Science and Innovation

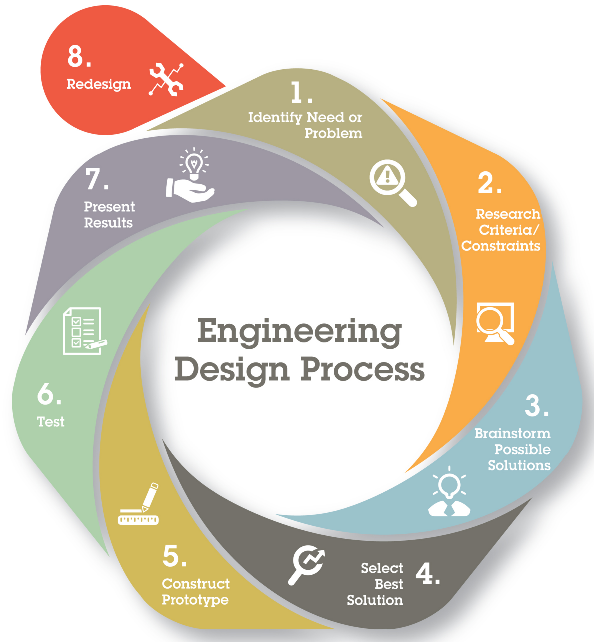
A Boeing/Teaching Channel Partnership

SOFT LANDING

Student Handbook

Tch Teaching Channel

Engineering Design Process



Step 1 Identify the Need or Problem

Describe the engineering design challenge to be solved. Include the limits and constraints, customer description, and an explanation of why solving this challenge is important.

Step 2 Research Criteria and Constraints

Research how others have solved this or similar problems, and discover what materials have been used. Be sure to thoroughly research the limitations and design requirements for success.

Step 3 Brainstorm Possible Solutions

Use your knowledge and creativity to generate as many solutions as possible. During this brainstorming stage, do not reject any ideas.

Step 4 Select the Best Solution

Each team member presents their solution ideas to the team. Team members annotate how each solution does or does not meet each design requirement. The team then agrees on a solution, or combination of solutions, that best meets the design requirements.

Step 5 Construct a Prototype

Develop an operating version of the solution.

Step 6 Test

Test your solution. Annotate the results from each test to share with your team.

Step 7 Present Results

Present the results from each test to the team.

Step 8 Redesign

Determine a redesign to address failure points and/or design improvements. The design process involves multiple iterations and redesigns. Redesign is based on the data from your tests, your team discussions as to the next steps to improve the design, and the engineering design process Steps 1 through 7.

Once your team is confident of a prototype solution, you present the results to the client. The client may:

- Accept your solution as is, or
- Ask for additional constraints and criteria to be included in the solution. At this point, you and your team revisit the engineering design process and resume the iterative redesign cycle.

Date	Student Reflections and New Questions
Day 1	
Day 2	
Day 3	
Day 4	
Day 5	

Date	Student Reflections and New Questions
Day 6	
Day 7	
Day 8	
Day 9	
Day 10	

Soft Landing Design Problem

The International Space Station is a microgravity laboratory with an international crew of six people. Crew members spend different amounts of time living and working on the space station. When a crew member's mission is over, the crew member returns to Earth to make room for a new crew member. Since November 2000, 222 people from 18 countries have visited the International Space Station!

As you can imagine. Transporting crew members back to Earth is not an easy task! One spacecraft that has been used to return crew members back to Earth is the Soyuz TMA spacecraft. The Soyuz can safely transport three crew members back to Earth.

Soft Landing Systems, a company involved in space travel, would like to design a spacecraft that is capable of transporting an entire crew (six people) back to Earth. Before designing a large-scale spacecraft and drop tower for testing, Soft Landing Systems wants to design and test prototypes of the drop tower and spacecraft capsule. By optimizing the prototype drop tower and capsule on a smaller scale prior to testing on a large scale, Soft Landing Systems will save valuable resources and money.

