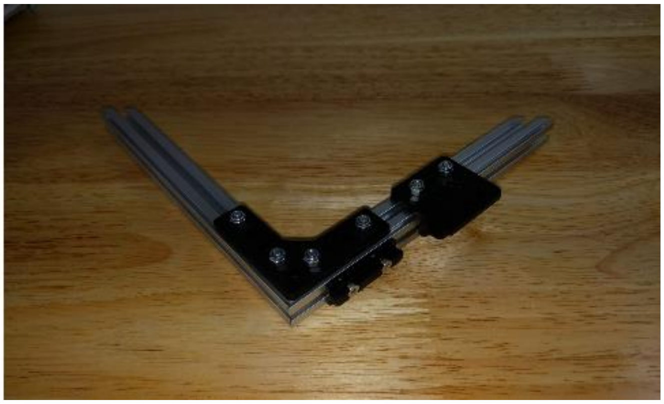
Lifting Mechanisms

The primary scoring method for the 2018 game is to deposit fuel cubes into scoring zones. A manipulator fixed to your robot can deliver fuel cubes into ground level scoring zones, but some method of lifting the cubes will be required to score in the elevated zones. In this example we will explore 3 potential methods of adding vertical lift to your manipulator.

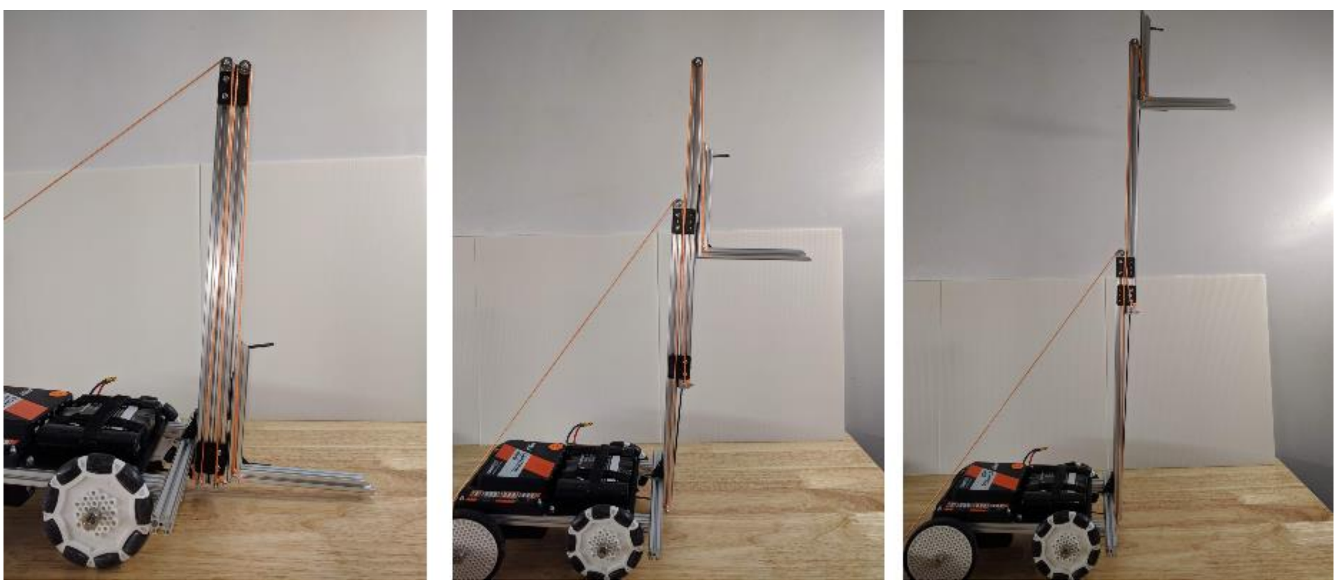
Example 1: Two Stage Lift

The game provides scoring opportunities for fuel cubes at up to approximately 60cm in height. In order to place fuel cubes in these scoring zones you will need to lift them at least 60cm. One method to achieve this goal in a very compact size is to create a telescoping lift, similar to fork lifts that are used in warehouses. Telescoping lifts are often labeled by the number of independent moving sections, known as *stages*. The longest sections of aluminum extrusion provided in the kit are 45cm in length, which means that a single stage lift will be limited to less than 45cm of height. In this example we will double the usable lift height by creating a two stage lift, which will provide the desired 60cm of height.

