

San José State University
Aerospace Engineering
AE 271 – Advanced Aircraft Design – Fall 2021



Electric VTOL aircraft by Joby Aviation

Course and Contact Information

Instructor:	Professor Sean Montgomery
Email:	sean.montgomery@sjsu.edu
Office Hours:	After class, Thursdays 3:00 to 4:00 pm, or by appointment.
Class Days/Time:	Mondays and Wednesdays 4:00 to 5:15 pm
Classroom:	Online, on campus TBD
Prerequisites:	Graduate standing in AE or instructor consent
GWAR:	This course satisfies the Graduation Writing Assessment Requirement

Course Description

This is a project course in which students complete the preliminary design of an airplane of their choice. The design process involves defining the mission requirements, weight sizing, performance sizing, fuselage design, wing design, high-lift system and lateral controls design, landing gear design, weight and balance, stability and control, drag polars, and final drawings. In the final report, students will also discuss environmental, economic and safety considerations for their airplane.

Course Goals

1. To provide graduate level experience in airplane design.
2. To develop students' creative abilities in solving open-ended, airplane design problems.
3. To develop an appreciation of the interrelationships between aerodynamics, propulsion, structures, flight mechanics, stability & control, manufacturing, maintenance, and cost in an integrated airplane design.
4. To develop students' engineering judgment as well as their confidence in making and accepting responsibility for design decisions.
5. To develop students' technical writing ability.

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. Describe the pros and cons of unconventional aircraft configurations such as canards, 3-surface, swept-forward wings, flying wings, tailless, V/STOL, stealth, etc.
2. Perform weight and performance sizing of a gas-powered and electric airplanes, including pertinent Title 14 of the U.S. Code of Federal Regulations (14 CFR Parts 23/25) and European standards (EASA CS23/25)
3. Design the fuselage, the wing, the empennage, and the landing gear of an airplane.
4. Perform weight and balance analysis of an airplane.
5. Perform a stability and control analysis of an airplane.
6. Compute the drag polars of an airplane.
7. Produce final drawings of an airplane.
8. Discuss environmental, economic, safety, and manufacturing issues related to an airplane.
9. Communicate the results of their design in a comprehensive, well written final report, following AIAA guidelines.

Required Texts

Textbook

There are two common aircraft design textbooks: *Airplane Design* by Jan Roskam and *Aircraft Design* by Daniel Raymer. Both have advantages and disadvantages. Both are good to have for reference.

First time aircraft design students are recommended to use Roskam Part I and Part II. Students designing supersonic or very unconventional aircraft are recommended to use Raymer's book. It is good to have both books for reference.

The 8 volume Airplane Design books by Jan Roskam are older, but easier for most students to follow since they provide a step-by-step guide to airplane design. The step-by-step design process Roskam describes works best for traditional airplane designs. The books contain a lot of data on many different types of standard aircraft. The detailed data alone make these books extremely useful. Only the first 2 volumes are essential. The other 6 volumes are mostly for reference for more detailed calculations.

Raymer's Aircraft Design book covers a larger variety of vehicles and has more information for unconventional designs and supersonic aircraft. A lot of Raymer's book is intended for the design of fighter jets, but it also has plenty of information for UAVs, general aviation, transport (airliner or cargo), rocket planes, and electric aircraft. The RDS^{win} design software is also based on the equations in Raymer's book. Many of the equations in Raymer's book are rule-of-thumb calculations that try to be good enough for design, but may not be appropriate for all situations. These rule-of-thumb equations are faster, but they rely more on the designer to know what is appropriate or not. For these reasons, Raymer's book is more useful as a reference book for people already familiar with aircraft design.

Textbook recommended for first time designers:

Roskam, J. (1985). Airplane design,

Part I: Preliminary sizing of airplanes

Part II: Preliminary configuration design and integration of the propulsion system

Part III: Layout design of cockpit, fuselage, wing and empennage: cutaways and inboard profiles

Part IV: Layout design of landing gear and systems

Part V: Component weight estimation

Part VI: Preliminary calculation of aerodynamic, thrust and power characteristics

Part VII: Determination of stability, control and performance characteristics
Part VIII: Airplane cost estimation: design, development, manufacturing and operating
Roskam Aviation & Engineering Corporation Rt.4, Box 274, Ottawa, Kansas 66067, USA.

