University of Michigan

AE481 Aircraft Design Syllabus and Guide

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Contents

Chapter 1

About This Course

We will be continuously updating this student guide during the semester. The major updates will be announced in the Canvas course website: `https://umich.instructure.com/courses/614796`.

1.1 Course Description

Multidisciplinary integration of aerodynamics, performance, stability and control, propulsion, structures and aeroelasticity in a system approach aimed at designing an aircraft for a set of specifications. Team based projects are overseen and graded by instructors and may also involve mentoring by representatives from external organizations.

This course will involve in-person lectures and group projects. In regular weeks, we will have two lectures and one lab/office hour per week. The lab/office hours are for you to work together with your team on the project assignments and ask your instructor(s) questions about the course material.

A key component of this course is the requirement for **independent research and self-directed learning** within your team's design project. The lectures will provide a strong foundation in the principles of aircraft design, integrating and reviewing core theories from your aerospace curriculum. However, the lectures are not intended to be a step-by-step guide for the specific project you are assigned. This approach is intentional. A critical learning objective of this course is for you to develop the ability to independently research concepts, find and evaluate resources, and read technical literature. This skill is essential for a practicing engineer, as real-world projects demand solutions that go beyond textbook examples. This course provides an opportunity to develop this capability in a structured academic environment.

1.2 About the Instructors

1.2.1 Faculty Instructor

My name is Dr. Gökçin Çınar (pronounced *gok-chin chin-r*; she/her/hers; `cinar@umich.edu`). I am an Assistant Professor in the Department of Aerospace Engineering, and the director of the **I**ntegrated **D**esign of **E**fficient **A**erospace **S**ystems (IDEAS) Laboratory. My research interests include aerospace systems design, analysis, and optimization with a special focus on advanced aircraft and propulsion concepts. I joined the University of Michigan in January 2022. Prior to that, I worked as a Research Engineer at Georgia Tech, where I also earned my master's and PhD degrees in aerospace engineering.

My early fascination with flying machines began with crafting wooden airplanes alongside my grandfather. This childhood curiosity led me to pursue a degree in aerospace engineering at the Middle East Technical University in Ankara, Türkiye. From there, my passion evolved into a career that beautifully merges engineering rigor with creative problem-solving.

As for this course, it's a unique opportunity to blend all the engineering principles you've learned so far with your creative thinking. I sincerely hope that together we will make this course as transformative as it is educational.

1.2.2 Graduate Student Instructor

GSI: Miranda Stockhausen (she/her)

Email: mstockha@umich.edu

Office Hours: TBD at Aerospace Learning Center.

My name is Miranda and I am your graduate student instructor. My research interests include aircraft systems modeling, sustainable aviation, and propulsion design. I graduated from The Ohio State University with a B.S.E. in aerospace engineering and a dual degree in political science, specializing in cooperation and conflict in 2023. I am also currently a student member of the American Institute of Aeronautics and Astronautics (AIAA).

I found aerospace engineering after high school, when a chance trip to see the National Museum of the USAF showed me that aerospace was an opportunity to combine my fascinations for aircraft history and mathematics. Continuing to lean into that combination of human and aerospace systems with my dual degree gave me the chance to see how unique perspectives can open up new solutions to even everyday problems, and I look forward to seeing how our teams can come together to bring out the best in each other's work. I have a passion for teaching and plan to enter academia as a research professor after completing my PhD. I'm looking forward to working with everyone, and a strong semester!

1.3 Course Culture

The engineering field does not operate separately from our identities, and we must work together to create an inclusive climate in our classroom. All of you are part of this class and belong here, and I will do everything in my power to ensure that all students in this course are supported and have an equitable learning opportunity. I am committed to a class culture that welcomes and serves students of all ages, ethnicities, genders and expressions, national origins, religious affiliations, sexual orientation, disabilities, socioeconomic backgrounds, and other visible and nonvisible differences.

I will foster a respectful, welcoming, and inclusive environment and expect each student to contribute. If at any time the words or actions of myself or your classmates make you feel uncomfortable, please let me know so that I can take appropriate and timely action if necessary. Your suggestions are encouraged and appreciated at any time. Please let me know by email if your pronouns or name differ from those on record with the university.

1.4 Schedule

Lectures: Mondays 3:30–5:30pm in A&AB2104 and Fridays 9:30–11:30am in 1014 DOW.

Lab and instructor office hours: Wednesdays 3:30–5:30pm in 2517 GGBL. This is a CAEN Lab, but there might not be enough computers for each student. You are highly recommended to bring your own laptops to the lab sessions.

Calendar: See the calendar on Canvas for important dates.

All sessions will be held in-person, unless otherwise announced. To enhance your learning experience, lectures will be recorded and can be accessed via the Lecture Recordings section on Canvas a couple of days up to a week after class. Please note that recordings of lab sessions and office hours will *not* be made available. While the lecture recordings are a supplementary resource, they are not a substitute for attending class in person. Attendance will be taken occasionally. There may also be occasional in-class activities that offer you the opportunity to earn class points.

Course Topics: refer to Table 1.1 for all topics covered in class this semester. Please note that the dates are subject to change during the semester.

1.5 Pre-requisites

This course requires students to have completed AE325. Programming experience is assumed for all students. You are expected to improve your programming skills, since the class project requires the development of a sophisticated multidisciplinary code that is to be developed collaboratively.

At least one member from each team should be proficient with CAD, and everyone is expected to learn some CAD to contribute to drawings required for the class project.

1.6 Online Tools

Canvas will be used to distribute the lecture videos, notes, slides, and other supplementary materials. Announcements will be posted on Canvas. For asking questions related to the course content, assignments, and logistics, please **use Piazza** (found on Canvas and also here: `https://piazza.com/umich/fall2024/aerosp481001fa2024`). However, please email Prof. Cinar or Miranda about any personal matters or private concerns that may arise during the semester.

1.7 Grading

Your grade will be based on the points you collect during the course. The opportunities for collecting points, along with the maximum points available for each assignment, are detailed in Table 1.2.

In the first three categories –Reports, Presentations, and Assignments– you'll collect points as a team, all contributing to your design project (see Chapter 2). Points for project reports and presentations are earned during two key design reviews:

- **Preliminary Design Review (PDR):** 40% of the report, presentation, and peer eval.
- **Critical Design Review (CDR):** 60% of the report, presentation, and peer eval. scores

Tip: These design reviews are essential stages of the design process. They mark the culmination of various design phases and represent periods of **peak activity** and you should plan ahead accordingly.

	Class Sessions	**Topics**
Week 1	8/25; 8/27; 8/29;	Course Info; Intro to Aircraft Design
Week 2	9/3; 9/5	Weight Estimation *No Class 9/1 (Labor Day)*
Week 3	9/8; 9/10; 9/12	Cost Analysis; Preliminary Sizing, Part 1
Week 4	9/15; 9/17; 9/19	Preliminary Sizing, Part 2; Sizing Plots and Configuration Selection
Week 5	9/22; 9/24; 9/26	Configuration and Layout; Aerodynamics
Week 6	9/29; 10/1; 10/3	Aerodynamics; Empennage & Stability
Week 7	10/6; 10/8; 10/10	Weights & Balances Landing Gear Sizing
Week 8	10/15; 10/17	PDR Presentations (17 Oct) *No Class 10/13 and 10/14 (Fall Study Break)*
Week 9	10/20; 10/22; 10/24	PDR Presentations (20 & 22 Oct); Sizing Refinement
Week 10	10/27; 10/29; 10/31	Guest Lecture (tentative) Aerodynamic Refinement
Week 11	11/3; 11/5; 11/7	Introduction to AVL; Guest Lecture
Week 12	11/11; 11/13; 11/15	V-n Diagrams; Structures
Week 13	11/17; 11/19; 11/21	Propulsion; Guest Lecture
Week 14	11/24	CDR Preparations *No Class 11/26 and 11/28 (Thanksgiving Break)*
Week 15	12/1; 12/3; 12/5	CDR Presentations; Poster Session
Week 16	12/8	*Class cancelled; independent work for CDR report*

Table 1.1: Weekly topics (tentative schedule).

PDR and CDR: At the PDR we evaluate the progress towards a more detailed design. Only one concept should be carried forward from this point. Oral presentations will be in class. For the CDR, we review the final detailed design, and uncover any areas of difficulty or uncertainty needing further attention. Around the CDR, there will be a project poster session where teams will have the opportunity to design and display a poster detailing their final concept. More information about the review format and expectations will be provided closer to the events. The reports are to be submitted according to the deadlines on Canvas, in the "Assignments" section. The assignments are included in these notes, in Chapter 3.

Tip: Follow the guidelines in Chapter 4 for design review expectations.

Tip: The design project assignments are designed to monitor the health of your project and keep you on track for PDR and CDR.