A great build guide for multi-stage lifts is available from REV robotics that will form the basis of our lift (http://www.revrobotics.com/content/docs/LiftKit-Guide.pdf). The cascading string method was chosen for this example, but a continuous string is equally effective. Instead of 2 full length stages as in the REV guide we will use a 45cm base extrusion, a full length stage with a 45cm extrusion, and shorter 2nd stage using a 15cm extrusion in order to reduce weight. The shorter stage was created by installing the single sided slider and one double sided slider as in the REV example, but one additional double sided slider was installed to the extrusion for better stability with the short length. In the pictures you will also see that there is another 15cm extrusion in place to act as a manipulator attachment area, but you should use whatever is needed for your manipulator.



As an example, this lift was installed on the practice bot. For use on a competition robot you will want to brace the lift to the frame with additional extrusions, as this install flexes excessively. You can see from the operation pictures that a high lift is achieved (over 60cm) while taking up very little space on the robot.



Additional notes:

1. Experiment with the slider installation method to understand how to minimize friction in the lift. A smooth lift will function more reliably and use less power.
2. The lift will operate best if you avoid placing a heavy load extended far from the sliders. Try to

balance the weight as well as you can.

3. Be careful when driving with the lift fully expended. The weight of a manipulator raised 60cm up can result in your robot tipping over.

Option 2: Single Pivot Arm

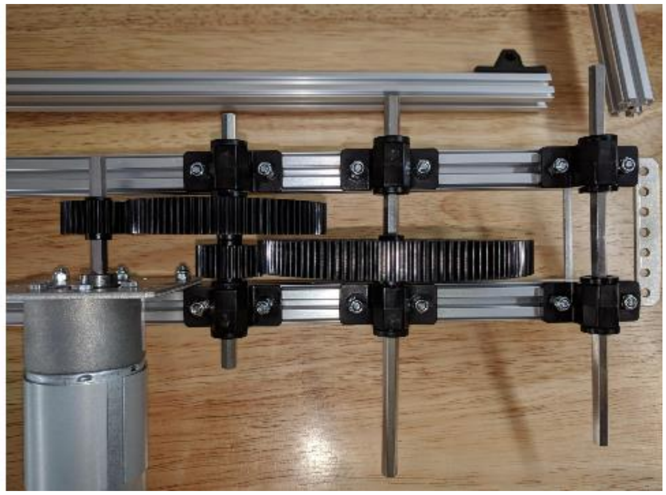
In our next example of a lifting mechanism we will build a motor-driven single pivot arm. With the 45cm extrusions that are available a total lift height of 60cm can be easily achieved as long as we place the pivot point high enough on our robot.

We will be powering the arm with an HD hex motor, but a core hex motor would also work well. The rotation rate and torque output (twisting strength) of the motor will need to be adapted to the purpose of lifting weight with a long arm. In order to do this we will reduce the rotation rate and increase torque via gear reduction. A single stage of reduction using the smallest and largest gear sizes available is not adequate for this purpose. We will need to use at least one additional stage to reduce the gearing further. A simple calculation can be performed to determine the amount of gear reduction you will require for a given arm length and weight, which is described in the REV Robotics motor guide (http://www.revrobotics.com/content/docs/Motor-Guide.pdf)

