

# AE 440A Aerospace Vehicle Design: Aircraft

FALL SEMESTER 2008

3-4:20 PM: Tuesdays/Thursdays at 163 Everitt

Department of Aerospace Engineering  
University of Illinois at Urbana-Champaign

Professor Eric Loth

321C Talbot Lab

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## Course Description

Introduction to the design of aerospace flight systems. The principles of systems engineering, as they apply to the design process, are presented. A general design methodology is introduced. These concepts are then applied to the initial sizing of both aircraft and spacecraft systems. Involves intensive technical writing *and* **technical communication skills**. 3 hours credit.

## Teaching Assistants

Michael Behrens	315 English Bldg	(402) 659-6963	<a href="mailto:behrens4@uiuc.edu">behrens4@uiuc.edu</a>
Alex Ghosh	319C Talbot Lab	(217)-721-2875	<a href="mailto:aghosh2@uiuc.edu">aghosh2@uiuc.edu</a>
Phil Martorana	302E Talbot	(815)-222-2289	<a href="mailto:pmartor2@illinois.edu">pmartor2@illinois.edu</a>

## Projected Area Specialties (for Written & Oral Reports)

Behrens	writing and oral composition and report integration
Ghosh	stability & control, performance, configurations
Martorana	structures, aerodynamics, propulsion

## Tentative

Office Hours for EL: 4-5:30 PM Wed & Fri and by appt.

Office Hours for AG: 4:30-6PM Tues & Thur and by appt.

Office Hours for PM: 4:30-6PM Mon & Wed and by appt.

Office Hours for MB: 10-11AM Mon, by appt, and after some 440 classes in 302 E Talbot

*If you need accommodations for a learning or physical disability, please see me ASAP.*

## Course Handout Attachments:

- [Aircraft Design Project Overview](#)
- [Grading Breakdown](#)
- [Course Schedule](#)
- [Reading Assignments & Reserve Books at Library](#)
- [Discipline Responsibilities](#)
- [Oral and Written Report Guidelines](#)

## Aircraft Design Courses Overview

### 1<sup>st</sup> part of AE 440:

#### *Initial Design Concept*

Learn preliminary weight sizing and constraint analysis. This defines the initial point design (defined by weight, wing-loading, thrust-weight ratio, etc.) and vehicle configuration. Give written reports and presentations on a subject related to your area of interest and related to the team design project.

### 2<sup>nd</sup> part of AE 440:

#### *Review Relevant Existing A/C → Determine Vehicle Concept*

From teams and review Team Design Project in detail. Consider candidate vehicle configuration based on historical and projected designs. From morphology process reduce to three primary design and select lead design concept. For selection, consider pre-determined theme and performance goals; but adjust as needed. This work will culminate in a Concept Report (CR) and Concept Presentation (CDP)

### 1<sup>st</sup> part of AE 441:

#### *Develop analysis tools and determine overall aircraft sizing and configuration*

Develop team-consistent sub-system analysis tools and using them to improve the design. This will end with an approximate sizing of all major dimensions. After this part, your configuration can not change but your sizing can change. Develop compatible tools for inter-disciplinary optimization. This work will culminate in a Preliminary Design Report (PDR) and Preliminary Design Presentation (PDP)

### 2<sup>nd</sup> part of AE 441:

#### *Detailed Analysis and Detailed Optimization*

Advanced sub-system analysis computational tools shall be developed and used. Detailed optimization (e.g. of wing span, cruise altitude, wing location, etc.) should be refined/finalized with analysis tools among various disciplines. This work will culminate in a Final Design Report (PDR) and Final Design Presentation (PDP)

**AE 440 – Fall 2008**  
**Aerospace Vehicle Design**

**GRADING**

	(%)
• Class Participation	10
• Initial Sizing Homework	10
• Constraint Analysis Homework	10
• Individual Research Presentations (avg. of instructor scores)	10
• Individual Research Reports (avg. of instructor scores)	10
• Concept Report (avg. of instructor scores)	25
• Concept Presentations	15
• Peer Evaluations of 2 <sup>nd</sup> part of 440 (avg. of team-mate scores)	10
	100%

Report and Presentation grades will be based upon organization, clarity of presentation, originality, technical soundness, depth of analysis, and overall integration.

