MAE 4415/5415  
Project #1  
Glider Design

Due: March 11, 2008

MATERIALS  
Each student glider must be able to be made from the following materials:  
1/16” x 4” x 18” balsa sheet  
3/16” x 1/2” x 18 balsa stick  
Clay ballast

DESIGN CONSTRAINTS  
- You will design your glider as if you were going to make it from the above materials  
- Wing span \( \leq 18 \) in  
- Ballasted gross weight \( \leq 1 \) oz  
- \( V_{\text{trim}} \leq 25 \) ft/s  
- The spreadsheet performance calculations do not account for control surface stall. Therefore, it is very important to avoid lift coefficients above \( \alpha_{\text{stall}} \). As a rule of thumb, keep \( C_L \) for the wing and horizontal stabilizer below 0.5.  
- No cells on the design worksheet (columns A through L) may be red (indicating you have violated a design constraint) at your design’s maximum range velocity. Cells may be red at your design’s maximum endurance velocity. Exceptions may be approved by your instructor once he/she has determined your design is reasonable.

CONCEPTUAL DESIGN  
Decide on a basic conceptual design, either a canard (tail-first) or conventional (tail-aft) configuration. Make a rough sketch of your design and have an idea of how your wings and tails will be cut from the balsa sheet.

PRELIMINARY DESIGN  
Copy the glider design project spreadsheet (Glider_Design.xls) from the course web page to begin your preliminary design. You will see your glider taking shape as you input the dimensions of each surface (wing, horizontal tail, vertical tail and fuselage). Experiment freely with modifications; you may even wish to design more than one glider to evaluate alternative design strategies. Be sure to manually update the value of \( V_{\text{TRIM}} \) (cell K21) to equal the new \( V_{\text{Rmax}} \) or \( V_{\text{Emax}} \) (cell E39 or F39) as you change your design.
DETAILED DESIGN
When you are satisfied with your glider’s layout, evaluate its stability and glide performance. Investigate different combinations of parameters to optimize L/D while satisfying stability constraints. Refer to the following table for stability guidelines:

<table>
<thead>
<tr>
<th>STABILITY TYPE</th>
<th>PRIMARY CONTRIBUTOR</th>
<th>DESIGN PARAMETER SUGGESTED RANGE</th>
<th>TO INCREASE DESIGN PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal (pitch)</td>
<td>Wing &amp; Horizontal Tail</td>
<td>0.01 &lt; SM &lt; 0.20</td>
<td>• add ballast to nose</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• move wing or tail aft</td>
</tr>
<tr>
<td>Directional (yaw)</td>
<td>Vertical Tail</td>
<td>0.001/° &lt; CN &lt; 0.003/°</td>
<td>• make horizontal tail larger</td>
</tr>
<tr>
<td>Dir/Lat ratio (yaw/roll)</td>
<td>Wing / Vert Tail</td>
<td>1/3 &lt;</td>
<td>CNp / CLp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• move tail aft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• sweep wings aft</td>
</tr>
</tbody>
</table>

GRADED RESULTS
A completed glider “paper design” is required for everyone and is worth 100 points (50 points for design and 50 points for questions). It must include the following:
1) Cover page with your name, course number, project name
2) Hard copy of answers to the attached questions
3) Two hard copies of your spreadsheet design page
   (one with the Vtrim for max range and one with the Vtrim for max endurance)
4) Graph of glide Endurance and Range as a function of velocity

EXTRA CREDIT (worth up to 20 points)
Purchase the balsa wood supplies at a hobby store, build your glider, and bring it to class on March 11th. We will fly them (indoors) and see how well they work compared with your predicted design.

GRADUATE STUDENTS
Do the following in addition to the glider design described above. Choose an existing full-scale glider and enter the dimensions for the glider into the spreadsheet (make a copy of the original spreadsheet for this part of the project). Determine the stability and performance characteristics of the glider using the spreadsheet. Compare you results with available “advertised” information and discuss how well the spreadsheet estimates compared with the “advertised” values. Discuss possible reasons for the differences you find. Present your results in a Powerpoint presentation that you will present to the class the week of March 10th.
Glider Design Project Questions

(50 Points)

1. (3 Points) Render a Cut Plan for your glider by sketching where each component will be cut from the 4” x 18” sheet of balsa depicted below (scale: each block is one inch square—Use a straight edge…neatness counts):

![Glider Cut Plan Diagram]

2. (8 Points) Based on your spreadsheet and graph, fill in the table below with the velocity, range, endurance and tail incidence corresponding to your glider’s max range and max endurance flight profiles: *(Note: your graph of range & endurance must be attached to receive credit on this question)*

<table>
<thead>
<tr>
<th>Glider Performance</th>
<th>V (ft/s)</th>
<th>R (ft)</th>
<th>E (s)</th>
<th>i_t (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Range:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Endurance:</td>
<td></td>
<td></td>
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</tbody>
</table>

3. (3 Points) If your glider were trimmed to fly at its maximum range velocity, describe how you would re-trim it to fly at its maximum endurance velocity (holding the weight constant)?

