

San José State University
Aerospace Engineering
AE 271 – Advanced Aircraft Design – Fall 2018

Instructor	Dr. Nikos J. Mourtos
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Office Hours	TR 6 – 7 pm & W 4:30 – 6:30 pm
Class Days/Time	TR 4:30 – 5:45 pm
Final Project Presentations	TBA
Classroom	Engr164
Prerequisites	Graduate standing in AE or instructor consent
Credit	3 units
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, high-lift system and lateral controls design, landing gear design, weight and balance, stability and control, drag polars, and final drawings. In their final report students 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 and safety issues related to your airplane.
9. Communicate the results of their design in a comprehensive, well written final report, following APA guidelines.

Required Text

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.

Additional Required Reading

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.

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.

Raymer, D. (2012). *Aircraft design: A conceptual approach*. AIAA Education Series, Reston, VA 2012 ISBN 978-1-60086-911-2

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.

Revised reports may be re-submitted (once each) with a **penalty of 20 points** in the scale of 1 to 100.

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

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

Grading Information

Design report, **written individually** = 75%

...consists of 12 chapters

with a total (for all chapters) of **8,000 words** (minimum)

each submitted weekly/bi-weekly through CANVAS,

as shown on the course schedule¹

1st oral progress report & oral exam = 10%

Final oral presentation & examination = 15%

All work is to be performed individually.

This course is **letter-graded** as follows:

850 points < A-, A, A+

700 points < B-, B, B+

650 points < C

600 points < D

599 points or less: F

For issues related to Canvas, please contact the eCampus Help Desk.

Phone: (408) 924-2337

Submit a help ticket using the following URL: <https://isupport.sjsu.edu/ecampus/ContentPages/Incident.aspx>.

While logged into Canvas, click on the word **Help** on the upper right corner of the screen.

University Policies

Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs' Syllabus Information web page at <http://www.sjsu.edu/gup/syllabusinfo/>

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

¹ Detailed guidelines for each report (chapter) is included in the syllabus

Approximate Course Schedule

The schedule is subject to change with fair notice on CANVAS.

Week	Date	Topics, Readings, Assignments, Deadlines	Due
1	8/21	Aircraft design overview	
2	8/27	Mission requirements. Figures of merit.	Chapter 1 – Mission Specification (50 points)
3	9/4	Configuration design – conventional configurations	Chapter 2 – Configuration Design (50 points)
4	9/10	Configuration design – unconventional configurations	Chapter 3 – Weight Sizing and Sensitivities (100 points)
5	9/17	Weight sensitivities, trade studies	
6	9/24	Performance sizing	Chapter 4 – Performance Sizing (100 points)
7	10/1	1 st Briefing (10 mins) – mission, configuration, weight sizing, performance sizing	Chapter 5 – Fuselage Design (50 points)
8	10/08	1 st Briefing (cont'd) – mission, configuration, weight sizing, performance sizing	Chapter 6 – Wing, High-Lift System, and Lateral Controls Design (50 points)
9	10/15	Fuselage, wing & empennage design	Chapter 7 – Empennage Design (50 points)
10	10/22	Landing gear design. Weight & balance.	Chapter 8 – Landing Gear Design (50 points)
11	10/29	Longitudinal stability & control	Chapter 9 – Weight & Balance (50 points)
12	11/5	Lateral stability & control	
13	11/12	Directional stability & control	Chapter 10 – Stability & Control Analysis (100 points)
14	11/19	Green Aviation (No Class On 11/24 – Thanksgiving)	Chapter 11 – Airplane Drag Polars (50 points)
15	11/26	Green aviation	Chapter 12 – Drawings. Environmental and Safety Considerations (50 points)
16	12/3	Green aviation	
17	12/14	<i>Final Design Review</i> (150 points) – Friday 14:45 – 17:00	

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:

