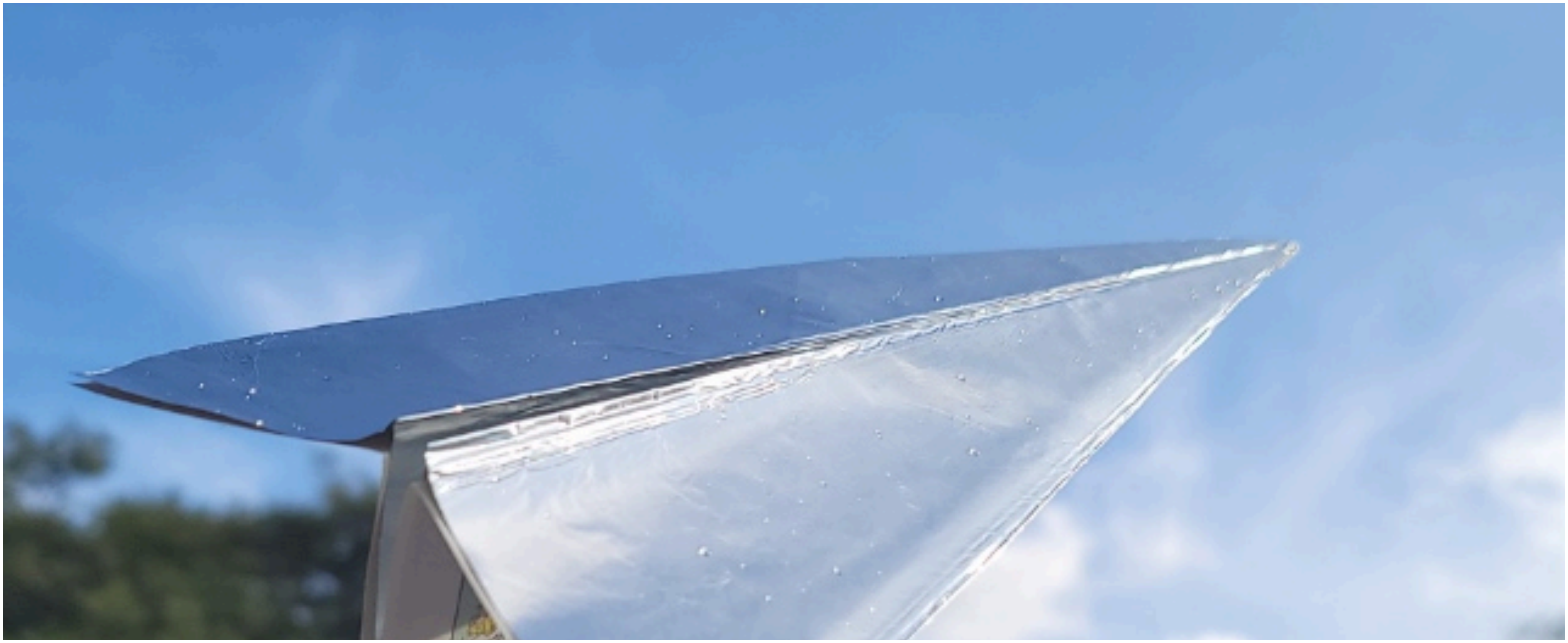

STEM
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Engineering Design Process (EDP) in Review

# Composite Airplane Activity

Saturday, March 27, 2021
8:00 a.m. Set-up and Connect via Zoom
8:30 a.m. – 12:00 p.m.

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# WELCOME

# INTRODUCTIONS

**STEM Pre-Academy**

**Guest Speakers and Subject Matter Experts**

**Pacific American Foundation**

**Teachers, Coach and Counselor**: *Ben Parker Elem, He'eia Elem, Ilima Inter, Jarrett Middle, Kahaluʻu Elem, Kāneʻohe Elem, Kāʻu High & Inter, Molokaʻi Middle*

# ANNOUNCEMENTS

- Turn on your chat feature
- Use chat feature to enter your questions at any time. Questions will be collected by Caroline and addressed during discussion and Q&A sections.
- Use chat feature if you are having any technical issues.



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# Objectives

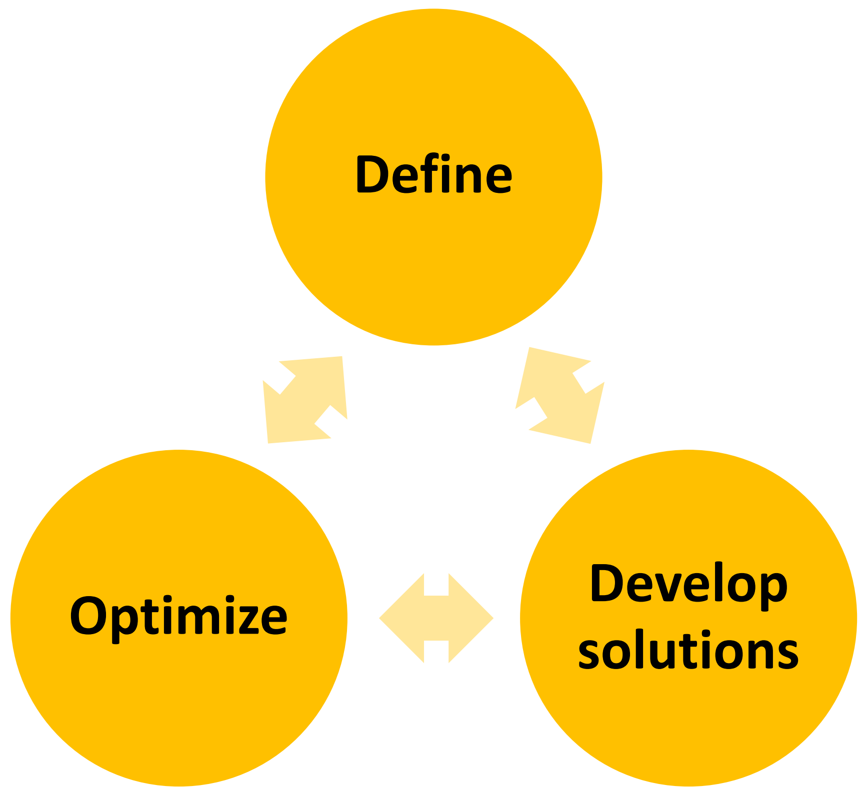
- Participants will apply prior knowledge and create a Composite Airplane that applies the Engineering Design Process (EDP).
- Participants will define and explain examples of composite materials.
- Participants will identify and discuss new science and technology concepts that will help expand student interest in areas of future studies and/or careers.
- Participants will discover and discuss connections between EDP and real world innovation in the Aeronautical and Space Engineering industry.

