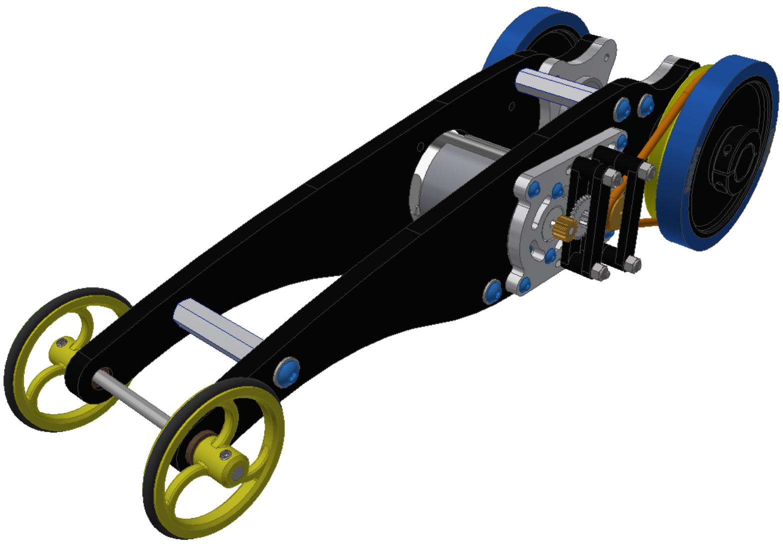
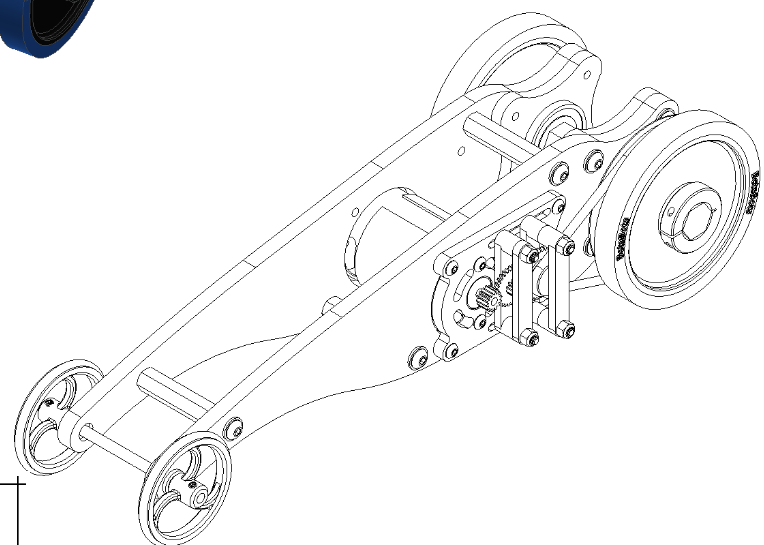
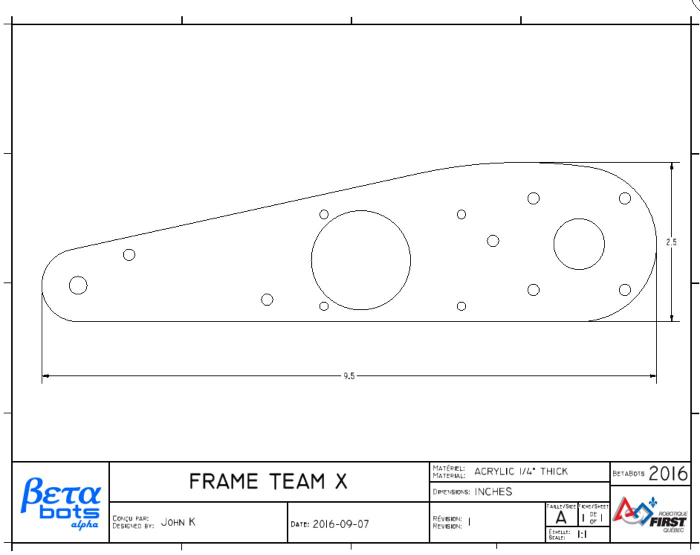
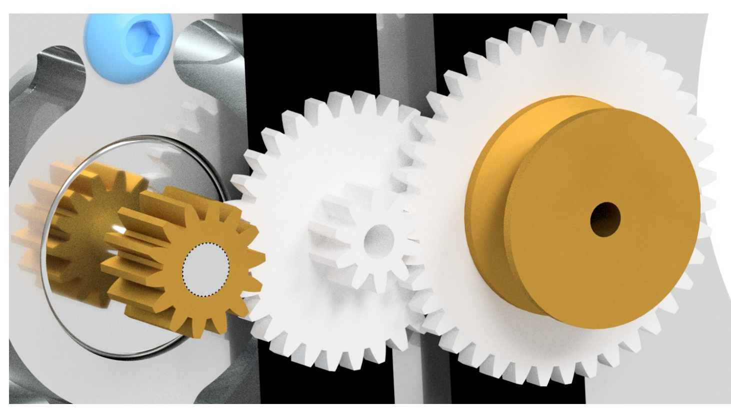
BetaBots Alpha

