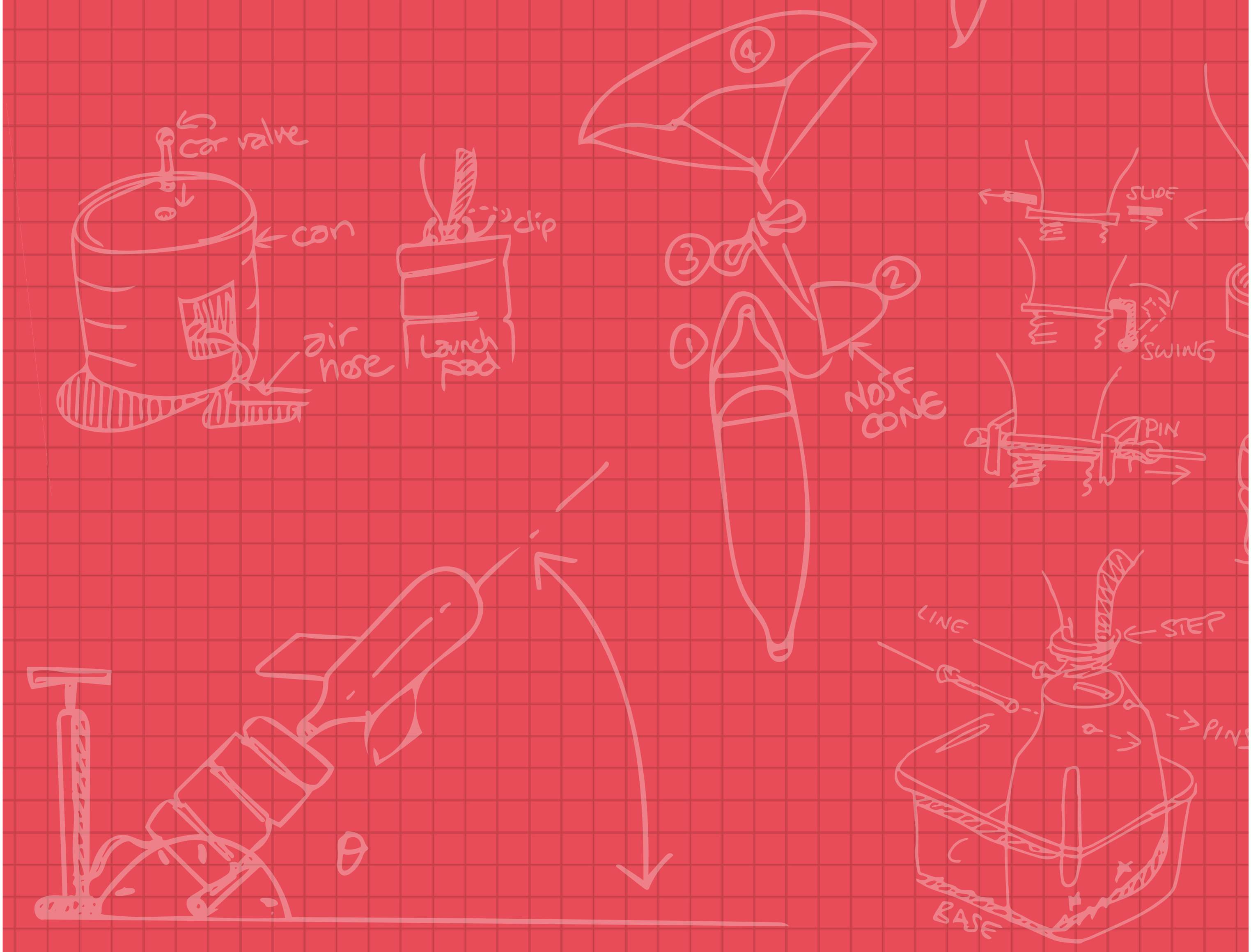
Name:

DESIGN FOLIO

The Bottle Rocket Challenge



SISP

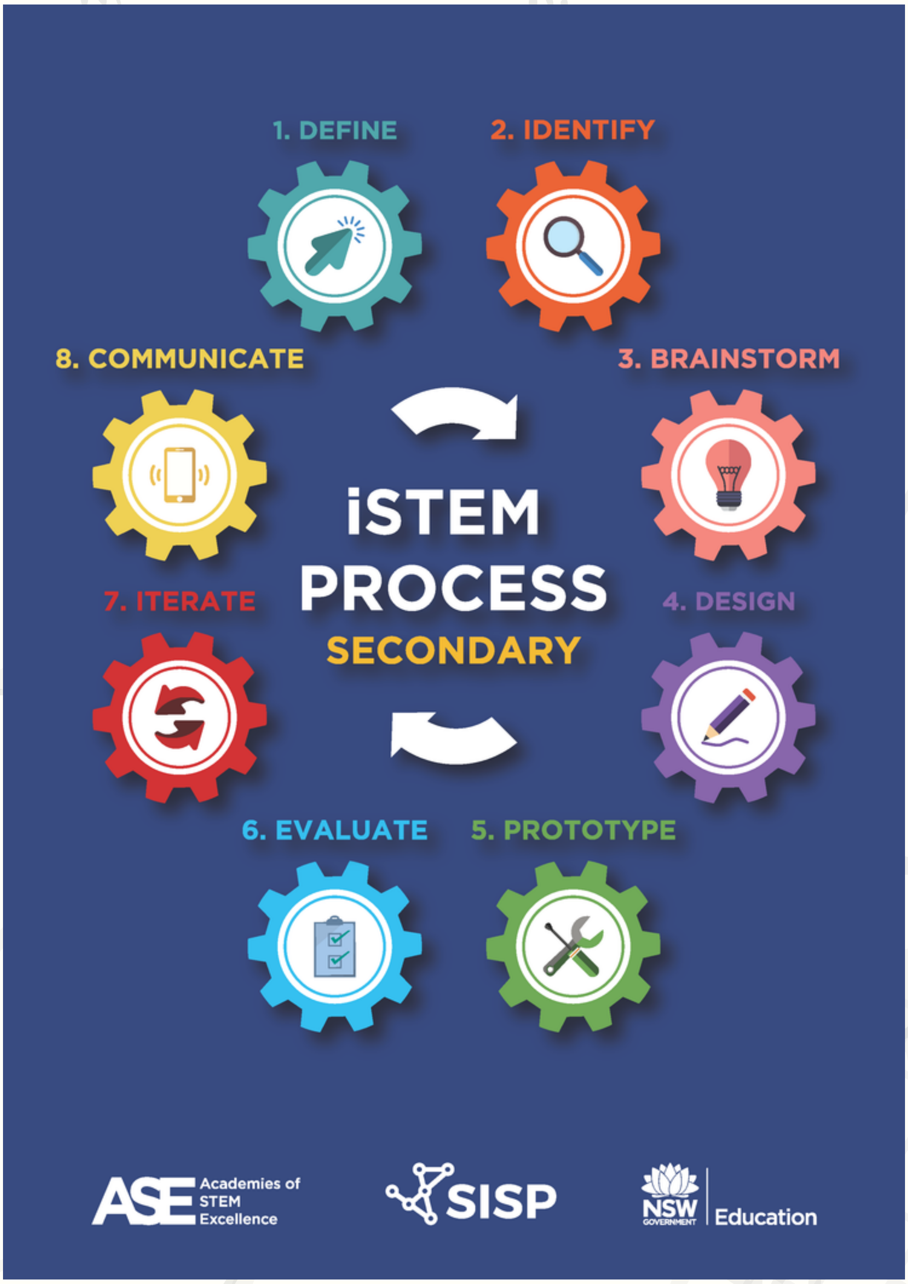
STEM Industry School Partnerships

Splat®

Think Draw Design

The Engineering Design Process

The iSTEM Process has been developed by the Cessnock Academy of STEM Excellence which is part of the STEM Industry School Partnerships program. It is a series of steps to guide students through the engineering design process. This eight step design process is for use in secondary schools, which is an extension to the primary school versions, developed for Stages 1, 2 and 3, which are available at the iTeachSTEM website.Instructional videos and materials that support this folio are also available at the website. Visit www.iteachstem.com.au for resources, or see the embedded links (pages 3, 8).
This design folio is free for use in schools.



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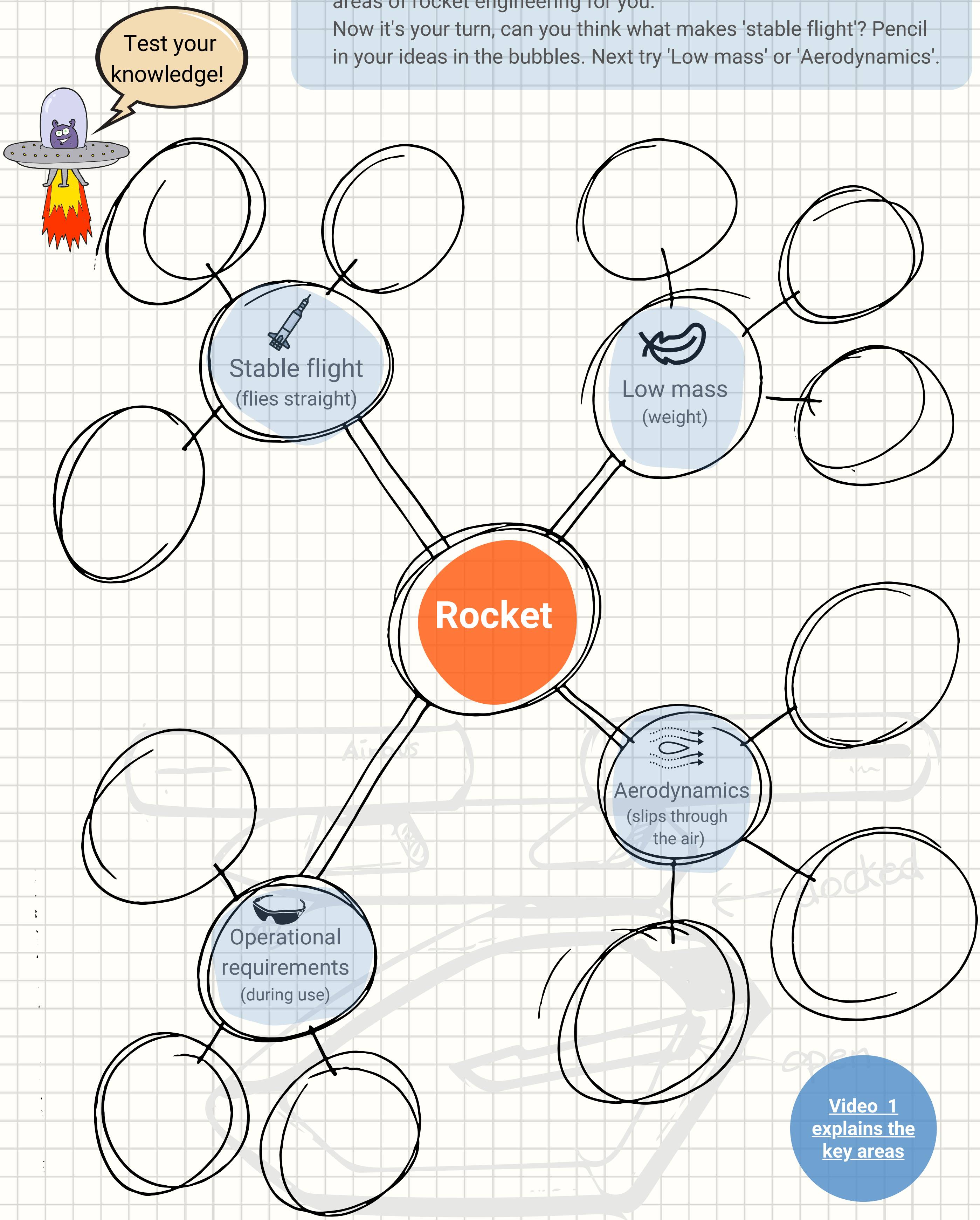
1. Define the problem

