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Introduction – Objectives and Goals

- To design, build and test a solar-powered remote controlled UAV capable of long range flight.
  - Pursue the world record for the farthest distance travelled in a straight line by such a vehicle.
  - FAI Regulations – FR-SOL Category.
- To further extend the range and endurance of the aircraft with both solar energy and hydrogen fuel cell technology.
  - Tandem power source
Presentation Overview

1. Limitations and Restrictions
2. Impact of Research
3. Methodology of Design Approach
4. Background
6. Wing
7. Optimization approach Towards a Coherent Fuselage and Tail Configuration
8. Tail Configuration
9. Fuselage Design
10. CFD Analysis
11. Further Drag Reduction Design Implementations
12. Onboard Electronics
13. Future Plans for L.A.S.E.R.
14. Acknowledgements
15. Questions?
Limitations and Restrictions

FAI F5-SOL Category

Aircraft Requirements:

• Electrical motor propulsion only.
• Radio controlled flight without the help of any self-correcting or self-guiding system, such as an autopilot.
• Maximum shadowed surface area of 1.5 m².
• Maximum weight of 5 kg.
• Apart from the onboard battery, only solar cells are permitted as the aircraft systems’ power source.
Impact of Research

• Outcomes of this project have significant implications for aviation and fields as well.
  – Innovative Airframe and Structural Designs
  – Power Systems and Management Theory
• Advances the state-of-the-science
• Demonstrates the applications of scientific advancements in real world applications and contexts.
• Exposes the practicality and feasibility of alternative sources of energy for aircraft.
Methodology of Design Approach

0. Basic Configuration Process
1. Aerodynamics Analysis
   - Plantform Design
   - Airfoil Analysis and Selection
   - CFD Analysis
   - Fuselage Design
   - Airfoil Analysis and Selection
   - Tail Configuration Design
2. Structural Design
   - Plantform Structural Configuration
   - Rib Design and Layout
   - Structural Configuration
   - Horizontal and Vertical Stabilizer Structural
3. Structural Analysis
   - Structural Analysis

Overall Configuration Generation
Background – Previous Iterations

**L.A.S.E.R – 03**
- Simplistic design, quick to manufacture.
- Practice flights
- Solar-powered test flight and electronics validation model.

**L.A.S.E.R – 04**
- Focused on furthering endurance.
- Efficient canard configuration.
- High-Risk Design
- More fragile and difficult to build.
Background – Previous Iterations

**LASER-05X**

- Regulation revision allowed increase in wingspan.
- High taper ratio decreases effective performance of the aircraft. Prone to wing tip stall.
- Cost and weight of winglets out weigh the benefits.
- Sailplane lifting body fuselage design. Too large.
- T-Tail to allow for improved glide ratio performance. Structurally unstable.
Current Iteration – L.A.S.E.R. - 05

- Larger and more aerodynamically efficient wing
- Conventional Tail. Structurally sound. Conventional control system
- Tail sizing accurately determined. (Analytically)
- Less Taper Ratio
- More efficient, powerful motor to support heavier aircraft.
- Same glider fuselage geometry (lifting body), but smaller in diameter and larger length
- Newer, more efficient wing mounting-joining system
- Newer, more structurally rigid wing design
- 2 piece wing

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Airfoil Analysis and Selection

- Bregeut Range Equation:
- Clark Y and Selig 7075 (9% thickness) were selected after analysis of a library of airfoils.
- Lift over Drag ratio plots:
Selig 7075 (9% thickness) was chosen for its favorable lift over drag values at relevant Reynold’s numbers.

