled by the department head; given the limited budget for TA and Teaching Aide positions, preference is typically given to senior Ph.D. students who are making good progress towards their dissertation, and thence to M.S. students who are making good progress in their research. **Milestones by which 'good progress' are assessed including finishing the M.S. and passing the qualifying exam within four academic semesters of starting in the graduate program and completing the comprehensive exam within three years of completing the M.S. and qualifying exam.** TA and TAide positions are typically not provided to M.Eng. students. To be considered for a TA or TAide position, the graduate student's advisor must recommend him or her to the department head, explaining his or her potential to be an effective contributor to the department's educational programs and describing his or her research progress towards a thesis; past performance in similar positions will also be evaluated.

TAs teaching (i.e. lab course 305W) should take ENGR 888 (1 cr.) the same semester. The remaining TAs should take the Grader's Seminar. Please see the Graduate Program Coordinator for more details and registration.

All graduate teaching assistants whose first language is not English must take and pass an oral language proficiency test known as AEOCPT (formerly Test of Spoken English). The AEOCPT is administered directly prior to the start of each semester. August testing occurs during the first two weeks prior to the start of fall classes. January testing occurs on the Thursday prior to the start of spring classes. Students must receive department approval to take the test. AEOCPT registration is available online at elp.la.psu.edu. The score an International Teaching Assistant (ITA) receives on this test will determine when he/she may assume teaching duties as a teaching assistant. Scores will be released to the department 72 business hours after the student has been tested.

TAs & RAs should register for the maximum number of 12 credits (including thesis research, AERSP 600).

SUMMER TUITION ASSISTANCE PROGRAM (STAP)

The Summer Tuition Assistance Program (STAP) is designed to provide tuition assistance to graduate students who have been appointed through the University on teaching or research assistantships or graduate fellowships or traineeships for the two preceding semesters, so that they can continue graduate studies during the summer.

Students may want to apply for STAP in the Summer Session to maximize tuition monies. Ph.D. students should request summer assistance if they plan to take Comprehensive Examination or Final Defense of Thesis as well as M.S. international students that plan to graduate. Faculty advisers and students will be informed of application dates.

6. Student Organizations

6.1. Aerospace Graduate Student Association (AeroGSA)

The purpose of AeroGSA is to promote and to enhance graduate studies within the aerospace engineering department through professional development activities, to promote interaction among the aerospace engineering graduate students and faculty, and to provide a forum for communication between graduate students, faculty, and administration within the department.

6.2. Vertical Flight Society

The Vertical Flight Society is the world's oldest and largest technical society dedicated to enhancing the understanding of vertical flight technology. Since it was founded in 1943 – just as the first US helicopter was being put into service – the Society has been the primary forum for interchange of information on vertical flight technology. According to the AHS Bylaws, the purpose of the Society is to advance the theory and practices of the science of vertical flight aircraft. Membership applications and information on the benefits of belonging to this organization may be obtained from the AHS faculty adviser, Dr. Edward Smith. AHS news and events are posted online at https://sites.psu.edu/pennstatevfs/

6.3. American Institute Aeronautics and Astronautics (AIAA)

The AIAA is the largest American technical society devoted to science and engineering in the fields of space, technology, rocket systems, aerodynamics, and marine systems. The mission of AIAA's Penn State chapter is to provide aerospace engineering students with unique learning opportunities in additional to what is given in a classroom setting. These opportunities are geared towards engaging students socially and promoting "hands on" engineering work. Membership applications and information on the benefits of belonging to this organization may be obtained from the AIAA faculty adviser, Dr. Robert Melton. Meetings and social events are held regularly during the academic year. Members can also attend the annual student conference for the Mid-Atlantic Region each April. AIAA news and events are posted online at https://sites.psu.edu/psuaiaa/

6.4. Engineering Graduate Student Council (EGCS)

The purpose of the Engineering Graduate Student Council (EGSC) is to promote and enhance graduate studies within the College of Engineering through professional development activities and to provide a forum for communication between graduate students, faculty, and administration within the College of Engineering. EGSC news and events are posted online at http://www.egsc.psu.edu/.