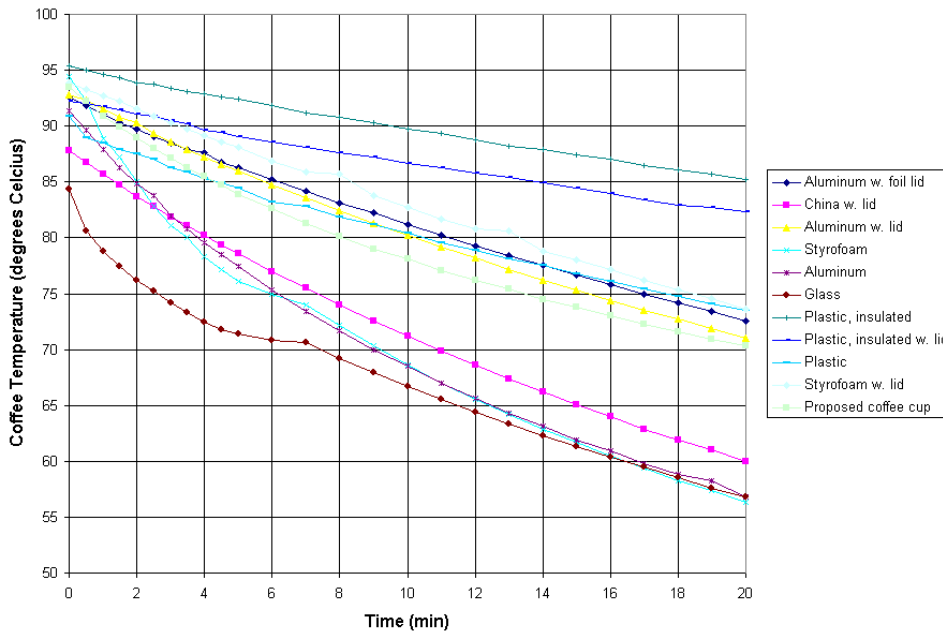


Figure 3.1 – Coffee temperature decline in various cups.

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		
() _{ro}	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

LIST OF SYMBOLS

Make your own and expand as necessary with each chapter.

Chapter 1 – Mission Specification and Comparative Study

What follows is a specification for the **minimum required content** for chapter 1. You may within each section add subsections, if you so desire. You may also add appendices.

1.1 Introduction

1.2 Mission Specification

1.2.1 Mission Requirements

List all the mission requirements for your airplane. Mission requirements should include (but not necessarily limited to):

- payload capacity (number of passengers, cargo weight and volume,...)
- number of crew members required
- range
- cruise speed and Mach number
- cruise altitude
- take-off field length
- landing field length
- approach speed
- noise requirements

1.2.2 Mission Profile

Sketch the mission profile of your proposed airplane.

1.2.3 The Need for this Airplane

Discuss the motivation for building such an airplane. What is the size of the market that justifies the production of this airplane? Attach articles from Aviation Week, Flight International, or other relevant publications which illustrate the need for such an airplane!

1.2.4 Technical and Economic Feasibility

Discuss briefly the technical and economic feasibility of designing, developing, and building such an airplane.

1.2.5 Critical Mission Requirements

Carefully review the mission requirements and prepare a list of those items which have a major impact on the design.

1.3 Comparative Study of Similar Airplanes

The objective of this step is to familiarize yourself with the competition and with work done by others. Perform a comparative study of airplanes with similar mission performance. Refer to "Jane's All the World Aircraft" for data on various airplanes. A collection of as many airplanes as possible should be included but not less than 5. Results of this study should include:

1.3.1 Mission capabilities and configuration selection

Make a table and show the capabilities and configuration of each airplane selected.

1.3.2 Comparison of Important Design Parameters

Make a table and show the various parameters for each airplane selected (W_{TO} , W_{PL} , W_E , W_F or W_{bat} , T , V_{cr} , R , h_{cr} , S , b , AR , l_f , type of PL, etc.).