L.A.S.E.R. – 05: Main Wing

- Coefficient of lift vs. AOA
- Lift over Drag Ratio
- Lift component at AOA of Max L/D
Planform Modulation and Analysis

- New shape best idealizes elliptical lift distribution using straight edges.
  - Easier to manufacture
- Smaller taper ratio ensures aircraft is not wingtip stall sensitive/prone.

\[
C_{D,i} = \frac{C_L^2}{\pi e AR} = \text{constant} \uparrow = \downarrow C_{D,i}
\]
L.A.S.E.R. – 05: Main Wing

Aerodynamics

Wing Name = 4867.200 mm
Wing Span = 4867.200 mm
Wing Area = 13008.428 cm²
Effective Span = 4867.200 mm
Root Chord = 330.200 mm
R.A.C. = 506.358 mm
X_Cp = 0.000 mm
Wing Area = 13008.428 cm²
XProj. Area = 13008.428 cm²
Plane Mass = 50.00 kg
Plane Load = 0.004 kg/cm²
Tip Twist = 0.00
Aspect Ratio = 14.00
Taper Ratio = 1.48
Root-Tip Sweep = 0.00

V = 45.3 m/s
Alpha = 0.000°
Sideslip = 0.000°
Bank = 0.000°
Control_pos = 0.0000
CL = 0.2998
CD = 0.0051
Efficiciency = 0.5840
CL/CD = 163.116
CL = -0.000
CD = -0.1772
X_Cp = 182.237 mm
Aerodynamics contd...

L.A.S.E.R. – 05: Main Wing
L.A.S.E.R. – 05: Main Wing

Aerodynamics contd...

[Image of a 3D aerodynamic model with parameters listed below the image]
L.A.S.E.R. – 05: Main Wing

**Structural Design-Wing Frame**

- **Ribs Carbon Fiber Plates** \((1.7 \text{ mm})\)
  - allows skin to resist global buckling

- **Spar**
  - **Forward Spar** \((0.5 \text{ in})\)
    - cylindrical carbon fiber rod
  - **Aft spar** \((0.25 \text{ in})\)
    - square carbon fiber rod
  - The Spars then absorb and distribute the span wise bending moments

- **Skin**
  - 1/16 Balsa Wood Sheets covered by *Monokote*
L.A.S.E.R. – 05: Main Wing

**Wing Joining-Mounting System**

- Forward Spar slides into Ferrule
- Ferrule epoxied to carbon fiber covered middle foam wing section
- Middle foam wing section epoxied to the fuselage
L.A.S.E.R. – 05: Optimization approach towards a coherent fuselage and tail configuration

- Dimensionalisation of fuselage affects the dimensions of the tail surfaces and vice-versa.
- Tradeoff:
  1. Lengthen the fuselage thereby resulting in a reduction in the area of the tail surfaces.
  2. Shorten the fuselage results in a larger tail configuration assembly.

\[
V_H = \frac{s_H L_H}{s_W c} \quad V_V = \frac{s_V L_V}{s_W b}
\]

- Decision: Lengthening the fuselage, reducing the area of the tail surface, would also result in more of a drag reduction than option 2.
## L.A.S.E.R. – 05: Tail Configuration

<table>
<thead>
<tr>
<th>Tail Configurations</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T-Tail</strong></td>
<td>Allows for smaller vertical tail</td>
<td>Deep Stall</td>
</tr>
<tr>
<td></td>
<td>Allows for smaller horizontal tail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better glide ratio</td>
<td></td>
</tr>
<tr>
<td><strong>V-Tail</strong></td>
<td>NACA research shows that area required is about the same, however there is still reduced interference drag.</td>
<td>Adverse roll-yaw effect: right rudder produces right raw + some left roll</td>
</tr>
<tr>
<td><strong>Conventional Tail (inverted T)</strong></td>
<td>No single point of failure</td>
<td>More Drag than V-tail configuration</td>
</tr>
<tr>
<td></td>
<td>Easy to manufacture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simplistic control system</td>
<td>Not as much glide ratio as T-tail configuration</td>
</tr>
</tbody>
</table>
Dimensionalization

- Developed in-house software which designs optimized tail configuration given aircraft’s weight, fuselage dimensions, and main wing dimensions for specified control criteria.

