

## INTRODUCTION TO ENGINEERING DESIGN

### Unit 5

# Human-Centered Aerospace Design

Use user research, ethics, sustainability, project planning, testing, and presentation skills to complete a meaningful aerospace design challenge.

#### Student goal

Design with people, evidence, and impact in mind.

#### Capstone focus

From need finding to portfolio reflection.



# Unit 5 Learning Arc

This unit turns your engineering skills into a complete human-centered capstone story.

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**1**

## Understand people

Stakeholders, users, interviews, and problem statements

**2**

## Define requirements

Criteria, constraints, ethics, risk, sustainability, and success metrics

**3**

## Plan and build

Team norms, project management, concepts, CAD, and prototypes

**4**

## Test and communicate

Data, iteration, final presentation, showcase, and portfolio

**“**

By the end of Unit 5, you will be able to explain not just what you made, but why it matters and how evidence shaped it.

## LESSON 5.1

# Human-Centered Aerospace Design

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### Essential question

How do aerospace designers make solutions that work for real people, not just technical requirements?

### What you will create

Human-centered design mindset notes



# What you need to understand

How do aerospace designers make solutions that work for real people, not just technical requirements?

## Big ideas

- Human-centered design starts with people, context, and purpose.
- Aerospace problems often involve safety, reliability, access, cost, and communication.
- A successful solution balances user needs with technical feasibility.



*Use visuals as evidence and inspiration, not as a final answer.*



Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Look beyond the object

Identify who uses, supports, maintains, pays for, or is affected by the design.

## 2 Separate assumptions from evidence

Do not treat what you think users need as proof. Gather evidence.

## 3 Translate needs into requirements

Turn user problems into design criteria that can guide decisions.

### Engineering habit



**Evidence loops back into the next decision.**

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Human-centered design mindset notes

## Evidence checklist

- Define human-centered design in your own words.
- Identify at least three user groups in an aerospace system.
- Explain how one design choice affects a user.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

LESSON 5.2

# Stakeholders, Users & Clients

## Essential question

Who is affected by an aerospace design problem, and how can their needs conflict?

## What you will create

Stakeholder map for a client problem



# What you need to understand

Who is affected by an aerospace design problem, and how can their needs conflict?

## Big ideas

- A user directly interacts with the design; a stakeholder is affected by it.
- A client defines the problem but may not be the only important voice.
- Needs may conflict, so engineers must prioritize and justify choices.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Map the people

List direct users, indirect users, operators, maintainers, decision makers, and people affected by failure.

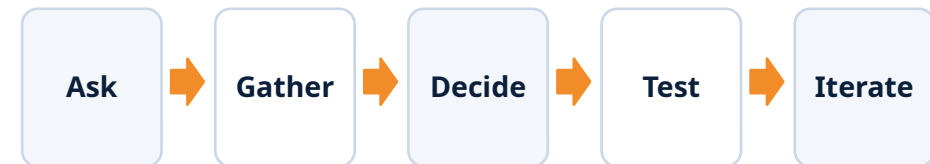
## 2 Name the need

Write needs as what people must accomplish, not as a specific product.

## 3 Watch for conflicts

A feature that helps one stakeholder may create cost, safety, or usability issues for another.

### Engineering habit



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# What your work should show

Use this lesson to produce: Stakeholder map for a client problem

## Evidence checklist

- Create a stakeholder map.
- Label users, stakeholders, and client.
- List at least two conflicting needs.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.3

# User Research & Empathy Interviews

### Essential question

How can you learn what users actually need before designing a solution?

### What you will create

Interview or observation plan



# What you need to understand

How can you learn what users actually need before designing a solution?

## Big ideas

- User research is evidence gathering, not opinion collecting.
- Open-ended questions reveal context, frustrations, and priorities.
- Observations can show problems users may not mention in an interview.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Ask open questions

Use prompts such as “Tell me about...” and “What makes this difficult?”

## 2 Avoid leading questions

Do not ask questions that push users toward your preferred solution.

## 3 Capture evidence

Record quotes, actions, pain points, and repeated patterns.

### Engineering habit



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# What your work should show

Use this lesson to produce: Interview or observation plan

## Evidence checklist

- Write 6–8 interview questions.
- Identify what evidence each question should reveal.
- Plan how notes will be documented.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.4

# Problem Statements & Design Briefs

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### Essential question

How do you turn user research into a clear engineering problem?

### What you will create

Draft design brief



# What you need to understand

How do you turn user research into a clear engineering problem?

## Big ideas

- A strong problem statement names the user, need, and context.
- A design brief explains what the solution must accomplish without naming the final design too early.
- Clear problem framing prevents teams from solving the wrong problem.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Use a problem frame

User + need + context + reason the problem matters.

## 2 Avoid solution language

Do not write “build a bracket” if the real need is alignment, safety, or repeatability.

## 3 Check the scope

The problem must be large enough to matter and small enough to solve.