# Why Engineering Education in Elementary and Middle Schools?

- 2013 Next Generation Science Standards (NGSS) integrates engineering into K-12 curriculum (Porter & Wes, 2018)
  - The application of scientific knowledge to solving practical problems and real-world challenges
  - Establish vital skills: problem solving, critical thinking, creative design, and teamwork
  - Engineering reiterates math and science concepts while applying them to practical uses
- 2016 Hawaii Board of Education adopts NGSS (Porter & Wes, 2018)

# Engineering Design in the NGSS:

K-2 Standards - 3-5 Standards - 6-8 Standards - 9-12 Standards




https://ngss.nsta.org/AccessStandardsByTopic.aspx
APPENDIX I-Engineering Design in the NGSS

# Engineering Notebook addresses All the Science and Engineering Practices (SEP)

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanation (for science) and designing solution (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

# Engineering Design Process Review

## Ask

- Identify Need
- Define Problem
- Define Specifications

## Imagine

- Sketch Possible Solutions
- Background Research

***the goal***

## Plan

- Evaluation Criteria
- Model
- Optimal Selection

## Create

- Build Prototype
- Test and Record Data

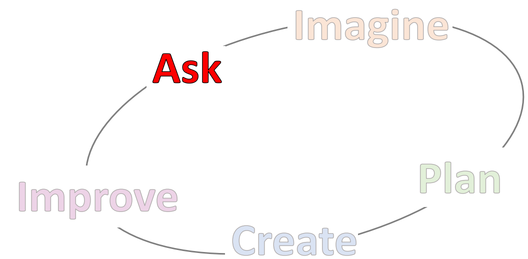
## Improve

- Re-Design
- Re-Build and Test
- Evaluate

Process is not a linear path

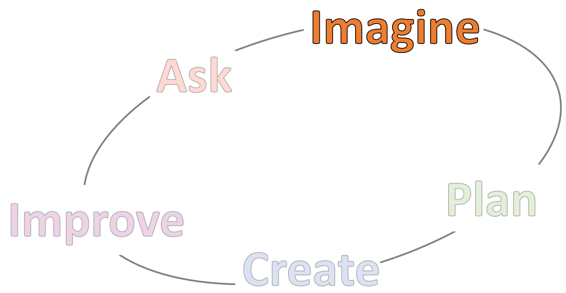
Based off the Boston Museum Graphic

# EDP Review - ASK



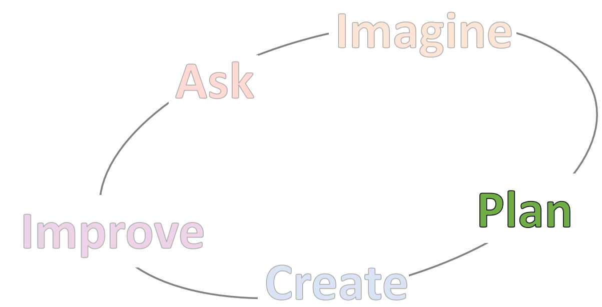

- Define the Problem Statement
- Define the specifications
- Reflection

# EDP Review - IMAGINE



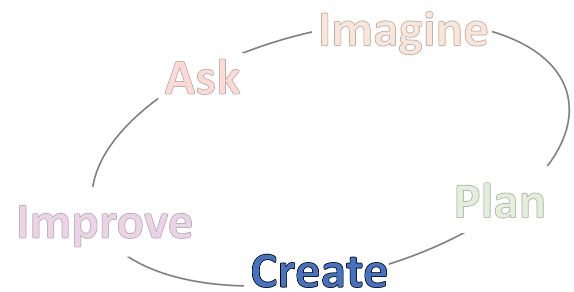

- Conduct background research and document
- Brainstorm and sketch
- List materials and quantities
- Reflection

# EDP Review - PLAN



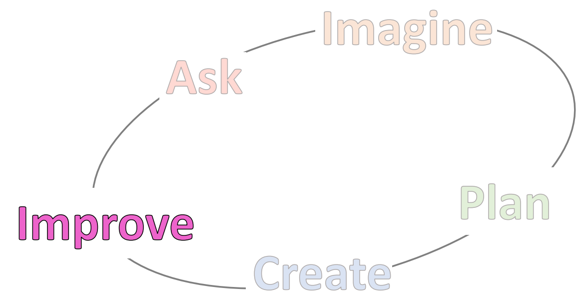

- Create a Project Timeline (Gantt chart)
- Create a Pugh chart and choose the best design and justify
- Draw a **detailed** sketch of your selected design and label the parts
- Write out the steps to create and to test
- List the materials and quantities
- Reflection

# EDP Review - CREATE




- Follow the Plan and Build Prototype
- Test the Prototype, Record Data and Observations
- Evaluate
- Reflection

# EDP Review - IMPROVE




- Sketch and label your improved design
- Write a description of the design change(s) and justify
- Write out the steps to create and test
- List the materials and quantities for your NEW design
- Follow your plan and create your improved prototype
- Test the Prototype, Record Data, and Observations
- Evaluate
- Reflection



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Engineering Design Process (EDP) in Review

# EDP REVIEW: PLAN REVISITED

## Project Planning

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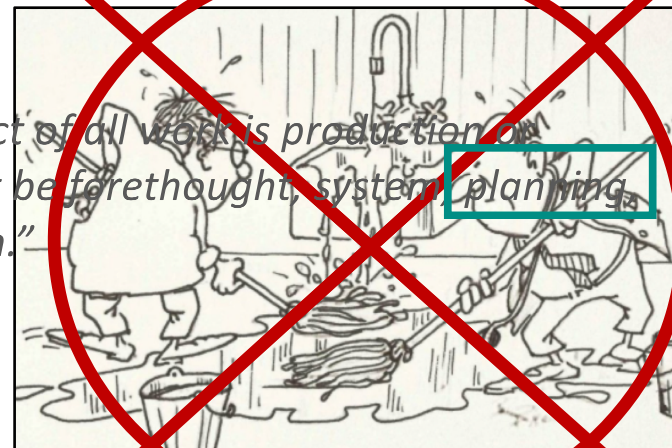
# Project Planning