Teacher's Guide









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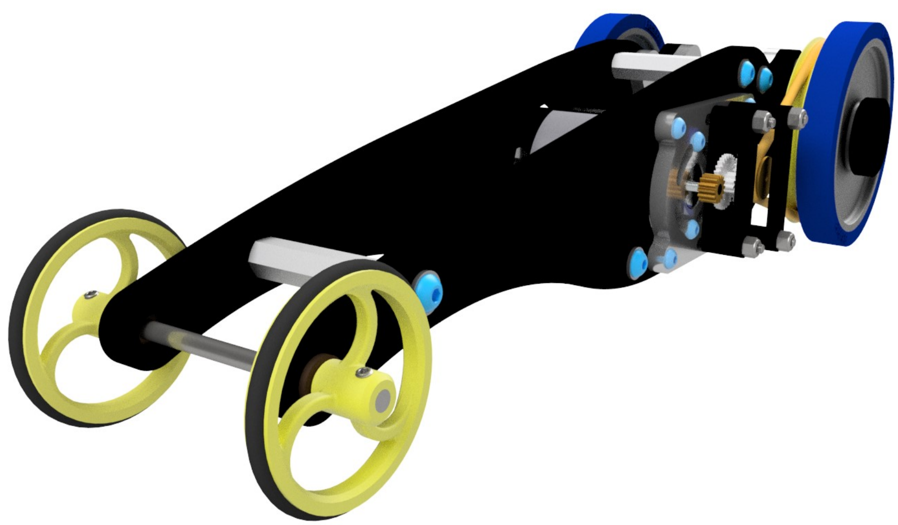
Introduction

BetaBots Alpha is a small scale robotics challenge designed to teach students the fundamentals of robotics. It is heavily focussed on 3D design, and has students send custom parts out for professional manufacture.

BetaBots Alpha uses components typically found on FIRST Robotics Competition robots in order to familiarize students with these parts. It is designed as a training exercise for the FIRST program in order to get students comfortable with basic aspects of design, manufacture and assembly.

The object of the competition is to design, manufacture, assemble and race a dragster. Using an RS550 motor (FIRST Robotics Competition legal), a customizable gearbox and a selection of other components, teams (ideally no more than 4 students) design components, choose gear ratios and optimize their dragsters. The last day of the challenge is the race day, where teams compete head to head and determine a winner.



This is not a turnkey project. While there are many guidelines and resources, the project remains open ended. It is possible that a team performs poorly because of a poor design. It is also possible that a team does not finish due to missing deadlines for manufacture. In the end, the hardest working teams will be rewarded by their performance as well as the skills they develop.

The following is a step by step overview and curriculum for the project. It can be done in class, or as an extracurricular activity.

Kit Contents

A BetaBots Alpha kit contains:

- 1 x BaneBots RS550 motor
- 1 x gearbox with assorted gears
- 2 x BaneBots wheels
- Urethane belt
- 2 x ½″ hex bearings
- 1 x ½″ hex shaft
- 2 x hex shaft collars
- 2 x ½″ hex spacers
- 2 x 4mm bushings
- 1 x 4mm shaft
- 2 x O-rings
- 3 x M4 hex standoffs
- 2 x M3x3mm set screws
- 2 x M3x8mm button head screws
- 4 x M3x16mm button head screws
- 6 x M4x10mm button head screws
- 4 x M3 nyloc nuts
- 4 x M3 washers
- 6 x M4 washers

Students design:

- Front wheels
- Frame
- Rear pulley

Front Wheels

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Lesson Plan:

Objective: Introduction to 3D design, produce front dragster wheels using Autodesk Inventor

Focus: Sketches, revolution, extrusion, cuts

Skills learned: Simple part design with some constraints

Required material: Computers running Autodesk Inventor 2016

Support material: Specially produced video with simple steps

Exercise: Complete design of front wheel within one session

Further material: Videos on projects, sketches, constraints, extrusions, revolutions on RFQ site

Special considerations: First time designing anything for most students, students likely working in groups, but everyone should get a chance to design their own part

Teacher Tips:

Once the basic requirements are met, students should be encouraged to be creative with their designs. This is a chance for them to explore the program and learn different features. While ultimately, only one design per team will be produced, every team member should get an opportunity to create their own wheel design.

