Making Aircrafts Lighter and Stronger through Structural and Materials Design

Objective

To equip the participants with our in-house research skills for structural analysis and materials modeling/selection/design in aerospace engineering, with a focus on making aircrafts lighter, stronger, and smarter through the deployment of modern tools, such as finite element analysis (FEA) and molecular dynamics (MD). The participating students will explore the basic concepts of airplane structural analysis, materials modeling, and selection through hands-on projects.

Expected Outcomes

By the end of this program, students will:

- Understand the structural analysis and material selection in aerospace engineering.
- Explore how engineers use FEA and MD to design and optimize aircraft structures.
- Gain hands-on experiences to predict how aircraft components (wings) deform.
- Gain hands-on experiences to pattern the aircraft surface structures for anti-icing.
- Present a mini project demonstrating their learning in a real-world context.

Audience: High school students (Grades 10–12) interested in engineering and science.

Duration: 4 weeks (8 sessions in total, 2 sessions/week)

Delivery: Lecture + Demo + Hands-on Activity

Tools: SimScale (cloud-based FEA tool), LAMMPS (MD simulation tool)

Syllabus Overview （Research workshop: Mon and Wed 8-9 EST）

Week-1, Session-1: Introduction to Aircraft Structures

- Why does an aircraft need to be both light and strong?
- Structural failure examples in aviation history.
- Overview of aircraft structural components (wing, fuselage, landing gear, etc.)
- **Activity:** Paper wing challenge – build a light but strong paper wing to carry weight

Ref: https://www.instructables.com/Worlds-best-Paper-Airplane-simple-and-sturdy/

Week-1, Session-2: Introduction to Aerospace Engineering Materials

- How does the aircraft structure respond to external forces?
- Materials selection for different components (wing, fuselage, landing gear) in aircrafts
- Common aerospace materials: aluminum, steel, titanium, composites, and so on.
- **Activity:** Hands-on Experiments for Material Property Comparison

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Week-2, Session-1: Introduction to Structural Analysis

- What is structural analysis?

- Concepts of deformation, strain, and stress
- Analytical, experimental, and numerical methods
- **Activity:** Watch a simple FEA simulation

Ref: https://www.youtube.com/watch?v=5uyY3eUJAOU

Week-2, Session-2: Basics of Finite Element Analysis

- Geometry, Materials Properties, Elements, Nodes
- Boundary Conditions and Loading
- Interpreting Simulation Results: Displacement, Stresses, Von-Mises Stresses
- **Activity:** Hands-on: Run a simulation of the deformation of a truss using SimScale

Ref: https://www.simscale.com/docs/tutorials/linear-static-analysis-of-a-crane-3/

Week-3, Session-1: Simulating How Air Flows around a Drone Propeller

Activity: hands-on experiences on SimScale

Ref: https://www.simscale.com/docs/tutorials/drone-simulation-rotating-zones/

Week-3, Session-2: Finite Element Simulation of the Bending of an Aircraft Wing

- Wing spars, ribs, and skin
- Loads on an aircraft wing
- **Activity:** Pre-built wing section simulation – modify the materials used in the simulation and analyze the effect of them on weight and stress

Ref: https://www.simscale.com/projects/lmxiong/dbf_aircraft_wing_structural_analysis_-_copy/

Week-4, Session-1: Modeling materials by tracking the motion of the atoms in them

- **Topics:** why do we care about the motion of the atoms?
- What is molecular dynamics (MD)?
- How is it useful in aircraft structure design?
- Ongoing Research Projects using MD: Simulating the Ice Formations on Aircraft Wings
- **Activity:** Download MD simulation tool, LAMMPS, and run an example problem

Ref: https://www.youtube.com/watch?v=7RtRerwJqQw

Week-4, Session-2: Simulating and understanding how ice forms on an aircraft wing

- **Topics: current research project funded by National Science Foundation**
- Visualize how ice is formed on the cold surface of an aircraft wing
- designing the wing surface structure to delay the ice formation on it
- **Activity:** hands-on experiences to simulate how water droplet is frozen into ice