## Why does it matter?

*“Being busy does not always mean real work. The object of all work is production or accomplishment and to either of these ends there must be forethought, system, planning, intelligence and honest purpose, as well as perspiration.”*

*– Thomas Edison*



# Project Planning
## What is it?

Limited resources → Effective management

(e.g. time, budget, labor, materials, supplies, tools, etc) → (e.g. project planning, risk mitigation, tracking, reporting, accountability, performance etc)

A project plan is your roadmap to success.
It defines:

1. What you are doing;
2. When you plan to do it;
3. Who is responsible for each task; and
4. Any relations between tasks

# Project Planning for students
## How do I do it?

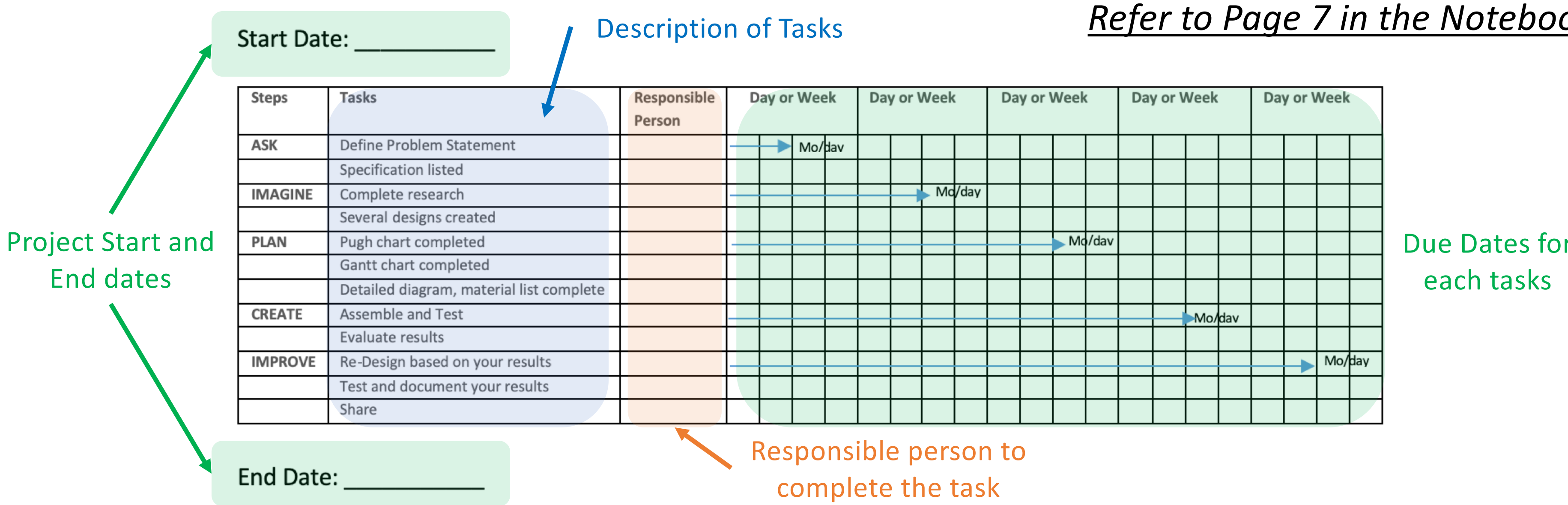
- Project Planning Tools - Examples
  - Bar charting (Gantt)
  - Critical Path Method (CPM)
  - Program Evaluation and Review Technique (PERT)
  - Precedence Diagramming (PDM)

Reference: Harrah, T., George, B. and Cyr, M. *Timelines and Student Project Planning in Middle School*, ASEE Conference (2002)

# What is a Gantt Chart?

- “A Gantt chart is a project management tool often used outside of education that can be easily incorporated into curriculum mapping, event planning, and other areas. It’s a way to visualize the tasks associated with a project, and see what items must be completed on a specific day. It also allows you to quickly see the start and end dates for your project.”[1]

*Refer to Page 7 in the Notebook*




[1]https://www.azk12.org/homeroom/2019/01/30/gantt-charts-teachers-edition



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# Benefits and Skills - Gantt Chart

- Leadership (Accountability)
- Self Responsibility
- Planning (Due Dates)
- Learning to work in teams
- Communications
- Breaking down tasks (Subtasks, Identifying Milestones)
- Reporting

# Samples of Gantt Chart in the Classroom

- Suggestions:
  - Lower Elem: Teacher heavily guides the tasks and due dates
  - Elem: Emoji's to represent on-time or late
  - Secondary: Students take ownership of the tasks and due dates
  - All: Tasks can be completed by individual or teams

**PLAN: Gantt Chart- TEAM CHECKLIST**

Start Date: ________________

| Steps | Period | Week 1 | Week 2 | Week 3 | Week 4 |
|---|---|---|---|---|---|
| ASK | Science | ☐ Mystery Science video- Part 1 and complete K of the KWL chart<br>☐ Kalo Park pollinator observation<br>☐ Define the problem<br>☐ Review and teach vocabulary<br>☐ Watch the Mystery Science video- Part 2 and complete W and L of the KWL chart | | | |
| | Reading | ☐ RI.2.2 Main topic- "Flowers Go Bats!" Article on bats and pollination | | | |
| IMAGINE/ PLAN | Science | ☐ Watch the Mystery Science video- Part 3-5 and complete W and L of the KWL chart | ☐ Review Gantt Chart<br>☐ Individual Designs *Partner 1 &2<br>☐ Decide on a design using the Pugh Chart and through collaborative conversations | | |
| PLAN/ CREATE | Math Science | | ☐Calculate and purchase supplies to create pollinator | ☐ Prototype 1<br>☐ Test<br>☐ Score and Reflect | |
| IMPROVE | Science | | | ☐ Revise<br>☐ Prototype 2<br>☐ Test<br>☐ Score and Reflect | |
| COMMUNICATION CLASS PRESENTATION | Science | | | ☐ Post Assessment *Add more to the L portion of the KWL chart | ☐ Teams present at the Curriculum Fair and test their handheld pollinators at Kalo Park |

Example: Grade 2 – Kahalu'u Elementary

# Gantt Chart Discussion – Classroom Application

- What are some of the challenges faced by students in project planning and in particular developing  a GANTT chart?