1.3.3 Discussion

1.4 Conclusions and Recommendations

1.4.1 Conclusions

1.4.2 Recommendations

Chapter 2 – Weight Sizing & Weight Sensitivities

What follows is a specification for the **minimum required content** for chapter 2. You may within each section add subsections, if you so desire. You may also add appendices.

2.1 Introduction

2.2 Mission Weight Estimates

2.2.1 Data Base for Takeoff Weights and Empty Weights of Similar Airplanes

- Include at least 10 airplanes in this data base.
- Tabulate the weight data, airplane types and data source.

- 2.2.2 Determination of Regression Coefficients A and B
 - Include a log-log plot of your weight data.
 - Compare your results with those in Roskam, part I
 - You must use the regression coefficients that you determined for the calculation of your TOW.
- 2.2.3 Determination of Mission Weights
 - 2.2.3.1 Manual Calculation of Mission Weights
 - You must perform and document at least one hand calculation to demonstrate an understanding of the procedure.
 - 2.2.3.2 Calculation of Mission Weights using the AAA Program
 - Include the appropriate screendump(s)

2.3 Takeoff Weight Sensitivities

- 2.3.1. Manual Calculation of Takeoff Weight Sensitivities
 - Perform and document at least one hand calculation for each sensitivity to demonstrate an understanding of the procedure.
- 2.3.2 Calculation of Takeoff Weight Sensitivities using the AAA Program
 - Study the sensitivity of the TOW with respect to as many of the following parameters as appropriate for your airplane:
 - payload weight W_{PL}
 - empty weight W_E
 - range R
 - endurance E
 - lift-to-drag ratio L/D
 - specific fuel consumption (SFC) c_p or c_j
 - propeller efficiency η_p
 - Calculate the corresponding growth factors.
 - Include the appropriate screendump(s)
- 2.3.3 Trade Studies
 - Perform trade studies of TOW vs. critical parameters in your mission (for ex. L/D, SFC, etc.)
 - In particular, do a trade study between range and payload as follows:
 - keep the TOW constant and trade R for W_{PL} or vice versa. Show the results on a W_{PL} vs. R graph (you may also want to set an upper limit for W_{PL} based on fuselage volume constraints and/or load bearing limits).
 - The results of all the trade studies should be presented in graphs.
 - Use the trade studies you performed to find the best design point relating to the mission of your airplane.

2.4 Discussion

- Discuss the results of your weight calculations.
- Discuss the significance of the TOW sensitivities and compare them against the trade studies results of 3.1.3

2.5 Conclusions and Recommendations

- 2.5.1 Conclusions
- 2.5.2 Recommendations

Chapter 3 – Performance Constraint Analysis

What follows is a specification for the **minimum required content** for chapter 3. You may within each section add subsections, if you so desire. You may also add appendices.

3.1 Introduction

Based on the mission requirements and the certification base (FAR's or Military) make a list of performance constraints to which the airplane must be sized.

3.2 Manual Calculation of Performance Constraints

- Start all hand-calculations with the constraint itself (i.e., what is it exactly that you are trying to do with this airplane? for example, $V_S = 61$ knots per FAR 23.61 or $S_{TO} = 5,000$ ft at 7,000 ft altitude, etc.) !!

- 3.2.1 Stall Speed
- 3.2.2 Takeoff Distance
- 3.2.3 Landing Distance
- 3.2.4 Drag Polar Estimation

- 3.2.5 Climb Constraints
- 3.2.6 Maneuvering Constraints
- 3.2.7 Speed Constraints

• You must perform and document at least one hand calculation for each performance constraint to demonstrate an understanding of the procedure.

3.3 Calculation of Performance Constraints with the AAA Program

• Include the appropriate screendump(s) in each section.