For final written presentation reports: 75% Individual + 25% Team

**Misc. Notes:**

- 1. Reports will be reduced by 1% for every ten minutes late.** Plan for contingencies!
- 2. Everyone must attend both classes every week and all the presentations.** The only exception is an excused absence by me for serious conflicts (e.g. health reasons and job interviews).

I look for natural breaks in the grade distribution for grading, but curved (if needed) to ensure at least 1/3 of class gets an A<sup>+</sup>, A or A<sup>-</sup> type of grade.

## AE 440 – Fall 2008 Course Schedule

Aug. 26 T	Course Introduction
Aug. 28 Th	<a href="#">Sample AE 441 Presentation</a> & <a href="#">Design Concepts &amp; Overall Process</a>
Sept. 2 T	Initial Sizing Theory I
Sept. 4 Th	Initial Sizing Theory II
Sept. 9 T	Constraint Analysis Theory I ( <b>Discipline/Team Choices Due</b> )
Sept. 11 Th	Constraint Analysis Theory II ( <b>Initial Sizing HW Due</b> ) & Teams Fixed
Sept. 16 T	Constraint Analysis Theory III
Sept. 18 Th	Written Research Report Guidelines by Loth - <b>Determine Leader &amp; Specialties</b>
Sept. 23 T	Discipline Lectures
Sept. 25 Th	Discipline Lectures & Team Meetings ( <b>Constraint Analysis HW due</b> )
Sept. 30 T	Discipline Lectures & Discipline Meetings
Oct. 2 Th	Written Report Guidelines by Behrens & Team Meetings
Oct. 7 T	Oral Report Guidelines by Behrens & Loth, Presentation Dates/Order Assigned
Oct. 9 Th	Q/A on Discipline Areas & Team Meetings ( <b>Written Research Reports due</b> )
Oct. 14 T	<b>Individual Research Presentations</b> (1/2 class) <b>Class 3-5:50PM 1109 Siebel Center</b>
Oct. 16 Th	<b>Individual Research Presentations</b> (1/2 class) <b>Class 3-5:50PM</b>
Oct. 21 T	Team Meetings to Determine Design Theme (& Consider Concepts)
Oct. 23 Th	Team Meetings to Discuss Initial Concepts
Oct. 28 T	Team Meetings to Finalize Candidate Design Concepts
Oct. 30 Th	Team Meetings to Group Concepts in terms of Morphology
Nov. 4 T	Team Meetings to Finalize Top Three Design Concepts
Nov. 6 T	Team Meetings to Analyze Top Three Design Concepts
Nov. 11 T	Team Meetings to Finalize Top Design Concept
Nov. 13 Th	Final Reports Discussion & Team Meetings to Organize Presentations
Nov. 18 T	<b>Team Concept Presentations</b> (1/2 of teams) <b>Class to 3-5:50PM 1109 Siebel Center</b>
Nov. 20 Th	<b>Team Concept Presentations</b> (1/2 of teams); <b>Class to 3-5:50PM</b>
<b>----- Fall Break ----</b>	
Dec. 2 T	Written Report Guidelines, Team Meetings to Organize Written Report
Dec. 4 Th	Team Meetings to Organize Written Report & Incorporate Feedback
Dec. 9 T	Team Meetings <b>Final Report Due Dec. 9    5 PM</b>

## AE 440 – Fall 2008 Aerospace Vehicle Design

### READING ASSIGNMENTS IN RAYMER (3rd Ed)

All Groups:	Chaps. 1-3, 6
Aero:	Chaps. 4, 5, 7, 12
S&C:	Chaps. 16, 17
Performance:	Chap. 17
Propulsion:	Chaps. 5, 10, 13 (also Chapter 8 Oates)
Structures:	Chaps. 8, 11, 14
Config:	Chaps. 7, 8, 9, 15, 18
Cost:	Chaps. 18, 19

### Grainger Engineering Library – Scheduled Reserves

#### **Required: Raymer, Daniel P.; Aircraft Design: A conceptual Approach**

Kuchemann, D.; Aerodynamic Design of Aircraft  
 Covan, James; Safety Engineering  
 Stewart, Rodney D.; Cost Estimator's Reference Manual  
 Gnedenko, Boris V.; Probabilistic Reliability Engineering  
 Summerfield, Martin; Machine Intelligence and Automation for Aerospace Systems  
 Nicolai, L. M.; Fundamentals of Aircraft Design  
 Stinton, D.; Anatomy of the Aeroplane  
 Stinton, D.; Design of the Aeroplane  
 Torenbeek; Synthesis of Subsonic Airplane Design  
 McCormick, Barnes, W. Jr.; Aerodynamics of V/STOL Flight

