Memorandum

To: The Faculty of the College of Engineering

From: The School of Aeronautics and Astronautics

Date: May 9, 2025

Re: New Graduate Course, **AAE 50900 Intermediate Aerospace Propulsion**

The faculty of the School of Aeronautics and Astronautics have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course no. **AAE 50900 Intermediate Aerospace Propulsion**
Spring, Lecture, Cr. 3

1. **Description:** This course is designed to offer a thorough treatment of both the theory and applications behind current and future aerospace propulsion systems. Propulsion systems convert some form of stored energy or energy that is freely available in the environment into kinetic energy to produce thrust. Since the energy involved is used to do work, the study of propulsion systems is based on concepts from thermodynamics. The course thus begins with a review of essential thermodynamics, which we then use to analyze thermodynamic cycles that form the basis of propulsion systems. In the vast majority of propulsion systems, the energy is stored in chemical bonds in a fuel and an oxidizer and released when these undergo a chemical reaction to produce heat. Such "chemical propulsion systems" thus involve combustion chemistry, which will be covered in the course. In many cases, the oxidizer is available in the surrounding atmosphere and only the fuel must be carried by the flight vehicle; such systems are referred to as "air-breathing propulsion systems". For other systems, especially those intended for use outside the atmosphere, both the fuel and oxidizer must be carried by the vehicle; the resulting system is then referred to as a "rocket propulsion system". Both these types of systems will be covered in detail in the course. We will cover both the analysis of such systems as well as their practical engineering implementation and integration into propulsion system components and complete propulsion systems. Credit cannot be earned in more than one of AAE 33800, AAE 33900, AAE 50900.

Reason: This course was first created and taught in 2010 in response to concerns from the Propulsion Committee that some propulsion major students struggled in advanced propulsion courses due to insufficient background in compressible flow and propulsion. While many undergraduate aerospace and mechanical

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engineering programs offer courses in compressible flow or aerodynamics, undergraduate propulsion courses are often not included. To address this gap, the course is designed to provide essential background in thermodynamics, compressible flow, heat transfer, airbreathing propulsion, and rocket propulsion, serving as a foundation for AAE 53800, AAE 53900, and AAE 53700 for students concentrating in propulsion who may lack the necessary background.

It also serves as an introductory course for students outside the propulsion concentration who are interested in learning about the field.

In addition to AAE graduate and undergraduate students, this course has been taken by students from other schools such as Nuclear Engineering, Mechanical Engineering, and Interdisciplinary Engineering.

This course is also taken by Naval Test Pilot School (NTPS) students. NTPS has partnered with Purdue Polytechnic Institute for a joint MS program since 2024 and identified two AAE courses that complement their curriculum but are not available at NTPS or Polytechnic. This propulsion course is one of those two courses (the other is intermediate applied aerodynamics). We anticipate a cohort of 30–35 NTPS students enrolling in this course during the Spring and Summer semesters.

William A. Crossley
J. William Uhrig and Anastasia Vournas Head of Aeronautics and Astronautics,
and Professor of Aeronautics and Astronautics

Enrollment History – Previously taught as AAE 590 Aerospace Propulsion

	Level	Major	2010 Fall	2011 Fall	2015 Fall	2017 Fall	2019 Fall	2021 Fall	2023 Fall	2024 Summer	2025 Spring
AAE59000 - Aerospace Propulsion PWL Enrollment	GR - Graduate School	AAEN - Aeronautics & Astronautics	2	2	7	1	2	6	8	6	6
		MECH - Mechanical Engineering									3
	AE - School of Aero and Astro Engr Undergraduates	AAE - Aero & Astro Engineering						1			1
	ME - School of Mechanical Engr	MECH - Mechanical Engineering									1
	NE - School of Nuclear Engineering Undergradautes	NUCL - Nuclear Engineering								7	1
AAE59000 - Aerospace Propulsion Pro Ed (CEC) Enrollment	GR - Graduate School	AAEN - Aeronautics & Astronautics	11		12	7	30	12	20	5	10
		MECH - Mechanical Engineering	2		1	1	3	4	5		8
		NUCL - Nuclear Engineering								1	1
		IDE - Interdisciplinary Engineering	8		10	9	2	4	4	32	13
		DVTI - Developmental Testing & Innov									35
		HYSN - Hypersonics									2
	AE - School of Aero and Astro Engr Undergraduates	AAE - Aero & Astro Engineering			1						
	Totals		**23**	**2**	**31**	**18**	**37**	**27**	**37**	**51**	**81**

		2011 Fall	2015 Fall	2017 Fall	2019 Fall	2021 Fall	2023 Fall	2024 Summer	2025 Spring	Totals
Undergraduate						1		7	3	11
Graduate	2	2	7	1		2	8	6	9	37
Prod Ed	21		23	17	35	20	29	38	69	252
Grand Total	**23**	**2**	**30**	**18**	**35**	**23**	**37**	**51**	**81**	**300**