- How do you build these planning and management skills from early age, How do you present it?

# Project Planning and Planning tools in the Industry

- Davin Sasaki – Former Global Program Manager
    - Global Projects involving multiple countries
    - Resource Management
    - Supply Chain Management
    - Risk Management
    - Project Prioritization

- Ren Ishii – Aerospace Application

# Project Planning and Management

## Why does it matter?

*"Being busy does not always mean real work. The object of all work is production or accomplishment and to either of these ends there must be forethought, system, planning, intelligence and honest purpose, as well as perspiration."*

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(e.g. time, budget, labor, materials, supplies, tools, etc)

(e.g. project planning, risk mitigation, tracking, reporting, accountability, performance etc)



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Engineering Design Process (EDP) in Review

# Composite Airplane Activity

Using the Engineering Design Process

# ASK Step

ASK

Refer to Page 4 Engineering Notebook

**Guiding Questions:** If a paper airplane is constructed out of a composite material, will it fly farther? Will it fly straighter?

**Problem Statement:** Composite materials combine two or more materials and can be specialized to meet unique specifications and constraints. The configurations of composite materials can result in desirable properties, present manufacturing challenges, such as orientation combinations, modeling, and reliability.

Your customer requests a composite airplane that can fly straight for at least 10 feet.

# ASK Step

ASK

**Design Challenge Activity:**

Design and build a composite airplane that will fly a distance of at least 10 feet and land within the 5 feet width of the flight path.

# Review the Specifications

ASK

Weights are scaled by importance (highest = most important)
Score are also usually scaled (highest = best) Score 3 to 1
Weighted Score = Weight x Score

| Specifications | Weight |
| --- | --- |
| The flight of the composite plane should fly straight within the 5 feet width. | 3 |
| The average of the flight distance (5 trials) of the composite plane should travel at least 10 feet. | 5 |

# IMAGINE Step

IMAGINE

- Pre-Session Assignment
  - Define composite
  - Identify three interesting things that are made from composite materials
  - Conduct your own background research

Engineering Design Process (EDP) in Review

# Introduction to Composite Materials

## *Background Research*

Troy Nakagawa, PhD Student in Aeronautics and Astronautics Engineering, University of Washington

March 27, 2021

# What are composite materials?

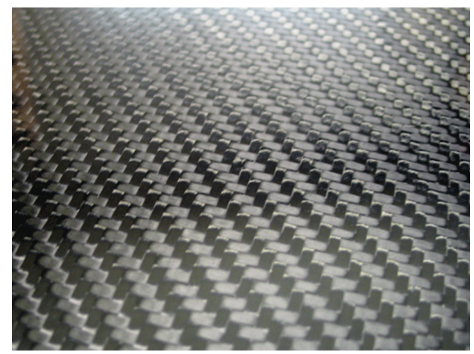
IMAGINE

**A composite material** is a material made from two or more constituent materials with significantly different properties that, when combined, produce a material with characteristics different from the individual components.

Examples:

Cellulose fibers (flexible) held together by lignin (stiffer)

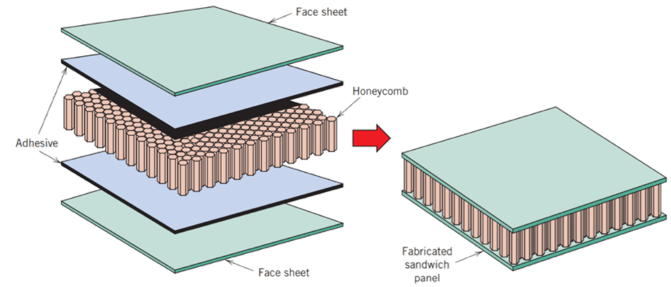
Cement, sand, aggregate, and steel reinforcements



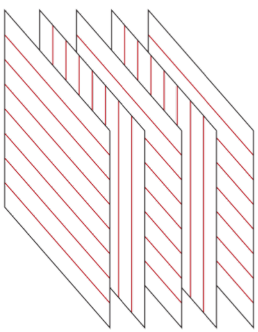
Carbon Fiber Reinforced Plastic (CFRP)

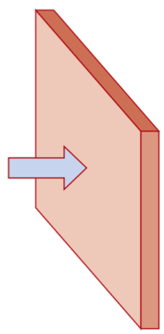
# Composite Classification

IMAGINE




- Composites
  - Particle-reinforced
    - Large-particle
    - Dispersion-strengthened
  - Fiber-reinforced
    - Continuous (aligned)
    - Discontinuous (short)
      - Aligned
      - Randomly oriented
  - Structural
    - Laminates
    - Sandwich panels