A clear statement describing the problem or challenge to be solved.

After investigating a problem, you often find there's more things to keep in mind than you thought. Below we have **defined** some key areas of rocket engineering for you.
Now it's your turn, can you think what makes 'stable flight'? Pencil in your ideas in the bubbles. Next try 'Low mass' or 'Aerodynamics'.



Video 1 explains the key areas

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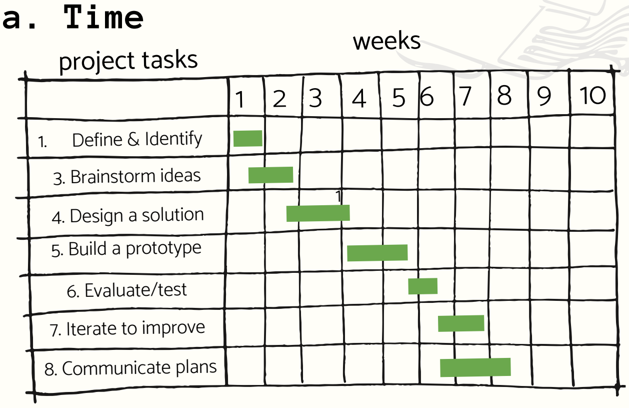
2. Identify constraints

A constraint is a limitation that must be satisfied by a design, e.g. project costs.

a. Time



A Gantt chart is commonly used by industry as a tool in project planning. In the project shown (left), 'Iterate' and 'Communicate' are scheduled for the same week.
Discuss: Why might that be?

Try scheduling your own project in the empty gantt chart (right) . Your teacher will specify a project completion date. You may also be given a date for 'deliverables'. It could be that you report on your progress at agreed 'milestones'.

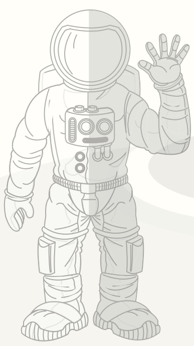
project tasks	week numbers 1	2	3	4	5	6	7	8	9	10
1. Define & Identify										
3. Brainstorm ideas										
4. Design a rocket										
5. Build a prototype										
6. Evaluate/test										
7. Iterate to improve										
8. Communicate plans										

b. Materials

List the materials that you have access to. Consider the:

- Fins
- Rocket body
- Nose cone

Some projects may also include a launch pad or a recovery system e.g. parachute



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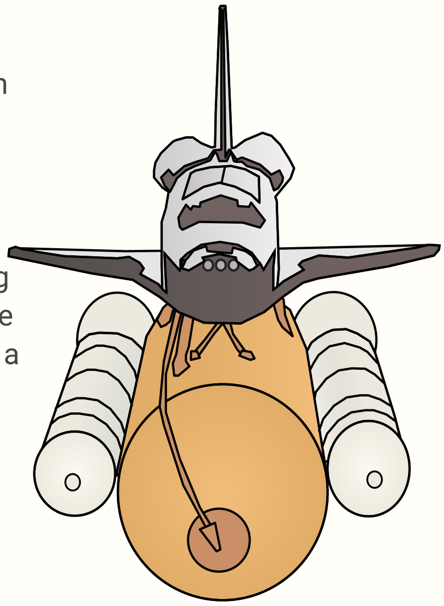
c. Criteria

Criteria are the attributes of a design that can be actually measured. List some 'criterion' for your project e.g height, distance or proximity to a target.



Did the NASA Space Shuttle use solid fuel or liquid propellent or both?

Now is a good time to check the tools, workspaces, and machinery you will have access to.

Any challenge or competition will have rules and guidelines to follow. Check them out carefully.

d. Tools and Equipment

Top safety tips

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3. Brainstorm multiple solutions

List or sketch *lots* of ideas to encourage creative thinking.

Thumbnails are small, quick sketches. They are 'thoughts on paper' with no time for neatness. Label the important parts.

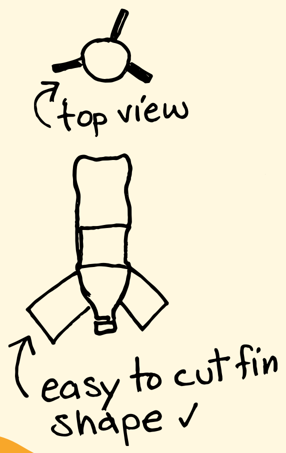
Explore enough options and potential solutions to create a good design. Build 'mockups' if it helps. A mockup is a rough but fast model/prototype to try-out an idea.