Syllabus

Course Information
AAE 50900 Intermediate Aerospace Propulsion, Spring 2025
Meeting time: **ASYNC Online**
3 credit hours
Course Brightspace page: https://purdue.brightspace.com/d2l/home/1208409

Instructor Contact Information
Instructor: Professor Li Qiao (*pronounced 'lee chul'*)
Office: ARMS 3221; Lab: ARMS 3097 & Zucrow ZL2
Phone: 765.494.2040
Email: lqiao@purdue.edu
Office hours: Fridays 2:00-4pm, via Zoom, https://purdue-edu.zoom.us/j/5755421818

TA#1: Holman Lau, PhD candidate
Email: lau80@purdue.edu
Office hours: Monday & Tuesdays 6-8pm, Thursdays 3-5pm, via Zoom, https://purdue-edu.zoom.us/j/2694279089

TA#2: Alex Zhou, MS student
Email: zhou1120@purdue.edu

When you email me and TAs, please have "AAE 50900 Aerospace Propulsion" in the subject line. We usually respond to your email within 48 hours.

Course Description

AAE 50900 Aerospace Propulsion is designed to offer a thorough treatment of both the theory and applications behind current and future aerospace propulsion systems. It can serve as a prerequisite to AAE 53800 and AAE 53900 for students whose major or minor area of concentration is propulsion. It can also serve as an introductory course for students whose concentration is not propulsion but are interested in learning propulsion. Additionally, it is one of the foundational courses for the new Hypersonics Graduate Online Certificate Program.

Propulsion systems convert some form of stored energy or energy that is freely available in the environment into kinetic energy to produce thrust. Since the energy involved is used to do work, the study of propulsion systems is based on concepts from thermodynamics. The course thus begins with a review of essential thermodynamics, which we then use to analyze thermodynamic cycles that form the basis of propulsion systems. In the vast majority of propulsion systems, the energy is stored in chemical bonds in a fuel and an oxidizer, and released when these undergo a chemical reaction to produce heat. Such "chemical propulsion systems" thus involve combustion chemistry, which will be covered in the course. In many cases, the oxidizer is available in the surrounding atmosphere and only the fuel must be carried by the flight vehicle; such systems are referred to as "air-breathing propulsion systems". For other systems, especially those intended for use outside the atmosphere, both the fuel and oxidizer must be carried by the vehicle; the resulting system is then referred to as a "rocket propulsion system". Both these types of systems

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Learning Outcomes

On completing this course, the student shall be able to:

- Demonstrate a knowledge of conventional propulsion system types, their form, the functions of their components, and the applications for which they are suited.
- Calculate the properties of 1D compressible flow with area change, energy exchange (heat and work), friction, and shocks.
- Apply laws of conservation and the 2nd Law of thermodynamics to calculate thrust and specific impulse.
- Calculate performance and efficiency of ramjets, turbojets, turbofans, turboprops and rockets and their components including inlets, compressors and pumps, combustors, turbines, and nozzles.
- Derive propulsion requirements from mission requirements and perform top-level sizing calculations of ramjets, gas turbine engines, liquid rockets, and solid rockets.

Learning Resources, Technology & Texts

- Required textbook: Hill, P. and Peterson, C., Mechanics and Thermodynamics of Propulsion, 2nd edition, 1992, ISBN 0201146592. (H&P)
- Additional reading materials and references will be uploaded on BrightSpace during the semester.

Course Schedule

Module 1: Introduction - H&P Chapter 1

Module 2: Mechanics and Thermodynamics of Fluid Flow

Lesson 2.1 Thermodynamics - H&P Chapters 2.1, 2.2, 2.3

Topics: Control Volume (CV) Analysis, conservation equations, gas properties, entropy and isentropic flow, case studies

Lesson 2.2 1-D Compressible Flow - H&P Chapters 3.1 – 3.3, 3.4, 3.6, 3.7

Topics: Stagnation state and isentropic relations, 1-D compressible flow analysis, 1-D variable area flow, Rayleigh flow, Fanno flow, case studies

Lesson 2.3 Thermochemistry - H&P Chapter 2.4

Topics: Fuel properties, chemical reactions, heat of combustion, enthalpy of formation, adiabatic flame temperature, chemical equilibrium, CEA, case studies

Module 3: Air Breathing Engines

Lesson 3.1 Engine Performance and Cycle - H&P Chapters 5.1, 5.2, 5.3

Topics: The Brayton cycle, effect of compression ratio and turbine inlet temperature, ideal vs. real cycle, performance parameters, comparison of turboprop, turbofan, turbojet and

ramjet engines, range, case studies

Lesson 3.2 Ramjets and Scramjets - H&P Chapter 5.3

Topics: Introduction to ramjets, ideal and real ramjet analysis, J-58 turbo-ramjet engine for Blackbird SR71, scramjet technology development

Lesson 3.3 Turbojets - H&P Chapter 5.4

Topics: Introduction to turbojets, ideal turbojet cycle analysis, real turbojet cycle analysis, case studies

Lesson 3.4 Turbofans - H&P Chapter 5.5

Topics: Introduction to turbofans, turbofan cycle analysis, performance comparison, low by-pass military turbofan, case studies

