ACTIVITY 5: Inspiration from Nature

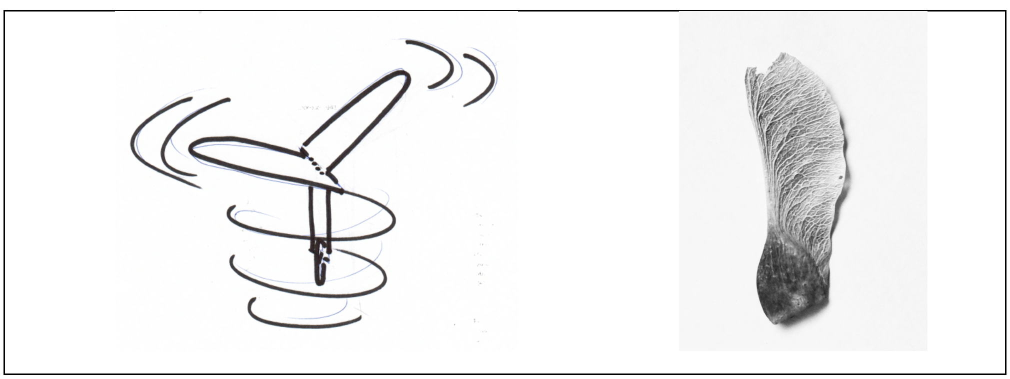
The Whirligig Challenge

Landing a spacecraft on another planet is not a simple procedure. To see how complex it can be, watch ***UCF-A5 – Movie 1*** (a 5-minute NASA video "Seven Minutes of Terror"), which describes how engineers designed the landing sequence for the robotic spacecraft that landed the *Curiosity* rover on Mars in August of 2012. In this activity you will design an alternative landing mechanism for a robot spacecraft that is to land on another world.

For a source of creative ideas, engineers often turn to *biomimetics*—the practice of studying natural systems in order to solve engineering problems. Activities involving biomimetics provides opportunities to learn biology, physics, and engineering at the same time.

The Whirligig

The Whirligig is an excellent example of biomimetics, since its function is similar to a maple seed.



The "Whirligig" (left) is an example of biomimetics. Images by Cary Sneider

Watch ***UCF-A5 – Movie 2*** to see how maple seeds act as tiny helicopters, enabling them to drop slowly to the ground, often some distance away from their parent tree.

The Challenge

Imagine you are part of a team of scientists and engineers that are planning to land a robot craft on Titan, a moon of Saturn that has a dense atmosphere (the surface air pressure is about 50% greater than Earth's).

Since Titan has a dense atmosphere, the team has decided that a whirligig type mechanism would be a good way to land the craft. However, some team members are worried that, with the current design, the craft will still be traveling too quickly when it lands, damaging the onboard computer. Your job is to improve the current model of the craft (whirligig), by changing its shape so that it falls more slowly, but stays upright as it falls. Because of an upcoming team meeting, you have 30 minutes to improve the model design to everyone's satisfaction, using only paper, scissors, paperclips, a ruler, and a stopwatch.

Recall that the engineering design process can be broken into three stages:

1. Define the problem, goals, and constraints

Problem:
Describe the problem are you trying to solve. (Note that your team has already chosen to use a whirligig mechanism, so your problem statement should address that mechanism, not whether to choose any other way to do it.)

Goals:
How will you know if your redesigned whirligig system is successful?

Constraints:
What are the limitations you will place on your redesign?

2. *Develop solutions*

Start by making a whirligig as currently designed. Use the diagram on the last page of this activity. Cut along solid lines and fold along dotted lines. Bend the "wings" in opposite directions. Add a paperclip at the bottom if needed for stability.

Drop your whirligig and note how it behaves.

This particular problem could be addressed using a 'trial and error' approach. However, it is important for engineers to understand the scientific principles behind their designs in order to know what changes are likely to have the desired effect. Understanding of the Whirligig Challenge involves analyzing the forces acting on the whirligig **while it is falling**.

After it is dropped, the only forces acting on your whirligig are the gravitational force of the Earth pulling it downward and a drag force (air resistance) pushing upward on it, so opposing its motion.

Immediately after it is released, for a short period of time the speed of the whirligig increases as it falls. What does that tell you about which of the two forces acting on it is stronger during this period? Briefly explain how you know.

The strength of the drag force acting on the whirligig depends on the speed at which it is falling. This means that as its speed increases, the strength of this force increases. However, after increasing in speed for a short period, the whirligig falls the rest of the way at a constant speed (called its 'terminal velocity'). What does that tell you about the strengths of the two forces acting on it now? Again, briefly explain how you know.

To change how the whirligig falls, you will need to make design changes that change the strengths of these two forces acting on it as it falls.

What changes to the design could you make to change the strength of the gravitational force pulling downward on the whirligig as it falls? Would you want to make this force stronger or weaker? Explain your reasoning.

What changes to the design could you make to change the strength of the drag force pushing upward on the whirligig as it falls? Would you want to make this force stronger or weaker? Again, explain your reasoning.

Suggest at least two easily made changes to the whirligig design you think might achieve your goal.

Make additional whirligig models that incorporate your suggested changes, and use them to plan and carry out an investigation to determine which model best solves the problem. ***Be sure that your investigation is a fair test of your different models.***

On the next page, describe your testing procedure and results.

Which of your suggested changes best addresses the problem? *Keep your best model for the next part of the activity.*

3. Optimize the most promising solution

Your instructor will ask all the groups in your class to describe, and show, their optimized designs. Which of these designs do you think would be most effective, and why?

Now your instructor will arrange for a competition between all the groups' final designs to see which is the most effective.

Describe the winning design below and participate in a class discussion as to why it is the most effective.

Science Meets Engineering in the NGSS

One of the most radical features of new science standards being adopted in many states is the idea that engineering design should be taught at the same level as science inquiry. However, that does not mean commonly presented activities such as bridge building and egg drop contests necessarily qualify. To meet Next Generation Science Standards, it is important that the engineering design activities be supported by science concepts.

The Whirligig Challenge is designed to provide the kinds of experiences that students will need to achieve two performance expectations at the middle school level in the NGSS:

> **Motion and Stability: Forces and Actions** MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
>
> **Engineering Design**: MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design is achieved.

There are many versions of this activity on the Internet. It requires very few materials, engages students in engineering design, and is a lot of fun for upper elementary and middle school students. Engaging students in such activities helps them deepen their learning of science concepts, models, and theories, while providing opportunities for them to be creative, leading to increased enjoyment, interest, and for some at least, motivation to continue learning science and engineering, and considering a career in a STEM field.