Stable flight - fins

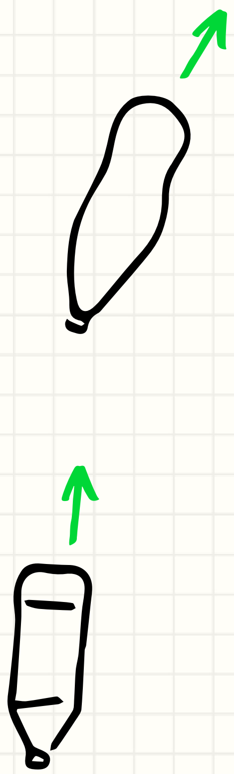
Activity: Practice being creative. Can you draw a 'thumbnail sketch' of five different fin shapes onto the rockets below?

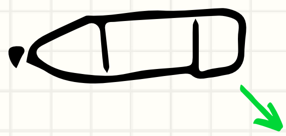
Extension: Think of a reason for each fin shape, keeping in mind the key areas from the 'Define' section.

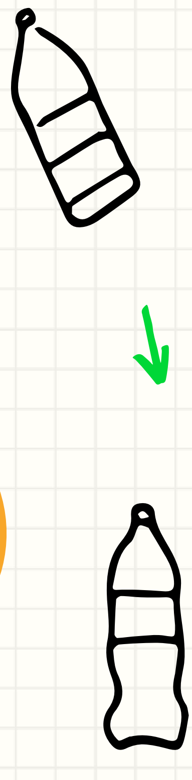
example of a thumbnail sketch



Discuss: What is the vertical speed of a rocket at it's 'appogee' ?







'Annotate your sketches' means use arrows and labels to help explain ideas.

'A person with good ideas is simply a person with *lots* of ideas!'

Activity: Draw 4 bottle rockets and include each rocket part (below). Research may be needed.

Two-stage rocket. | Engine gimbal | Canards | Retro-rockets

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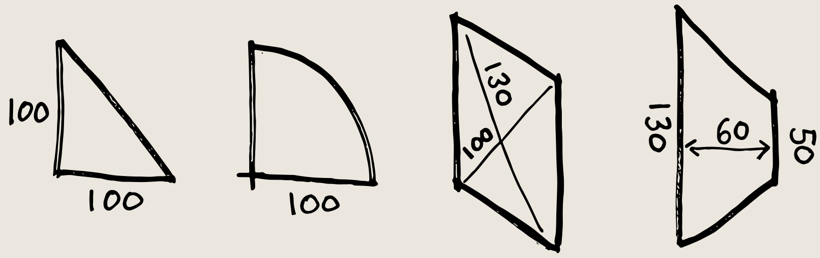
Activity: Can you find the surface area for each fin shape?



triangle	quadrant	rhombus	trapezium
________	________	________	________

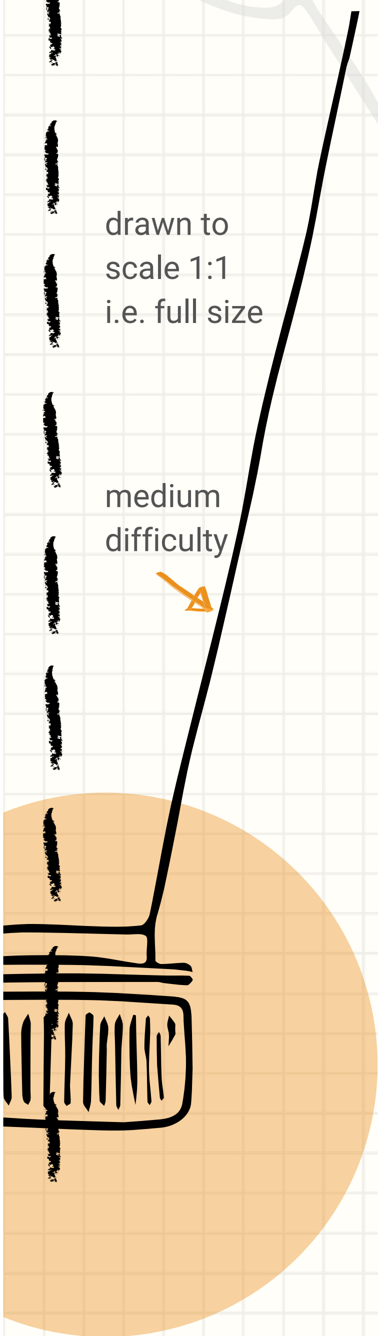
Activity: Design a fin outline onto the bottles below:

- The surface area must be 5000 mm sq. (approx.).
- The fin must fit the shape of the bottles.
- Fin must not touch the circles (i.e the launcher).