**Horizontal Stabilizer**

**Vertical Stabilizer**

**RESULTS - Total Horizontal Stabilizer**
- Total Span: 34 in
- Total Area: 147 in²
- Mean Chord Length: 7 in
- Mean Aerodynamic Chord Long: 7 in
- Aspect Ratio: 9
- Percent of Wing Area: 7.0617 %
- Taper Ratio: 1

**RESULTS - Half-Span Horizontal Stabilizer**
- Area: 7.5 in²
- 25% MAC from Root Leading Edge: 1.75 in
- Location of 50% Point: 4 in
- Location of 25% Point: 1.75 in
- Sweep Angle (Measured from Leading Edge): 0 degrees

**RESULTS - Total Vertical Stabilizer**
- Total Span: 14 in
- Total Area: 105 in²
- Mean Chord Length: 7.5 in
- Mean Aerodynamic Chord Long: 7.5 in
- Aspect Ratio: 1.0667
- Percent of Total Wing Area: 5.223 %
- Location of 50% Point: 1.4 in
- Location of 25% Point: 0.5 in

**RESULTS - Top Portion**
- Area: 105 in²
- 25% MAC from Root Leading Edge: 3.3 in
- Mean Chord Length: 7.5 in
- MAC: 7.5 in
- Taper Ratio: 1.0667
- Sweep Angle: 0 degrees

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L.A.S.E.R. – 05: Tail Configuration
L.A.S.E.R. – 05: Wing-Tail Interaction
**Fuselage Design**

- **Bulbous geometry**
  - Allows room for larger payload capacity
  - Slimmed down from previous iteration to cut drag and needless weight
- **Elongated fuselage**
  - Allows for size reduction of tail surfaces
L.A.S.E.R. – 05: Fuselage

**Structural Analysis**

**ANSYS Bending Analysis:**
Fixed at the nose, a 10g inertial load was applied to the end of the fuselage to simulate a violent belly landing.

Tail tip displacement = \(3.48\ mm\)
L.A.S.E.R. – 05: Fuselage

**Construction**

- Carbon fiber sleeve fit over foam inner shell
- Sleeve hung from ceiling with weights attached to the bottom
- Carbon fiber covered in epoxy
- Heat shrink sleeve applied to ensure a tight fit
25 mph free stream at sea level

0° AOA

7° AOA
Fuselage with a non-folding stationary propeller during gliding (unpowered) flight produces almost 4 times the drag of the fuselage alone.

- Folding propeller folds onto fuselage during gliding (unpowered) flight.
- Excluding landing gear decreases drag significantly.
- Due to large size of aircraft there are limitations to hand-launching such a vehicle.
L.A.S.E.R. – 05: Onboard Electronics

**Electrical System Overview**

- **Green: custom electronics**
  - Boost-Buck Converter
  - 5V Regulator
  - Battery Protection and Monitoring
  - Transmitter

- **Blue: Off-the-shelf components**
  - 3-Cell lithium-polymer battery
  - Ardupilot
  - GPS
  - RC receiver
  - Electronic speed control (ESC)
  - Servo motors
  - Main propeller motor
  - Control Transmitter
Solar Cells

Properties
- Double-junction amorphous silicon
- Very flexible and durable
- Very lightweight
- Roughly 5% efficient

Our Array
- One 12” x 90” pannel across the main wing
- 15.4 volts, 1.5 ampers
- 23.1 watts in full sun
L.A.S.E.R. – 05: Onboard Electronics

**Flight Profile**
Aiming for a $\frac{1}{4}$ duty cycle or better

![Flight Profile Diagram](image)

- $h_{\text{max}}$
- $h_{\text{min}}$
- Initial Ascent
- Distance and Time
- $T$
- $T_a$
- $T_d$

Not to Scale
L.A.S.E.R. – 05: Onboard Electronics
L.A.S.E.R. – 05: Future Plans

- Implement Ardupilot.
- Create KiCAD models of solar power converter and battery protection boards.
- Ground test electronics system.
- Begin flight tests of L.A.S.E.R – 05. (Flight are currently banned by FAA)
- Determine necessary information for long range flights.
L.A.S.E.R. – 05: Acknowledgements

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Questions?