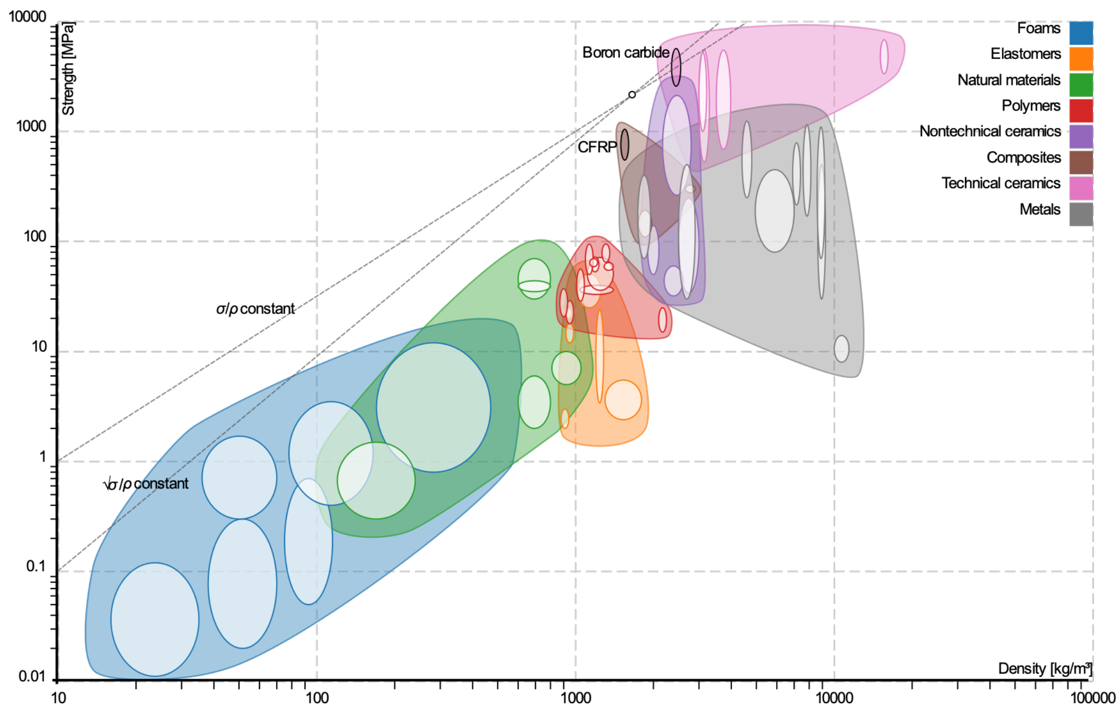




Materials Science and Engineering, William Callister

# Why Use Composites?

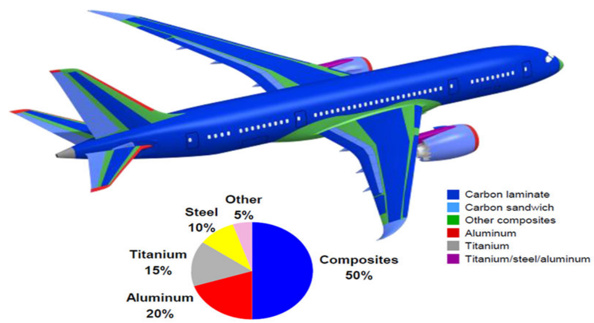
IMAGINE




- Composites can have **better properties** than their individual components (i.e. fiber reinforced plastics)
- CFRPs have **similar strength to many metals** while being much **lighter**

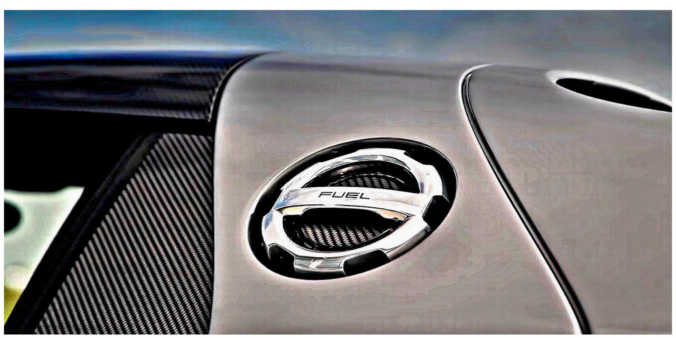
# Composite Applications

IMAGINE




Composite structures: the first 100 years
Roeseler et al.

- Boeing 787 is 50% composites by weight
- Plywood floors and composite counter tops
- Many cars have carbon fiber
- Sports such as tennis and baseball use carbon fiber for equipment



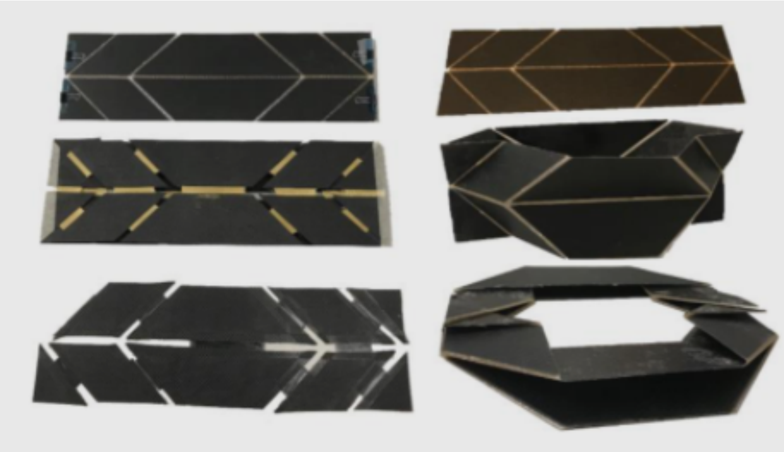

Porsche 918 Spyder

Wood and carbon fiber tennis racket

Wood floors and composite countertop

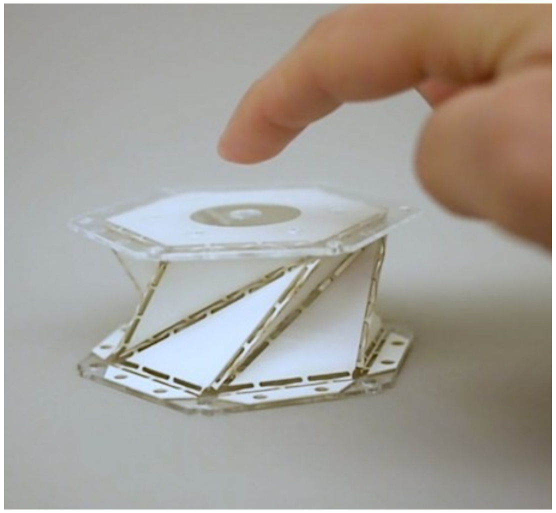
# Composite Research

IMAGINE



Composite origami

- Composite origami to soften impacts and for deployable structures
- Automated Fiber Placement (AFP)
- Discontinuous Fiber Composites (DFC)