### Engineering habit



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# What your work should show

Use this lesson to produce: Draft design brief

## Evidence checklist

- Write a first draft problem statement.
- List the client or stakeholder need.
- Identify what success would look like.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.5

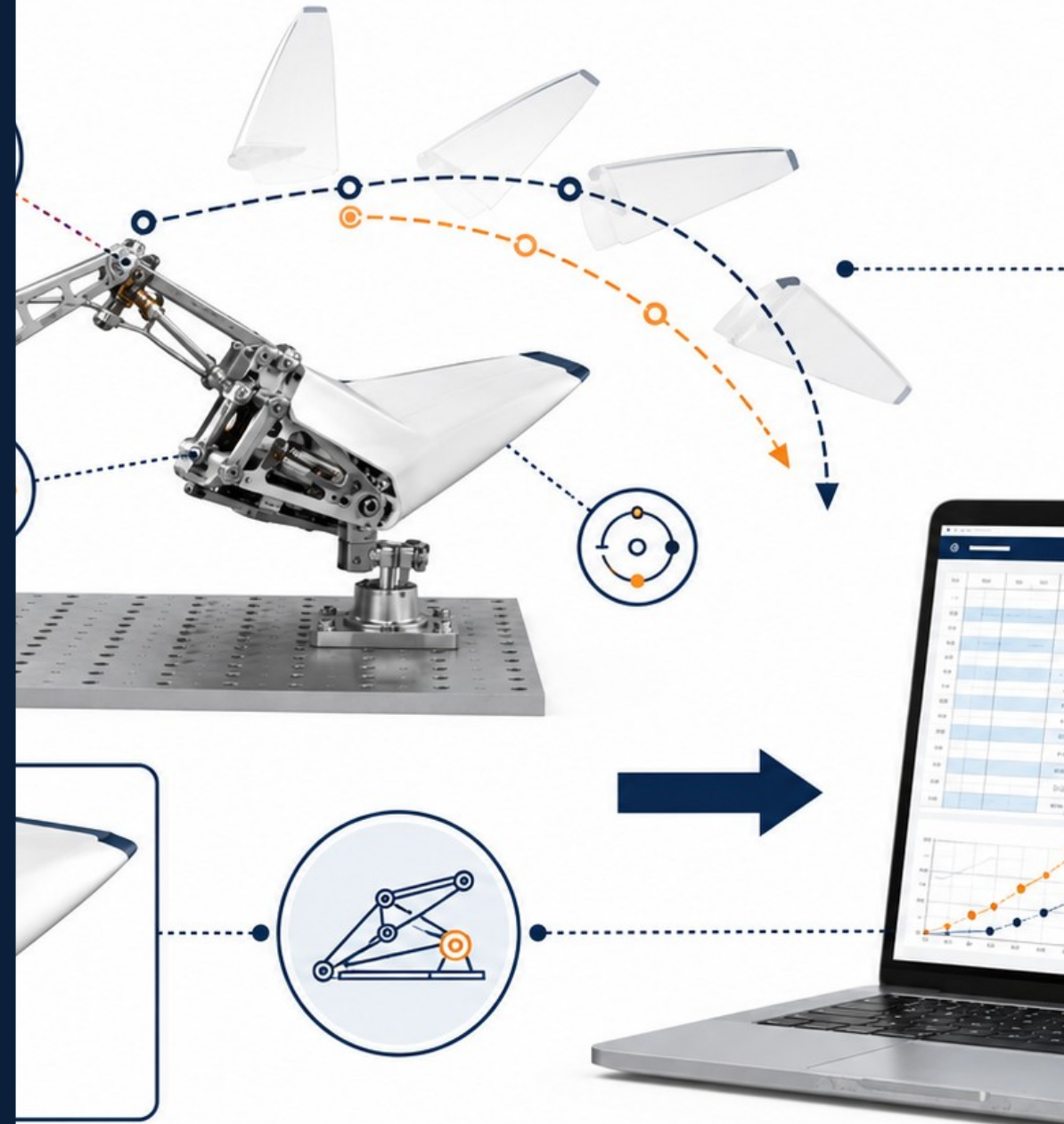
# Criteria, Constraints & Success Metrics

### Essential question

How can design requirements be written so a solution can be tested fairly?