#### **Roskam Books**

Airplane Design Part I: Preliminary Sizing Of Airplanes  
 Airplane Design Part II: Preliminary Configuration Design And Integration Of The Propulsion System  
 Airplane Design Part III: Layout Design Of Cockpit, Fuselage, Wing & Empennage : Cutaways & Inboard Profiles  
 Airplane Design Part IV: Design Of Landing Gear & Systems  
 Airplane Design Part V: Component Weight Estimation  
 Airplane Design Part VI: Preliminary Calculation Of Aerodynamic Thrust And Power Characteristics  
 Airplane Design Part VII: Determination Of Stability, Control & Performance Characteristics: FAR And Military Requirements  
 Airplane Design Part VIII: Airplane Cost Estimation: Design, Development, Manufacturing And Operating

## AE 440/441 Aerospace Vehicle Design SUGGESTED DISCIPLINE RESPONSIBILITIES

**Items in *italics* primarily for AE441**

### I. Major Technical Areas

1. Performance
  - a. Define flight requirements & develop trajectory model for all flight segments
  - b. Determine drag for all segments based on lift for given wing (from aerodynamics)
  - c. Determine fuel for all segments based for given engine (from propulsion)
  - d. *Determine minimum power/lift. for safety: engine-out, take-off, etc. (to propulsion/aero)*
  - e. *Calculate overall mission performance (alert sub-systems of shortcomings)*
  - f. *Define concept of flight operations (number of flights, airports, etc.)*
  
2. Aerodynamics
  - a. Aerodynamic design including external configuration of *airfoil*, wing geometry and fuselage for cruise, take-off and landing configurations (to configuration person)
  - b. *Component and total system lift-and-drag coefficient relationships (drag-polars)*
  - c. Develop model for lift & drag for cruise, take-off and landing (to performance)
  - d. *Estimate spanwise air-loads (to structures)*
  - e. *Wing lift-and-moment coefficients (data to stability/control)*
  - f. *Employ CFD Analysis to check airfoil performance at Reynolds number*
  
3. Propulsion
  - a. Select and scale engine for max power/thrust reqts. (size/weight to configuration)
  - b. *Determine general propulsion system integration losses (& engine-out losses)*
  - c. Establish model for SFC as a function of power, speed & altitude (to performance)
  - d. *Design fuel system and fuel tanks (to internal configuration)*
  - e. *Estimate acoustic and environmental engine emissions (for analysis)*
  
4. Stability and Control; Flying Qualities
  - a. Select/design/size *all* control surfaces, e.g. horizontal tail, vertical tail, *etc.* (sizes to aerodynamics & configuration)
  - b. Determine/Ensure static margin range for all flight conditions
  - c. *Evaluate longitudinal and lateral stability (suggest needed changes to configuration)*
  - d. *Specify avionics and any digital control system (weight/size to internal configuration)*
  - e. *Evaluate dynamic stability (phugoid & short-period) and evaluate flying qualities*
  
5. Structural Design; Material and Manufacturing
  - a. Determine V-n relationships and establish a V-n diagram
  - b. Establish and maintain load paths
  - c. *Carry out a detailed structural design of the wing box and wing attachment and determine materials (weights and dimensions to configuration)*
  - d. *Structurally design landing gear (weights & dimensions to configuration)*
  - e. *Employ FEM Analysis to check load path and maximum stress regions on wing spar?*

## 6. Configuration

- a. Design and determine the location, relationship and weights of primary component parts (give total weight to all other groups)
- b. *Validate/modify weight/size formulas with relevant aircraft data and sensor data*
- c. Calculate the center-of-gravity *range and moments of inertia* (to stability & control)
- d. Integrate and control *all* external and internal dimensions *including cross-sectional and plan-form aspects and consider and implement performance-driven aspects*
- e. Estimate all Fly-Away & Operating Costs from a cost-model (*show detailed validation!*)
- f. *Consider marketing/customer aspects*

## II. Team Leader

- a. Lead team meetings\*
- b. Establish mechanisms for weekly data interaction
- c. Maintain balance and coordinate work in technical areas.
- d. Determine responsibility for each of the requirements & specifications
- e. Negotiate compromises.
- f. Conduct final run-through of presentations or reports.