Some things to keep in mind when creating parts in Inventor:

- Most part features (revolutions, extrusions etc) require a sketch. The feature 'consumes' the sketch, which will no longer be visible after the feature is complete.
- Part features can be edited in two ways. The feature itself can be changed, or the sketch consumed by the feature can be altered. Editing a feature changes parameters concerning it (length of an extrusion, angle of a revolution etc.), whereas editing a sketch changes the definition of the feature (its shape or contour). Double clicking the feature can change its parameters, clicking the '+' sign beside a feature and double clicking the sketch can change its definition.
- In order for extrusions to work properly, its sketch must contain a closed loop. Sometimes a loop appears closed, but certain constraints are missing for it to be considered closed by the program. This is often the case when using patterns on sketches. This can be solved with the sketch doctor. The sketch doctor is accessed either by clicking the red '+' on the feature dialog box or by right clicking while editing the sketch and choosing the sketch doctor option. Open loops can be closed with this tool and the extrusion can be completed.
- Sketches can be made on any plane. This includes part geometry, but also includes origin planes. In order to make the hole for the set screw in the hub, it is necessary to make a sketch on an origin plane. These are found in the origin folder in the model browser (left side window). These planes can be chosen with the 2D sketch command.

Frame

Teacher's Guide

Lesson Plan:

Objective: Design dragster frame using Autodesk Inventor

Focus: Sketches, extrusion, holes

Skills learned: Consideration for spacing / alignment of components, visualization of finished product using supplied component dimensions

Required material: Computers running Autodesk Inventor

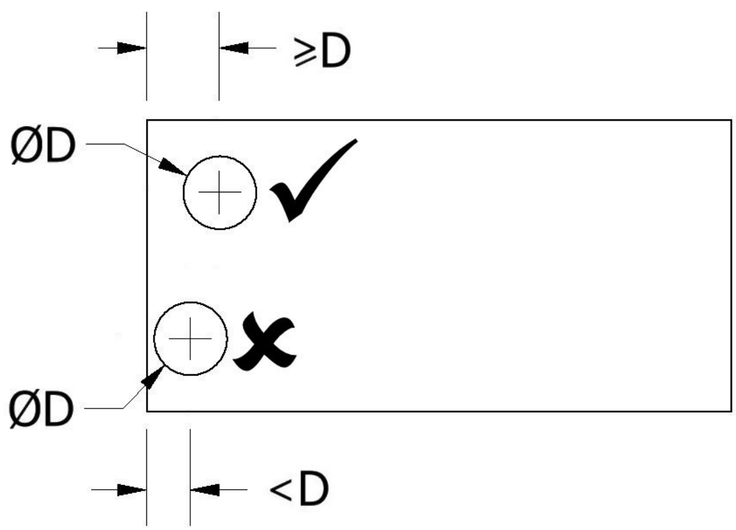
Support material: Specially produced video with simple steps

Exercise: Finish frame design in 1-2 sessions

Further material: Videos on sketches, constraints, extrusions, holes, blocks on RFQ site

Special considerations: Dimensions for front and rear wheels as well as gearbox should be available

Teacher Tips:



Holes should not be too close to an edge in order to keep the frame strong. As a general rule, the center of a hole should be at least its diameter away from any edge.

Students should not use splines or ellipses in their sketches - these shapes can not be cut by laser cutting machines. Straight lines, arcs, polygons and slots can be used without any problem.

For this part, the use of construction features can be beneficial. Construction features are used for the designer's reference only, and can not be chosen for physical features. Construction circles can be used to represent the front and rear wheels, in order to make sure the frame does not touch the ground, as well as to see how the frame will sit on the ground.

Sketch blocks can be useful as well. These are groups of sketch geometry that can be treated as single pieces of geometry. These can be used for the gearbox mounting holes and the bearing plate mounting holes. They can easily be edited if necessary.