- 3.3.1 Stall Speed
 - Include a T/W (or W/P) vs. W/S graph for different C_{Lmax} (fixed V_S)
- 3.3.2 Takeoff Distance
 - Include a T/W (or W/P) vs. W/S graph for different C_{LmaxTO} (fixed S_{TO})
- 3.3.3 Landing Distance
 - Include a T/W (or W/P) vs. W/S graph for different C_{LmaxL} (fixed S_L)
- 3.3.4 Drag Polar Estimation
- 3.3.5 Climb Constraints
- 3.3.6 Maneuvering Constraints
- 3.3.7 Speed Constraints
- 3.3.8 Summary of Performance Constraints
 - Make your matching graph and select
 - $(T/W)_{TO}$ or $(W/P)_{TO}$
 - $(W/S)_{TO}$
 - C_{Lmax} (clean)
 - C_{LmaxTO}
 - C_{LmaxL}
 - A (wing aspect ratio)

Then determine your required T_{TO} or P_{TO} and the required S.

Submit a cleaned up version of your matching graph with only one curve per constraint.

3.4 Discussion

• Discuss the results of your calculations, especially the matching graph and your selection of the parameters T/W or W/P and W/S.

3.5 Conclusions and Recommendations

- 3.5.1 Conclusions
- 3.5.2 Recommendations

Chapter 4 – Configuration Selection

What follows is a specification for the **minimum required contents** for chapter 4. You may within each section add subsections, if you so desire. You may also add appendices.

4.1 Introduction

4.2 Discussion of Items which have Major Impact on the Design

- 4.2.1 List of items with major impact on the design
 - This list may or may not be the same as the one you presented in chapter 1. It should be updated as needed based on the results of your matching graph.
- 4.2.2 Discussion

4.3 Comparative Study of Airplanes with Similar Mission Performance

- 4.3.1 Comparison of Weights, Performance and Geometry of Similar Airplanes.
 - Tabulated comparison of weights, performance and key geometrical parameters of the airplanes that you have found to be closest to yours. You may use the same material that you presented in report no. 1 if all the information is there.
- 4.3.2 Configuration Comparison of Similar Airplanes
 - Include 3-views (photocopies) of the 5 airplanes similar to yours.
- 4.3.3 Discussion
 - A critical discussion of the configurations of these airplanes, as seen from their three-views. In particular, try to explain why, in your opinion, these airplanes look the way they do (i.e., why they have high/mid/low wing, why they have T-tail or canard, etc.).

4.4 Selection of Propulsion System

- 4.4.1 Selection of the Propulsion System Type

- See Roskam, part II, section 5.1
- 4.4.2 Selection of the Number of Engines
See Roskam, part II, sections 3.3.3.1, 3.3.3.2, 5.2
- 4.4.3 Propeller Sizing (if appropriate)
 - propeller diameter
 - number of blades
 - propeller rpm

4.5 Configuration Selection

- 4.5.1 Overall Configuration
See Roskam, part II, section 3.3.1
- 4.5.2 Wing Configuration
See Roskam, part II, section 3.3.4
- 4.5.3 Empennage Configuration
See Roskam, part II, section 3.3.5
- 4.5.4 Integration of the Propulsion System
See Roskam, part II, sections 3.3.3.3 and 5.3
- 4.5.5 Landing Gear Disposition
See Roskam, part II, section 5.1
- 4.5.6 Proposed Configuration
Prepare a preliminary CAD drawing of your airplane.
In each subsection discuss the reasons for your choices as well as the pros and cons for each choice.

Chapter 5 – Fuselage Design

What follows is a specification for the **minimum required contents** for chapter 5. You may within each section add subsections, if you so desire. You may also add appendices.

Follow the procedure in section 4.1, vol.2, in Roskam, to develop a first cut of the fuselage of your airplane.

5.1 Introduction

5.2. Layout Design of the Cockpit

Prepare a preliminary, scaled drawing of the cockpit layout. Study the layout examples in Roskam vol.3 before making your own! Include CAD drawings: top-view, side-view, front-view, rear-view and 3-D view at an appropriate angle. Show dimensions and details of the cross-section, plan-view, and elevation.