7. Guide to Graduate Student Resources

The Affirmative Action Office is committed to the concept of affirmative action to ensure equal opportunity in all aspects of employment for those historically excluded and to foster diversity in the University community. https://affirmativeaction.psu.edu/

Career Services assists students of all academic programs and class years with identifying and achieving their individual career goals. http://studentaffairs.psu.edu/career/

The Center for Spiritual and Ethical Development (CSED) offers a welcoming, safe, inclusive environment for the Penn State community to explore a multitude of faith traditions in a compassionate, open-minded setting. CSED aims to promote an environment that stretches beyond tolerance to a genuine appreciation of and respect for religious and spiritual diversity. http://studentaffairs.psu.edu/spiritual/

Counseling & Psychological Services (CAPS) is designed to enhance students' ability to fully benefit from the University environment and academic experience. CAPS can help students resolve personal concerns that may interfere with their academic progress, social development, and satisfaction at Penn State. Some of the more common concerns include anxiety, depression, difficulties in relationships (friends, roommates, or family); sexual identity; lack of motivation or difficulty relaxing, concentrating or studying; eating disorders; sexual assault and sexual abuse recovery; and uncertainties about personal values and beliefs. http://studentaffairs.psu.edu/counseling/

Directorate of International Students & Scholars Advising (DISSA) provides answers to questions and needs that are unique to international students. The office is located at 410 Boucke Building. https://global.psu.edu/

The Office for Disability Services (ODS) provides information and assistance to students with disabilities. http://equity.psu.edu/ods/

Graduate and Professional Student Association (GPSA) is the representative body for all graduate and professional students. The GPSA addresses issues of concern to graduate students and elects members to sit on shared-governance bodies of the University. The GPSA also organizes social events for graduate students. http://gpsa.psu.edu/

The Graduate Writing Center (GWC) is sponsored by the Graduate School and provides assistance to graduate students who wish to enhance their writing skills. Graduate students are invited to schedule appointments for one-on-one discussions of their writing projects. http://gwc.psu.edu/

The Office of Human Resources provides resource booklets on child care facilities in the State College area and summer programs and camps for school-age children. http://ohr.psu.edu/

Lions Pantry is to help provide sustenance to Penn State students experiencing food insecurity. http://sites.psu.edu/lionspantrypsu/

The Office of Off-Campus Living (OCL) opportunities are posted through online classifieds or for specific questions visit 230 HUB-Robeson Center. http://studentaffairs.psu.edu/offcampus/

The Office for Research Protections (ORP) provides information and resources to ensure that Penn State research is conducted in accordance with federal, state and local regulations and guidelines that protect human subjects, animals, students and personnel involved with research. http://www.research.psu.edu/orp

Safe Walk Service is operated under the auspices of Auxiliary Police and will provide walking accompaniment for Penn State students, employees and visitors who may feel unsafe walking alone on campus at night. The escort service may be reached at 814-865-WALK (9255). http://www.police.psu.edu/up-police/services/safe-walk-service.cfm

The Office of Student Aid is a good place to begin the search for financial assistance. http://studentaid.psu.edu/

The Office of Student Conduct is responsible for dealing with violations of the Code of Conduct including sexual assault, harassing, stalking, and physical assault. http://studentaffairs.psu.edu/conduct/

Union and Student Activities (USA) complements the academic experience by offering students opportunities in leadership, social responsibility, citizenship, volunteerism and student employment. http://studentaffairs.psu.edu/hub/

University Police & Public Safety is committed to protecting our community through professional service, education, diversity and ethical accountability by promoting safety and security. http://www.police.psu.edu/psu-police/

Problem resolution: Graduate students occasionally have difficulties with their advisors, their programs or an academic matter associated with their programs. The first step in problem resolution is always to talk with your advisor and then with the program chair or department head and then the associate dean of your college. If satisfactory resolution remains elusive, the associate dean of the Graduate School is available to provide guidance and maintain neutrality. Issues discussed during meetings with the associate dean will remain confidential if requested by the student. Appointments may be made by calling 814-865-2516.

Academic Integrity: The University does not tolerate violations of academic integrity, which include but are not limited to: plagiarism, cheating, falsification of information, misrepresentation, or deception.

Plagiarism: Plagiarism is often a confusing concept. At Penn State, plagiarism means taking someone's words and presenting them as your own. Cutting and pasting from a website is considered plagiarism. Copying verbatim from any source without using quotation marks and the full reference is plagiarism.

Plagiarism is a serious violation of academic integrity regardless of whether it is a homework exercise, an exam, a thesis, or a manuscript for publication.