Rear Pulley

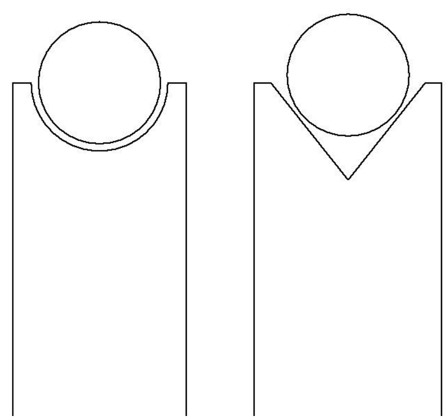
Teacher's Guide

Lesson Plan:

Objective:	Design rear pulley using Autodesk Inventor
Focus:	Revolution, extrusion
Skills learned:	Design of power transmission component with several constraints
Required material:	Computers running Autodesk Inventor
Support material:	Specially produced video with simple steps
Exercise:	Finish pulley design in 1-2 sessions
Further material:	Videos on sketches, constraints, extrusions, revolutions on RFQ site
Special considerations:	Pulley must transmit power from round belt to hex shaft, best design uses large pulley, but must not be larger than rear wheel (including belt)

Teacher Tips:

The rear pulley is a critical part on the dragster. A well designed pulley can give one team a significant advantage over another.



The main features of the pulley are the groove, hexagonal hole, and overall size.

The pulley's groove should be designed differently from the groove in the front wheels. A semi-circular groove was used for the front wheels, but this shape will not be as effective for the rear pulley. In fact, this shape can introduce friction, since the belt can rub on the side of the groove. A more effective groove for power transmission is a V-groove. This reduces friction, and has the benefit of increasing the grip on the pulley when tension in the belt increases.

The shaft used on the rear of the dragster is a ½" hexagonal shaft. The ½" dimension is measured across parallel planes. However, if the hole in the pulley is made this exact dimension, it is unlikely that it will fit without some filing. On the other hand, too large a hole will make the pulley loose on the shaft. A good size to use is 0.501". This seems like a very small amount of clearance, and indeed it is - about 4 times thinner than a human hair - but when dealing with mechanical components, 1/1000 of an inch can be the difference between a part that fits and a broken part.

The size of the pulley can play a part in the performance of the dragster. For the same gearbox ratio, a larger pulley will have a higher acceleration with a lower top speed, while a smaller pulley will have lower acceleration with a higher top speed. Ultimately, the gear ratio can be changed in order to optimize acceleration and top speed. However, the pulley should not be so large that it (or the drive belt) touches the ground instead of the back wheel.

CAD Assembly

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Teacher's Guide

Lesson Plan:

Objective: Assemble various components to create final dragster design

Focus: Placing components, adding constraints, modifying components if necessary

Skills learned: Completing a design, assembling many components into a finished product

Required material: Computers running Autodesk Inventor

Support material: Specially produced video with simple steps

Exercise: Finish dragster design in 1-2 sessions

Further material: Videos on assemblies, placing components, applying constraints, modifying parts, projecting geometry, adaptive parts on RFQ site

Special considerations: Some parts previously designed may need modification in order to fit properly. Final design should be representative of finished product, with all components placed in order to minimize errors in physical assembly

Teacher Tips:

The assembly is where the model comes to life. It is important to include every part in the assembly, so there are no surprises during the physical assembly of the dragster; for example, the head of a screw interfering with a component.

It's important to ground the first component placed in an assembly. This way, it is evident when a part is properly constrained.

There are many different types of constraint. Mates put two faces against each other, but can also be used on axes, edges and points. Flush constraints align two faces so that they face the same direction, this kind of constraint can only be used on flat planes. A very useful constraint when using fasteners is the insert constraint. This allows for the selection of two references - an axis as well as a face - and can significantly speed up the assembly process. Angular constraints can be used to align the hexagonal shaft with hexagonal holes, be sure the 'directed angle' option is selected. Other constraints such as tangent and symmetry are of limited use for this project.

Constraints are not limited to a component's physical geometry, they can also be added to origin planes or axes, as well as work planes, axes or points. This can be useful when aligning the rear pulley to the gearbox pulley, or when constraining the hexagonal shaft to other components.

It will probably be necessary to modify components in the assembly. This is easily done by double clicking on the component within the assembly. The rest of the assembly becomes translucent, and part's modeling operations become visible in the model tree. If the part is within a subassembly, the piece must be double clicked again, until it is the only opaque object. There is no limit to the amount of sub-assemblies within assemblies in Inventor.

One possible modification to make is one to the rear pulley. A hub can be created to act as a spacer, to make sure the pulley does not move between the rear wheel and the frame. The hub will likely need to have different spacing on each side of the pulley.