### What you will create

Requirements table

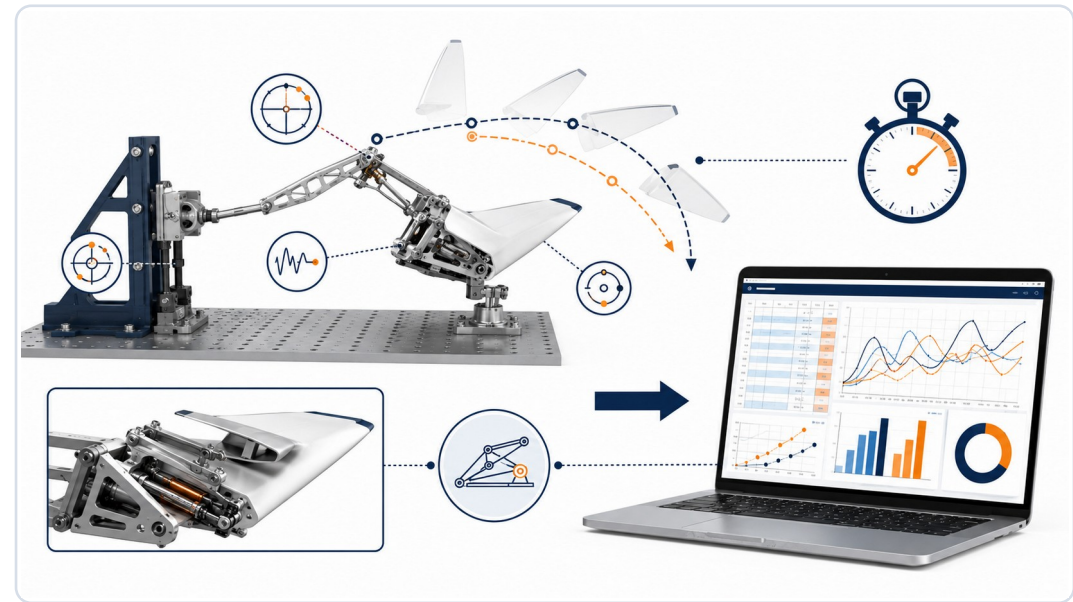


# What you need to understand

How can design requirements be written so a solution can be tested fairly?

## Big ideas

- Criteria define what a successful solution should do.
- Constraints define limits such as time, material, cost, tools, or safety.
- Success metrics make requirements measurable.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Make criteria measurable

Replace “stable” with a measurable test such as “does not tip during three trials.”

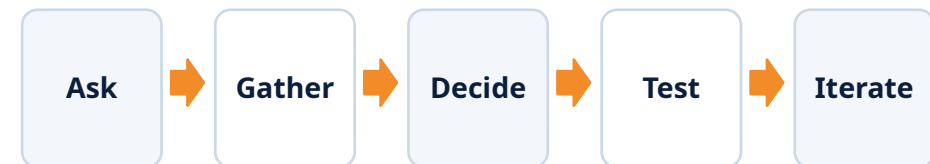
## 2 Separate must-have from nice-to-have

Teams need to know what is required versus preferred.

## 3 Connect metrics to tests

Every major metric should have a planned way to measure it.

### Engineering habit



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# What your work should show

Use this lesson to produce: Requirements table

## Evidence checklist

- Create a requirements table.
- Label criteria and constraints.
- Write at least three measurable success metrics.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

LESSON 5.6

# Engineering Ethics in Aerospace

## Essential question

What responsibilities do engineers have when designs affect safety, trust, and public systems?

## What you will create

Ethics scenario response



# What you need to understand

What responsibilities do engineers have when designs affect safety, trust, and public systems?

## Big ideas

- Engineering decisions can affect safety, cost, access, and public trust.
- Ethical design requires honesty about limitations, risks, and evidence.
- Aerospace systems require careful documentation because failures can have serious consequences.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Identify who could be harmed

Consider users, operators, the public, and the environment.

## 2 Use evidence honestly

Do not exaggerate test results or hide known failure modes.

## 3 Escalate concerns

When a design may be unsafe, engineers must communicate clearly and early.

### Engineering habit



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# What your work should show

Use this lesson to produce: Ethics scenario response

## Evidence checklist

- Analyze one aerospace ethics scenario.
- Identify affected stakeholders.
- Write a justified decision or recommendation.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.7

# Sustainability & Life-Cycle Thinking

### Essential question

How can engineers reduce waste and environmental impact across a product's life?

### What you will create

Life-cycle analysis sketch



# What you need to understand

How can engineers reduce waste and environmental impact across a product's life?

## Big ideas

- A product has impacts before, during, and after use.
- Material choice, manufacturing method, reparability, and disposal all matter.
- Sustainable design balances performance with responsible resource use.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Trace the life cycle

Raw materials → manufacturing → use → maintenance → end of life.

## 2 Look for waste points

Identify where material, energy, time, or replacements are wasted.

## 3 Design for repair or reuse

A part that can be replaced or repaired may reduce total impact.

### Engineering habit



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# What your work should show

Use this lesson to produce: Life-cycle analysis sketch

## Evidence checklist

- Create a life-cycle diagram.
- Identify one design choice that reduces waste.
- Explain a tradeoff between performance and sustainability.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.8