Table 1.2: Grading Scale and Assignment Points

Category	**Type**	**Points**
Reports (total)	Team	25
PDR		*10*
CDR		*15*
Presentations (total)	Team	14
PDR		*4*
CDR		*6*
CDR Poster		*2*
CDR 3D Printed Model		*2*
Project Assignments	Team	20
Peer eval. (total)	Individual	10
PDR		*4*
CDR		*6*
Quizzes	Individual	30
A^3 Tournament	Individual	3
Class Participation & Mini-assignments	Individual	3
Total		**105**

Peer evaluations: Aircraft design is a multi-disciplinary effort that requires multiple people to work together collaboratively. The design project will be a reflection of the real-world environment, on a micro-scale level. Each member of the team will assume a critical leadership role and take ownership of an important piece of your design project. It is the team's responsibility to create a safe and supportive environment so that *all* team members thrive and fulfill their potential. It is also your individual responsibility to do your best work for your team's success. Throughout the semester, your individual efforts will be evaluated by your team members. If you actively try and do your best, you can score up to 10 points. However, if you do not collaborate with your teammates or take ownership of your tasks, you will ***lose*** up to 3 points.
Tip: Peer evaluation is the only mechanism through which you could potentially lose points in this course. Periodic health checks within your team can proactively address any unintentional lack of support.

Quizzes: There will be a total of ten weekly online quizzes in this class. The quizzes will be based on the recent topics covered in class (including lectures, lab, and questions covered in the A^3 Tournament), the relevant chapters in the metabook, and any additional assigned reading materials. The timing and duration of the quizzes will be announced on Canvas.

A^3 Tournament: The All About Aircraft (A^3) Tournament is a specialized aviation trivia game designed to enrich the course experience. Through this engaging competition, you have the opportunity to both create and answer questions related to aircraft and aviation, thereby earning points that contribute to your final class grade. See Chapter 5 for more information.

Class Participation & Mini-Assignments: This includes attendance and participation in brief in-class assignments, such as surveys, presentations, or short homework. These tasks are lighter than project assignments. While consistent attendance is strongly encouraged, occasional absences are understandable. Attendance is particularly important on design review days and is also expected during regular class hours.

Final class grades: Table 1.3 shows how your final points are converted to a letter grade at the end of the semester.
Tip: The total possible points you can score is 105. That is 12 points more than you need for an A.

Points	Letter Grade
97	A+
93	A
90	A-
87	B+
83	B
80	B-
77	C+
73	C
70	C-
67	D+
63	D
60	D-

Table 1.3: Final points converted to letter grades.

Important Rules

- The reports and presentations must be submitted by 11:59 pm on the due date. The late policy is a 33% penalty per day. If you think you cannot submit on time due to exceptional circumstances, please let us know in *well in advance*.
- Assignment submissions must be made through Canvas by uploading: (1) a copy of your Aircraft Data Sheet; (2) a PDF file with your report; and (3) a ZIP file with the source code. Please follow the given directions for submission exactly. All file names (with exception to the source code itself) should start with your group number. The ZIP file should expand to a directory whose name also starts with the group number.
- Do not use email to ask questions, unless it does not make sense to ask them on Piazza.
- To earn a grade higher than **D+**, you must deliver a presentation and attend both PDR and CDR.
- To be eligible for a grade higher than **B+**, you must complete at least six regular assignments (in addition to the design review assignments) on time. Late submissions won't count.
- **Honor Code:** All students are expected to abide by the University of Michigan College of Engineering Honor Code. While discussion of ideas is encouraged, the work you submit must be your own. Individual assignments, such as quizzes and the A^3 Tournament, should not be discussed with others until the questions have been made public in class by the course instructors.
- Online quizzes are open-notes unless otherwise specified, but the use of AI tools is explicitly forbidden. Any indication of use during quizzes will be reported to the College of Engineering

for investigation as academic misconduct, and subject to consequences like failing the quiz or failing the course depending on the scope and severity of the actions taken.

1.8 Course Policy on the use of AI

1.8.1 Why You Should Not Use AI During Quizzes

This is the senior design capstone course, and therefore your final step before becoming a professional aerospace engineer. These quizzes are designed to prepare you for that. They focus on fundamental concepts that every engineer should know by heart. In a job interview or a team meeting, you will be expected to recall these principles without any assistance. The short time limit on each question is intentional–it encourages you to internalize this knowledge until it becomes second nature.

Mastering this material is a point of pride for you and the entire University of Michigan aerospace engineering community. A recruiter's positive impression of one UM graduate helps all future alumni. By ensuring you and your classmates have a strong command of these fundamentals, we collectively build a reputation for excellence that benefits everyone.

To support your learning, you can take each quiz twice. My goal is not to penalize mistakes but to encourage genuine learning. After your first attempt, you will have a one-hour break before you can retake it. Use this time to review the material and reinforce your understanding. The questions may differ between attempts, so focus on the concepts, not just the answers. As the semester progresses, quizzes will become cumulative, pulling from all previous topics. The final quiz will be comprehensive and offer unlimited attempts, so you can be confident that you have mastered the material. This is your chance to demonstrate your knowledge and integrity as you prepare for your career.

1.8.2 Use of AI in Other Coursework

This course is designed to equip you with the skills and knowledge you will need as a professional aerospace engineer. The use of AI tools in certain contexts can be a valuable part of this process, helping you to work more efficiently and explore new ideas.

For all assignments, coding, presentations, and reports, you are permitted to use AI tools as long as you adhere to the following guidelines:

- You are fully responsible for all work you submit, regardless of how it was generated. This means you must carefully review, verify, and understand any content produced with AI. Any errors in the final work are your responsibility.
- You must clearly and accurately disclose any use of AI in your work. This disclosure should be made within the body of your submission, such as in a footnote or a dedicated section of your report and assignments.

By following these rules, you can leverage AI as a tool to support your learning and design process while maintaining academic integrity and preparing for the ethical responsibilities of a professional engineer.

1.9 Student Mental Health

Stress and anxiety are more common than the national average among undergraduate and graduate students. These environmental stressors, combined with past and current personal circumstances, can severely affect a student's academic performance and their quality of life in general. Unfortunately, the symptoms of these mental health difficulties often go unnoticed. I encourage you to be supportive of your classmates as you share this learning experience. The Department, the University, and I are committed to advancing your mental health and well-being. I would also like to make you aware of the available resources to help address any learning or emotional barrier you may be experiencing.

The UM Counseling and Psychological Services provide resources for students who feel overwhelmed, depressed, anxious, or need support. To learn more about the resources they offer, please visit their webpage: https://caps.umich.edu/mitalk.

1.10 Student Accommodations

I am deeply committed to building an accessible learning environment that fosters the academic success of all students, and I aim to abide by any accommodations granted by the University Services for Students with Disabilities (SSD) Office.

If you have a disability, you can request accommodations to the SSD office at https://ssd.umich.edu/ or by phone: (734)763-3000. They will then issue a verified individual services accommodation (VISA) form. You should email me this form so I can provide the accommodations.

1.11 Student Sexual Misconduct Policy

Title IX prohibits discrimination on the basis of sex, which includes sexual misconduct – including harassment, domestic and dating violence, sexual assault, and stalking. I understand that sexual violence can undermine students' academic success. I encourage anyone dealing with sexual misconduct to talk to someone about their experience, so they can get the support they need. Confidential support and academic advocacy can be found with the Sexual Assault Prevention and Awareness Center (SAPAC) on their 24-hour crisis line, 734.936.3333 and at https://sapac.umich.edu/. Alleged violations can be non-confidentially reported to the Office for Institutional Equity (OIE) at https://oie.umich.edu/.

1.12 Religious/Cultural Observance

Students who have religious or cultural observances that coincide with this class should let the Instructor know via email within the 3 weeks from the start of the course. Students who expect to miss classes or other assignments as a consequence of their religious observance will be provided with an alternative opportunity to complete their academic responsibilities.

1.13 Other Resources

- Diversity, equity, and inclusion resources: https://aero.engin.umich.edu/info/dei-resources/
- Academic, financial, and wellness support: CARE center (https://care.engin.umich.edu/)
- Network and computer support: CAEN (https://caen.engin.umich.edu/, Aero Tech Center (David McLean, dmclean@umich.edu)
- Free aero tutoring: SGT (sgt-academic@umich.edu)

- Psychiatric Emergency Services (734-996-4747)
- Services for Students with Disabilities (734-763-3000; 734-615-4461 [TDD]; 734-619-6661 [VP]; ssdoffice@umich.edu)

Feel free to reach out to me to talk about any of the above issues that concern you. I am available for individual scheduled meetings outside regular class and office hours.

1.14 Land Acknowledgment

The University of Michigan resides on the ancestral, traditional, and contemporary lands of the Anishinaabeg: The Three Fire Confederacy of the Ojibwe, Odawa, and Potawatomi Nations, and the Wyandot Nation. Acknowledging the past in itself is not enough to account for the ongoing consequences of colonization but, developing a thorough understanding of the past may empower us to strive for a future that supports equity, inclusion, and justice for all individuals.

1.15 Course References

There is no required textbook, but useful material can be found in numerous books and other references cited in the notes [5]. A few comments on the most useful references follow.

1.15.1 About the Course Notes (Metabook)

The course notes [5] were created to be *the* reference for the course. While the notes contain most of the basics, students are expected to check the original sources when they require more details. The original sources are all listed at the end of each section.

The motivation for these notes comes from the fact that I believe that the needs for this aircraft design course are not covered satisfactorily by one single book (or even two). These notes are a "metabook" that gathers what I consider are the most essential facts and best explanations, together with pointers to good references.