4. (3 Points) We have discussed three types of drag that comprise an aircraft’s total drag: induced drag, parasite drag and wave drag. Base your answers on the theory presented in class and the text.

   a) If your glider were flying at its maximum range velocity, what percent would each of these three drags contribute to the total drag (your 3 answers must add up to 100%)?

      \[
      \% D_i + \% D_p + \% D_w = 100\% D
      \]

   b) If, instead, your glider were flying at its maximum endurance velocity, what percent would each of these three drags contribute to the total drag (your 3 answers must add up to 100%)?

      \[
      \% D_i + \% D_p + \% D_w = 100\% D
      \]
5. (3 Points) Now discuss *induced* drag, *parasite* drag and *wave* drag based on the *calculations* from the glider design spreadsheet.

   a) If your glider were flying at its *maximum range* velocity, what percent would each of these three drags contribute to the total drag (your 3 answers must add up to 100%)?

\[
\% D_i + \% D_p + \% D_w = 100\% D
\]

   b) If, instead, your glider were flying at its *maximum endurance* velocity, what percent would each of these three drags contribute to the total drag (your 3 answers must add up to 100%)?

\[
\% D_i + \% D_p + \% D_w = 100\% D
\]

6. (5 Points) What is your glider’s *chord* based Reynolds number when it is flying at its maximum range velocity? Assume 7,000 ft standard day conditions. Show all work in the space provided below.

7. (5 Points) We have discussed two types of boundary layers that can occur when air flows over a surface: *laminar* and *turbulent*. Approximately what percentage of the boundary layer flow over your glider’s wing is laminar when it is flying at its maximum range velocity? Assume the critical Reynolds number is 500,000. Show all work in the space provided below.

8. (5 Points) Based on your answers to questions 6 and 7 above, comment on the magnitude of your wing’s $C_{l_{\text{max}}}$ and $\alpha_{\text{stall}}$. Do you expect them to be large or small -- and *why*?

9. (5 Points) You build your glider and take it out for some test flights. Your glider enters a slowly increasing right bank on the first test resulting in a boomerang effect. In the next test it does the same thing to the left. What is one way to fix this problem?
   a) Add more ballast to the nose
   b) Decrease the ballast to the nose
   c) Throw it faster
   d) Throw it slower
   e) Increase the wing dihedral
   f) Decrease the wing dihedral
You are trying to optimize the performance of your hand-launched balsa glider by flight testing it. Answer questions 10 and 11 based on the following selection of choices. The same answer may be used more than once. (note—if you answer part a correctly then you may answer the remaining questions by referring to the $C_{M\alpha}$ plot you chose)

A) increases (becomes more positive or less negative)
B) decreases (becomes more negative or less positive)
C) remains the same

10. (5 Points) Starting with the baseline configuration, you decrease the tail incidence angle. Answer the following questions based on this change:

a) The trim diagram changes according to graph: _____, (answer I, II, III, or IV, or No Change)

b) The slope of the pitching moment coefficient curve: $C_{M\alpha}$ _____ , (answer A, B or C)

c) The zero-lift moment coefficient: $C_{M_0}$ _____ , (answer A, B, or C)

d) The trim angle of attack: $\alpha_{trim}$ _____ , (answer A, B, or C)

e) The trim velocity: $V_{trim}$ _____ . (answer A, B, or C)

11. (5 Points) Starting from the baseline configuration, you remove some clay from the nose. Answer the following questions based on this change:

a) The trim diagram changes according to graph: _____, (answer I, II, III, or IV, or No Change)

b) The slope of the pitching moment coefficient curve: $C_{M\alpha}$ _____ , (answer A, B or C)

c) The zero-lift moment coefficient: $C_{M_0}$ _____ , (answer A, B, or C)

d) The trim angle of attack: $\alpha_{trim}$ _____ , (answer A, B, or C)

e) The trim velocity: $V_{trim}$ _____ . (answer A, B, or C)