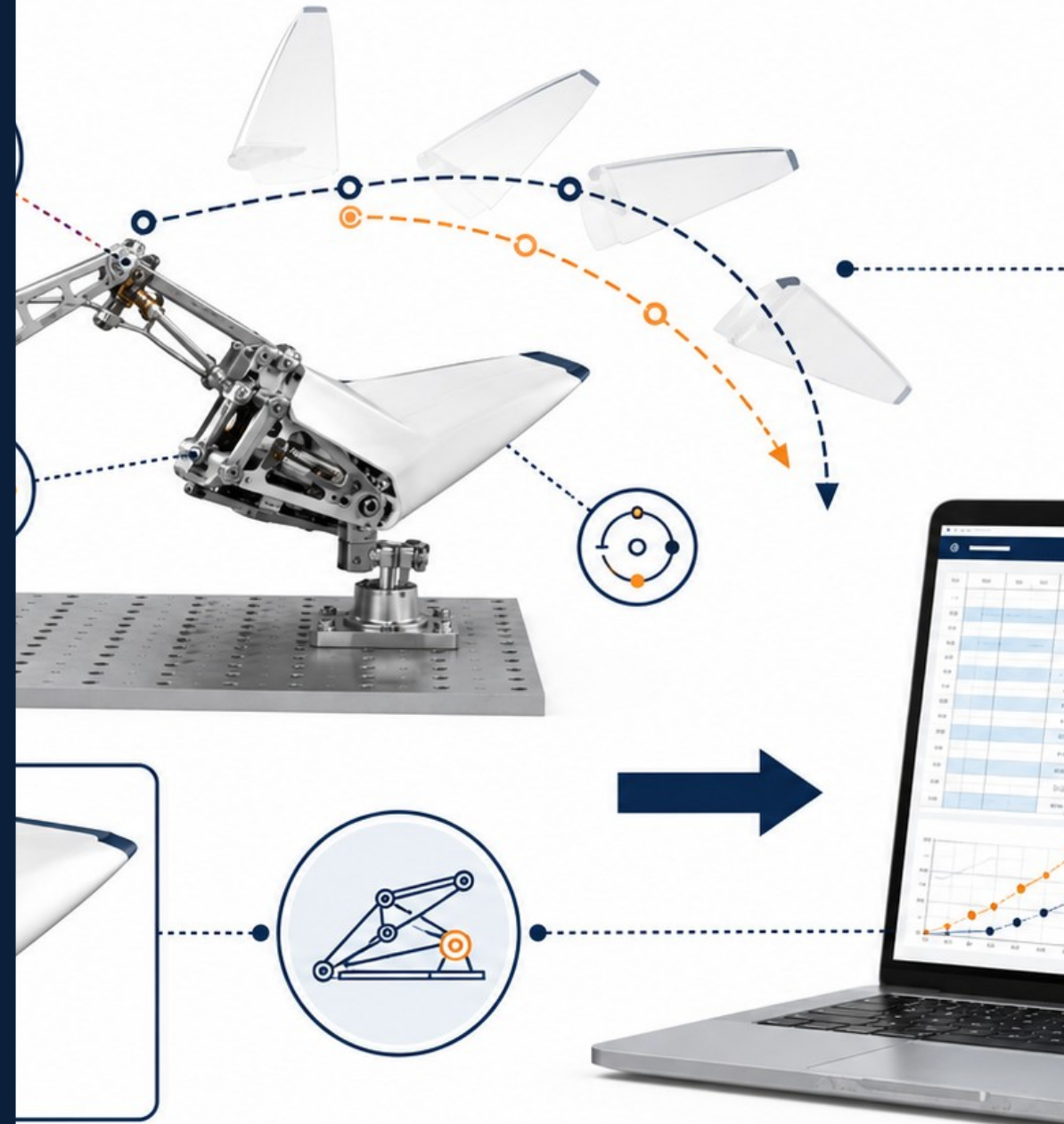
# Safety, Risk & Failure Modes

### Essential question

How can you predict what might go wrong before testing a prototype?

### What you will create

Failure mode table

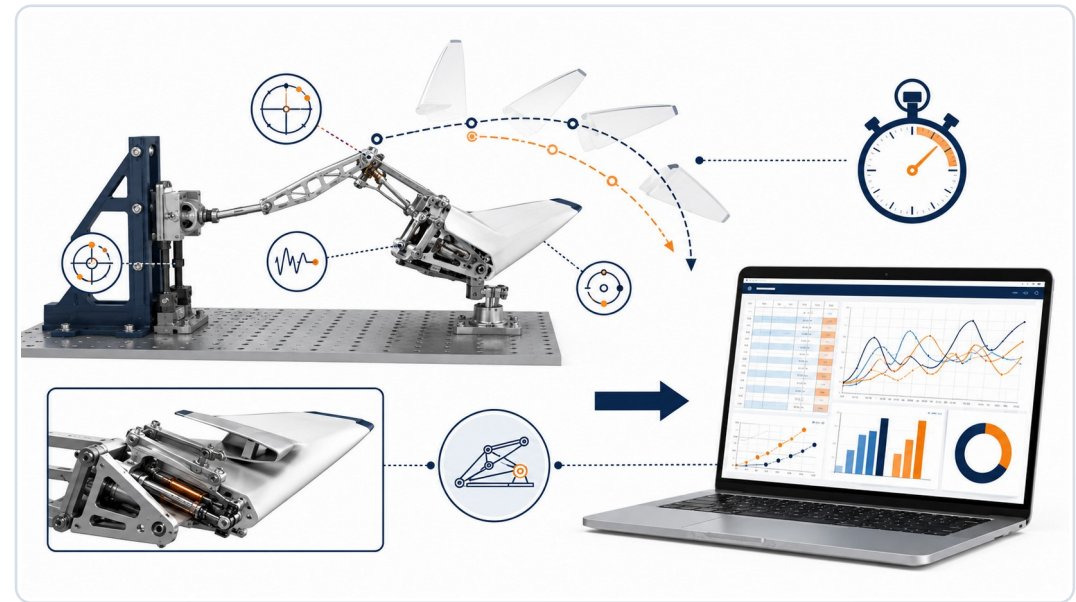


# What you need to understand

How can you predict what might go wrong before testing a prototype?

## Big ideas

- A failure mode is a specific way a design could fail.
- Risk depends on both likelihood and consequence.
- Good testing plans focus on the most important risks first.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 List failure modes

Think about breaking, slipping, tipping, binding, overheating, confusing use, or unsafe misuse.