1.15.2 Aircraft Design Books

There are many books on aircraft design and several of them are recommended. Here is the AERO 481 guide for library access: https://guides.lib.umich.edu/aero481

Aircraft Design: A Conceptual Approach, by Raymer [12] , is a popular book, now in its 5th edition. The book is comprehensive and contains some practical formulas—such as weight and cost estimates—that are hard to find in one single reference. The shortcoming of this book is that it often lacks the physical explanations that would help build your intuition, and the sources and derivations of many of the formulas are unclear. However, this would be a good first book to add to your library.

Fundamentals of Aircraft and Airship Design, by Nicolai and Carichner [8] is a recently published book written by Lockheed Martin Skunk Works engineers. It contains a lot of information, with several examples involving recent aircraft. The full book is available online from the UofM domain at: http://www.knovel.com/web/portal/basic_search/display?_EXT_KNOVEL_DISPLAY_bookid=3908.

Airplane Design, by Roskam [14] is a collection of books that provides the most detailed coverage on the subject with step-by-step procedures and numerous examples. The collection is composed of seven volumes:

Part I : Preliminary Sizing of Airplanes (1985)

Part II : Preliminary Configuration Design and Integration of the Propulsion System (1985)

Part III : Layout Design of Cockpit, Fuselage, Wing and Empennage: Cutaways and Inboard Profiles (1986)

Part IV : Layout Design of Landing Gear and Systems (1986)

Part V : Component Weight Estimation (1985)

Part VI : Preliminary Calculation of Aerodynamic, Thrust and Power Characteristics (1987)

Part VII : Determination of Stability, Control, and Performance Characteristics: FAR and Military Requirements (1988)

Part VIII : Airplane Cost Estimation: Design, Development, Manufacturing and Operating (1990)

The only disadvantage of this collection is that it is rather dated.

Civil Jet Aircraft Design, by Jenkinson et al. [2] is a very good book specialized for civil transport design. The introduction includes a great overview of the big picture for civil transports, including economics and environmental impact. The fuselage layout section is particularly useful.

Jet Sense: The Philosophy and Art of Jet Transport Design, by Pastakia [10] is a recent book written from the industry perspective of Boeing's Director of Derivative Improvements and Advanced Concepts. It offers a focused guide specifically on commercial jet transport design. It reflects how the industry approaches design, emphasizing the interplay between market analysis and product functionality. The book features an innovative approach to initial sizing tailored for commercial aircraft and is supported by extensive data and visuals.

Synthesis of Subsonic Airplane Design, by Torenbeek [18] is a comprehensive text, although a bit dated. The rationale for making each design decision required is explained. It includes a vast list of references and a large amount of design data.

Advanced Aircraft Design, by Torenbeek [19] is another excellent book by Prof. Torenbeek that can be seen as a modern version of his previous book (see above). Like that book, it focuses on civil subsonic airplanes, and it provides good explanations. It includes a chapter on flying wings and another on aircraft design optimization. The full book is available electronically at UofM: `http://onlinelibrary.wiley.com/book/10.1002/9781118568101;jsessionid=10FD6ABB6A008462F5481102E9FDAD78.d02t03`

The Design of the Airplane, by Stinton [15] focuses on light aircraft. It includes excellent illustrations and numerous insightful physical explanations.

The Aerodynamic Design of Aircraft, by Kuchemann [3] is a classic book that explains aircraft aerodynamics applied to various configurations. This book is an excellent source for building intuition in aircraft aerodynamics.

Aerodynamic Design of Transport Aircraft, by Obert [9] is for those who are keen to learn more advanced aerodynamic design. Unfortunately the print quality is low, and the text is not well edited, but it contains a trove of real world data, and advanced practical insights in aircraft aerodynamics.

Introduction to Transonic Aerodynamics, by [20] is inspired in the book above and was written to complement it with the mathematical and physical models. Another excellent source of aerodynamic knowledge.

Understanding Aerodynamics, by McLean [7] is a comprehensive book on aircraft aerodynamics. In spite of the title, this is not an introduction to aerodynamics, but a book that will deepen your knowledge and intuition of aerodynamics once you already have been introduced to the basic concepts. It is a unique book in the physical explanations it provides, including many nuggets of aerodynamic wisdom and intuition that is extremely useful in aerodynamic design. The full book is available online at: http://onlinelibrary.wiley.com/book/10.1002/9781118454190

Aircraft Engine Design, by Mattingly et al. [6] : while it focuses on engine design and component selection, this book has great content on aircraft design as well. Chapters 1, 2, and 3 are particularly useful for an introduction to design, constraint analysis, and mission analysis at the system (aircraft) level.

More general books on aviation: There are many inspiring books on aviation. I highly recommend these: Irving [1], Sutter and Spenser [16], Rich and Janos [13], and Tennekes [17].

1.15.3 Other References and Resources

Prof. Mason's aircraft design course: http://www.dept.aoe.vt.edu/%7Emason/Mason_f/SD1.html

Jane's All the Worlds Aircraft online: http://www.lib.umich.edu/database/link/8467

Federal Aviation Regulations (FAR) parts 23 and 25 , available in Canvas.

NASA Technical reports server: http://ntrs.nasa.gov/search.jsp

AIAA Electronic Library: https://aiaa.org/IframeTwoColumn.aspx?id=4745

Google Scholar: http://scholar.google.com

Webfoil airfoil database: http://webfoil.engin.umich.edu

IDEAS Lab's FAST Aerobase: https://gokcincinar.com/software/aerobase/

1.15.4 Library Research Guides

The University of Michigan library has a list of additional books (in both physical and digital forms) relevant to the topics covered in this course. You may access this list via https://guides.lib.umich.edu/aero481. For additional assistance, your may contact Paul Grochowski (grocho@umich.edu), the Aerospace Engineering Subject Librarian.

1.16 Course Material Acknowledgment

This course builds upon the foundational material developed by Prof. Joaquim Martins at the University of Michigan. While the core structure remains, additional content and modifications have been made to enhance the learning experience.

Chapter 2

2025-2026 Project: Next Generation Carrier-based Strike Fighter Aircraft

2.1 AIAA Design Competition

This year, the design project will match AIAA's Undergraduate Team Design Competition. Some aspects of the project will be covered in this syllabus, but please refer to the Request for Proposals (RFP) on Canvas for a comprehensive list of details and design requirements. It is our hope that some of you will be able to refine your work from the semester and submit it to this competition.

If your team is interested in participating in the competition, there will be ample time for preparation after the semester concludes. Should you choose to enter your 481 design into this competition, I would be delighted to act as your faculty advisor. You are also welcome to take my 490 or 590 section in the Winter semester to receive course credit for your efforts in this competition. The deadline for submitting team rosters for the competition is February 6, 2026, well into the Winter Semester, and the final proposal (paper) is due by May 15, 2026.

For complete information about the design competition, please visit AIAA Design Competitions. The RFP that corresponds to our design project is the Undergraduate Team Aircraft Design Competition RFP.

2.2 Background

The following background information is taken directly from AIAA's Undergraduate Team Design RFP:

The objective of this study is to consider a candidate strike fighter aircraft replacement for the F/A-18E/F aircraft with improved performance at a comparable unit acquisition cost. This is not a trivial challenge. As illustrated by "Augustine's Law", combat aircraft unit cost has been inexorably increasing with time. In order to maintain the number of aircraft in the Navy's inventory, this trend must be broken.

The candidate will be carrier-based and will perform missions currently conducted by the legacy aircraft, including air-to-air combat, strike, and electronic attack. The targeted initial operational capability (IOC) date is 2035.

2.3 Objective

The objective of this project is to design a new, affordable, carrier-based aircraft that will provide credible combat capability in an advanced air defense and counter air environment. Key elements of this project are to design conceptual aircraft which meet mandatory carrier suitability requirements, meet the unit recurring cost requirement and provide the maximum combat performance consistent with the carrier suitability and cost requirements.

2.4 Aircraft Requirement Overview

Your team's aircraft concept must satisfy the following requirements. The AIAA's design requirements are somewhat different than what you may have seen elsewhere, so please see the RFP for more details. The information provided below are *only a summary* of the full requirements outlined in the RFP. Please note that the RFP may be updated by AIAA until October 1 2025, and students should check the document regularly for updates.

Aircraft Type & Configuration: Fixed wing strike fighter aircraft, suitable for operation from CVN-68 and CVN-78 class aircraft carriers. You may select aircraft configurations, features, propulsion system, materials, subsystems, and storage location as necessary to maximize cost-efficacy with performance. See RFP Sections 3.1 and 3.2 for more details.

Maximum Payload: The aircraft must carry equipment and ordinance for two combat conditions: air-to-air and strike. See RFP Section 3.3 for more details.

Mission profile: The design must satisfy requirements for two combat mission types: air-to-air and strike. The missions both have a minimum required range of 700 nm and specifications for dash and other key performance considerations. See RFP Section 3.4 for mission requirements and Section 3.2 for launch and recovery (i.e., takeoff and landing) performance.

Maneuvers: Your aircraft must meet the performance requirements outlined in RFP Section 3.5, at the corresponding environmental or fuel condition.

Fuel Volume: You must determine the fuel weight that will satisfy the mission and performance requirements, with reserves. The reserve fuel weight shall be sufficient for a 20-minute loiter at 10,000 ft and two landing attempts while carrying 25% maximum fuel weight and 50% store weight.