Lesson 3.5 Turboprops and Electrified Aircraft - H&P Chapter 5.6

Topics: Introduction to turboprops, electrified aircraft

Lesson 3.6 Turbomachinery - H&P Chapter 7.1-7.8

Topics: Introduction to axial compressors, velocity triangles, Euler's work equation, stage efficiency, degree of reaction, preliminary design of an axial compressor, compressor map, introduction to axial turbines, turbine cooling, preliminary design of an axial turbine

Lesson 3.7 Inlets & Combustors - H&P Chapters 6.1 – 6.4

Topics: Subsonic inlet and diffuser, supersonic inlet, normal and oblique shocks, combustors, case studies

Module 4: Space Propulsion

Lesson 4.1 Rocket Fundamentals - H&P Chapters 10.1, 10.2, 10.3, 10.4, 10.6, 11.1, 11.2

Topics: Introduction to rockets, rocket classification, orbital mechanics, the Rocket Equation, Saturn V, rocket performance parameters, case studies

Lesson 4.2 Liquid Rockets - H&P Chapter 11.3, 12.1 – 12.3, 12.5, 13.1

Topics: Liquid rocket engine components, rocket propellants, engine cycles, Space Shuttle main engine, thrust chamber, injector, C-D nozzle theory, ideal nozzle, nozzle performance and flow separation, comparison of nozzle designs and advanced concepts, heat transfer, case studies.

Lesson 4.3 Solid Rockets - H&P Chapters 12.6, 12.7

Topics: Solid rocket motor, propellant grain design, burn rate and models.

Module 5: Conclusion

Grading:

Homework: 40%
Team literature review project: 30%

Team final design project: 30%

- Homework assignments will typically be made every 1-2 weeks and submission is through Gradescope.
- **No extensions for late homework will be granted for ANY reason**; therefore, please start early and submit your assignments on time. For NPTS students, if your flight schedule conflicts with your course progress, please contact me directly to discuss accommodations.
- Solutions will be posted on Brightspace after the due date.
- Homework must be neat, legible, and organized. You should understand the work you turn in; no credit will be given for copied homework.
- Guidelines for the two group projects will be given shortly.

Grading Scale
In this class grades reflect the sum of your achievement throughout the semester. You will accumulate points as described above, with each assignment graded according to a rubric. At the end of the semester, final grades will be calculated by adding the total points earned and translating those numbers into letter grades.

Changes and Emergencies
In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructor via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Copyright
Among the materials that may be protected by copyright law are the lectures, notes, and other material presented in class or as part of the course. Always assume the materials presented by an instructor are protected by copyright unless the instructor has stated otherwise. Students enrolled in, and authorized visitors to, Purdue University courses are permitted to take notes, which they may use for individual/group study or for other non-commercial purposes reasonably arising from enrollment in the course or the University generally.

Academic Integrity: "Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern."

Students with disabilities: "Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247."
Gradescope accessibility. https://help.gradescope.com/article/lpvwbzvqy2-faq-accessibility

COVID-Specific Protocols: This course will be taught in compliance with the Protect Purdue policies and guidelines. Please refer to https://protect.purdue.edu/.

Diversity & Inclusion Statement

1. In our discussions, structured and unstructured, we will explore a variety of challenging issues, which can help us enhance our understanding of different experiences and perspectives. This can be challenging, but in overcoming these challenges we find the greatest rewards. While we will design guidelines as a group, everyone should remember the following points:
   a. We are all in the process of learning about others and their experiences. Please speak with me, anonymously if needed, if something has made you uncomfortable.
   b. Intention and impact are not always aligned, and we should respect the impact something may have on someone even if it was not the speaker's intention.
   c. We all come to the class with a variety of experiences and a range of expertise, we should respect these in others while critically examining them in ourselves.
2. This course, as with every course offered at Purdue, plays a part in creating and sustaining a welcoming campus where all students can excel. There are many initiatives in our department and supported by the university focused on this goal, and this course is designed to take advantage of those resources. Learning experiences and assignments address diversity and inclusion, not because they are "topics," but because they are necessary to prepare students to be successful in a diverse, global environment.
3. We strive for equity, providing equal access and opportunity, and working to maximize student potential. This requires both instructor and students to identify and remove barriers that may prevent someone from full access or full participation. You can help by:
   a. Contacting me, anonymously if needed, if you see a potential barrier for someone or yourself in participating fully in the class. This might be a physical barrier such as access to technology or a personal situation.
   b. Suggesting ways in which members of our class can support each other. Virtual study groups and discussion boards are examples, but I encourage you to be creative in your ideas.
   c. Getting to know each other as contributing members of our learning community. Everyone has something to contribute, and while I designed the course to take advantage of the wealth of knowledge, expertise, and experience we bring together, I cannot do it well without your participation. There are many opportunities built into this course for this type of work. It is important we do it together.

Nondiscrimination Statement

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips,

available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructor via email. You are expected to read your @purdue.edu email on a frequent basis.