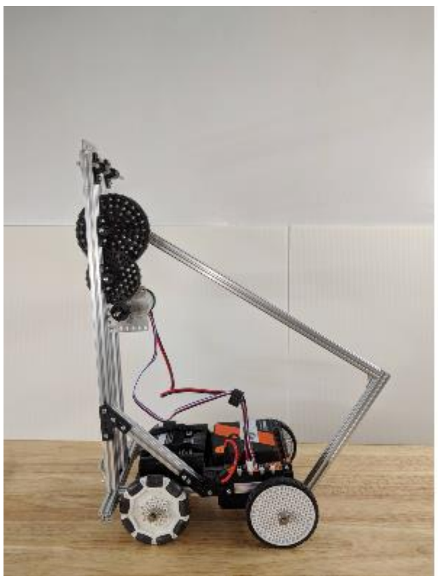
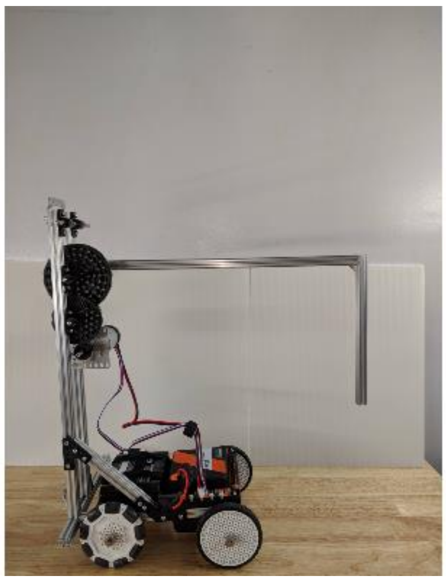
The parts to build a single pivot arm are shown below. Some parts are also shown for the next example of a 4-bar linkage arm, as these two designs are interchangeable. First, we will build the tower that everything will attach to and then the transmission which will power the arm. The tower is simply two 45cm extrusions that are connected at the top and bottom with a pair of re-purposed servo mount brackets to set the correct spacing between them. We then add pairs of pillow blocks for each shaft (only 2 pairs are required for a single pivot arm). A motor mounting bracket with motor installed will complete the parts attached to the extrusions.

The next step is to choose your transmission gears. In this example we have have chosen two 30T gears, one 90T gear, and one 125T gear. One 30T gear is installed on the motor shaft and the other is installed on the lower shaft. Each of these 30T gears are meshed with a larger gear to reduce the speed of the output. In the example the 30T gear on the motor drives the 90T gear on the lower shaft, which in turn spins the second 30T gear, which drives the 125T gear on the output shaft where the arm will be attached. The total reduction ratio for this configuration is (90/30)*(125/30) = 12.5. This means that the top shaft will spin 12.5 times slower than the motor and produce 12.5 times as much torque.

Finally, we will create an arm. For this simple example we will join a 45cm extrusion and a 22.5cm extrusion with a 90 degree bracket to form the arm structure. A hex pillow block is then installed at the end of the 45cm extrusion. The arm is installed to the transmission by pressing the hex pillow block onto the upper transmission shaft. For demonstration and experimentation purposes the tight fit of the bearings and hex pillow block on the shafts is adequate to hold the pieces in place. For extended use you will need to install shaft collars on the ends of each shaft or the parts will come loose. A high strength hex hub can also be tied into the arm for enhanced strength.

The images below show the assembled arm system installed on the practice bot. Note the brace that was added to the bottom of the arm support tower for stiffness. These three pictures show the arm at three points in its range of motion, approximately 45 degrees apart. The raised position easily achieves 60cm of height, but also rotates the arm end 45 degrees from vertical. This could be either an advantage or disadvantage, depending on the design of your manipulator.

Additional notes:

1. With a heavy load on the arm, one of the gears will likely be damaged. This can also occur from driving into objects with the robot. To avoid this, you can stack multiple gears together to share the load as shown in the REV Robotics gearing guide (http://www.revrobotics.com/content/docs/Gear-Guide.pdf).
2. Instead of gears, the transmission can be made with chains and sprockets for improved durability.
3. Since this arm is unable to slip relative to the motor, the encoder output can be used to determine rotation angle for precise control without additional sensors. You will need to account for the transmission gear ratio in your calculations. It may also be a good idea to add

an end stop sensor at the lower end of the arm travel to set a zero point in the control software.