Textbook recommended for supersonic and very unconventional aircraft:

Raymer, D. (2018 6th ed.). Aircraft Design: A Conceptual Approach.
5th edition is almost identical except for a chapter on electric aircraft design.

Required Software

RDS^{win} Student V10 (requires Windows operating system and a CD drive to install)

<http://aircraftdesign.com/rdsstud.html>

Previous versions have more bugs, less features, and may not work with Windows.

Amazon: <https://www.amazon.com/exec/obidos/ASIN/1624105734/danraymesaircrde>

AIAA: <http://aircraftdesign.com/bookout.html>

This software may seem expensive, but it will save you hundreds of hours of time and allow you to complete your design in one semester.

XFLR5 (free, runs on Windows, Mac, Linux) <http://www.xflr5.tech/xflr5.htm>

Free software based on XFOIL and AVL to analyze airfoils, wings, and aircraft lift, drag, stability and control.

Alternative Software

Advanced Aircraft Analysis (matches Roskam's book, should be available on AE computers)

OpenVSP (CAD for aircraft, limited analysis capability) <http://openvsp.org/>

AVL (wing and tail aerodynamics, stability, and control analysis) <http://web.mit.edu/drela/Public/web/avl/>

XFOIL (2-D airfoil analysis and design) <https://web.mit.edu/drela/Public/web/xfoil/>

MATLAB & Simulink (can be useful to perform your own analysis, create graphs, or do more advanced controls design)

Other References

Bradley, M.K. & Droney, C.K. (2012, May). Subsonic ultra green aircraft research phase II: N+4 advanced concept development. *NASA/CR-2012-217556*.

Bradley, M.K. & Droney, C.K. (2015, April). Subsonic ultra-green aircraft research phase II: Hybrid electric design exploration. *NASA/CR-2015-218704/Volume II*.

Bradley, M.K., Allen, T.J. & Droney, C.K. (2014, April). Subsonic ultra-green aircraft research phase II: Truss braced wing aeroelastic test report. *NASA/CR-2015-218704/Volume III*.

Mourtos, N.J. (2012, January-June). Defining, teaching, and assessing engineering design skills, **Invited Paper**, *International Journal for Quality Assurance in Engineering and Technology Education*, Special Issue, 2(1), 14-30.

Riboldi, C.E.D. & Gualdoni, F. (2016). An integrated approach to the preliminary weight sizing of small electric aircraft. *Aerospace Science and Technology*, 58, 134-149.

Torenbeek, E. (1982). *Synthesis of subsonic airplane design*. Springer. Also available as e-book. ISBN 978-94-017-3202-4

Course Requirements and Assignments

Reports will be graded for **English** (grammar, spelling, punctuation, etc.) as well as for **technical content**. Please see general guidelines for professional reports below.

Written reports not meeting minimum writing proficiency standards will be returned without a grade.

If your report is returned for English please seek help from the **SJSU Writing Center**

<<http://www.sjsu.edu/writingcenter/tutoring/index.html>>

Success in this course is based on the expectation that students will spend, for each unit of credit, a minimum of 45 hours over the length of the course (normally three hours per unit per week) for instruction, preparation/studying, or course related activities, including but not limited to internships, labs, and clinical practice. Other course structures will have equivalent workload expectations as described in the syllabus.