\*Team meetings can be informal (during or outside of class) and should be chaired by team leader (good to have a deputy leader/secretary sometimes). Each member should present oral reports/updates to group on work completed, issues, and plans. The emphasis of team meetings should be primarily on specialty reporting, team interaction, work coordination, group decisions and planning.

**(portions in orange do not apply to the October individual reports)**

**AE 440 – Fall 2008  
Aerospace Vehicle Design  
Presentation GUIDELINES**

- 1) **LENGTH:** should average out to be 5/min per team member, **there will be 5 minutes for team questions afterwards**
- 2) **SLIDES:** Should be clearly legible, no small font, avoid too much information, use graphs vs. tables when possible. In bottom right hand corner on *all* slides, put last name of presenter (for judges) and slide number.

**AE 440 – Fall 2008  
Aerospace Vehicle Design  
Written Report GUIDELINES**

- 1) **REPORT:** Submit written report by the due date and time as a PDF file (can include color). Write report as if person reading it has a general knowledge of A/C design, e.g. a senior from another university who is not aware of this particular competition. **Have another team member read your work to check for overall clarity, conciseness, “power”, spelling, and grammar. Make sure that all sections of your report are consistent in style (all figures and tables have the same font, format, etc.) and consistent technical content (e.g. take-off weight is the same in all sections!).**
- 2) **LENGTH:** *"The interest a manager has in a report is inversely proportional to the length of the report."* Total report length **divided by the number of team mates** should be a *maximum* of 2000 words and should be a maximum of 10 pages. There is *no minimum*. This includes all pages (e.g. cover page, figures, references, appendices, etc.) All text is **double-spaced** and 12 point Times New Roman (or similar) font.
- 3) **TABLE OF CONTENTS:** **Identify main single person who was primarily responsible for each section by adding last name in parentheses (in text as well)**
- 4) **EXECUTIVE SUMMARY:** After a Title page and after a Table of Contents, the text should begin with a 1 page executive summary that overviews the aircraft design (and rationale) and the key characteristics, e.g. takeoff and landing weight for the conventional mission, and a couple of other key performance features (in table or sentence format). It should also refer to a three-view and isometric view of the aircraft (which notes the major dimensions) shown on the immediate following page.
- 5) **SECTIONS:** Each section should have a primary author and this should be designated at the start of the section. One should include figures of various configurations and concepts which were considered and results of your analysis for

various configurations and trade-off studies. One should justify and concretely explain all major design decisions. Explain your configurations with quantitative analysis (list assumptions) and/or logical decisions. Separate any analysis portions (formally or informally) into: a) introduction, b) methodology, and c) results.

- 6) EQUATIONS: Make sure all symbols are defined in the text at the point of introduction (or beforehand), i.e. “the weight of the wing ( $W_{\text{wing}}$ ) was estimated ...” Use section to number the equations and right-justify the numbering, e.g.

$$W_{\text{wing}} = W_1 + W_2 \quad (4.1)$$

Define all symbols used in text when first introduced and be consistent throughout report. Use AIAA format:

[www.writetrack.net/aiaa/documents/Manustyleformat.pdf](http://www.writetrack.net/aiaa/documents/Manustyleformat.pdf)