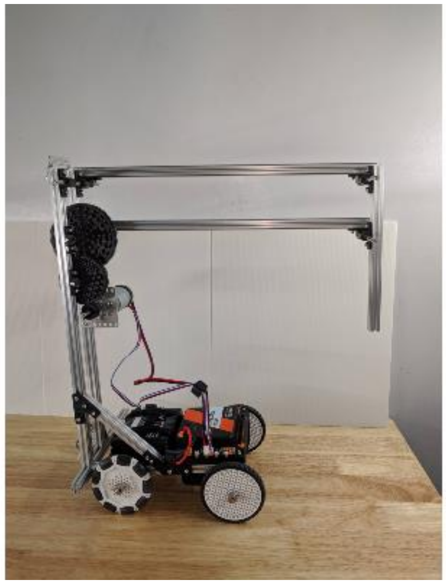
4-Bar Linkage Arm

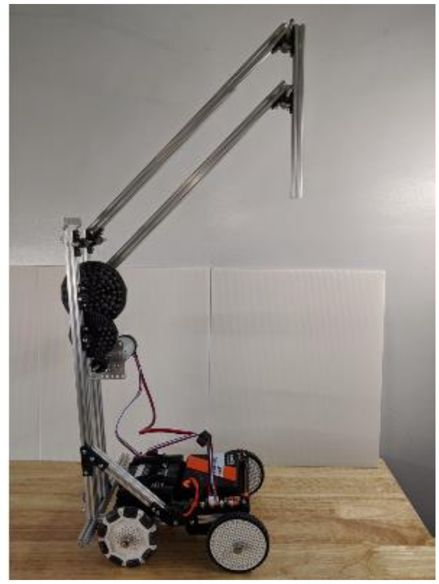
As mentioned in the pivoting arm example, the rotation of the arm end as it is pivoted can cause difficulties in use. By the addition of a linked arm you will gain the ability to control the rotation of the arm end throughout its travel range, though at the cost of additional weight and complexity. The 4-bar linkage and similar designs are commonly used for automobile suspension systems to ensure that the wheel stays vertical for optimal tire contact with the road surface.

In this example we will use parallel bars for all links in the system to achieve planar motion, which means that the arm end remains at the same angle throughout the travel range. For some use cases you may want the arm end to rotate out of plane as it raises and lowers. Changing the length of individual bars and spacing between the bar pivots will provide such rotation. You are encouraged to experiment with this to understand how rotation can be accurately controlled using a linkage arm. If you know the angle of the bar attached to the gears and the distance between all pivots the angles of the other bars can be readily calculated at any point throughout the travel.

The parts required to create a 4-bar linkage arm are the same as for the single pivot arm, with the addition a few extra pieces. In the top of the picture below you can see the single pivot arm (left) next to the linkage arm (right). To make the linkage arm we will begin by installing another pair of pillow blocks and a shaft with bearings at the top of the arm support tower above the transmission output shaft. We will then install one pillow bearing block and one hex pillow block on two 45cm extrusions, at opposite ends of each extrusion. Next, install two hex pillow blocks on a 22.5cm extrusion, set the same distance apart as the top shaft and transmission output shaft on the support tower. Simply press shafts into the hex pillow blocks on the 22.5cm extrusion and then the press the other ends of the arms onto the support tower shafts. As mentioned for the single pivot arm, shaft collars should be added to all shafts for extended use to avoid spontaneous disassembly.

The assembled 4-bar linkage arm in shown in the set of 3 pictures below, mounted to the practice bot. You can see that through the entire range of motion the end of the arm stays vertical.





Additional ideas:

1. As mentioned for the non-linkage arm design, large loads will require a stronger transmission for reliability. Below are some images of an alternative design that replaced the second stage of the transmission with a chain and sprockets.