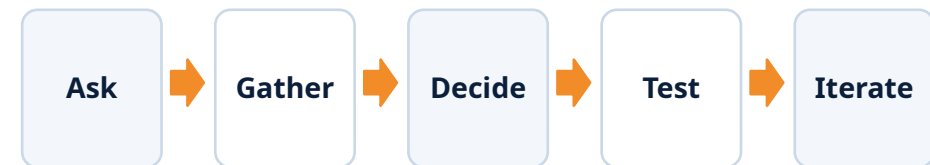
## 2 Rate risk

Rank the likelihood and severity of each failure.

## 3 Plan mitigation

Change the design, add instructions, strengthen a part, or improve the test.

### Engineering habit



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# What your work should show

Use this lesson to produce: Failure mode table

## Evidence checklist

- Identify at least five possible failure modes.
- Rate risk for each.
- Choose two design changes or controls.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.9

# Team Norms & Project Roles

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### Essential question

How do design teams organize work so every member contributes to the final solution?

### What you will create

Team contract and role plan



# What you need to understand

How do design teams organize work so every member contributes to the final solution?

## Big ideas

- Team norms describe how the group communicates and makes decisions.
- Roles help divide responsibility without isolating team members.
- Strong teams document decisions and hold each other accountable.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Agree on norms

Set expectations for communication, attendance, shared work, and conflict.

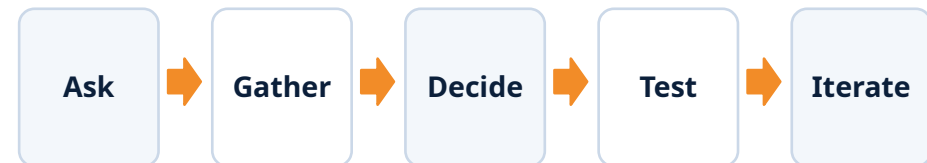
## 2 Assign responsibilities

Use roles such as project manager, CAD lead, documentation lead, testing lead, and presentation lead.

## 3 Track decisions

Record what changed, why it changed, and who is responsible for next steps.

### Engineering habit



### Evidence loops back into the next decision.

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# What your work should show

Use this lesson to produce: Team contract and role plan

## Evidence checklist

- Write team norms.
- Assign roles and backups.
- Create a simple responsibility tracker.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.10

# Project Management & Milestones

### Essential question

How can a team break a large design project into manageable steps?

### What you will create

Project timeline with milestones



# What you need to understand

How can a team break a large design project into manageable steps?

## Big ideas

- Milestones are checkpoints that show progress toward the final deliverable.
- A good plan includes dependencies: some tasks must happen before others.
- Project management is a design skill, not paperwork.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Start with the deadline

Work backward from the final presentation and prototype due dates.

## 2 Build checkpoints

Include research, concept selection, CAD, prototype, test, iteration, and presentation milestones.

## 3 Adjust based on evidence

A plan should change when testing reveals new information.

### Engineering habit



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# What your work should show

Use this lesson to produce: Project timeline with milestones

## Evidence checklist

- Create a milestone timeline.
- List task owners.
- Identify the next three actions for the team.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.11

# Concept Generation for Client Problems

### Essential question

How can teams create multiple solution ideas before choosing one direction?

### What you will create

Individual and team concept sketches



# What you need to understand

How can teams create multiple solution ideas before choosing one direction?

## Big ideas

- Strong teams generate many ideas before narrowing.
- Different sketches can explore different functions, users, or constraints.
- Early concepts should be fast, visual, and imperfect.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Sketch individually first

Individual thinking prevents the group from settling too early.

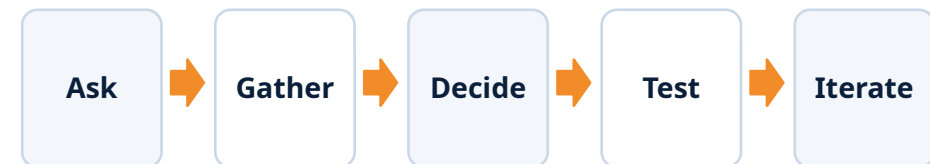
## 2 Share and combine

Look for useful features from multiple ideas.

## 3 Create concept families

Group ideas by strategy: support, protect, align, store, guide, move, or measure.

### Engineering habit



### Evidence loops back into the next decision.

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# What your work should show

Use this lesson to produce: Individual and team concept sketches

## Evidence checklist

- Create individual concept sketches.
- Share and annotate team ideas.
- Combine parts of multiple concepts into a team direction.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

LESSON 5.12

# Decision Matrices & Justification

## Essential question

How can design teams choose a concept using evidence instead of preference?

## What you will create

Decision matrix and recommendation



# What you need to understand

How can design teams choose a concept using evidence instead of preference?

## Big ideas

- A decision matrix compares concepts against weighted criteria.
- Scores should be based on evidence, not popularity.
- Justification explains why the selected idea best meets the problem.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Choose criteria carefully

Use requirements from the design brief, not random preferences.

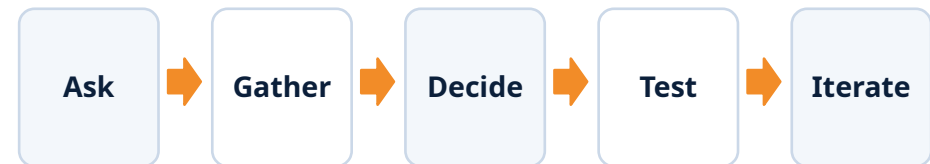
## 2 Weight what matters most

Safety or usability may deserve more weight than appearance.