Technology: All systems and subsystems technologies (including avionics and mission systems) must be currently at technology readiness level (TRL) 6 or higher. The propulsion system must use an existing production engine and all selected materials must be available in production quantities.

Regulations: Unless otherwise specified by the RFP, the aircraft must satisfy Part 25 of the Federal Aviation Regulations (FAR) including noise and exhaust gas emission restrictions. See Raymer [11, Appendix F] for a summary of the regulations.

Entry into service year: Initial operational capacity date is 2035, with a service life of 25 years.

Cost: The unit cost for a production run of 500 aircraft of your design must not exceed that of the legacy aircraft.

Crew: Depending on the model (E vs F), the legacy aircraft carries 1 or 2 passengers. Your team should justify your crew capacity choice during the design process.

2.5 Report Requirements

The following are the report requirements taken directly from Section 4 of the RFP. These tasks are intended to show how your team proposes to develop the design of a new aircraft.

- Justify the final design and describe in detail the technologies and technical approach used to meet the mission requirements.
- Provide carpet plots used to optimize the final selected design.
- Include a dimensioned 3-view general arrangement drawing.
- Include an inboard profile showing the general internal arrangement.
- Include an illustrated description of the primary load bearing airframe
- structure and state rationale for material selection.
- Include performance flight envelope, payload-range, and V-n diagrams.
- Quantify aerodynamic characteristics (drag in particular) for key mission segments.
- Show a weight breakdown of major components and systems, and center of gravity travel.
- Provide performance estimates and demonstrate aircraft stability for all flight and loading conditions.
- Provide unit cost for a production run of 500 aircraft.
- The discussion of additional roles, use-cases, or potential design variants is encouraged.

2.6 Key Terms from RFP

For those unfamiliar with aircraft design for military aircraft carrier applications, you may encounter some terms in the RFP that you don't know. Hopefully this list will help you out.

Air-to-Air Combat: This refers to direct combat engagement between two or more aircraft, either at close range or beyond visual range using RADAR.

Arrestment: The process of landing via some form of arresting gear on an aircraft carrier, typically using hooks and cables.

Catapult Minimum End Airspeed: In short, this is the airspeed at which the aircraft can remain airborne when it leaves the carrier deck. It is technically defined as the airspeed required at the end of the catapult stroke to support the aircraft, with consideration for conditions of altitude loss, lift limit, pitch rate limit, and longitudinal acceleration specified for catapulting.

Combat Radius: This is the maximum distance which a military aircraft could travel from its base, perform a mission, and safely return home. The radius generally assumes a remaining reserve fuel load.

CVN-XX Class: CV is the official designation used by the US Navy for fixed wing aircraft carriers. CVN-68 (Nimitz class) and CVN-78 (Ford class, the most recent) are both nuclear powered.

Dash: Cruise at maximum speed.

Egress: Flight path leaving the mission target area.

Ingress: Flight path entering the mission target area.

Launch and Recovery: These are the takeoff and landing (respectively) processes on an aircraft carrier, which depend on systems of equipment such as launch catapults and arresting gear.

Maximum thrust: This is the most thrust the engine can produce when the use of afterburners and augmentors is allowed.

Military Thrust: Also known as intermediate thrust, this refers to the most thrust the engine can produce *without* the use afterburners or augmentors.

Ordnance: The RFP is asking you to develop designs which can carry a variable number of missiles. While storage location of these weapons is left up to the designer, internal storage is desirable for strategic purposes.

Specific Excess Power (P_S): Defined as $P_S = v(T - D)/W$. Velocity times the difference between thrust and drag, normalized by weight. Note $g \neq 9.81 m/s^2$ in a maneuver where the aircraft experiences higher g forces.

Spot Factor: This is the amount of deck or hangar space taken up by a carrier aircraft, expressed as a ratio. The fraction is calculated relative to the footprint of the F/A-18C, which is assigned a spot factor of 1.0.

Static Stability: The tendency of an aircraft to return to its original attitude after a perturbation. Statically stable designs are *positive* (return to their original attitude), while statically unstable designs are *zero or negative* (stay in perturbed attitude or move further away from it).

Stowed Configuration: This is the more compact configuration of the aircraft used to maximize aircraft storage capacity on a carrier, typically involving folding or rotating the wings toward the fuselage.

Strike Attack/Combat: A ground attack combat mission.

Strike Fighter: A multi-use fighter aircraft capable of both strike and air-to-air attacks. Similar to the old fighter-bomber, it primarily flies in enemy airspace.

2.7 Parameters for validation and comparison

Table 2.1 lists parameters from the Boeing F/A-18E/F Super Hornet that should be used to validate your computations. You can use these specifications and estimates to validate your weight estimation and preliminary sizing codes.

Feel free to research other similar aircraft and their specifications if your team would like any additional points of reference. However, keep in mind that this is the legacy aircraft called out in the RFP requirements (Section 3).

Note that armaments such as cannons do not count against the weapons payload. I.e., the 9,400 pound capacity is for additional munitions.

Parameters	Boeing F/A-18E/F Super Hornet	Units
Payload	9,450	lbm
Number of Crew	1-2	
Range	1,275	nm
Combat Range	$\sim$ 444	nm
Maximum Mach Number (40,000 ft)	1.8	
Maximum Mach Number (SL)	1.06	
Maximum L/D	$\sim$ 10	
Powerplant	2x F414-GE-400	
Military Thrust	26,000	lbf
Maximum Thrust	44,000	lbf
Wing Aspect Ratio	4.0	
MTOW	66,000	lbm
Gross Weight	47,000	lbm
Empty Weight	32,081	lbm
Maximum Carrier Landing Weight	42,900	lbm
Fuel Weight - with external tanks	27,270	lbm
Fuel Weight - w/o external tanks	14,230	lbm
Wing Reference Area	500	ft^2
Wingspan	44.7	ft
$C_{L_{\mathrm{max,takeoff}}}$	$\sim$ 1.57	
$C_{L_{\mathrm{max,landing}}}$	$\sim$ 1.24	
Design Load Factor	7.5 g	

Table 2.1: Parameters for validation

2.8 Using GitHub for Code Collaboration

Since the design project is computationally-focused, your team must find a way to repeatedly update your code. One online resource that allows you to do this is GitHub, a version control platform.

Each time you want to modify your team's code, you can download the most recent version from the GitHub repository (location with the most up-to-date code) and make changes on a local copy (that only you have access to). Once you finish updating the code, you then commit (or share) those changes to the repository. GitHub also allows you to track the history of your code in the repository and revert back to a previous version if needed (in the event that a recent code commit/update created a bug or other issue).

We highly recommend that you consider using GitHub or some other version control tool rather than sharing code via email, Dropbox, or Google Drive, to name a few. You can create a free GitHub account at https://github.com/ and can access all necessary GitHub documentation at https://docs.github.com/en.

Chapter 3

Assignments

- These assignments are meant to be milestones to keep your progress towards the design reviews in check and to correct any major problems with your calculations and design.

- Please name all files such they start with your group number, e.g., `01-spreadsheet.xlsx`. For zipped directories, they should expand to a directory with a name that also starts with the group number (the files inside the directory do not need be named this way). Do not change the format of the cells on the spreadsheet and do not enter the unit names or any other text for cells that are formatted to take numbers. This is to ensure a consistent view for those who are grading.

- Please include your answers to any enrichment questions within the assignment report uploaded to Canvas (do not put it in a zip file). This way we can provide feedback to you through the system built into canvas.

- In each assignment report, please submit a list of references you consulted while completing the assignment. The references should be cited in a widely used format, such as APA (preferred), MLA, or Chicago.

- Please attach all your codes used for the assignment in a zip file.

- From the beginning, try to use functions and make your code as modular and organized as possible. This will help with the continuous refinement of the analyses as the term progresses and will also help with the trade studies and optimization phases.

- For each assignment, when applicable, type up and describe the equations and methods used for the different analyses. Explain and show the values used for the various parameters. This will make it easier to identify mistakes and will help while writing the PDR and CDR reports. (This does not have to be very formal.)

- For each assignment please include a very brief paragraph or small table describing what each team member contributed to your team's submission. In this section, summarize the team member contributions **as percentages**. Every member does not have to do something every week. Some weeks you may do more than others. Just report this to keep yourselves accountable and keep the instructors aware of participation.

3.1 Assignment 0: Team Formation

If the class has voted for self organizing teams, students will form teams and select a team leader. The team leader makes sure that all members registered to an available team in Canvas under People – Project Teams. The minimum and maximum number of members will be announced in class. All students should have a team by the assignment deadline.

The team leader, in addition to their design tasks, will be responsible for submitting all the assignments, setting up the group meetings, and making sure the team functions smoothly.

3.2 Assignment 1: Team Initialization and Data Gathering

For your first assignment you will:

A. Name your aircraft and design a logo. Note: you will still use the assigned group number as an identifier in all the correspondence. Create a PDF file with the team name, team leader, and the logo (or place your logo in the General-Overall sheet in the provided Excel workbook).

B. Gather data on currently flown aircraft that are the closest to the specifications of the project and fill out the General-Overall and General-Comparison aircraft sheets in the Excel workbook. At this stage, the row for your airplane in the General-Overall sheet can be left blank.