5.3 Layout Design of the Fuselage

Prepare a preliminary, scaled drawing of the fuselage layout. Study the layout examples in Roskam vol.3 before making your own! Include CAD drawings: top-view, side-view, front-view, rear-view and 3-D view at an appropriate angle. Show dimensions and details of the cross-section, plan-view, and elevation.

5.4 Discussion

Include a drawing of the complete airplane to date!

Chapter 6 – Wing, High-Lift System & Lateral Control Design

What follows is a specification for the **minimum required contents** for chapter 6. You may within each section add subsections, if you so desire. You may also add appendices.

6.1 Introduction

6.2 Wing Planform Design

From chapter 3 the following wing parameters are known:

- gross area S
- aspect ratio A

The following additional wing parameters must now be selected (read appropriate sections in Roskam vol. 2 and 3):

- taper ratio $\lambda = c_t/c_r$ (ratio of tip chord to root chord)
- dihedral angle Γ

6.2.1 Sweep angle - thickness ratio combination

If your airplane will be flying at high-subsonic speeds which necessitate wing sweep, or if you are going to sweep the wing for other reasons, perform a trade off study between

- sweep angle Λ
- thickness ratio t/c

and plot the results as a curve showing all the possible combinations from $\Lambda = 0$ all the way to $\Lambda = 90$ degrees which satisfy the M_{DIV} requirement for your airplane. On the same graph, plot also W_{wing} / W_{TO} (Roskam vol.5) for all of these combinations and select the one which minimizes W_{wing} (**Figure of Merit**). Make sure you justify all your assumptions!! (read Roskam vol. 3)

Assume $M_{cruise} = M_{div}$. The relationship between M_{CC} , t/c , C_L , and Λ is given below (check also Roskam fig 6.1, vol.2):

$$\frac{M_{cc}^2 \cdot \cos^2 \Lambda}{\sqrt{(1 - M_{cc}^2 \cdot \cos^2 \Lambda)}} \cdot \left[\left(\frac{\gamma + 1}{2} \right) \cdot \frac{2.64 \cdot \left(\frac{t}{c} \right)}{\cos \Lambda} + \left(\frac{\gamma + 1}{2} \right) \cdot \frac{2.64 \cdot \left(\frac{t}{c} \right) (0.34 \cdot C_L)}{\cos^3 \Lambda} \right]$$

$$+ \frac{M_{cc}^2 \cdot \cos^2 \Lambda}{1 - M_{cc}^2 \cdot \cos^2 \Lambda} \cdot \left[\left(\frac{\gamma + 1}{2} \right) \left(\frac{1.32 \cdot \left(\frac{t}{c} \right)}{\cos \Lambda} \right)^2 \right] +$$

$$M_{cc}^2 \cdot \cos^2 \Lambda \cdot \left[1 + \left(\frac{\gamma + 1}{2} \right) \cdot \frac{(0.68 \cdot C_L)}{\cos^2 \Lambda} + \left(\frac{\gamma + 1}{2} \right) \cdot \left(\frac{(0.34 \cdot C_L)}{\cos^2 \Lambda} \right)^2 \right] - 1 = 0$$

where $M_{div} = 1.02 M_{CC}$. In making your decision, keep in mind the following:

- t/c cannot be less than 0.1 to allow enough room for the wing structure, the fuel and the retraction of the main landing gear.
- t/c should not be over 0.2 because the profile drag of the wing is going to be too high.
- the larger the sweep angle, the worse the low speed performance of the wing, which may necessitate a complex and heavy high lift system to make up for it.

6.3 Airfoil Selection

The following wing parameters must also be selected:

- type of airfoil(s)
- incidence angle i
- twist (aerodynamic and geometric)

Again, make sure you justify all your selections !!

6.4 Wing Design Evaluation

Use the AAA program to verify the wing C_{Lmax} .