## 3 Explain the result

A matrix supports a decision, but the team must still justify tradeoffs.

### Engineering habit



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# What your work should show

Use this lesson to produce: Decision matrix and recommendation

## Evidence checklist

- Build a decision matrix.
- Score at least three concepts.
- Write a short recommendation.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.13

# Low-Fidelity Prototyping

### Essential question

How can quick prototypes answer design questions before committing to a final build?

### What you will create

Low-fidelity prototype and test notes



# What you need to understand

How can quick prototypes answer design questions before committing to a final build?

## Big ideas

- Low-fidelity prototypes are quick, rough, and useful.
- A prototype should answer a specific question.
- Early prototypes reduce risk before a team spends time on detailed CAD or fabrication.



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Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Prototype one question

Focus on fit, reach, stability, layout, motion, or user interaction.

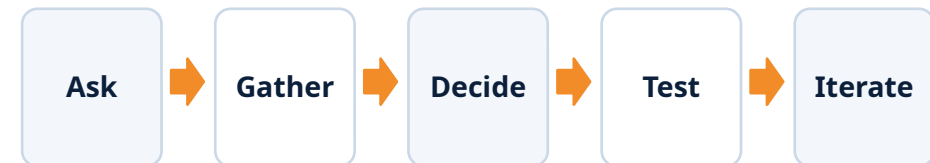
## 2 Use quick materials

Cardboard, paper, tape, scrap parts, or simple prints can reveal major issues.

## 3 Observe use

Watch how someone interacts with the prototype and record what happens.

### Engineering habit



### Evidence loops back into the next decision.

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Low-fidelity prototype and test notes

## Evidence checklist

- Build or sketch a low-fidelity prototype.
- Write the question it tests.
- Record observations and improvement ideas.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.14

# CAD Development & Prototype Planning

### Essential question

How do teams move from concept to a manufacturable prototype?

### What you will create

CAD plan and fabrication checklist



# What you need to understand

How do teams move from concept to a manufacturable prototype?

## Big ideas

- CAD should communicate design intent, not just shape.
- Prototype plans must consider dimensions, tolerances, materials, and assembly.
- Manufacturing decisions affect cost, time, quality, and reliability.



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# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Build from requirements

Use criteria and constraints to decide features and dimensions.

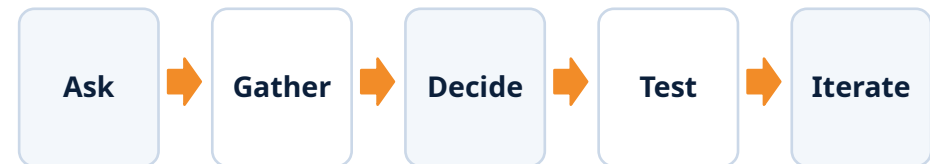
## 2 Plan assemblies

Identify how parts connect, align, fasten, or move.

## 3 Check before fabrication

Review size, print orientation, material, tool access, and safety.

### Engineering habit



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When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: CAD plan and fabrication checklist

## Evidence checklist

- Create a CAD development plan.
- List parts to make or modify.
- Complete a fabrication readiness checklist.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.15