Grading Information

Conceptual Design Presentation = 5%

Conceptual Design Report = 10%

Preliminary Design Presentation = 5%

Preliminary Design Report = 20%

Final Design Presentation = 10%

Final Design Report = 40%

Homework/Classwork/Collaboration = 10%

A+	>97%	C-	70% - 73%
A	≥ 93%	D	60% - 70%
A-	90% - 93%	F	< 60%
B+	87% - 90%		
B	83% - 87%		
B-	80% - 83%		
C+	77% - 80%		
C	73% - 77%		

University Policies

Per [University Policy S16-9](http://www.sjsu.edu/senate/docs/S16-9.pdf) (<http://www.sjsu.edu/senate/docs/S16-9.pdf>), relevant information to all courses, such as academic integrity, accommodations, dropping and adding, consent for recording of class, etc. is available on Office of Graduate and Undergraduate Programs' [Syllabus Information web page](http://www.sjsu.edu/gup/syllabusinfo/) at <http://www.sjsu.edu/gup/syllabusinfo/>

AE Department Policies and SJSU policies are posted at <http://www.sjsu.edu/ae/programs/policies/>

Fall 2021 Online

Zoom

Class will meet online via Zoom. You can find the links to join these meetings under the “Zoom” section on Canvas. They are also posted on the Calendar.

Technology Requirements

Students are required to have an electronic device (laptop, desktop or tablet) with a camera and built-in microphone. SJSU has a free [equipment loan program](#) available for students. Students are responsible for ensuring that they have access to reliable Wi-Fi during tests and quizzes. See the [Learn Anywhere](#) website for current Wi-Fi options on campus.

Connection Issues

If you experience connection issues with the Zoom class session, attempt to rejoin. If you are unable to resolve the issues, you may watch the recording of the class to see what you missed.

Zoom Classroom Etiquette

- **Mute Your Microphone:** To help keep background noise to a minimum, make sure you mute your microphone when you are not speaking.
- **Be Mindful of Background Noise and Distractions:** Find a quiet place to “attend” class, to the greatest extent possible.
 - Avoid video setups where people may be walking behind you, people talking/making noise, etc.
 - Avoid activities that could create additional noise, such as shuffling papers, listening to music in the background, etc.
- **Position Your Camera Properly:** Be sure your webcam is in a stable position and focused at eye level.
- **Limit Your Distractions/Avoid Multitasking:** You can make it easier to focus on the meeting by turning off notifications, closing or minimizing running apps, and putting your smartphone away (unless you are using it to access Zoom).
- **Use Appropriate Virtual Backgrounds:** If using a virtual background, it should be appropriate and professional and should NOT suggest or include content that is objectively offensive or demeaning.

Recording Zoom Classes

This course or portions of this course (i.e., lectures, discussions, student presentations) will be recorded for instructional or educational purposes. The recordings will only be shared with students enrolled in the class through Canvas. The recordings will be deleted at the end of the semester. If, however, you would prefer to remain anonymous during these recordings, then please speak with the instructor about possible accommodations (e.g., temporarily turning off identifying information from the Zoom session, including student name and picture, prior to recording).

Students are not allowed to record without instructor permission. Students are prohibited from recording class activities (including class lectures, office hours, advising sessions, etc.), distributing class recordings, or posting class recordings. Materials created by the instructor for the course (syllabi, lectures and lecture notes, presentations, etc.) are copyrighted by the instructor. This university policy (S12-7) is in place to protect the privacy of students in the course, as well as to maintain academic integrity through reducing the instances of cheating. Students who record, distribute, or post these materials will be referred to the Student Conduct and Ethical Development office. Unauthorized recording may violate university and state law. It is the responsibility of students that require special accommodations or assistive technology due to a disability to notify the instructor.

AE 271 – Advanced Aircraft Design Approximate Course Schedule

Tentative schedule subject to change. See CANVAS for updated schedule.

Week	Topics, Readings, Assignments, Deadlines
1	Aircraft design overview
2	Mission requirements. Figures of merit.
3	Weight sizing
4	Performance sizing
5	Performance sizing
6	Configuration design
7	Conceptual design review
8	Fuselage, wing & empennage design
9	Landing gear design. Weight & balance.
10	Longitudinal stability & control
11	Lateral and directional stability & control
12	Preliminary Design Review
13	Drag Polar
14	Stealth
15	Green Aviation
16	Safety
17	Final Design Review

GENERAL GUIDELINES ON PROFESSIONAL REPORT WRITING

Each report must meet minimum standards of professionalism. Unprofessional reports will be **severely downgraded even if** the technical content is correct. The following items explain some of the features of a professional report.