- 7) FIGURES and TABLES: These are very valuable in a report, especially if clear and insightful. I recommend having a simple and clear table or a figure on most technical pages. Introduce all Figures and Tables in the text and in the order in which they are numbered, e.g. (Fig. 4.2), and place them just after (or soon after) the paragraph in which they are mentioned. When introducing a figure or table in the text use a three-step process: a) explain what figure is showing, b) comment on any trends/results, c) explain why trends/results occur and/or significance.
- 8) FIGURE AND TABLE FORMAT For figures, do not use any internal grid lines and do not add extra box outside of figure. Use symbols on axis labels, e.g. H (ft) and word description in caption, e.g. altitude. Keep figures clean with enough trend lines to show trend. Employ appropriate non-dimensionalization when possible. Keep figure font as 12 point *or larger* (except for sub-scripts) – I can’t stand trying to read small font. Look at an AIAA journal paper for examples.
- 8) DATA: Data should be reported with significant figures consistent with uncertainty, e.g. if the uncertainty on cost is at least 5%, then reporting a cost of \$13,000,000 is OK (but reporting a cost of \$13,123,478.66 is not!). Units should be *always* be reported. You may use SI (e.g. m/s) for computation and then give final performance results in English dimensions (e.g. ft/s).
- 9) REFERENCES: You **must** reference all key technical items (figures, equations) that *you did not derive, write, or draw yourself!* References in the text should be in AIAA format: <http://www.writetrack.net/aiaa/documents/Manustyleformat.pdf>
- 10) HIGHLIGHT NOVEL WORK: You should give details on any equations or models that you personally developed (these show innovative thinking), e.g. equation revision (based on different conditions), model re-calibration (based on more recent and/or more relevant data), or unique configuration you c. Show graphically all curve-fits you developed (use symbols for data and lines for curve fits).

**SAMPLE FORMAT:**

**AE 440**  
**Aerospace Vehicle Design**  
**Aircraft Design Section**  
*IDR Report, Presentation, and overall work*  
**INTERNAL (YOUR-TEAM) PEER GRADING SHEET**  
**Due December 10??, 2008**

Please grade the other members of your design team on the basis of their work up to the mid-term. This will be treated as confidential information. Use the following grade schedule. A short explanation comment would be helpful for our overall (sanitized) feedback that we will give students.

- 10 **Excellent;** the major contributor, spark plug
- 9 **Very good;** reliable performer, ready to help, gave extra effort
- 8 **Satisfactory;** did what was required, and helped when necessary
- 7 **Weak;** inconsistent performer, needed prodding
- 6 **Poor;** let others do some of his/her work, a liability to the team

<u>Last Name</u>	<u>Score</u>	<u>Sanitized comments (Good &amp; Bad)</u>
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- 1)
- 2)
- 3)
- 4)
- 5)
- 6)

Points awarded should average 9 pts per rated member (no more, no less). Do not just give the same grade for each person, unless warranted.

Your name:

**Note your score will be reduced if you do not turn this form in on time.**

**SAMPLE FORMAT:**

**AE 440**  
**Aerospace Vehicle Design**  
**Aircraft Design Section**  
*IDR Presentation*  
**EXTERNAL (OTHER-TEAM) PEER GRADING SHEET**  
**Due December 10??, 2008**

Please grade the other design team members on the basis of their presentations. This will be treated as confidential information. Use the following grade schedule. A short explanation/comment would be helpful for our overall (sanitized) feedback that we will give teams.

- 10 **Excellent;** clear, concise, and interesting talks, imaginative & logical design
- 9 **Very good;** covered all bases, only a few minor deficiencies
- 8 **Satisfactory;** did what was required, some high points and some low points
- 7 **Weak;** appeared to have design flaws, talks were unpolished and lackluster
- 6 **Poor;** design explanation was at points confusing, talks were disorganized

<u>Team Name</u>	<u>Score</u>	<u>Comments (Good &amp; Bad)</u>
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- 1)
- 2)
- 3)
- 4)
- 5)
- 6)

Points awarded should average 8.5 pts per rated team (no more, no less). Do not just give the same grade for each team, unless warranted.

Your name:

**Note your score will be reduced if you do not turn this form in on time.**

**AE 440 – Fall 2008  
Aerospace Vehicle Design  
Aircraft Design Section**

**TEAM COMPOSITION  
Due Thursday 28th, 2008 5PM (by e-mail)**

**I. Discipline Areas (Name)**

Aerodynamics \_\_\_\_\_

Propulsion \_\_\_\_\_

Performance \_\_\_\_\_

Stability and Control \_\_\_\_\_

Structural Design \_\_\_\_\_

Configurations \_\_\_\_\_

**III. Team Leader** \_\_\_\_\_

**IV. Deputy Leader** \_\_\_\_\_

**V. Team Name** \_\_\_\_\_

**VI. Aircraft Name** (if decided) \_\_\_\_\_

**VII. Design Theme:** \_\_\_\_\_

**VIII. Team Photo:**