Soft Landing Systems has hired you as consultants on this project. They have asked you to work as a team of engineers to:

- Design a prototype drop tower to drop the spacecraft capsule (simulating the return of the spacecraft to Earth)
- Design a control circuit to hold the spacecraft at the top of the test tower until the start of the test (to prevent accidental drops that can be very costly with large-scale equipment)
- Design a capsule to protect the spacecraft

For your prototype, Soft Landing Systems has requested that you use an egg to simulate the astronauts in the spacecraft. Your task will be to design the drop tower, control circuit system, and capsule to protect your spacecraft upon impact with the Earth.

Group Norms

List your group norms in the space provided. Remember to use the sentence stem "We will…" to begin each norm.

Soft Landing Design Problem
Scoring Guide

Category	Criteria/Constraints	Points Earned	Points Possible
SPACECRAFT			
Meeting Design Trades	• Protect the egg: Most important goal • Lightweight: Less weight means a spacecraft can carry more of something else, like fuel or people • Easy access: Should not be hard to get egg in and out		5
Meeting Criteria	• Must keep egg safe • Must include plastic zip bag for egg • Must include steel plate (tin can lid) to hold to magnet		5
Meeting Constraints	• Less than 500 cubic centimeters in volume • No side greater than 15 centimeters • Maximum weight (including egg) 1,200 grams		5
Justification	• Includes a written justification for all design decisions • Based on evidence and includes scientific reasoning		15
Total			**30**
TEST HARDWARE BOX			
Meeting Design Trades	• Portable (for example, foldable solutions are good for transporting) • Sturdy		5
Meeting Criteria	• Able to hold the spacecraft when there is no power and allow it to be released by the magnet • For example, a shelf that slides under would work—it holds the craft until the magnet can hold it and then the shelf is removed		5
Meeting Constraints	• Dimensions: No more than 1 meter x 1 meter x 2 times the maximum egg drop height (width, depth, height) • Must suspend egg capsule at least 2 times the maximum egg drop height (may rest on chairs, for example, for added height, if desired) • Should allow viewing of the egg drop via cut out windows • Use only a box and cardboard along with joining materials, like glue, tape, and so forth (except, of course, for the electronics)		5
Justification	• Includes a written justification for all design decisions. • Based on evidence and includes scientific reasoning		15
Total			**30**

(Continued)

CIRCUIT			
Meeting Design Trades	• Safety: More switches allow for safety lockouts • Reliability: More switches mean more possible failures • Cost: More switches means more cost • Convenience: More switches could allow for multiple operating stations		5
Meeting Criteria	• Safe—must not drop egg accidentally • Avoid likely failure		5
Meeting Constraints	• Limited number of batteries, switches, and magnets; each one used drives up the cost		5
Justification	• Includes a written justification for all design decisions • Based on evidence and includes scientific reasoning		15
Total			**30**
BUDGET ($20)	Switches $2 Wire $.50 Can $1 Egg - Free Wire nuts $.50 Electrical tape $.25 per foot Sand $.25/cup Newspaper $.50 Battery $2 Nail $.50 Bolt + nut $1 Plastic zip bag $2 Rice cereal $1/cup Small box $1 Washer $.50 Electric box $1 Mag wire $.5 Card box $4 Raw oatmeal $.50/cup Sponge $1.50		10
DESIGN TOTAL			**100**

KLEWS Chart

K: Know	*What do we already know about the design problem?*	
L: Learn	*What do we want to learn about the design problem? What do we still need to know?*	
E: Evidence	*What evidence have we gathered to help us with our design problem?*	
W: Wonder	*What do we still wonder about the design problem?*	
S: Science Ideas	*What science ideas helped us with the design solution?*	

Fishbowl Rubric

Observer name: ___________________ Partner name: _____________________ Date: ______

Discussion subject: ____

Directions: Make a tally mark each time your partner demonstrates one of the following.

1. **Speaks** constructively in the discussion.

2. **Adds** to and advances an **interpretation** or **analysis** of the problem.