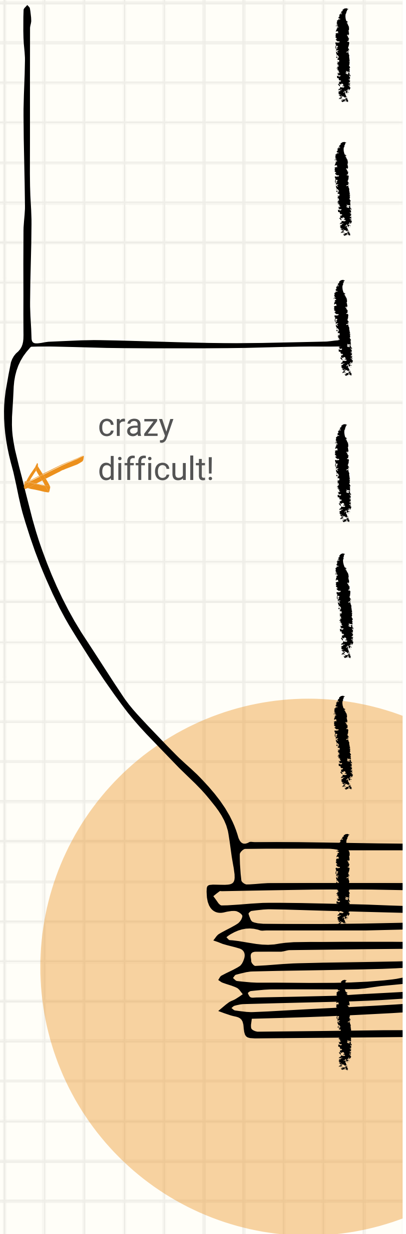
TIP: fins work better the lower they are.

drawn to scale 1:1 i.e. full size

medium difficulty



crazy difficult!



Extension:
Show how to calculate the **volume** of a plastic bottle.

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Stable flight – Centre of Pressure & Centre of Mass

Demonstrate your understanding of Centre of Pressure (CP) and Centre of Mass (CM) by completing the following practical activity.

Follow the plans below to construct (at home) a simple rocket. Label your work. Check your name is clearly visible.

Experiment. Rocket Science!!

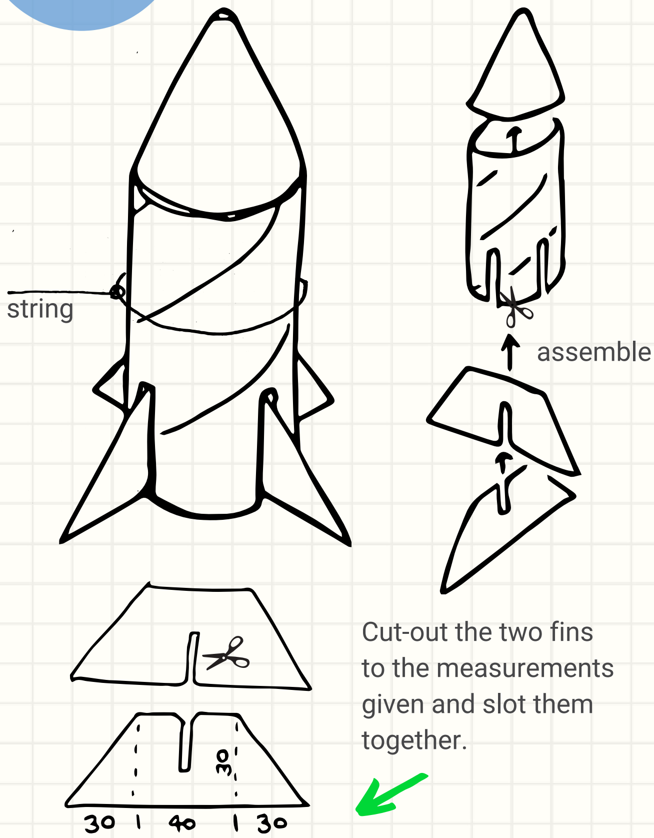
Video 2 demonstrates this experiment

Safety tip:
Check that nobody is near when testing.

Aim:
To understand how the distance between the Centre of Mass (CM) and the Centre of Pressure (CP) affects the stability of a rocket during flight.

Method:
Construct and test a model rocket. To make the rocket, attach a nosecone at one end of a cardboard roll and paper fins at the other (measurements shown). Tie a 1m length of string around the rocket body, and swing the rocket in a flat circle above your head. Observe if the rocket tumbles or not.

Test 1:
Mark the CM & CP positions on the rocket, test rocket for stability in flight and record results in 'Test 1' below.
Test 2:
Add a small amount of nose ballast. Mark the new CM, then retest the flight stability. Add results under 'Test 2"
Test 3:
Now remove the nose ballast but slide the fins further toward the bottom. Find new CP and re-test.
Test 4:
Make fins that are double the size. Find CP then retest.



Cut-out the two fins to the measurements given and slot them together.

Conclusion:
Write a conclusion in your own words (remember the aim of the experiment).

Test 1
Distance between the CM and CP
_________ mm
stable/unstable flight

Test 2
Distance between the CM and CP
_________ mm
stable/unstable flight

Test 3
Distance between the CM and CP
_________ mm
stable/unstable flight

Test 4
Distance between the CM and CP
_________ mm
stable/unstable flight

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Stable flight – Spin stabilisation

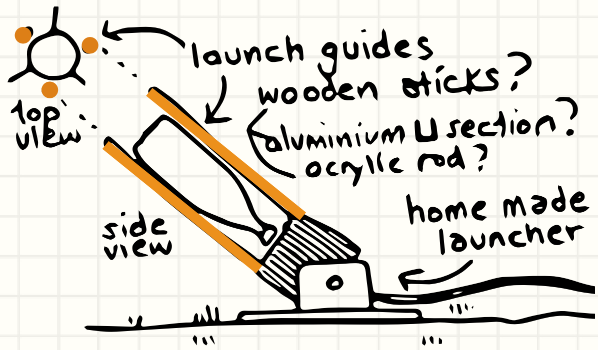
Activity: After viewing the first video resource, write an explanation for the statement below.