1. All reports must be prepared with a **word processor**.
2. Organize reports using a **decimal numbering system**. The chapters, Sections, Sub-Sections should be indicated as follows:
 4. **TITLE OF CHAPTER**
 - 4.1 **TITLE OF SECTION**
 - 4.1.1 **Title of Sub-Section**
 - 4.1.1.1 **Title of sub-sub-section**
3. Many reports require **calculations**. At least one "hand" calculation **must** be performed and documented for each case in a separate sub-section. These hand-calculations do not have to be typed but should be clearly written and well organized. **If they are lengthy (i.e. more than 2 pages)**, they should be placed in a separate appendix but the results should be discussed in the main body of the report.
4. **All** pages must be numbered. Start the introduction at page 1. Pages in the main body of the report are numbered: 1, 2, 3, etc. Preliminary pages such as Table of Contents, List of Symbols etc. are numbered sequentially: i, ii, iii, iv, etc.
5. A minimum **margin of one inch** must be observed on all pages including graphs, figures, tables, computer print-outs, etc.
6. The report must be written in good **English**. All words must be properly spelled. You are expected to proofread your reports before handing them in.
7. Avoid using sentences longer than 2 lines. If you do not, your report will have a high "**Fog Index**" (i.e. it will be difficult to read).
8. **Do not** use I, You, We, They, etc. in a technical report. Also, **do not** treat an airplane or airplane components as persons, i.e., **DO NOT** write: *the airplane's landing gear is of the retractable type*. Instead, write: *the landing gear of the Cessna 182 is of the retractable type* or, even better, *the airplane has a retractable landing gear*.
9. **Do not use** the words '**in order to ...**'. Remember, the words 'in order' are nearly always out of order!
10. Make use of the technique called "**bulletizing**".
Instead of: *in this chapter, the results of calculations of wing-loading, maximum lift coefficients, thrust-to weight ratio, lift-to-drag ratio and cruise lift coefficients are presented.*
Write: *In this chapter the following characteristics of the Spartan Jet are presented:*
 - *Wing Loading*
 - *Maximum Lift Coefficients*
 - *Thrust-to-Weight Ratio*
 - *Lift-to-Drag Ratio*
 - *Cruise Lift Coefficient*
11. Make sure that no **symbols** are **omitted** from your equations. Again, it is important to proofread your reports before handing them in!
12. All **equations** must be numbered and numbered sequentially. Within a chapter use a decimal numbering system. For example:
$$X = Y + Z \qquad (4.17)$$
13. **References** must follow APA rules, found here: < <http://www.apastyle.org/learn/faqs/index.aspx>>
14. All **figures** and **graphs** must be **numbered** and numbered sequentially. They must also have descriptive **titles**. Titles must appear **below** the figure. All **axes** must have scale and descriptive **labels** including **units** whenever appropriate. **Curves** must also have descriptive **labels**. All lettering must be at least 3 mm high to be legible! For example:

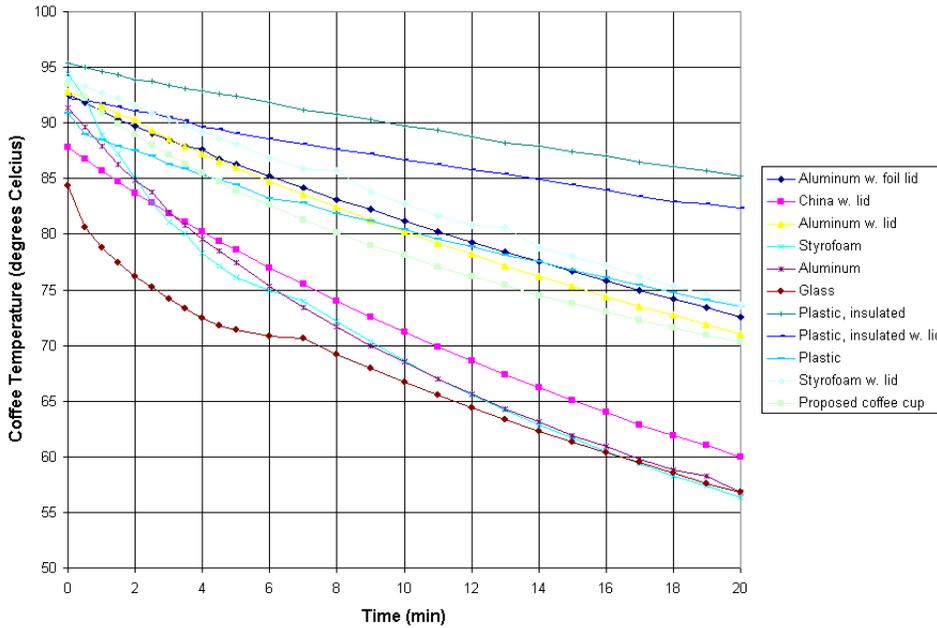


Figure 3.1 – Coffee temperature decline in various cups.

15. All **tables** must be **numbered** and numbered sequentially. They must also have descriptive **titles**. Titles must appear **above** the table. Again, all lettering must be at least 3 mm high to be legible!

Table 5.1 - The heaviest ten airplanes. MTOW = Maximum take-off weight, MLW = Maximum landing weight, TOR = Take-off run (SL, ISA+15°, MTOW), LR = Landing run (SL, ISA+15°, MLW)

Type	MTOW [tons]	MLW [tons]	TOR [m]	LR [m]
Antonov An-225	640			
Airbus A380-800F	590	427		
Boeing 747-8I	439.985	306.175		
Antonov An-124	405			
Airbus A340-500	368	240	3050	2010
Boeing 777-300ER	351.535	251.29		
MD-11	273.314	195.04	3115	2118
Ilyushin IL-96M	270	175		
Boeing 787-9	244.94			
L-1011-500	231.54	166.92	2636	

16. When presenting **aerodynamic data** in a table, graph or figure it is mandatory that you include the following information:

- Reference geometries: S, c and b in ft (or inches) and m (or cm).
- Moment center information in fractions of the m.g.c.
- Airplane weight consistent with the presentation of the data.
- Airplane configuration information, such as:
 - Clean
 - Flaps down, gear up
 - Flaps down, gear down
 - Thrust or power setting
 - Speed brake deployment
 - Flight condition
 - Cg location in fractions of the mgc

17. Remember: **tables, graphs** and **figures** are much easier to understand than **prose** so use them as much as possible.

18. Do not put **lengthy derivations** in the main body of the report. Put such material in an appendix (or appendices) and **summarize** the result in the main part of the report.

19. **Plagiarism** will result in **total loss of credit for the entire report!** If you decide to use

material, which was not generated by you, clearly identify the source of such material.

20. A **list of symbols** must be included in your report. This list must define all symbols used anywhere in the report (including figures, appendices, etc.). Do not include symbols which are not used in your report! Do not copy a list of symbols from another reference! The list of symbols must be presented in the following manner:

Symbol	Definition	Units (SI)
W	Weight	lbs (N)
Greek Symbols		
α	Angle of attack	deg or rad
Subscripts		
() _{TO}	Takeoff	-----
Acronyms		
APU	Auxiliary Power Unit	-----

21. Never make an **unsubstantiated claim!** Example: if you claim that you have optimized airplane weight, you are expected to prove it. If you cannot, do not make the claim!
22. **Avoid** the use of **superlatives**, (e.g. *this is the best airplane ever designed* or *the wing area selected is the smallest possible for this type of airplane*).
23. If you **extrapolate** data or if you extrapolate existing technology, discuss the consequences to your design of not being able to achieve the extrapolated characteristics.
24. Include **units** (both systems) with all your results.
25. Appendices must be sequenced using capital letters and must have specific titles. For example:
 Appendix A - Hand Calculations
 Appendix B - Design Parameters of Comparable Aircraft