Motion from industry:
There are many industrial robotic applications. Many of them involve some rearrangement of objects, for example, parts on a conveyer belt. Standard approach would be moving and separating one by one. We want to manipulate many objects at the same time and make these applications more efficient.

Broader relevance:
In our lab, we are interested in the manipulation of object ensembles. These are large groups of mechanical and biological objects that all move in response to the same applied forces and are coupled by local interactions. These systems are typically non-linear, high-dimensional, and under actuated.

Goals
- Design of wiper blade that will attach to the arm of the robot. This wiper blade is made of two aluminum pieces held together by two L-brackets.
- Create a parameterized trajectory that will successfully move an object from one given point to the next given point for a motion primitive
- Implement program into C++

Fundamental Questions/Challenges
- What trajectory would be the most useful for object manipulation?
- How should the trajectory be parameterized?
- Is it always possible to rearrange a large group of objects using a given trajectory?

Research Plan
- Create a trajectory that moves the wiper blade perpendicular to the length of the blade:
- Compute a sequence of waypoints that cause the robot to execute the trajectory:
  1. Robot Origin
  2. Next step: Move down z-axis
  3. Move to new x, y-coordinate
     \( (x + d \cos \Theta, y + d \sin \Theta) \)
  4. Move back up z-axis
- Implement the trajectory in C++ and integrate it with the robot control software

Research Results
- The algorithm that was used in the program ran a successful trajectory
- The above graph shows the object beginning at the robot origin and moving to its first position. It then moves down the z-axis and over a distance and a theta. It then moves back up the z-axis
- Future hardware improvement: The wiper blade needs a strip of rubber attached to it.
- Future work will focus on planning sequence trajectories to move around large groups of objects