3. Provides **evidence** for claims.

4. **Interrupts** or cuts off another speaker without acknowledgment.

Directions: After the discussion, answer these questions.

What is the most interesting statement made by your partner? Why?

Directions: After the discussion, count the marks above to evaluate your partner's performance.

	4: Exceeds Expectations	3: Meets Expectations	2: Nearly There	1: Not Yet
Speaks	more than 5 times	4 times	4 times	3 times or less
Asks Questions	more than 3 times	3 times	3 time	1 time or less
Provides Evidence	more than 3 times	3 times	2 times	1 time or less

Total: _____ /10 points

Total interruptions _____

Investigation: How Mass and Drop Height Relate to Impact Force

Develop an investigation to explore how mass and drop height relate to impact force. Record the steps of your investigation below. Record the data from your investigation in the data table provided.

Investigation Steps:

Data Table

Object	Mass	Height	Impact Force	Notes

What conclusions can you draw from your investigation?

Investigation

The Maximum Impact Force an Egg Can Survive

As part of the design challenge, you must prevent an egg (astronaut) from breaking (astronaut fatality) when dropped from a certain height. To do so, determine the maximum impact force and height an egg can survive.

Start at a very low height, drop the egg (in a plastic bag) on the sensor plate. Record the height and the impact force. Steadily increase the height until the egg breaks. Repeat the experiment with a second egg. Average the maximum height and impact force for both trials. *Note: The maximum height and impact force should be the drop just before the drop that breaks the egg.*

Trial 1

Height	Impact Force	Broken?	Notes

Trial 2

Height	Impact Force	Broken?	Notes

The Maximum Impact Force an Egg Can Survive (Part 2)

What was the average maximum height for your egg?

What was the average impact force for your egg?

Record your data on the board to create a class data set.

What was the average maximum height for your class?

What was the average impact force for your class?

SUMMARY

Double the maximum height for your class: ____________________

Your drop tower must be at least this tall.

Record the average impact force (astronaut fatality) for your class: ____________________

Your test capsule must be able to withstand more than this amount of force.

Investigation

How to Make an Electromagnet Stronger

After “tinkering” with your electromagnet, select three different setups that you think will yield the strongest electromagnet.

Test the strength of each setup using the dual force sensor. Alternatively, you can hang a string from a tin can lid, and then add washers one by one. The mass of the lid plus the washers gives a relative strength of the magnet. Explain why you think each setup yielded the results you recorded.

Setup Sketch	Strength of Electromagnet	Explanation

Egg Engineering Workspace

Blueprints

Begin the design phase of your models—circuit, spacecraft, and test hardware box. You need to create a blueprint of your models with dimensions and labels.

Blueprint Criteria for Success

- You must include metric measurements for all three models—circuit, spacecraft, and test hardware box.
- You must label all parts of all three models.
- You must have sufficient detail on your blueprint so someone could build what is on your blueprint without having to ask questions.
- You must incorporate data from Days 1 through 3 to justify your design decisions. Labels should show how certain design features contribute to meeting criteria. For example, if you label the kinetic energy and force that would squash an unprotected astronaut, what features mitigate this disaster? What is the estimated mass of the capsule? Does your planned magnet have enough strength, plus a little excess? Justifications should include data collected in previous lessons or during testing, science ideas developed in previous lessons, and physical laws at play.

Circuit

Spacecraft

Test Hardware Box

Blueprint Feedback Reflection

Critical Feedback and Suggestions Made by Other Teams

Team Reflection	Adjustments and Action Plan

Student Time Tracker

Date	Time	Individual	Task	Justification

Expense Report Form				
Material Purchased	Cost of Material	Quantity Needed	Total Cost	Justification for Purchase