Cut Frame

Teacher's Guide

Lesson Plan:

Objective:	Export frame design for laser cutting
Focus:	Exporting face to DXF, make drawing
Skills learned:	Exporting a part for a supplier to manufacture
Required material:	Computers running Autodesk Inventor
Support material:	Specially produced video
Exercise:	Prepare part for export in 1 session
Further material:	Checklist, example files
Special considerations:	Supplier will not be able to make part if there are errors / missing information

Teacher Tips:

It's important that this step be performed well in order for the part to be properly manufactured. Any missing information will cause delays in production.

When naming the files, have the students include their group name or number so that every name is unique. Once all of the files have been collected (PDF and DXF for each team), they can all be zipped together and submitted to a laser cutting manufacturer. One reliable manufacturer is CBR Laser, located in Plessisville. They have an online submissions form, generally give estimates within an hour and parts are generally received within a week of confirmation. They do not, however, stock any plastic - this must be supplied by the client. Laser cutting manufacturers in Montreal who stock plastic are Spikenzie Labs and Umake.

It can be tricky to be sure that everything is correct in this step. Do not hesitate to contact FIRST Quebec to help with any issues.

3D Printing

Teacher's Guide

Lesson Plan:

Objective:	Export front wheels and rear pulley for 3D printing
Focus:	Exporting parts as STL file, using correct units, correct orientation of parts
Skills learned:	Preparing a part for 3D printing, submitting part to supplier
Required material:	Computers running Autodesk Inventor
Support material:	Specially produced video
Exercise:	Prepare part for export in 1 session
Further material:	Checklist
Special considerations:	Orientation of part is important, easier for supplier if several parts are in a single assembly

Teacher Tips:

This step is quite a simple one. The most important part is making sure the parts are properly oriented, and that all parts lie on a common plane. Wheels should be oriented such that the Z axis can act like the wheel's axle.

Some 3D printers do not handle overhangs very well. This depends on the technology used. The ones that use a support material can make very complex shapes, while the ones without a support material have more difficulty with this. Depending on the type of printer used, parts with large overhangs may require additional finishing steps (sanding and filing).

A popular printing service is 3D Hubs. This service has people who have their own 3D printers take jobs from the public. The price is set by the printer's owner, so the cost can vary greatly from one owner to another.

Assemble

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Teacher's Guide

Lesson Plan:

Objective: Assemble dragster using custom and supplied components

Focus: Completion of dragster

Skills learned: Mechanical assembly, following a plan

Required material: Custom parts (front wheels, rear pulley, side plates), supplied parts (standoffs, bushings, shafts, bearings, shaft collars, motor, gearbox, gears, fasteners) components, tools (hex keys, wrenches, files, soldering iron)

Support material: Assembly views created by students

Exercise: Finish assembly within 1 session

Further material: Example assembly views, checklist

Special considerations: Teams with complete 3D assemblies and detailed views will have a much easier time

Teacher Tips:

Teams who have produced drawings of the assembled dragster will have an easier time when assembling their final model.

Tools required for assembly are as follows:

- 2.5mm hex key for M4 screws
- 2mm hex key for M3 screws
- 1.5mm hex key for M3 set screws
- 0.9mm hex key for 4mm shaft collars (if used)
- 8mm wrench for M4 standoffs
- 5.5mm wrench for M3 nuts
- 3/32” hex key for hexagonal shaft collars
- Small files (round and flat)

Test Ratios

Teacher's Guide

Lesson Plan:

Objective: Optimize gear ratio in gearbox

Focus: Finding the best ratio for the team's dragster

Skills learned: Gear ratio calculation, plotting ratio vs. time

Required material: Completed dragster, control system, long power wires, 25ft course, stopwatch, assembly tools

Support material: Printout explaining gear ratios and how to plot ratio vs time

Exercise: Test at least 3 different ratios, plot results

Further material: Example plots

Special considerations: Ratio vs time plot will follow a curve. This curve is not necessarily linear; more tests reveal the shape of the curve. Several trials at one ratio can reveal variations.

Teacher Tips:

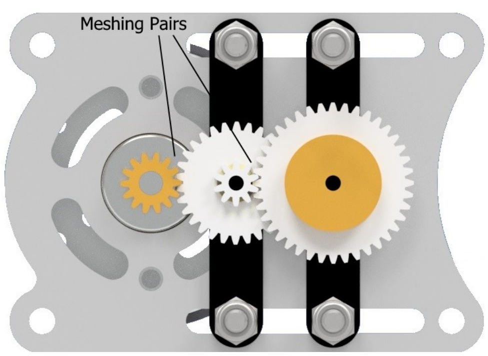
A gear ratio is usually represented in the form X:1, where X is any positive number. The ratio represents the number of turns the motor makes for every rotation of the output. In the ratio 10:1, the motor turns 10 times for every rotation of the output. This means the output has 10 times more torque, but 10 times less speed than the motor. The ratio 0.5:1 has the output spinning twice as fast as the motor with half the torque.