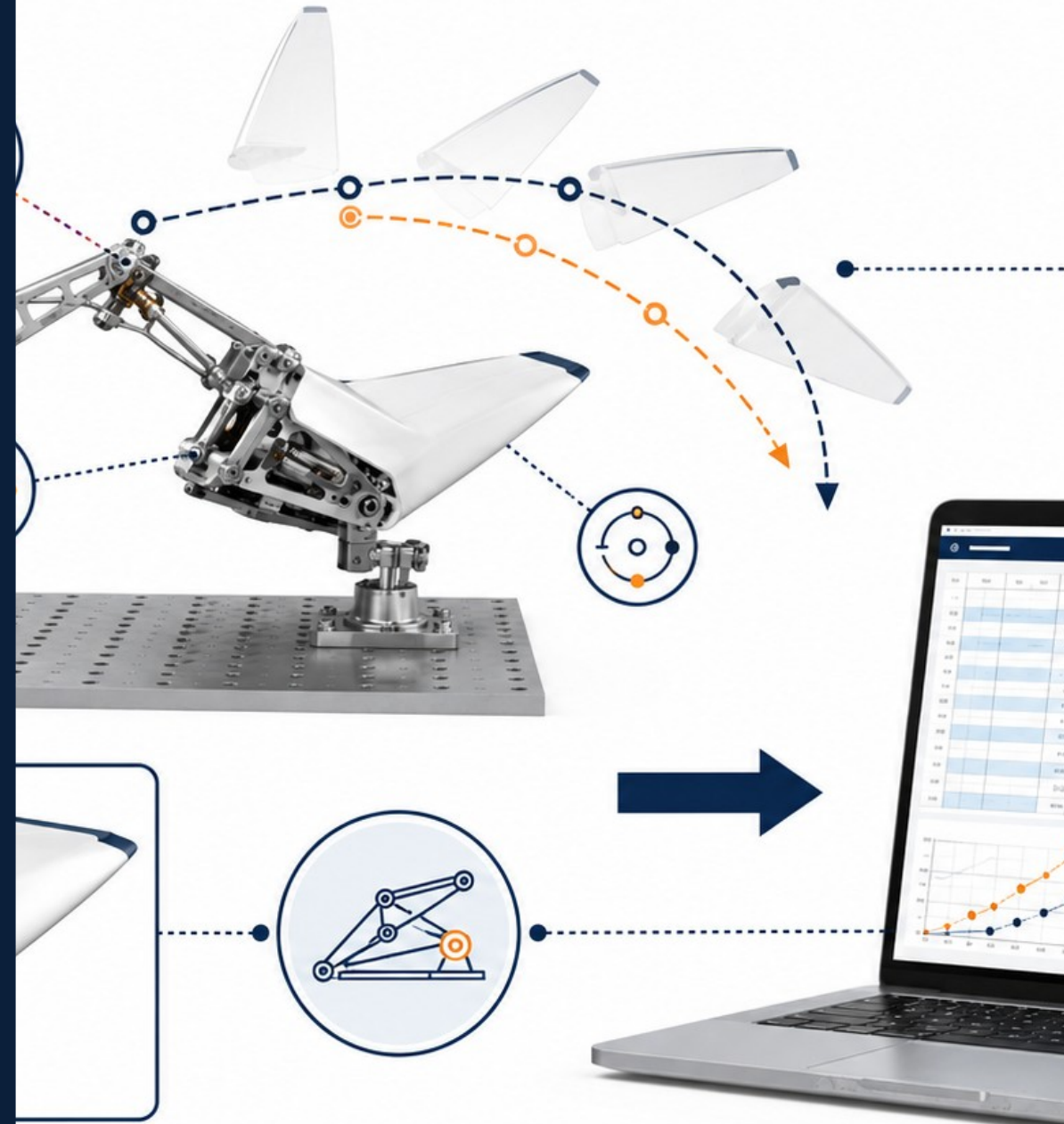
# Testing Plans & Data Collection

### Essential question

How can testing prove whether a design meets the requirements?

### What you will create

Test plan and data table

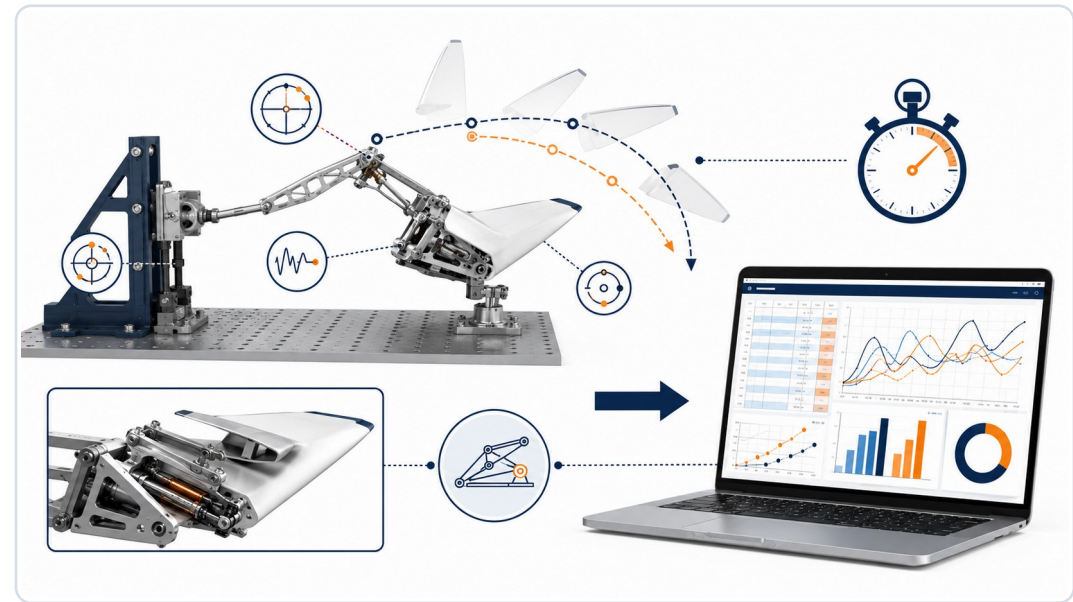


# What you need to understand

How can testing prove whether a design meets the requirements?

## Big ideas

- Testing must connect directly to success metrics.
- Good data is repeatable, organized, and tied to a clear procedure.
- A failed test is useful if it tells the team what to improve.



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Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Write the procedure

Define setup, variables, number of trials, and what will be measured.

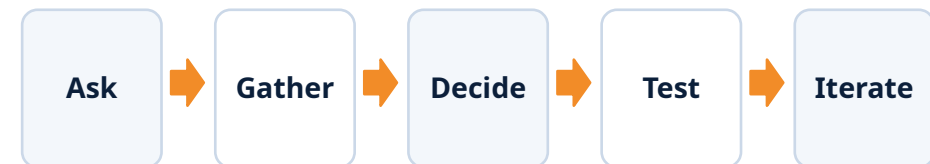
## 2 Collect clean data

Use tables, units, labels, and consistent measurement methods.

## 3 Compare to requirements

Decide whether results meet, exceed, or fall short of criteria.