University policies may be viewed online at http://guru.psu.edu/policies/. Important policies include:

Sexual Harassment (AD85)

Professional Ethics (AC47)

Parking Rules (BS04)

Intellectual Property (IP01)

Graduate Student Policies are available at

http://gradschool.psu.edu/graduate-education-policies/

Important policies include:

GCAC-801 (Conduct)

GCAC-802 (Procedures for Resolution of Problems)

GCAC-803 (Procedures for Termination of the Degree Program of a Graduate Student for unsatisfactory scholarship)

GCAC-804 (Procedures for Termination of Assistantships due to Inadequate Performance)

Appendices

1. Core Course Requirements

Basic Field Theory: complete one course in each of the following categories

Fluid Mechanics:

AERSP 508*	Foundations of Fluid Mechanics
AERSP 504	Aerodynamics of V/STOL Aircraft
AERSP 511	Aerodynamically Induced Noise
AERSP 524	Turbulence and Applications to CFD: DNS & LES
AERSP 525	Turbulence and Applications to CFD: RANS
AERSP 583	Wind turbine aerodynamics

Dynamics and control:

EMCH 520*	Advanced Dynamics
AERSP 506	Rotorcraft Dynamics
AERSP 518	Dynamics and Control of Aerospace Vehicles
AERSP 550	Astrodynamics
AERSP 597	Autonomy

Solid Mechanics:

AERSP 470*	Advanced Aerospace Structures
AERSP 571	Foundations of Structural Dynamics & Vibrations
AERSP 597	Multifunctional Structures
AERSP 597*	Advanced Composites

Applied Mathematics: complete one course

EMch 524 *	Mathematical Methods in Engineering
MATH 515	Classical mechanics and variational methods
STAT 500	Applied statistics

Note: Classes with * are designated foundational classes in each core area. Students are recommended to take these classes if they have not covered the material being covered in these courses in their prior degree program.

2. Courses that will be offered in 2024/2025

2.1. Fall semester

Course	*Credits*	*Title*
504	3	Aerodynamics of V/STOL Aircraft
508	3	Foundations of Fluid Mechanics
514	3	Stability of Laminar Flows
524	3	Turbulence and Applications to CFD: DNS and LES
571	3	Foundations of Structural Dynamics and Vibration
575	3	Aerospace Materials
590	1	Colloquium
596	1-9	Individual Studies
597-1	1	Aerospace Practicum
597-2	1-3	Advanced Air Mobility
597-3	3	Aerospace Autonomy
597-4	3	Advanced Aerospace Structures
597-5		TBA
597-6		TBA
597-7		TBA
597-8		TBA
597-9		TBA
600	1-15	Thesis Research
601	0	Ph D Dissertation Full-Time
610	1-15	Thesis Research Off Campus
611	0	Ph D Dissertation Part-Time

2.2. Spring semester

Course	*Credits*	*Title*
505	3	Aero and Hydroelasticity
509	3	Dynamics of Ideal Fluids
511	3	Aerodynamically Induced Noise
518	3	Dynamics and Control of Aerospace Vehicles
525	3	Turbulence and Applications to CFD: RANS
550	3	Astrodynamics
565	3	System Identification
575	3	Aerospace Materials
583	3	Wind Turbine Aerodynamics
590	1	Colloquium
596	1-9	Individual Studies
597-1	1	Doctoral Career Prep
597-2		TBA
597-3		TBA
597-4		TBA
597-5	3	Nonlinear Dyn: Theory & App
597-6		TBA
597-7		TBA
597-8	3	Signal Proc-Computer Vision
597-9		TBA
600	1-15	Thesis Research
601	1-15	Ph D Dissertation Full-Time
610	1-15	Thesis Research Off Campus
611	1-15	Ph D Dissertation Part-Time

3. Qualifying Exam

Purpose: The Ph.D. qualifying examination is intended to provide an additional measure (beyond what can be determined from the admissions documents) of a student's preparation for doctoral work. This is particularly useful for a student whose earlier degrees were obtained in non-aerospace engineering programs and/or from other institutions. To be successful in a Ph.D. program, students must understand a range of subjects beyond the particular topic of their dissertation research; hence, the qualifying exam should assess breadth of knowledge, posing questions from the primary fields that constitute our discipline: dynamics, fluids, mathematics, and structures. The exam does not require mastery of all four fields, but instead allows the student some choice in demonstrating a sufficient level of understanding in several areas.

Any graduate student seeking to qualify into the doctoral program is required to take the qualifying examination no later than the third semester of entering the Ph.D. program or the fifth semester of entering our graduate program; any student electing a second attempt at the qualifying exam must take it the next semester after the first attempt. The qualifying exam can be taken by students currently enrolled in the M.S. program; indeed, this is recommended so that M.S. students who are considering the Ph.D. program can learn whether they qualify in time to plan to stay for the Ph.D. – or make alternate arrangements – without a delay after completing their M.S.

Format: Faculty will prepare three questions in each of the four subject areas, following the respective syllabus. Each problem is to be appropriate for a senior-level undergraduate or introductory-level graduate treatment of the subject. The exam is closed book, except for formulas provided with the examination questions and students may bring two sheets of notes (standard US Letter paper, both sides). You may obtain this formula book to familiarize yourself with what is provided from the Graduate Staff Assistant prior to the exam.