To calculate the gear ratio, the number of teeth of every gear in the system must be known. Isolate pairs of meshing gears, and determine which gear is driving and which is being driven. Divide the number of teeth of the driven gear by the number of teeth of the driving gear. This will give a ratio for a particular pair of gears. Multiply all of these ratios together to determine the final ratio of the gearbox. The result represents X in the ratio X:1.

$$X = \frac{Teeth\ of\ driven\ gear}{Teeth\ of\ driving\ gear} * \frac{Teeth\ of\ driven\ gear}{Teeth\ of\ driving\ gear} * \ldots$$

In the image at right, the motor has 14 teeth, the double gear has 30 and 10, and the output has 40 teeth. The calculation becomes:

$$X = \frac{30}{14} * \frac{40}{10} = 8.57$$



The dragsters' gearboxes will likely have two pairs of meshing gears

The gearbox ratio is 8.57:1, meaning that the for every 8.57 turns of the motor, the output gear and pulley turn once. There is a further reduction between the gearbox pulley and the rear pulley. This can be calculated with the pulley diameters in the same way as the gears. The final ratio determines how many rotations of the motor cause one rotation of the rear wheels.

Race

Teacher's Guide

Lesson Plan:

Objective: Determine fastest dragster with head to head races

Focus: Performance, team dynamics

Skills learned: How to prepare for a competition, how to deal with issues and solve them under pressure

Required material: Dragsters, teams, control system, 25ft course, assembly tools, spare parts

Support material: Awards, timing apparatus

Exercise: Competition

Further material: Tournament control software, example competition format

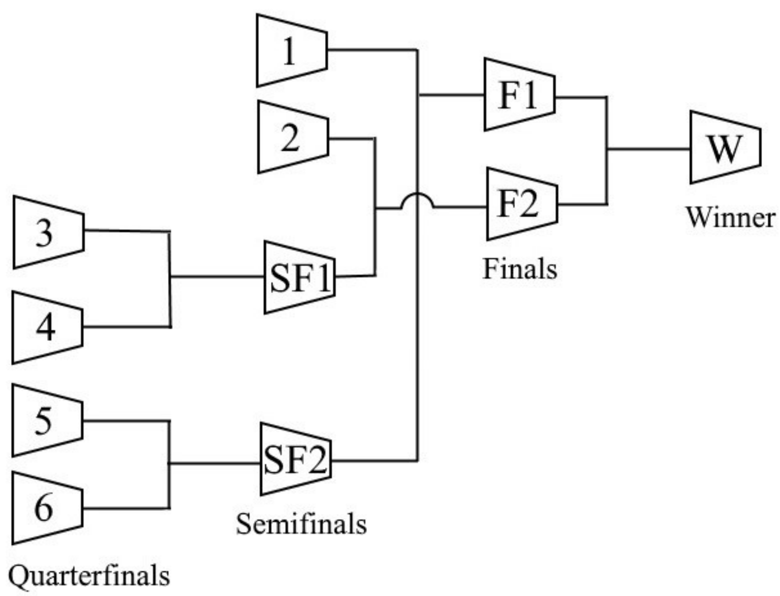
Special considerations: Competition should have two components, heats and eliminations. Heats would allow teams to race against various other teams, and their time would determine a rank. Ranked teams would then compete head to head in elimination rounds to determine a winner

Teacher Tips:

Try to have each team race as many times as possible. Qualifying matches could have each team racing against every other team. This could happen several times depending on how many teams there are. Record the time for every run.

For ranking, consider adding up the times of a team's best three runs. This allows for teams to eliminate bad runs. For playoff rounds, it may be possible to include every team. In order to save time, consider having the top teams skip the first round of playoffs. This gives teams an incentive to perform well during qualifying matches. Depending on the time available, playoff matches can be straight elimination, a best-of series, or cumulative time across several runs.

Multiple prizes can be awarded, not simply one for the fastest dragster. Prizes for best design, creativity, team spirit and imagery can be given, along with any other ones deemed appropriate.



Example of possible playoff bracket