C. Please submit the files(s) through the Canvas assignments system.

D. *Enrichment questions:*

   D.1 What is the average empty weight to MTOW ratio for the aircraft you gathered data for?

   D.2 What is the variance for the empty weight to MTOW ratios?

   D.3 Try to identify 3 features of the aircraft you researched that you do not understand (e.g., why are the engines of commercial aircraft always mounted below the wing?).

3.3 Assignment 2: Preliminary Weight

A. Please fill out the following sheets in the attached Excel workbook:

   - General-Overall
   - Weights-Overall

B. Complete regressions based on your aircraft investigations from Assignment 1 to study key trade-offs. This should include, but is not limited to: single vs. multi-engine configurations , internal vs. external ordnance carriage , and crew size (1 vs. 2). Run high-level regression studies on these parameters to select a preliminary design concept(s) and justify your choice(s), ensuring you respect the maximum takeoff gross weight constraint of 90,000 lbs. You do not need to pick one definitively until after PDR.

   Your team leader will be the one to submit the file via Canvas. Note that this is not an endorsement of the use of spreadsheets for you calculations; it's just a convenient way to submit your results.

3.4 Assignment 3: Cost and Weights Validation

A. Submit one workbook, updating and filling out the following sections:

- General-Overall
- Weights-Overall
- Cost-DOC

B. Use the specifications given in Table 2.1 to validate your weight estimation code. This means using the specifications of other aircraft with your model and code to check if the results are reasonable and close to the actual values. Comment on the differences between your weight estimates and the listed values.

C. Refine your design choices, stop investigation of infeasible designs.

D. Start getting an idea of additional costs that you may need to produce your aircraft. For example, research costs associated with developing new technology required for your preliminary design. (Remember Flyaway costs as well as operating costs!).

3.5 Assignment 4: Sizing and Performance: $T/W - W/S$ or $P/W - W/S$

A. Submit one workbook, filling out the following sections:

- Performance-Overall,
- Performance-Aerodynamics
- Performance-Engine
- Performance-Launch & Recovery

B. Submit plots of the various constraints for your design in the $T/W - W/S$ space. Make sure you shade the feasible region and label all the constraint lines. Vector graphics or high resolution images only.

C. Make sure that the key performance constraints from the RFP are clearly shown on your diagram. This includes, but is not limited to, the Mach 1.6 dash speed at 30,000 ft , the 8.0 deg/sec minimum sustained turn rate , and the necessary performance for catapult launch and arrested recovery.

D. *Enrichment questions:*

D.1 Consider an aircraft with $AR = 9$. If the AR is increased by 5% without changing the reference area and assuming that the weight does not change, how much does the level flight induced drag change based on the quadratic drag polar equation? (Use $C_{D_i} = C_L^2/(\pi ARe)$ and $e = (1.05 + 0.007\pi AR)^{-1}$ for this and the next question.)

D.2 If the span of the original wing is increased by 5% and the reference area is also increased by 5% (also giving an aspect ratio 5% greater than the original wing), how much does the level flight induced drag change assuming that the weight, speed, and altitude did not change?

3.6 Assignment 5: Sizing and Performance: $T - S$ or $P - S$

A. Submit plots of the various constraints for your designs in the $T - S$ (or $P - S$) space (takeoff weight must be a function of T or P and S). Overlay contours of the objective function. Make sure you shade the feasible region and label all the constraint lines. Vector graphics only or high resolution images only.

B. Comment on what you observe and select the design point. Remember you should choose an existing engine, meaning there are discrete points that will be feasible. Do not forget the engine offtakes. Give yourselves some wiggle room!

C. Use the specifications given in Table 2.1, and other specifications available online (if required), to validate your code. Validate both your updated weights estimation code and the $T - S$ ($P - S$) plot.

D. Continue to include the performance and maneuver constraints derived from RFP Sections 3.2, 3.4, and 3.5.

E. Choose a specific, existing production engine model that meets your thrust requirements, as mandated by the RFP. Justify your selection and account for power and airflow offtakes for subsystems.

3.7 Assignment 6: Wing, Fuselage, Empennage, and Drawings

A. Fill out the following spreadsheets in the workbook:

- Layout-Lifting surfaces
- Layout-Fuselage
- Layout-Engines
- Layout-Control surfaces

Remember to update any other data that has changed.

B. Additionally, please include the location of the relevant avionics, weapons, and other GFE required by your design.

C. Submit the Dash-1 CAD drawings for your configuration(s). The drawings should be three-view and show the control surfaces and high-lift devices. Also show the landing gear tip-over and rotation angles. Your drawings must clearly illustrate compliance with the carrier suitability dimensional constraints, including the maximum unfolded wingspan (60 ft), folded wingspan (35 ft), overall length (50 ft), and height (18.5 ft). A view showing the aircraft in its stowed (wings folded) configuration is required. Dimension the drawings as you see fit. Keep the CAD simple and parametric for now so that you can easily make design changes later.
Note: At the end of the semester, you will utilize your CAD drawings to 3D print a subscale model of your aircraft. Please ensure that there are no discontinuities in the outer mold line.

D. Calculate the neutral point location and static margin.

E. *Enrichment questions:*

E.1 What is the role of wing twist?

E.2 What is the role of wing sweep?

E.3 What is the role of wing incidence?

E.4 What is the difference between the center of pressure, aerodynamic center, and neutral point?

E.5 What are the advantages and disadvantages of having a large static margin?

E.6 What is the net effect on the static margin of moving your wing forward by 10% MAC relative to the fuselage?

3.8 Preliminary Design Review Presentations

The presentations will be held during class time on October 17, 20, and 22. Please plan on being in the classroom 5 minutes before class starts so that we can start immediately at 9:30 am. Each team will have a fixed time to present (typically 15–20 minutes, depending on the total number of teams), and there will be 5–10 minutes allocated for clarifications, questions and answers. Make sure to take note of the feedback so that you can improve your report. Note that it is in your interest to give concise answers so that you can get as much feedback as possible.

The order of the presentations is random and will be announced the day before PDR starts. The final slides are due in the Canvas web site by 11:59 pm on Wednesday, October 16, for all teams. In the interest of fairness, even if you present on another day, you cannot change the slides. Teams will present from the slides uploaded to Canvas by the deadline.

The dress code is business casual for those that are presenting. Everyone is required to attend all presentations. Each student is expected to ask at least one meaningful, critical question to a presenting team (other than their own) during both the PDR and CDR. This will count toward your participation grade.

The presentations will be graded for:

A. Team attendance

B. Three-view dimensioned drawing

C. Comparison table (your aircraft and comparable actual aircraft)

D. T-S or P-S plot showing feasible region and chosen point

E. Other technical content

F. Overall presentation style

G. Timing (try to use most of your time, but do not go over time)

H. Answers to questions

The presentation file should be in PDF format and the first characters of the filename should be your team number. Make sure that the PDF file displays everything as you intended and that the slides are numbered. You may include a file in PowerPoint format in addition, but there will be no guarantee that it will display correctly. The distribution of paper copies of your presentation is not allowed.

3.9 Preliminary Design Review Report

Please submit your PDR report and code according to the expectations described in Sec. 4.2. The report file should be in PDF format and the first characters of the filename should be your team number. This must be submitted before 11:59 pm on Sunday, October 26.

3.10 PDR Peer Evaluation

Effective teamwork is critical to the success of any complex engineering project. To ensure that individual contributions are recognized fairly, you are required to complete a peer evaluation for each major design review. This evaluation is a significant component of your individual project grade. Its purpose is to provide constructive feedback and to hold all team members accountable for their contributions.

The evaluation process is based on a contribution-based assessment. You will distribute a fixed budget of points among your teammates, justified against a clear set of criteria. All submissions are confidential. An anonymous summary of the collective feedback each team member receives will be shared with that individual.

3.10.1 Instructions

For this assignment, you are provided with an Excel Sheet template attached to the relevant assignment in Canvas. Each student must:

A. Rename the file to `PDR_Peer_Eval_[YourLastName]`.

B. Complete all three parts of the form: Point Allocation, Rubric-Based Justification, and Self-Evaluation.

C. Submit the completed file in the corresponding assignment on Canvas by the deadline.

Failure to submit a complete evaluation on time will result in a 33% penalty per day on your personal peer review score for this project phase.

3.10.2 Part A: Contribution Point Allocation

You have **100 points** to distribute among your teammates (do not include yourself). This distribution should reflect your assessment of each member's **relative contribution** to the project's success during this phase. The Google Sheet will automatically check that your points sum to 100.

Example Allocation for a 4-person team (evaluating 3 teammates):

Team Member Name	Points Allocated
Teammate A	45
Teammate B	35
Teammate C	20
Total	**100**

3.10.3 Part B: Rubric-Based Justification

Your point allocation must be justified with qualitative feedback for **each teammate**. This feedback is the most important part of the evaluation. It should be constructive, specific, and professional. Refer to the criteria in the rubric below. For each team member, you must provide:

- A specific example of a key contribution they made.
- A specific and constructive suggestion for improvement.