A student taking the exam must attempt any eight of the 12 problems; the time limit for the exam is six hours.

Administration: The Director of Graduate Studies will form four committees, one in each field, giving each the responsibility to: (1) generate three problems, with solutions; (2) carefully check the problems for clarity and appropriate level of difficulty; (3) grade student answers.

Following the exam, the department faculty will then meet to review the grades and determine the outcomes. A student who fails the exam on the first attempt is allowed to take the subsequent exam (typically offered near the beginning of each semester). In the event of a second failure, a student is then removed from the Ph.D. program. A student who fails the exam twice may petition the Graduate Academic Committee in writing for an oral qualifying examination. If the petition is granted, the Director of Graduate Studies will form a committee of three faculty to

administer the oral exam and request that they make a recommendation of “pass” or “fail;” the Graduate Committee will then make the final decision.

3.1. Fluids

Material is based on AERSP 306, 311, and 312. The recommended graduate level course is AERSP 508.

Control volume analysis

- Continuity, momentum and energy equations, applications

Differential analysis of fluid motion

- Kinematics
- Rotation, vorticity, circulation
- Continuity equation
- Navier-Stokes equations

Incompressible inviscid flow

- Euler equations
- Bernoulli equation
- Velocity potential and stream function
- Elementary flows
- Forces and moments acting on a body
- Thin airfoil theory
- Lifting-line theory
- Slender-body theory

Dimensional analysis and similitude

- Application to problems in aerodynamics, hydrodynamics, rotating machinery, etc.

Incompressible laminar and turbulent flows

- Exact solutions of the Navier-Stokes equations
- Laminar and turbulent pipe flow
- Blasius boundary layer solution
- Integral methods for laminar and turbulent boundary layers
- Similarity analysis of laminar and turbulent boundary layers
- Laminar jets and wakes
- Eddy viscosity and mixing length concepts
- Reynolds averaged equations

Compressible flows

- Thermodynamics
- One-dimensional compressible flow
- Speed of sound and Mach number

- Alternative forms of the one-dimensional energy equation
- Stagnation, static and critical quantities
- Normal and oblique shock relations, shock polar
- Hugoniot equation
- One-dimensional flow with heat addition
- One-dimensional flow with friction
- Supersonic flow over wedges
- Prandtl-Meyer expansions
- Prandtl-Glauert equation
- Linearized theory for thin airfoils
- Full potential equation

Example references:

- White, F.W., *Fluid Mechanics*, 2nd edition, McGraw-Hill, 1989.
- Anderson, J.D., *Modern Compressible Flows, with Historical Perspective*, 2nd ed., Wiley, 1994.
- Anderson, J.D., *Fundamentals of Aerodynamics*, 2nd ed., McGraw-Hill, 1991.
- Munson, B.R., Young, D.F., Okiishi, T.H., *Fundamentals of Fluid Dynamics*, 2nd ed., Wiley, 1994.
- Cengal and Cimbala, Fluid Mechanics, 4th Edition, 2018

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.2. Structures

Material is based on AERSP 301, AERSP 304, and EMCH 315. A course that can count towards graduate course requirements is AERSP 470.

Stress and strain

- Definitions; tensor vs. engineering notations
- Differential equations of stress equilibrium
- Linear strain-displacement relation; compatibility equations
- Stress (/strain) transformation under coordinate change, principal stresses (/strains), and maximum shear stresses (/strains)

Material behavior

- Linearly elastic constitutive relations: isotropic, transversely isotropic, and orthotropic
- Design based on yield and failure criteria (von Mises, Tresca, and max stress/strain) and factor/margin of safety

Static analysis of simple structural members (rods, beams, and shafts)

- Differential equations of equilibrium: boundary conditions, compatibility, St. Venant's principle
- Cross-section properties: solid, thin-walled and thick walled, open and closed, multi-cell, monocoque/semi-monocoque
- Neutral axis, centroid, second moment of inertia, modulus-weighted centroid
- Shear center, center of twist Rigidity, displacements, strains, and stresses of
- Rod extension
- Euler–Bernoulli beam bending, shear flow
- Torsion
- Plate extension and bending
- Structural idealization
- Classical laminated plate theory: stress/moment resultants, A/B/D matrices

Energy methods of simple structures (rods, beams, trusses, and plates)

- Work and potential; strain energy; kinetic energy
- Principle of virtual work; principle of stationary total potential energy Ritz method
- Finite element method

Elastic stability of columns and plates

- Column buckling; effects of initial imperfections or load eccentricity
- Rectangular plate buckling under in-plane loads

Structural vibration of continuum structures

- Analysis of continuum system vibration in bending
- Energy methods of continuum system vibration in extension and bending: Ritz method and FEM

Example references

- Megson, T.H.G., Aircraft Structures for Engineering Students, John Wiley & Sons.
- Donaldson, B.K., Analysis of Aircraft Structures, An Introduction, McGraw-Hill.
- Reddy, J. N., Mechanics of Laminates Composite Plates and Shells: Theory and Analysis, CRC Press.