Composite origami

NASA AFP for fuel tank

Thermoset DFC

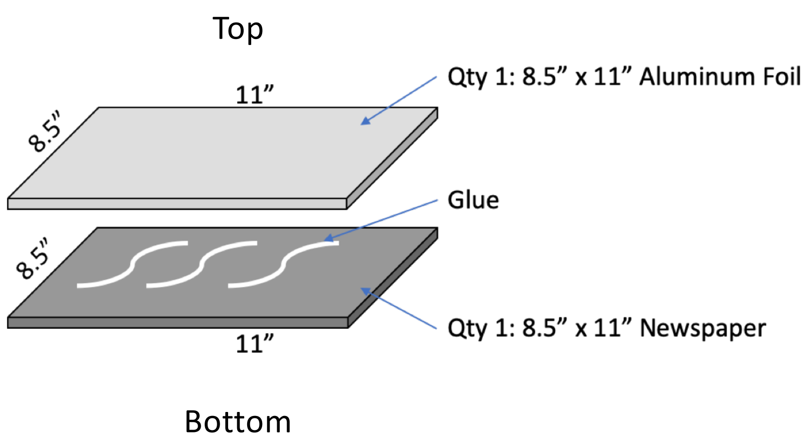
# IMAGINE Step

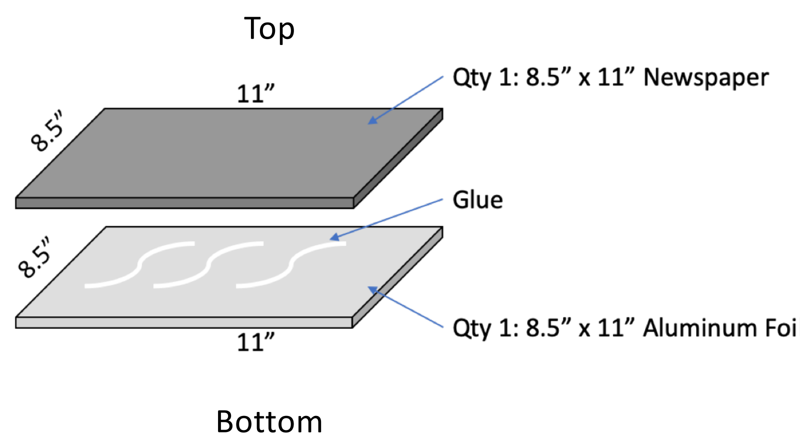
IMAGINE

- *This step was completed for teachers.*

*Refer to Page 6 in the Notebook*

- Sketch your 2 composite designs and identify the components.
- List the materials and quantity for each composite.



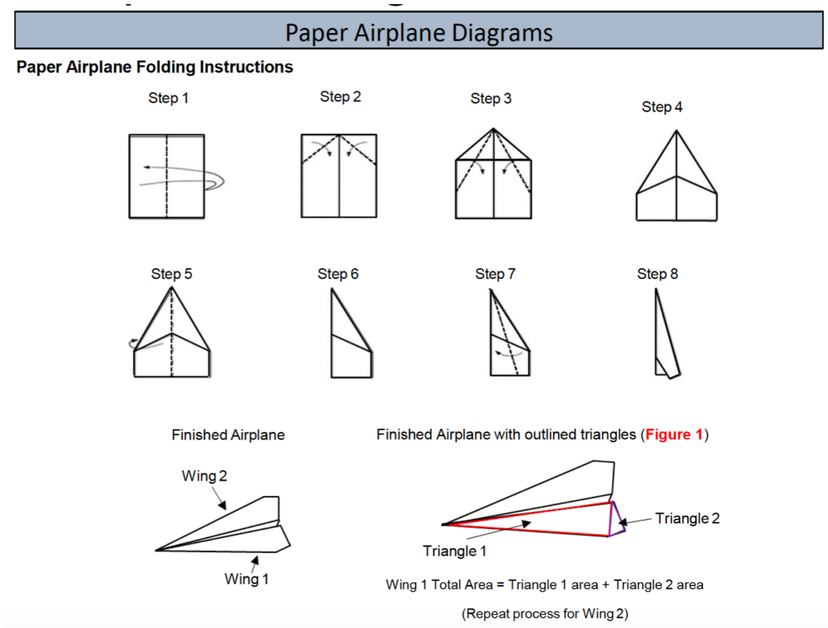



# PLAN Step

PLAN

*Will Skip this step for today's activity.*

- Gantt Chart is used to plan and establish a schedule for tasks
- Select *one design based on your score using the Pugh chart.*
- Justify and explain your design choice.
- Write out steps to build your prototypes, testing protocols and how to record the data.




Reference: https://www.nasa.gov/stem-ed-resources/shape-your-flight.html

# CREATE Step: Building your composite plane

CREATE

- Get the following paper labeled “Use this Copy paper during the session when instructed” and follow the folding instructions below (**~3 min**)

- **Instructions**: [http://bit.ly/SYFInstructions](http://bit.ly/SYFInstructions)

- **Video Tutorial (Instructions 1:20-3:34):** [http://bit.ly/SYFVideo](http://bit.ly/SYFVideo)

- **Choose 2 out of 3** composite materials you created before the session (*Refer to Page 9-10 in the Notebook)*