Total Amount Spent: $________________________________

PRESENTATION RUBRIC				
	No Evidence	Beginning	Developing	Advanced
Quality of Design Product NOTE: This section should be tailored to assess specific module and performance expectations.	Design product fails to address most aspects of the performance task. Design product shows no evidence of thoughtful problem solving. Design product shows evidence of low-quality craftsmanship.	Design product addresses some aspects of the performance task. Design product shows little evidence of thoughtful problem solving. Design product shows evidence of mediocre-quality craftsmanship.	Design product addresses most aspects of the performance task. Design product shows some evidence of thoughtful problem solving. Design product shows evidence of mostly high-quality craftsmanship.	Design product addresses all aspects of the performance task. Design product shows clear evidence of thoughtful problem solving, deliberation, and decision making. Design product shows clear evidence of high-quality craftsmanship.
Explanation of Science Ideas Science ideas include science and engineering practices, disciplinary core ideas, and crosscutting concepts. NOTE: This section should be tailored to assess specific module and performance expectations.	Relevant science ideas are not addressed. Evidence is not cited.	Most relevant science ideas are stated and partially described in relation to the design problem. Some evidence is cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are stated and described in relation to the design problem. Several lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are clearly stated and described in detail in relation to the design problem. Multiple lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.
Organization	The presentation does not include all of the required components. The presentation does not have a main idea or presents ideas in an order that does not make sense.	The presentation includes most of the required components. The presentation moves from one idea to the next, but the main idea may not be clear or some ideas may be in the wrong order.	The presentation includes all of the required components. The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing main points in a focused, coherent manner.	The presentation includes all of the required components and either provides additional information for each component or adds additional components relevant to the presentation. The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing the main points in a focused, coherent manner. (CC 6-8. SL.4)

Presenting Skills	The presenter does not look at the audience and reads notes or slides. The presenter wears clothing inappropriate for the occasion. The presenter mumbles or speaks too quickly or slowly. The presenter speaks too softly to be understood.	The presenter makes infrequent eye contact and reads notes or slides most of the time. The presenter dresses professionally. The presenter speaks clearly most of the time, although sometimes too quickly or slowly. The presenter speaks loudly enough for most of the audience to hear, but may speak in a monotone.	The presenter keeps eye contact with audience most of the time and only glances at notes or slides. The presenter dresses professionally. The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4) The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)	The presenter engages the audience by drawing their sustained attention. The presenter maintains eye contact with the audience most of the time and only glances at notes or slides. (CC 6-8.SL.4) The presenter dresses professionally. The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4) The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)

Apparatus Feedback Reflection

Critical Feedback and Suggestions

Team Reflection	Adjustments and Action Plan

Final Test Report

Prepare a test report for Soft Landing Systems to justify your design decisions and argue for the adoption of your capsule and tower design. Your argument should present evidence and reasoning to support your claim that your capsule will keep astronauts safe and your testing apparatus is safe, reliable, and cost-effective.

Your report should include the following:

- Design challenge with criteria, constraints, design trades, and budget
- Initial design and redesign(s)
- Science ideas informing the initial design and redesign(s)
- Recommendations for future designs to correct failure points and/or optimize the design
- Final argument to support your claim that your capsule will keep astronauts safe and your testing apparatus is safe, reliable, and cost-effective

Aspect of the Argument	Point Value 0	1	Comments or Suggestions
Identify role, audience, and task (1)			
Accurately complete task		X2	
Claim			
The claim is sufficient.			
The claim is accurate.			
Evidence			
Includes data/research			
Includes an analysis of the data/research			
Includes an interpretation of the analysis			
Reasoning: Justification of the Evidence			
Explains why each piece of evidence is important/relevant			
Links the evidence to a scientific concept or principle			
Identifies a line of logic or values that define success			
Reasoning: The Challenge			
Alternative explanation(s) explained clearly			
Demonstrates why the alternative explanation is inaccurate			
Mechanics			
Order and arrangement of sentences enhances argument			
Appropriate word usage, spelling, grammar, and punctuation			
Total Score	/15		

Adapted from: Sampson, Victor, and Sharon Schleigh. *Scientific Argumentation in Biology*. Arlington, VA: NSTA, 2013