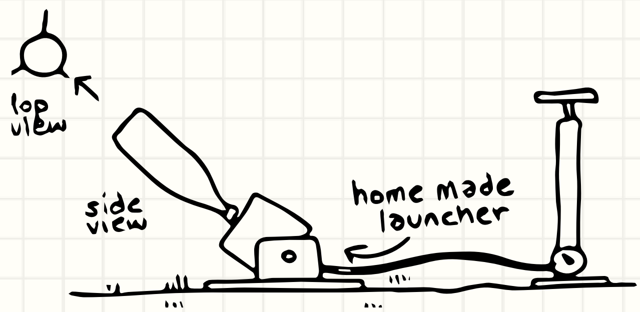
'Spin stabilisation counteracts asymmetry in the thrust and aerodynamics in achieving stable flight'.

Stable flight – Launch pad guides

Imagine a rocket being launched at an angle, as shown below. At lift-off, the rocket's air-speed is low and it needs some kind of guide. Some launchers use a tube inside the bottle as a guide. The launcher pictured below uses rods.

Activity: Brainstorm two ideas to guide a rocket during a side-ways lift-off, other than the sticks example shown below.





We need your best engineering to avoid injury from a rocket that turns corners!

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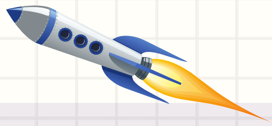
4. Design
the most promising solution

Design drawings show the shape, material and size of all physical components.

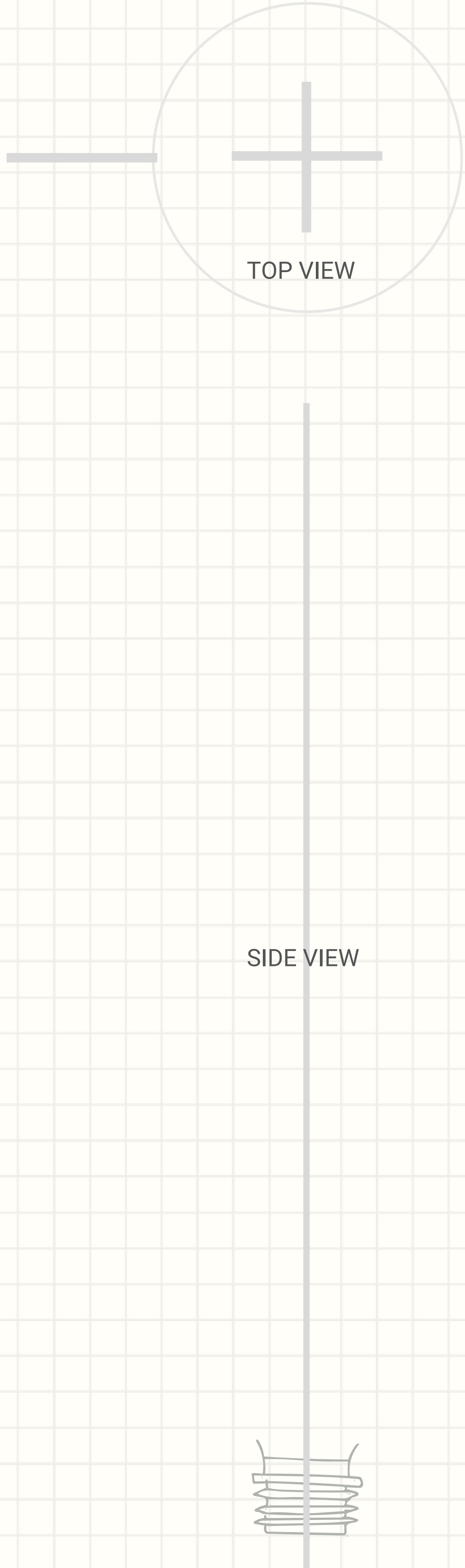


You're doing great! It's time to pull it all together into a design drawing.

These are **not** your final drawings, so it's OK if they are a little rough in places. They are mainly for planning how to build your prototype. They show the design decisions made, given the many *competing factors*.

Competing factors is when two elements that you would like to see on your design compete against each other. For example, larger fins add stability to a rocket but make it harder to keep the overall weight low. In this case a trade off must be struck. Engineers and designers deal with lots of competing factors. It is what will make your design an original!

Activity:
Draw a front view and a top view to a half-scale. The screw thread is drawn at half-scale. You may prefer to attach your drawings, depending on the complexity of your design.