**Data Collection Table A** Weight of the Plane: ________________

Composite Materials: Top Side: ________________ Bottom Side: ________________

- **Build** 2 prototypes based on the same folding instructions above

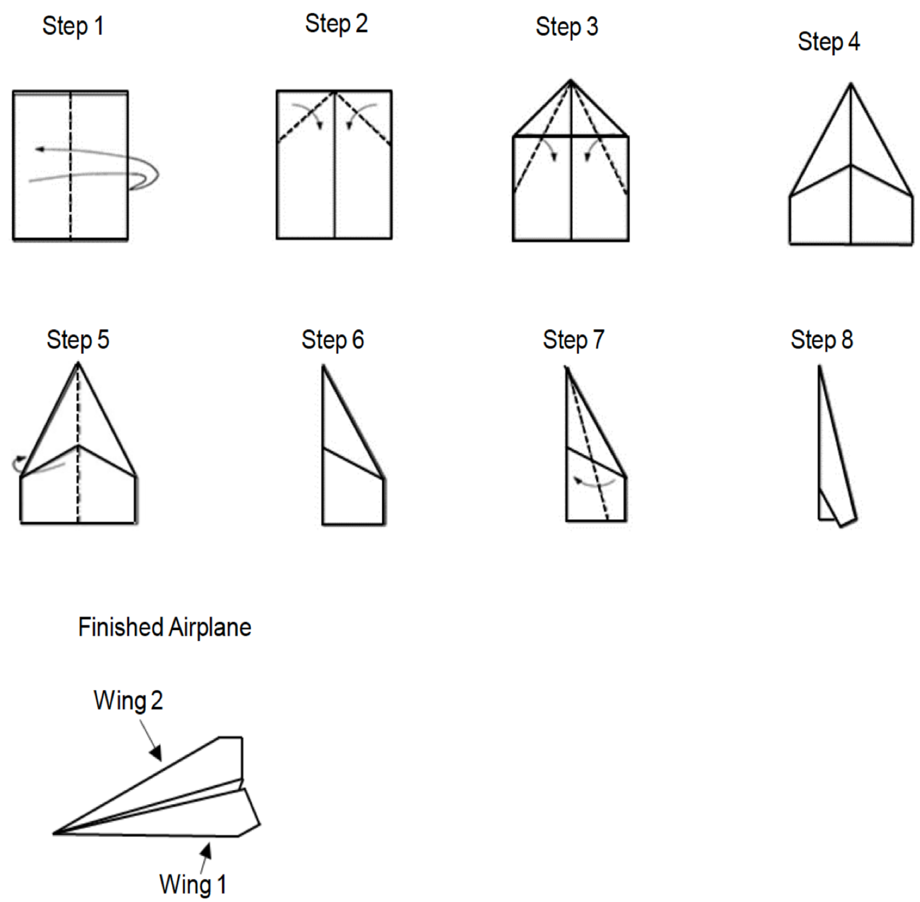
- **Time** for building your prototypes: **~15 min**

# CREATE Step: Building your composite airplane

CREATE

## Paper Airplane Diagrams

**Paper Airplane Folding Instructions**



# CREATE Step: Performance Testing Scoring

CREATE

*Refer to Page 9 in the Notebook*

| Width | Score for Straightness |
| --- | --- |
| Within 3ft | 3 |
| Between 3ft and 5ft | 2 |
| Greater than 5ft | 1 |

New

| Distance (ft) | Score for Distance |
| --- | --- |
| 0 – 5 ft | 5 ft |
| Between 5ft and 10ft | 10 ft |
| Greater than 10ft | 15ft |

| Criteria | Exceeds 3 | Meets 2 | Needs Improvement 1 |
| --- | --- | --- | --- |
| The flight of the composite plane should fly straight within the 5 feet width. | Average score of straightness is between 2.6-3 | Average score of straightness is between 2-2.5 | Average score of straightness is less than 2 |
| The average of the flight distance (5 trials) of the composite plane should travel at least 10 feet. | Average of 5 trials is equal to 15 feet | Average of 5 trials is between 10-15 feet | Average of 5 trials is less than 10 feet |

# CREATE Step: Test Data Sheet

CREATE

*Refer to Page 9-10 in the Notebook*

| Criteria | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Average | Observations |
|---|---|---|---|---|---|---|---|
| Straightness (Score) | | | | | | | |
| Distance (ft) | | | | | | | |

| Criteria | Weight<br>A | My Rubric Score<br>B | Total<br>AxB | Why did it succeed? Why did it fail? | What can I improve on? |
|---|---|---|---|---|---|
| | | | | | |
| The flight of the composite plane should fly straight within the 5 feet width. | 3 | | | | |
| The average of the flight distance (5 trials) of the composite plane should travel at least 10 feet. | 5 | | | | |
| **TOTAL** | | | | | |

# CREATE Step: Activity Sharing

CREATE

- Sample Data Results (average is based on 5 trials):

| | | | Average | |
|---|---|---|---|---|
| Plane # | Materials | Weight (g) | Distance | Straightness |
| 1 | Foil + Paper (Glued) | 7.7 | 15 | 2.8 |
| 2 | Foil + Newspaper (Glued) | 5.5 | 15 | 2.6 |
| 3 | Newspaper + Foil (Glued) | 5.6 | 15 | 3 |
| 4 | Newspaper + Paper (Glued) | 7.8 | 15 | 2.4 |
| 5 | Paper + Foil (Glued) | 7.9 | 15 | 2.2 |
| 6 | Paper + Newspaper (Glued) | 7.7 | 15 | 2.8 |
| 7 | Paper | 4.8 | 15 | 2.2 |
| 8 | Newspaper | 2.5 | 15 | 2.8 |
| 9 | Foil | 2.6 | 15 | 2 |

# CREATE Step: Activity Sharing

CREATE

- Share Data results (email Davin your Data Table)

- Expanding and Adapting the Composite Plane Design Challenge Activity



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# Questions?

# Their Journey:  Featured Guest Speakers from Aerospace Engineering

**Troy Nakagawa,** PhD Student in Aeronautics and Astronautics Engineering, University of Washington; former STEM Pre-Academy Summer Intern

*Moanalua Elementary, Intermediate and High School*

- My journey researching, testing and advancing our knowledge of composite materials is propelled by passion, preparation, perseverance and the joy of discovery.

Troy

**Ren Ishii,** Lead Engineer for 787 Interior Certification Integration, former Lighting Engineer, The Boeing Company

*Noelani Elementary, Kawananakoa Middle and HBA*

- My journey of becoming an engineer - the unexpected connections between schooling (elementary/middle/high school through university) and professional success.