6.5 Design of the High-Lift Devices

Follow the procedure in Roskam part II, chapter 7.

From chapter 3 the following wing parameters are known:

- maximum take-off lift coefficient C_{LmaxTO}
- maximum landing lift coefficient C_{LmaxL}
- maximum lift coefficient for a clean (cruise) configuration C_{Lmax}

Determine the type and size of high-lift devices needed to meet the C_{LmaxTO} and C_{LmaxL} requirements.

6.6 Design of the Lateral Control Surfaces

Determine the lateral control surfaces size and layout and make sure they are compatible with the high-lift devices

6.7 Wing Drawings

Now you can calculate the following parameters for your wing:

- span b
- root chord c_r
- tip chord c_t
- mac (mean aerodynamic chord)
- mgc (mean geometric chord)
- leading-edge sweep angle Λ_{LE}
- trailing-edge sweep angle Λ_{TE}
- coordinates of the aerodynamic center (x_{ac}, y_{ac})

Draw the wing planform and show all of the above parameters. If the mission calls for variable wing geometry (such as variable sweep), the effect of this on the planform must also be determined.

On your drawings show also as many of the following as apply on your design:

- front and rear spar lines
- ailerons
- spoilers
- flaps

- leading-edge devices

Compute also the wing fuel volume (if you plan to put fuel in the wing).

6.8 Discussion

Include a drawing of the complete airplane to date showing how your wing, high-lift system, and lateral controls fit into your airplane!

6.9 Conclusions

Chapter 7 – Design of the Empennage & the Longitudinal and Directional Controls

What follows is a specification for the **minimum required contents** for chapter 7. You may within each section add subsections, if you so desire. You may also add appendices.

7.1 Introduction

7.2 Overall Empennage Design

- Review the overall empennage configuration that you chose in report 4.
- Determine the location of the empennage (x_h , x_v , x_c).
- Determine the size of the empennage (S_h , S_v , S_c)

7.3 Design of the Horizontal Stabilizer

Choose the following for the horizontal stabilizer:

- aspect ratio
- taper ratio
- sweep angle
- thickness ratio
- airfoil(s)
- incidence angle
- dihedral angle

Compare your choices with the corresponding parameters of airplanes similar to yours. Justify all assumptions and choices.

7.4 Design of the Vertical Stabilizer

Choose the following for the vertical stabilizer:

- aspect ratio
- taper ratio
- sweep angle
- thickness ratio
- airfoil(s)
- incidence angle
- dihedral angle

Compare your choices with the corresponding parameters of airplanes similar to yours. Justify all assumptions and choices.

7.5 Empennage Design Evaluation

Use the AAA program to verify the performance of both your horizontal and your vertical stabilizer.

7.6 Design of the Longitudinal and Directional Controls

Determine the size and the layout of the longitudinal and directional controls surfaces.

7.7 CAD Drawings

Draw the planforms of all the empennage surfaces and show all of the appropriate parameters. Show also the control surfaces on your drawings. Include a drawing of the complete airplane to date showing how the empennage fits into your airplane!

7.8 Discussion

7.9 Conclusions

Chapter 8 – Landing Gear Design

What follows is a specification for the **minimum required contents** for chapter 8. You may within each section add subsections, if you so desire. You may also add appendices.

NB: An iteration is needed between the design of the landing gear and the weight and balance!!

8.1 Introduction

8.2 Estimation of the Center of Gravity Location for the Airplane

8.3 Landing Gear Design

- 8.3.1 Number, type and size of tires.
- 8.3.2 Length and diameter of the struts.
- 8.3.3 Preliminary arrangement.

- Show with drawings how your proposed design satisfies the various tip over criteria
- 8.3.4 Retraction feasibility.
- Include a CAD drawing with dimensions showing the space used for retraction and your landing gear.

8.4 Discussion

- Include a drawing of the complete airplane to date showing how the landing gear fits into your airplane!