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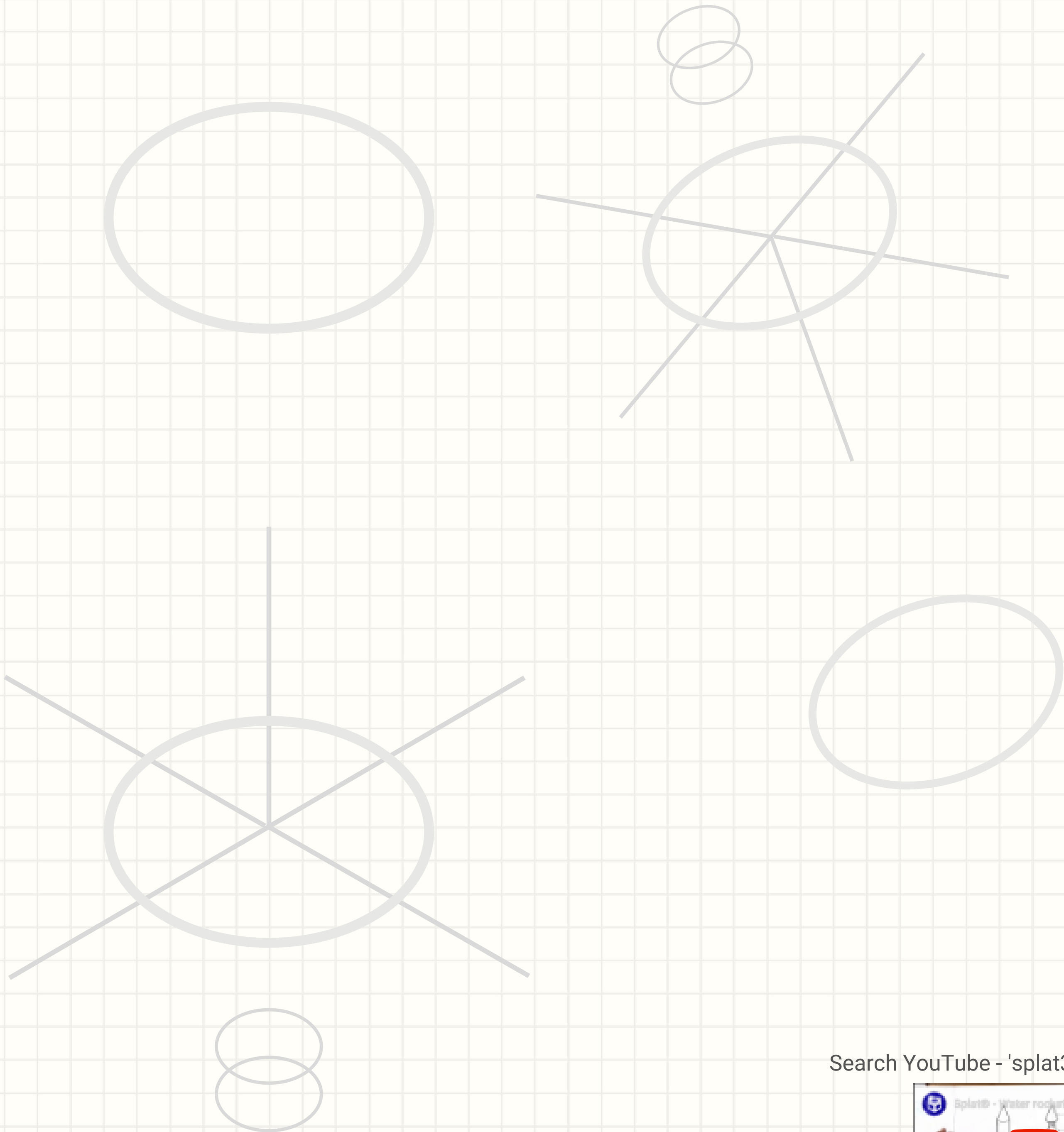
Activity:
Try sketching
an **pictorial** view of your design. Isometric views are one type of 'pictorial' or 3D type drawing.

Annotate your design using notes with arrows. Explain the highlights of your design.

Identify the materials in your design.

Visit Splat3d on YouTube to see bottle rockets drawn using a template.



ISOMETRIC VIEW

Search YouTube - 'splat3d rocket'

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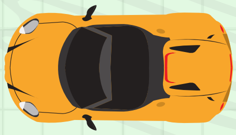
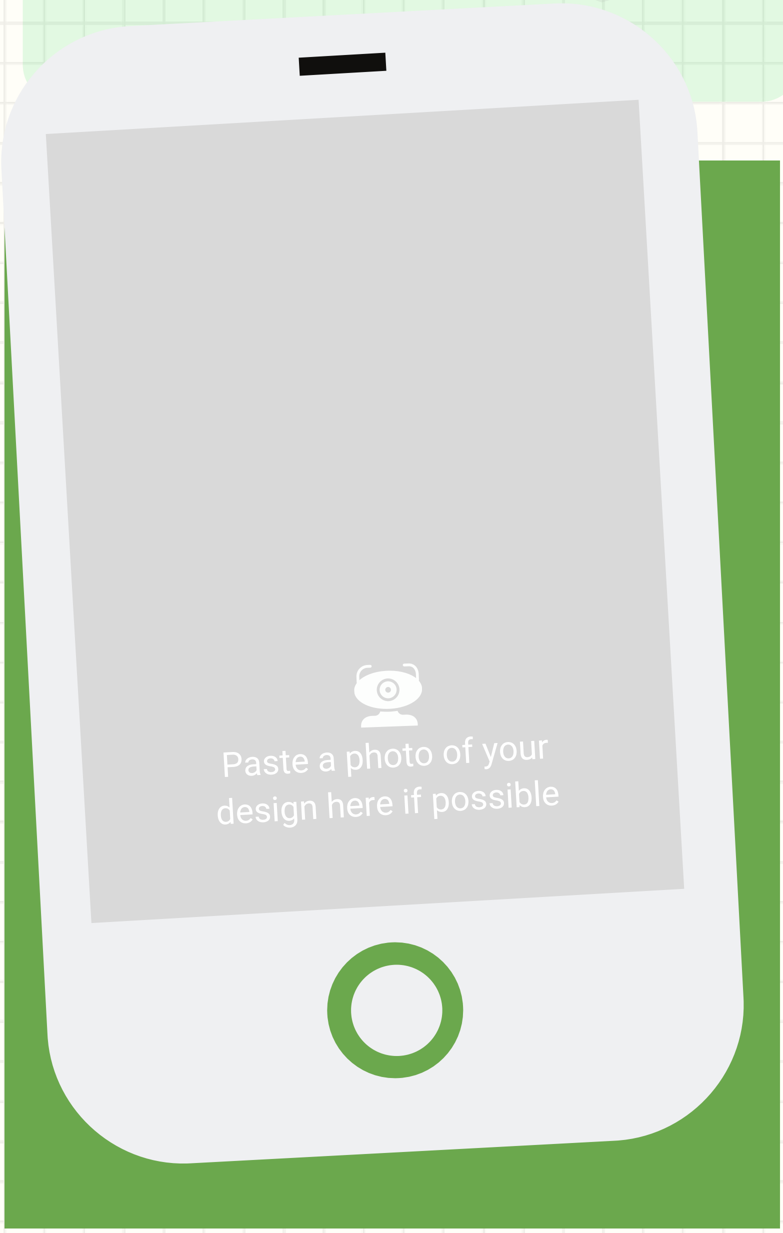
5. Prototype your solution