Ren



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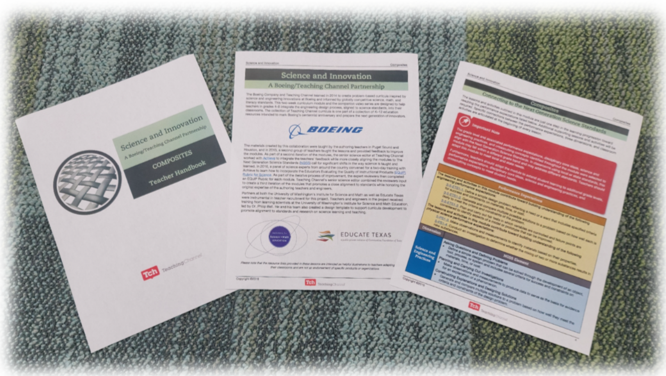
# Closing

- STEM Pre-Academy – EDP Landing Site: https://stempreacademy.hawaii.edu/castle

- Teaching Channel / Boeing Partnership Website: http://bit.ly/TCBA-Composites

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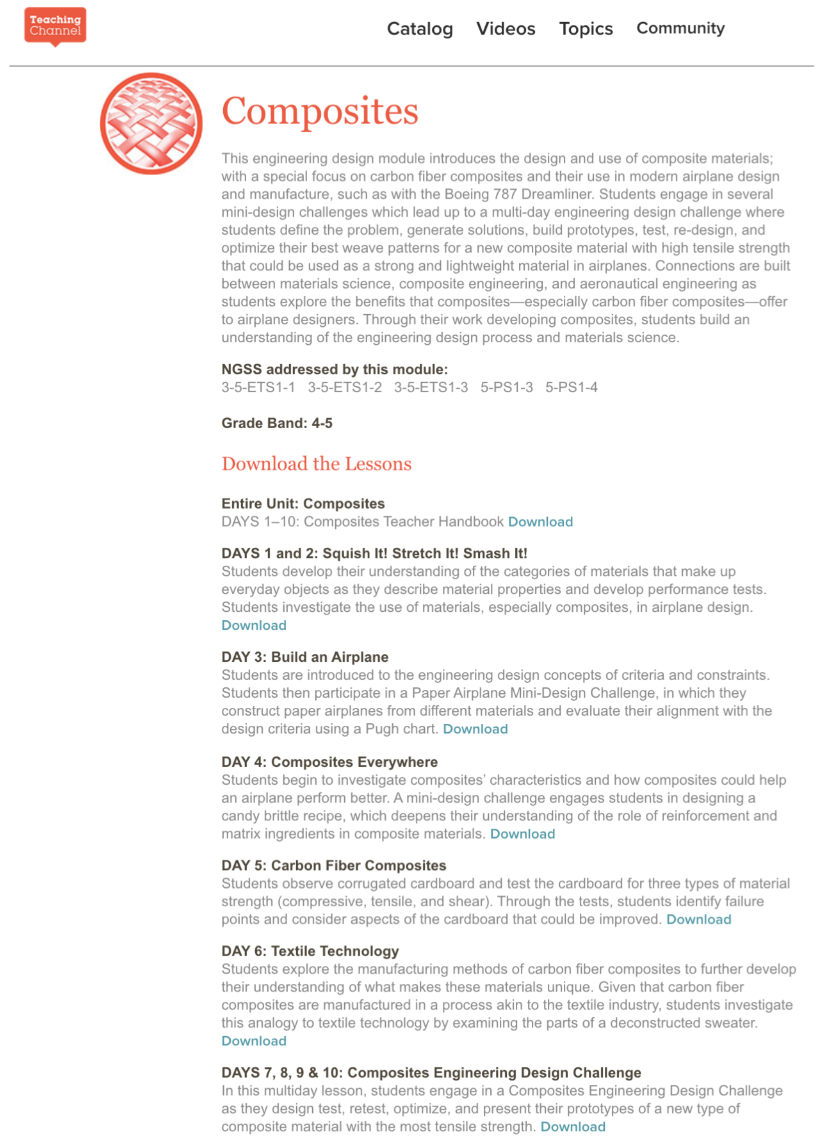

Teaching Channel

Catalog Videos Topics Community

## Composites

This engineering design module introduces the design and use of composite materials; with a special focus on carbon fiber composites and their use in modern airplane design and manufacture, such as with the Boeing 787 Dreamliner. Students engage in several mini-design challenges which lead up to a multi-day engineering design challenge where students define the problem, generate solutions, build prototypes, test, re-design, and optimize their best weave patterns for a new composite material with high tensile strength that could be used as a strong and lightweight material in airplanes. Connections are built between materials science, composite engineering, and aeronautical engineering as students explore the benefits that composites—especially carbon fiber composites—offer to airplane designers. Through their work developing composites, students build an understanding of the engineering design process and materials science.

**NGSS addressed by this module:**
3-5-ETS1-1 3-5-ETS1-2 3-5-ETS1-3 5-PS1-3 5-PS1-4

**Grade Band: 4-5**

### Download the Lessons

**Entire Unit: Composites**
DAYS 1–10: Composites Teacher Handbook Download

**DAYS 1 and 2: Squish It! Stretch It! Smash It!**
Students develop their understanding of the categories of materials that make up everyday objects as they describe material properties and develop performance tests. Students investigate the use of materials, especially composites, in airplane design. Download

**DAY 3: Build an Airplane**
Students are introduced to the engineering design concepts of criteria and constraints. Students then participate in a Paper Airplane Mini-Design Challenge, in which they construct paper airplanes from different materials and evaluate their alignment with the design criteria using a Pugh chart. Download

**DAY 4: Composites Everywhere**
Students begin to investigate composites' characteristics and how composites could help an airplane perform better. A mini-design challenge engages students in designing a candy brittle recipe, which deepens their understanding of the role of reinforcement and matrix ingredients in composite materials. Download

**DAY 5: Carbon Fiber Composites**
Students observe corrugated cardboard and test the cardboard for three types of material strength (compressive, tensile, and shear). Through the tests, students identify failure points and consider aspects of the cardboard that could be improved. Download

**DAY 6: Textile Technology**
Students explore the manufacturing methods of carbon fiber composites to further develop their understanding of what makes these materials unique. Given that carbon fiber composites are manufactured in a process akin to the textile industry, students investigate this analogy to textile technology by examining the parts of a deconstructed sweater. Download

**DAYS 7, 8, 9 & 10: Composites Engineering Design Challenge**
In this multiday lesson, students engage in a Composites Engineering Design Challenge as they design test, retest, optimize, and present their prototypes of a new type of composite material with the most tensile strength. Download



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# Feedback Form

http://bit.ly/EDPC_FF3