Chapter 9 – Weight & Balance Analysis

9.1 Introduction

9.2 Component weight breakdown.

- Present your component weight breakdown in a table.
- Include a drawing of your airplane showing the cg of the various subgroups.

9.3 Center of Gravity Location for Various Loading Scenarios

- Determine whether or not the cg of your proposed design is in the right place for different loading scenarios.
- Draw the cg excursion diagram (potato curve).

9.4 Discussion

Chapter 10 – Stability and Control Analysis

What follows is a specification for the **minimum required contents** for chapter 10. You may within each section add subsections, if you so desire. You may also add appendices.

NB: An iteration is needed between the design of the landing gear, the weight & balance, and the stability & control analysis!!

10.1 Introduction

10.2 Static Longitudinal Stability

- Include your longitudinal X-plot and discuss your design point on the plot. Compare the size of the horizontal stabilizer you came up with in report 7 and the size dictated by your X-plot.

10.3 Static Directional Stability

- Include your directional X-plot and discuss your design point on the plot. Compare the size of the vertical stabilizer you came up with in report 7 and the size dictated by your X-plot.
- Address the minimum control speed requirement with one engine out (for multi-engine aircraft only).

10.4 Empennage Design – Weight & Balance – Landing Gear Design – Longitudinal Static Stability & Control Check

- Inspect the results obtained in chapters 7, 8, 9, and 10 and check whether there is
 - (a) A tip-over problem
 - (b) Too much cg travel
 - (c) Too much or too little longitudinal and/or directional stability
 - (d) A V_{mc} problem

Make whatever changes are necessary to fix all the problems. Then redo steps 7, 8, 9 and 10.

10.5 Discussion

10.6 Conclusion

Chapter 11 – Drag Polar Estimation

What follows is a specification for the **minimum required contents** for chapter 11. You may within each section add subsections, if you so desire. You may also add appendices.

11.1 Introduction

11.2 Airplane Zero Lift Drag

- Airplane total wetted area S_{wet}
- Equivalent parasite drag of the airplane f
- Clean zero-lift drag coefficient C_{D0}

11.3 Low Speed Drag Increments

11.3.1 High-lift device drag increments for takeoff and landing.

11.3.2 Landing gear drag.

11.4 Compressibility Drag

- ΔC_{D0} (for subsonic airplanes).

11.5 Area Ruling

- Cross-sectional area plots for $M = 1$

- Cross-sectional area plots for $M = M_{\text{cruise}}$ and
- Cross-sectional area plots for one more Mach number in between (for supersonic airplanes).

11.6 Airplane Drag Polars

- Show equations and graphs for the Cruise, TO and LND drag polars of your airplane.

11.7 Discussion

11.8 Conclusion

Chapter 12 – Drawings, Environmental and Safety Considerations

12.1 Drawings

Prepare a dimensioned 3-view which reflects all the changes made as a result of the iterations involved in the last few steps of the preliminary design sequence. Include tabulations of the most important design parameters.

12.2 Environmental Considerations

- What are the most important environmental issues related to your airplane?
- Were any of these issues relevant 10 years ago? 25 years ago? 50 years ago?
- How were they addressed 10 years ago? 25 years ago? 50 years ago?
- What technical solutions have been proposed recently to address these issues?
- What is the cost involved in implementing these solutions?
- What are the economic tradeoffs?
- Which solution you think is best and why?
- Do you have any solutions to propose?
- Make sure you read and cite several references.

12.3 Safety Considerations

- What are the most important safety issues related to your airplane?
- Were any of these issues relevant 10 years ago? 25 years ago? 50 years ago?
- How were they addressed 10 years ago? 25 years ago? 50 years ago?
- What technical solutions have been proposed to address these issues?
- What is the cost involved in implementing these solutions?
- What are the economic tradeoffs?
- Which solution you think is best (for each problem) and why?
- Do you have any solutions to propose?
- Make sure you read and cite several references.

REFERENCES

APPENDICES