A prototype is where you construct a working example of your design.

Unlike a static model, a prototype is for testing whether the design will work as expected. Usually new insights are gained once the engineers get to experiment with a physical product in their hands.

Prototypes may be shown to potential customers to gain support. For example, prototypes of new car designs are displayed at motor shows to measure people's response and sometimes to gain pre-production orders.





Activity: Research and describe two processes for 'rapid prototyping'.

1

2

Activity: Check the recycle number on your bottle (see recycle arrows). Research which plastic (polymer) it is made from.

Activity: Describe the bottle's properties.

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6. Evaluate
& test your design

Prototypes are tested and evaluated against constraints and criteria.

You will need to launch your rocket from a rocket launcher to evaluate its performance.

PMI is a quick method for evaluating ideas. Write down all the positive points of your design, then all the negative. Note anything interesting, e.g. questions that need to be answered to improve on the design.

Record the results of your testing here

Test results Based on your criteria e.g distance/height/accuracy.

Plus Consider all the things that your design does well and write them down.

Minus Consider where your design did not perform as well as expected.

Interesting Observations that are neither plus or minus, although worth noting.

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7. Iterate to improve your solution

An iteration is the next or improved version of a design.

Often with school projects, we don't get time to make an improved version/iteration. If you are working from home, you may have more time. Let's at least *design* a second iteration !

Apply the lessons that you learnt during testing and evaluation. Suggest one possible improvement in each of the four boxes below.

Tip: Try to be very specific and explain with sketches and notes: Work like an engineer!

Areas for improvement include; change of shape, size, materials, nosecone ballast, joining methods, durability (crash landings), aerodynamics, stability, build accuracy, aesthetics, weight saving, water-proofing, ease of maintenance/repair, branding (e.g. SpaceX brand).

1

2

3

4

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8. Communicate & share with the world

Records of the design are kept, usually as a digital (CAD) file. This information allows other team members to update or modify the design in the future.

Students learn to work collaboratively in preparation for work in industry. When working in a team, complex projects rely on people's ability to create drawings that accurately communicate technical information.

Activity:
Produce an orthogonal drawing (a front and top view) as well as a 'close up' view of any parts that are too small to see clearly on the other views.

Include dimensions (measurements) on your plans. Dimension lines are very thin lines, so that they do not distract from the actual drawing.

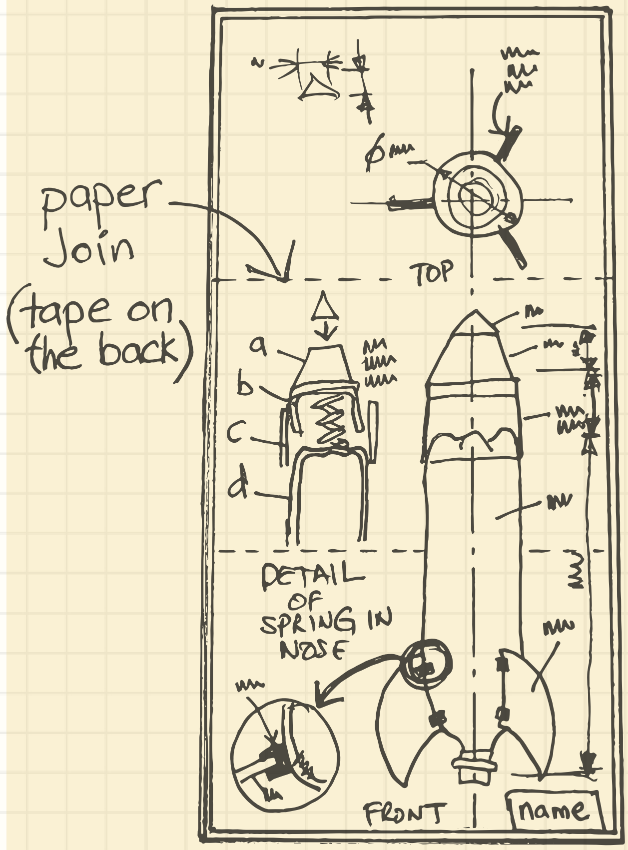
If possible, draw your plans full size (scale 1:1).

https://www.newcastle.edu.au/study/engineering

You will need to join three sheets of A4 paper together to draw the rocket at full size (see below). Rule a margin. Add your name in a title block. Use a ruler and sharpened pencil and make these the drawings neat and tidy.

Placing the top view above the front view is the correct way of arranging your views on a drawing.

These sheets can be folded on the joins to fit inside an A4 display folder.



Plans

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