### Engineering habit



### Evidence loops back into the next decision.

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Test plan and data table

## Evidence checklist

- Write a test plan.
- Create a data table with units.
- Explain how results will be judged.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

LESSON 5.16

# Iteration & Final Design Decisions

## Essential question

How should teams use feedback and test data to improve the design?

## What you will create

Iteration log and final design update



# What you need to understand

How should teams use feedback and test data to improve the design?

## Big ideas

- Iteration is purposeful change based on evidence.
- A final design should reflect what the team learned from users and tests.
- Every major change should be documented and justified.



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Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Review evidence

Use test results, user feedback, and failure modes to decide what must change.

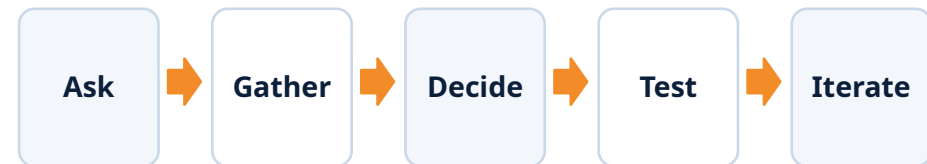
## 2 Prioritize improvements

Fix high-risk, high-impact issues before cosmetic changes.

## 3 Document revisions

Show before/after changes and explain the reason for each.

### Engineering habit



### Evidence loops back into the next decision.

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Iteration log and final design update

## Evidence checklist

- Create an iteration log.
- Identify the final design changes.
- Explain what evidence drove each change.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.17

# Final Presentation & Storytelling

### Essential question

How can a design team clearly communicate the problem, evidence, solution, and impact?

### What you will create

Final presentation draft



# What you need to understand

How can a design team clearly communicate the problem, evidence, solution, and impact?

## Big ideas

- A strong presentation tells the story of the design process.
- Evidence matters more than describing every step.
- The audience needs to understand why the final solution is justified.



*Use visuals as evidence and inspiration, not as a final answer.*



Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Start with the problem

Explain who needed help and why the problem mattered.

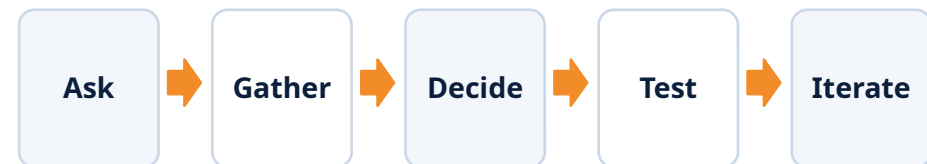
## 2 Show key evidence

Use research, requirements, testing, and iteration to support claims.

## 3 End with impact

Explain how the final design meets user needs and what could improve next.

### Engineering habit



### Evidence loops back into the next decision.

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Final presentation draft

## Evidence checklist

- Draft final presentation slides.
- Add evidence visuals.
- Practice a concise explanation of the final design.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.

## LESSON 5.18

# Portfolio, Showcase & Reflection

### Essential question

How can you use a finished project to show growth as an engineering designer?

### What you will create

Final portfolio entry and reflection



# What you need to understand

How can you use a finished project to show growth as an engineering designer?

## Big ideas

- A portfolio shows process, not just the final object.
- Reflection helps you identify what you learned and what you would improve.
- Engineering evidence includes sketches, CAD, prototypes, tests, decisions, and communication.



*Use visuals as evidence and inspiration, not as a final answer.*



Strong designs start with a clear understanding of people, requirements, and evidence.

# How to approach the work

Use a repeatable process so your design decisions are clear and defensible.

## 1 Select strong artifacts

Choose items that show research, design decisions, prototyping, testing, and iteration.

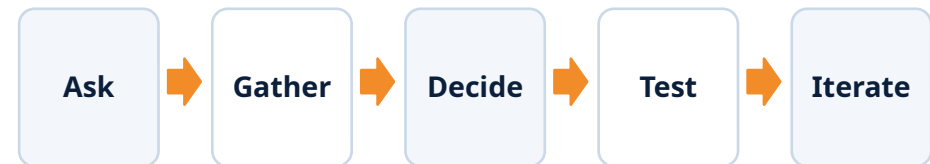
## 2 Explain your role

Describe what you contributed and how you helped the team improve.

## 3 Reflect honestly

Use specific evidence to show growth, challenges, and next steps.

### Engineering habit



**Evidence loops back into the next decision.**

When you cannot explain why a design changed, you may be iterating randomly instead of engineering intentionally.

# What your work should show

Use this lesson to produce: Final portfolio entry and reflection

## Evidence checklist

- Create a final portfolio entry.
- Prepare for the showcase.
- Write an individual reflection on your engineering growth.

## Quality check

Can another person understand what you decided, why it matters, and what evidence supports it?

## Notebook / portfolio connection

Capture sketches, notes, tables, test results, photos, CAD screenshots, and reflections. Your final portfolio depends on evidence collected throughout the unit.



## UNIT 5 WRAP-UP

# Your final design story

A finished prototype is only part of the work. The complete engineering story includes the problem, users, requirements, decisions, tests, iteration, and impact.



### Portfolio reminder

Show your process clearly enough that someone outside your team can understand and trust your decisions.