Evaluation Rubric	
1. Technical Contribution	Quality, accuracy, and depth of engineering analysis (e.g., weight estimation, sizing, aerodynamics). Quality of graphics, drawings, and documentation.
2. Reliability & Work Ethic	Consistently completed assigned tasks on time and to a high standard. Was prepared for meetings. Produced work that did not require significant rework by others.
3. Teamwork & Communication	Communicated clearly and respectfully. Listened to others' ideas. Provided constructive feedback. Contributed positively to team cohesion and meetings.
4. Initiative & Leadership	Took initiative to identify problems, suggest solutions, or organize tasks without being asked. Helped motivate the team and took on leadership roles when necessary.

3.10.4 Part C: Self-Evaluation

Finally, you must conduct an honest and objective self-evaluation. This is a separate exercise from the peer evaluation in Part A.

- Determine your self-assessed contribution score. After you have allocated 100 points among your teammates, decide where your own contribution would fall on that same scale. Assign yourself a score that reflects this ranking.

  For example: In a 4-person team, after giving Teammate A (45 pts), Teammate B (35 pts), and Teammate C (20 pts), if you believe your contribution was the second highest on the team, you would assign yourself a score between 35 and 45. If you believe you contributed the most, you would assign yourself a score above 45.

- Describe your specific contributions to the project, citing tasks, analyses, or deliverables to justify your self-assessed score.
- Identify one area where you could have improved your performance.

Note: Your self-assessed score is for reflection and instructor review only. It is *not* added to the 100 points distributed in Part A and will *not* be used to directly calculate your grade.

In the unlikely event of serious disputes between team members over peer review grades, participation in team assignments will be taken into consideration.

3.11 Assignment 7: Refined Weight, Landing Gear Sizing, and Dash-2 Drawings

A. List three (3) adjustments that you'll make after receiving feedback from the PDR Presentations. Explain why you have decided to make these adjustments.

B. Start to narrow down to one design if you have multiple at this point.

C. For your down-selected configuration:

- C.1 Improve your weight estimates using the improved fuel weight estimation methods.
- C.2 Improve your weight estimates using the component weights method (at this stage you should use at least two of the more elaborate wing weight estimates that use parameters such as λ and Λ). List the components, their weights in pounds, and their CG locations in ft, in the "Weights - Overall" spreadsheet and submit it.
- C.3 Account for all GFE weights in your breakdown, including the specified 2,500 lb avionics/sensors suite and the required ordnance loads for both the Air-to-Air and Strike missions as detailed in RFP Section 3.3.
- C.4 Update engine weight if necessary. Engine option should be finalized at this point. Ensure power and airflow offtakes will not push engine outside the feasibility envelope.
- C.5 Compare the new weight estimates to your earlier estimates and comment on the differences.
- C.6 Size the landing gear. Pay special attention to the high sink rates and loads associated with arrested landings on a carrier deck.
- C.7 Make new drawings (Dash 2), including the landing gear (showing tip-over, rotation, and overturn angles), and submit it as a one page PDF. Make sure you consider how the gear will be retracted and stowed.
  Note: At the end of the semester, you will utilize your CAD drawings to 3D print a subscale model of your aircraft. Please ensure that there are no discontinuities in the outer mold line.

D. *Enrichment questions:*

- D.1 Why do airliner nose gears retract forward?

3.12 Assignment 8: Refined Aerodynamics

A. Produce refined drag polar plots using the component build-up method (make sure you include trim drag for the cruise drag polar).

B. List and briefly explain the different components considered for each curve.

C. Estimate $C_{\mathrm{l_{max}}}$ for the flapped sections of your wing for takeoff and landing flap deflections.

D. Estimate $C_{\mathrm{L_{max}}}$ for your aircraft for the takeoff and landing configurations.

E. Revise flap sizing if target $C_{\mathrm{L_{max}}}$ values are not met.

F. Ensure static margin is within required bounds. Additionally, ensure that the aircraft has the requisite avionics if it is statically unstable!

G. Perform trade studies on internal vs external carriage of weaponry and additional fuel tanks.

H. Revise your design trades/optimization and report any changes.

I. **Optional:**

   I.1 Use AVL (or equivalent) and the critical section method to estimate $C_{\mathrm{L_{max}}}$ for takeoff and landing.

   I.2 Revise flap sizing if target $C_{\mathrm{L_{max}}}$ values are not met.

   I.3 Show elevator deflections for trimmed cruise, landing, and takeoff configurations. Revise elevator sizing if required deflections are too large.

Submit the results in one PDF file, using the usual naming convention.

3.13 Assignment 9: Design Trades

For your down-selected configuration:

A. Improve (or optimize) the objective function of your aircraft by choosing a better wing area, aspect ratio, sweep, taper, thickness-to-chord ratio, cruise speed/altitudes (if applicable).

B. Analyze critical configuration trade-offs specific to a carrier-based strike fighter. Justify your final selections based on their impact on performance, cost, and mission effectiveness. At a minimum, your analysis should include:

   B.1 Survivability vs. Aerodynamic Performance: Trade the use of internal versus external ordnance carriage. Quantify the impact on aerodynamic drag for key mission segments and discuss the qualitative benefits for survivability (e.g., reduced radar cross-section).

   B.2 At least one more critical trade determined by your team. Some examples are: Trading a single-engine versus a multi-engine configuration using existing production engines (analyze the impact on weight, cost, and the ability to meet single-engine rate of climb requirements for launch and approach), a single-seat versus a two-seat cockpit design (analyze the effects on fuselage size, empty weight, acquisition cost, and mission effectiveness, particularly for the complex strike and potential electronic attack roles), etc.

C. Discuss how your design choices balance the competing requirements of the Air-to-Air mission (e.g., high dash speed, sustained turn rate) and the Strike mission (e.g., sea-level dash performance, payload capacity).

D. Summarize and discuss the major changes resulting from your trade studies, including relevant plots (e.g., sensitivity analysis, carpet plots) that illustrate your optimization process and justify your final design point.

E. Report the final flyaway, direct operating, and life-cycle cost analyses for your design, ensuring the unit cost for a production run of 500 aircraft does not exceed that of the legacy aircraft.

F. Update your spreadsheet and submit it along with your report.

3.14 Assignment 10: V-n Diagram and Environmental Analysis

A. Show V-n diagrams for minimum and maximum weights; gust lines for 20,000 ft.

B. Explain how the $C_{\mathrm{L_{max}}}$ values used for the stall curves were estimated.

C. Ensure that your aircraft's structure can withstand the required maneuver loads as defined in the V-n diagram and meets the design vertical load factor (Nz) requirement of greater than 7g specified in RFP Section 3.5.a.

D. Submit the results in one PDF file, using the usual naming convention.

3.15 CDR Presentation

See instructions for the PDR presentation (Sec. 3.8). All presentations must be submitted on Canvas by Monday, December 1, at 12:00 pm *(note the time change)*. The presentations will be held in-class on December 1-5. The report and peer evaluations are due on Monday, December 8, at 11:59 pm.

Additionally, you will 3D-print a subscale model of your aircraft, focusing on the outer mold lines (interior layout is optional), using your CAD drawings. You will bring these models to the CDR presentations. We might also showcase your models in the FXB Atrium. 3D printing instructions will be provided later in the semester.

3.16 CDR Poster

We will hold a poster session during the CDR week at the FXB Atrium. The exact date and time will be announced closer to the event. You are welcome (and encouraged!) to invite friends, professors, and family to show off your hard work at the end of the semester (and get some feedback for your report and for the AIAA Design Competition, if your team is participating).

3.17 CDR Report

Please submit the CDR Report following the attached expectations document. All reports must be submitted on Canvas by Monday, December 8, at 11:59 pm.

3.18 CDR Peer Evaluation

See instructions for the PDR peer evaluation (Sec. 3.10).

Chapter 4

Design Review Expectations

4.1 Introduction

This document contains guidelines for both oral and written components of AE481's design reviews: the preliminary design review (PDR) and the critical design review (CDR). It provides the required content, organization and formatting information that you should follow while preparing the oral presentation and written report. Ultimately, it is the students' responsibility to convey the information on the best way possible so your performance on the metrics for which you are being evaluated is clearly identifiable. Keep in mind that this is an open ended design project, and as such, what is stated below is the minimum required. Use your judgment on how to best present the information and what else to include.

4.2 Preliminary Design Review

The main goal of the PDR is to present your initial concept(s). You must show the results and calculations for your design in your report. Each team must submit one report. All submissions are to be electronic (through Canvas). The submission must be in the form of one PDF file for the report, and one zipped directory containing source code and any other auxiliary material. The ZIP file and the PDF files must start with your group number using two digits, e.g. `01-report.pdf`. The ZIP file must expand to a folder whose name starts with the team number as well (the filenames inside the directory do not need to start with the team number).

The page limit for the PDR report is **30 pages**, excluding cover, table of contents, and appendices; use 11 pt font and single line spacing. Make sure the PDF file looks like what you expect; check the equations in particular. Please see Sec. 4.4 for style guidelines.
At the minimum, each of the following sections should be included in the report.

Cover: This should display your team number, your names, and a perspective view of the aircraft.

Table of Contents: This comes in the pages after the cover page. The items in the table should be hyperlinked to the respective section. In addition to having a table of contents on the report pages, the PDF file should contain the complete contents as a nested list of bookmarks (open this file in a PDF reader and you can see the table of contents in the navigation box no matter which page you are viewing).