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.3. Dynamics and Control

Material is based on AERSP 304 and AERSP 309. Courses that can count towards graduate course requirements are AERSP 470 and EMCH 520.

Kinematics

- Orthogonal coordinate systems and transformations
- Cartesian, cylindrical, spherical systems
- Motion in inertial and accelerating reference frames
- Rectilinear/curvilinear velocities and accelerations; Coriolis acceleration

Momentum and impulse

- Momentum and impulse – linear and angular
- Newton's laws and D'Alembert's principle

Work and energy principles

- Hamilton's principle
- Lagrange's equations

Rigid body dynamics

- Inertia tensor
- Euler's equations
- Torque-free motion
- Gyroscopic devices

Vibration and structural dynamics

- Lump-parameter systems
- Single and multiple DOF discrete systems
- Algebraic eigenvalue problem; natural frequencies and mode shapes
- Forced response of damped systems

Systems Analysis (AERSP 304)

- Linear systems (linear algebra, least squares, state transition matrix, controllability, observability, similarity transformations)
- Linearization/Taylor series approximations (Equilibrium and stability of equilibria)
- Frequency domain system analysis (via Laplace transform for continuous time systems)
- Control System Analysis and Design (AERSP 304)
- Stability of the closed loop system (frequency domain: poles/zeros, Routh Hurwitz criterion)
- Controller characteristics and compensator design (PD/PID, pole placement)
- Robustness analysis and performance measures (Bode/Root locus, stability margins)

Example references:

- Greenwood, D.T., *Principles of Dynamics*, 2nd ed., Prentice-Hall, 1988.
- Marion, J.B. and Thornton, S.T., *Classical Dynamics of Particles and Systems*, 4th ed., Saunders College Pub.,1995.
- Thornson, W.T., Vibration Theory and Applications, 4th ed., Prentice-hall, 1993
- F. Golnaraghi and B. C. Kuo, *Automatic Control Systems*, McGraw-Hill, 2017.
- K. Ogata, *Modern Control Engineering*, Pearson, 2009.
- R. C. Dorf and R. H. Bishop, *Modern Control Systems*, Pearson, 2016.
- G. F. Franklin, J. D. Powell, A. Emami-Naeini, *Feedback Control of Dynamical Systems*, Pearson, 2015.
- Thornson, W.T., *Vibration Theory and Applications*, 4th ed., Prentice-hall, 1993

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)

3.4. Mathematics

Material in this section is based on AERSP 313 and its prerequisites. Relevant courses that can be used to satisfy graduate requirements are EMCH 524 and MATH 441.

Ordinary differential equations

- First- and second-order equations
- Homogeneous and inhomogeneous equations
- Systems of ordinary differential equations
- Elementary Laplace transforms
- Series solutions
- Sturm-Liouville equation

Partial differential equations

- Classification of equations
- Separable solutions
- Boundary and initial value problems
- Green functions
- Bessel functions
- Similarity solutions
- Characteristics

Vector calculus

- Scalars and Vectors
- Dot and cross products
- Conformal mapping
- Evaluation of line integrals
- Method of residues
- Evaluation of real integrals

Fourier series

Fourier and Laplace transforms, inverse Laplace transforms

Linear algebra

- Matrix operations
- Systems of equations
- Eigenvalues and eigenvectors
- Gaussian elimination
- LU factorization

Numerical analysis

- Interpolation and root finding
- Numerical integration
- Finite difference approximations
- Solution of ordinary differential equations Solution of partial differential equations

Probability

- Averages
- Probability: Probability distributions, conditional probability
- Correlations and spectra

Example references:

- Kreysig, E. *Advanced Engineering Mathematics*, 10th Edition, John Wiley & Sons, 2011
- Arfken, G. B. *Mathematical methods for physicists*, 7th Edition, Academic Press, 2013
- Wylie, C. R. and Barrett, L. C., *Advanced Engineering Mathematics*, 6th Edition, McGraw Hill, 1995

(Note: given some duplication of material in these references, students need not review them all; students are also encouraged to consult sources in addition to those listed here.)