A. Summary

A.1 Executive summary: One page.

A.2 Dimensioned three-view drawings and perspective for your design(s). The three views should have the same scale, align with each other, and be on the same page. The drawings should include:

1) CG location
2) Neutral point location
3) Landing gear disposition[1]; rotation, tip-back, tip-over, and overturn angles
4) Control surfaces and high-lift devices
5) A view of the aircraft in its stowed (wings folded) configuration showing dimensional compliance
6) Locations for the specific ordnance loads for both Air-to-Air and Strike missions

A.3 Table with major geometric and performance parameters for the aircraft, plus at least three comparable existing aircraft. Use one page only and include the following in this order:

1) Takeoff weight (lbs)
2) Empty weight (lbs)
3) Air-to-Air Mission Payload (lbs)
4) Strike Mission Payload (lbs)
5) Combat radius (nm)
6) Air-to-Air Mission Fuel Burn (lbs)
7) Strike Mission Fuel Burn (lbs)
8) Cruise L/D (not required for comparison aircraft)
9) T/W or P/W (hp/lbs)
10) W/S (lbs/ft^2)
11) Engine type and maximum sea-level-static thrust or rated power
12) Engine cruise SFC (try to find estimates for comparison aircraft)
13) Span (ft)
14) Reference area (ft^2)
15) Aspect ratio
16) Average wing t/c (not required for comparison aircraft)
17) Cruise Mach no. (Maximum and economic)
18) Static margin (not required for comparison aircraft)
19) Maximum landing distance (ft)
20) Maximum takeoff distance (ft)
21) Flyaway cost for a 500-unit production run (USD 2025)
22) If you have space, you may include other metrics you find relevant.

B. Introduction (mission, aircraft requirements, etc.)

C. Configuration (Describe the configuration and justify your choices.)

D. Preliminary Sizing (Includes: initial weight estimate, T/W or P/W vs. W/S, improved weight estimate, T or P vs. S plot with objective function contours overlaid.)

[1] Landing gear sizing not needed; for CDR only.

E. Interior Layout (three-view drawings with dimensions showing the cockpit layout based on your justified crew selection (1 vs. 2 members), pilot sight lines, weapons bay, and fuel tanks, etc.)

F. Weights and Center of Gravity (improved weight and CG estimates, CG travel, weight and CG breakdown, etc.)

G. Stability and Control (static margin, wing MAC and spanwise location, empennage, control surfaces, etc.). Include discussion on static stability and requirements for additional avionics.

H. Aerodynamics (wing design, airfoil selection, drag polars[2], stall speeds, etc.)

I. Method Validation (Use the specifications of an existing aircraft with your weights estimation and sizing plot codes. Compare the estimated weights to actual values and discuss discrepancies. Plot the actual aircraft point on the sizing plot and discuss discrepancies.)

J. Objective Function (describe the calculations in detail and discuss the contributions from the different components)

K. Propulsion System (selection and integration)

L. Government Furnished Equipment (integration of the required 2,500 lb avionics/sensors suite and mission ordnance, justifications)

M. Cost (Components for DOC, DOC in USD/lbm-nmi. This section is only necessary if not included in the objective function section.)

N. Computation Procedure (use XDSM [4] showing the sequence of your calculation and iteration loops[3])

O. Software Design (optional for presentation; must be in report: explain the organization of your code, how the various scripts and functions are structured, and what data structures you use)

P. Conclusions

Q. References

R. Appendices, including:

   R.1 List of symbols
   R.2 Supplementary engineering drawings
   R.3 Details of the analyses not already included in the main body (e.g., values used in the constraint equations, weight estimates, etc.)
   R.4 Anything else you think is important

The presentation should follow roughly the same structure as the report. You will receive some feedback in the question period after your presentation that you are encouraged to address in your report.

[2]Show the operating points on the polars and end them at stall.

[3]You can use your favorite drawing software for this. There LaTeX code to generate these:
https://mdolab.engin.umich.edu/content/xdsm-overview
And also a Python package:
https://github.com/mdolab/pyXDSM

4.3 Critical Design Review

The main goal of the CDR is to present your final design. The report submission guidelines are the same as for the PDR.

The page limit for the CDR report is **50 pages**[4], excluding cover, table of contents, and appendices; use 11 pt font and single line spacing. Make sure that the PDF file looks like what you expect; check the equations in particular. Please see Sec. 4.4 for style guidelines.
At the minimum, each of the following sections should be included in the report:

Cover: This should display your team number, your names, and a perspective view of the selected aircraft.

Table of Contents: The items in the table should be hyperlinked to the respective section. In addition, the PDF file should contain the complete table of contents as a nested list of bookmarks (open this file in a PDF reader and you will see all these features).

A. Summary

A.1 Executive summary: One page (include a description of your work before the PDR)

A.2 Dimensioned three-view drawings and perspective for your design. The three views should have the same scale, align with each other, and be on the same page. The drawings should include:

1) CG location and excursion
2) Neutral point location
3) Control surfaces and high-lift devices
4) Rotation, tip-back, tip-over, and overturn angles
5) A dimensioned view of the stowed (wings folded) configuration.
6) Weapons locations (and visual if they are external)
7) Landing gear

The dimensions should be in meters or feet.

A.3 Table with major geometric and performance parameters for your aircraft, plus at least three comparable existing aircraft. Use one page only and include the following in this order:

1) Takeoff weight (lbs)
2) Empty weight (lbs)
3) Air-to-Air Mission Payload (lbs)
4) Strike Mission Payload (lbs)
5) Combat radius (nm)
6) Air-to-Air Mission Fuel Burn (lbs)
7) Strike Mission Fuel Burn (lbs)
8) Cruise, landing, and takeoff C_{L} (not required for comparison aircraft)
9) Cruise L/D (not required for comparison aircraft)
10) T/W or P/W (hp/lbs)
11) W/S (lbs/ft^2)

[4] You may go up to 100 pages if you are submitting your design to the competition. See Sec. 4.4.

12) Engine type and maximum sea-level-static thrust or rated power
13) Engine cruise SFC (try to find estimates for comparison aircraft)
14) Span (ft)
15) Reference area (ft^2)
16) Aspect ratio
17) Average wing t/c (not required for comparison aircraft)
18) Cruise Mach no. (Maximum and economic)
19) Static margin (not required for comparison aircraft)
20) Maximum landing distance (ft)
21) Maximum takeoff distance (ft)
22) Flyaway cost for a 500-unit production run (USD 2025)
23) If you have space, you may include other metrics you find relevant.

B. Introduction (mission, aircraft requirements, the new technology, etc.)

C. Configuration (Describe the configuration and justify your choices.)

D. Preliminary Sizing (including contour plots, trade studies and optimization)

E. Interior Layout (three-view drawings with dimensions showing the cockpit layout based on your justified crew selection (1 vs. 2 members), pilot sight lines, weapons bay, and fuel tanks, etc.)

F. Weights and Balance (component build up approach, CG location and excursion, loading sequence)

G. Stability and Control (static margin, wing MAC and spanwise location, empennage, OEI rudder sizing and control authority for launch and approach, [optional] elevator deflections for critical flight conditions, etc.). Include discussion on static stability and requirements for additional avionics.

H. Aerodynamics (wing design, airfoil selection, flap sizing, $C_{\mathrm{L_{max}}}$ estimates, trimmed drag polars for whole aircraft using refined approach, drag breakdown, stall speeds, etc.)

I. Propulsion System (selection and integration of engine, etc.)

J. Government Furnished Equipment (integration of the required 2,500 lb avionics/sensors suite and mission ordnance, justifications)

K. Landing Gear (sizing, disposition, retraction, and rotation, tip-back, tip-over, and overturn angles, etc.) including an analysis of the loads from arrested landing and compatibility with the specified arresting gear performance)

L. Method Validation (Use the specifications of an existing aircraft with your weights estimation code. Compare the results to actual values and discuss discrepancies.)

M. Computation of the objective function (describe the calculations in detail and discuss the contributions from the different components)

N. Design Refinement (trade studies, with or without optimization)

O. Final sizing plot (show a T or P vs. S plot for the final design)

P. Structures (load paths, V-n diagrams, distribution of air loads on the wings, maneuverability)

Q. Cost (components for DOC, DOC in USD/payload-nmi, aircraft and engines cost. This section is only necessary if not included in the objective function section.)

R. Computation Procedure (use XDSM as in the PDR)

S. Conclusions

T. References

U. Appendices, including:

 U.1 List of symbols

 U.2 Supplementary engineering drawings

 U.3 Details of the analysis (values used in the drag and weight breakdown, constraint equations, cost breakdown, etc.)

 U.4 Anything else you think is important

The presentation should follow roughly the same structure as the report.

4.4 Style Guidelines

The report should be submitted as a team. It should be well organized, and you should maintain a consistent look throughout. Please consider the points highlighted below.

AIAA technical paper format: You must use the AIAA technical paper format for your team reports. The Overleaf and PDF templates can be found here. Templates are available in other file formats are available through the AIAA website.

Hyperlinks and bookmarks: Your PDF file must be properly hyperlinked: e.g., citations, table of contents, websites, figure and table references, etc. Also make sure that the file has bookmarks with the complete table of contents (check under the Bookmarks tab in Acrobat Reader). This document is a good example of a PDF that is properly hyperlinked. If you use LaTeX, all you need to do is use the `hyperref` package.

References: Make sure your references are complete and consistently formatted. See the various reference sections in these notes for guidance. If citing URLs, they should be hyperlinked. If citing scientific articles, they should have a DOI.

Whitespace: Minimize within reason (e.g. margins 1”, 11 pt font, single line spacing).

Source code: Do not include the source code in the report, it should be in the zip file, but feel free to refer to it. Please include comments in the source code so that it is easily readable.

Main text vs. appendix: Key formulas and figures should be included in the main text.

Grammar: Poor grammar makes it difficult to understand what you mean. Proofread your own work thoroughly. If it’s clear that you don’t care about what you’ve written, how much will the marker care? Have your team members proofread for clarity, continuity between sections, spelling and grammar.

Figures:

- All figures must be in a vector graphics format or high-resolution bitmaps[1]. If you use a bitmap, make sure you have at least the equivalent of 300 dpi when printed. There is no excuse for seeing pixels!
- Tables vs. text: Tables win.
- Graphs vs. tables: Graphs win.
- Make sure you label the axes properly with a readable font, complete with the units used.
- One set of data per plot vs. multiple sets of data per plot: When plotting the same quantity for different parameters, you should show all results in one plot, within reason. Make sure to include legends as necessary.
- Make sure they have a descriptive caption and that the caption is in the same page as the figure. There is not need for a figure title in addition to the caption.
- 2D contour plots are preferable to 3D surfaces. The contours should be smooth (i.e., use a fine enough grid of values).
- Refer to figures explicitly in the text. Figures have a purpose and this should be stated when referring to it (e.g., what did the plot tell you?)
- Avoid reproducing figures from the class notes; you can just reference them by chapter and slide number or original source.
- Include anything worth noting in your plots (maxima, minima, optimum). What did these values tell you?
- Use 3D CAD software to generate technical drawings.

AIAA Formatting: "Electronic reports should be no more than 100 pages, double-spaced (including graphs, drawings, photographs, and appendices) if it were to be printed on 8.5"x11.0" paper, and the font should be no smaller than 10 pt. Times New Roman, unless otherwise stated in the relevant competition RFP."

Please try to limit your report submissions to 50 pages, however if you plan on submitting your design to the competition and you need pages 50 to 100, that is okay too. General tip: be concise! Superfluous information will not award you more points.

[1] Using vector graphics, shapes are represented by mathematical expressions, and therefore you can magnify the figure indefinitely without loosing fidelity. Bitmaps, on the other hand, describe the figure as a limited number of pixels. For more details and examples, see http://en.wikipedia.org/wiki/Vector_graphics

Calculations:

- Include detailed calculations in an appendix if you don't have space in the main section of the report.
- A list of variables and their symbols is helpful.
- Present calculations in a clear and rational manner. Cite the source of your formulae.
- Use equation typesetting software (such as MS Equation Editor or LaTeX)
- State any assumptions or simplifications made.

References:

- Cite the origin of any information that is not in the class notes. See these notes for examples on how to cite.
- Format your bibliography in an appropriate and consistent style providing complete information. Again, see the bibliographies in these notes as an example.
- Try to rely as much as possible in technical references, e.g.:
  - Books
  - NASA Technical Reports Server http://ntrs.nasa.gov/search.jsp
  - AIAA publications (journal papers and conference proceedings) https://aiaa.org/publications/
  - Papers in other journals
- Follow the trail of papers by checking the references cited in the papers you find relevant. Journal papers are usually better quality articles and more reliable, but sometimes the latest developments can only be found in conference papers.
- When searching try alternative equivalent keywords, e.g. "unducted fan", "propfan", "open rotor".

Chapter 5

All About Aircraft Tournament

Welcome aboard the A^3 Tournament, your non-stop flight to aviation trivia glory! Created exclusively for this course, the past three years' tournaments were nothing short of sky-high success. And get this: our alumni co-pilots are still impressing their ground crews, friends, and families with the trivia treasures they gathered on board!

Ready for takeoff? Your mission, should you choose to accept it, is to accumulate points in two distinct ways: by engineering perplexing questions in the hangar before the game and by acing the answers in the cockpit during the game. On select Wednesdays, we'll taxi down the runway with a series of questions that explore every rivet and wingtip of aircraft and aviation. Some of these questions might just take you into uncharted airspace-topics you've never encountered in your academic flight plan.

So, what's your role going to be? Quizzer, Contestant, or a daring double-duty ace? Fasten your seatbelts and stow your tray tables, because up next are the in-flight rules that will guide you through the A^3 Tournament adventure!

5.1 Game Play

Before the Game:

- **Quizzers:** Prepare questions related to aircraft and aviation that you believe every aerospace engineer should know. These questions should ideally cover topics not typically included in a standard aerospace engineering curriculum. For each question, prepare one slide, and for each answer, prepare one to three slides. All answers must be properly cited and followed by a References slide. For example, a question could be: "Why do airplane cabin windows have small holes?" Consult the A^3 course slides for additional examples and guidelines.

  Tip: Submitting high-quality questions early in the semester is the best way to score high points. If you wait until later, your questions might not be used due to limited time and an abundance of submissions. Early submissions will be given priority for selection in the game.

- **Questions:** Quizzers will submit their questions as a PowerPoint file on Canvas. All questions will be collected in a question bank. Each week, the Judges (your course instructors) will select a set of questions from this bank to be asked during the tournament.

- **Question Timing:** A question may be submitted one week and asked in a subsequent week. For instance, a question could be asked two weeks after its initial submission.

- **Game Day:** On the day of the game, you will receive a link to join the game on an online platform (most likely https://buzzin.live/ unless otherwise stated). You'll use this link to '*buzz in*' and answer questions. No software installation is necessary; however, you will need a mobile device with internet access. If you don't have a personal device, you may use the computers in the computer lab. Please note that each computer or device can be used by only one person, and there may not be enough computers for every contestant. Therefore, it's advisable to bring your own device if possible.

During the Game:

- Questions are posed one at a time. Contestants can *buzz in* using their mobile devices or computers. The game system will rank the buzzers from fastest to slowest. You are allowed to buzz in at any point during the answering period, once the buzzer is unlocked.
- The fastest Contestant to buzz in will get the opportunity to answer the question.
- If the Contestant answers correctly, the game proceeds to the next question.
- If the Contestant answers incorrectly or fails to provide an answer within 5 seconds, the opportunity to answer passes to the second-fastest Contestant. This cycle continues until one of the following occurs:
  A. A Contestant answers correctly.
  B. All Contestants answer incorrectly.
  C. One minute passes without a correct answer.
- Contestants are permitted to buzz in multiple times if their initial answer and all the subsequent answers from other contestants in the initial round are incorrect.
- Participants can play as both a Contestant and a Quizzer simultaneously, but they are not allowed to answer their own questions.

At the end of each game:

- Quizzers whose questions were posed but not answered correctly will have up to 3 minutes to present slides containing the correct answer.
- All participants will vote for the "Participants' Question of the Week" Trophy.
- Both Quizzers and Contestants will accumulate points, as detailed below. The points will be shown on a scoreboard.

5.2 Tournament Points System

The Tournament Points (TP) you accumulate during the game will be converted to Class Points (CP), which contribute to your final letter grade. The total available class points for this assignment is 3.

- **Contestants receive:**
  - 500 TP for each correct answer. No partial credit will be awarded unless otherwise specified by the judges.
  - 0 TP for incorrect or unanswered questions.

- **Quizzers receive:**
  - 500 TP for each question selected for the tournament by the judges.
  - An additional 500 TP if their question is chosen as the "*Judges' Question of the Week.*" A well-thought-out question and excellently prepared slide will qualify you for this honor.
  - An additional 500 TP if their question is voted as the "*Participants' Question of the Week.*"

- **Tournament Points (TP) to Class Points (CP) Conversion:**
  - 0.5 CP for those who accumulate at least 750 TP or score within the first quartile.
  - 1 CP for those who accumulate at least 1,500 TP or score within the second quartile.
  - 1.5 CP for those who accumulate at least 2,500 TP or score within the third quartile.
  - 2 CP for those who accumulate at least 3,500 TP or are the second or third highest scorers.
  - 2.5 CP for those who accumulate at least 5,000 TP or are the highest scorer.

- **Award points:** Participants who meet at least one of the following criteria will receive an additional CP, up to the maximum points available in the tournament. A participant can only receive an award for one of the listed categories.
  - Tournament Winner (highest overall scorer): +0.5 CP
  - Second and third highest scorers: +0.25 CP each
  - Participant with the most questions included in the tournament: +0.5 CP
  - Participant with the most questions selected for the "Judges' Question of the Week" Trophy: +0.5 CP
  - Participant with the most "Participants' Question of the Week" Trophy selections: +0.5 CP

We will play this tournament during select lab sessions, in segments lasting up to 20 minutes each. The frequency and duration will depend on the availability of project time and the number of questions submitted for the week.

After the tournament ends, you will have access to a slide deck with all the questions (and answers) that were asked this semester. We hope that you find this resource useful as many of you graduate soon and begin the next phase of your career!

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