**describe the build process, and potentials for scaling the demonstration larger or smaller**

The large-scale Gravity-Based model used to demonstrate parallel assembly was manufactured from laser cut acrylic, plastic dowel rods and 1/8” by 1/8” neodymium magnets. The workspace was made from a two by one foot sheet of quarter inch thick white acrylic. A laser cutter was used to make a grid of slider tracks an eighth inch deep in the workspace as well as four holes around each intersection of the grid for stop blocks to be securely placed. The tracks were sanded to remove excess material and soften sharp edges. The stop blocks are made of similar black acrylic with four plastic dowel rods placed through them so they may be securely placed onto the workspace. The particles or sliders were made from similar red and blue acrylic sheets and are approximately an inch in diameter. The sliders have eight slots laser cut into them to house the neodymium magnets which were then super glued in place and have a small plastic dowel rod inserted in the center to ensure the sliders follow the tracks of the workspace. The bottom of each slider was also sanded to remove sharp edges and prevent the sliders from catching onto the workspace tracks. The placement of the magnets within the sliders was designed to prevent sliders of the same color, or same charge, from repelling each other out of the tracks of the workspace while still maintaining the ability to connect with oppositely charged sliders. A larger scaled model of this demonstration could be built, although some limitations on this would be that a person must be able to properly handle the size and weight of a larger workspace or build a mechanism specifically that can handle the workspace. In the case of reducing the scale of this Gravity-Based demonstration, it would be difficult to do so as manufacturing smaller sliders with the same internal magnet arrangement would pose many challenges. However, a smaller scale demonstration has been successful when using magnetic force as the global input rather than gravitational force.

**this demo uses gravity for a global force, magnetism for connecting, and friction to slow the system. What is the strength of the relative forces?**

When the large-scale demonstration is tilted at an angle of 20 degrees most of the sliders will break free from the average static friction force of 0.0074 Newtons and move across the workspace. At this angle the average force of weight contributing to the motion of the sliders is 0.0092 Newtons, just enough to overcome the friction. Due to the uneven surfaces created to form the grid of the workspace there are instances where friction could halt the motion of a slider, so the workspace and slider must be properly sanded. Since the average magnetic breaking strength of the sliders is 0.1 Newtons, sliders of opposite charge should be able to connect and overcome the force of motion of the sliders. However, there are instances where this connection does not overcome the force of motion due to a slider’s momentum, especially if the slider is not favorably aligned so that the outermost magnets will connect while approaching another slider.

**discuss the difficulties of transitioning from computer simulation to the real world demo, such as the fact that gravitational forces can sometimes overcome the magnetic forces of the sliders, causing them to attach to the wrong slider or not attach at all. Because of this the work space needed to be redesigned to allow the proper assembly to be fabricated.**

When using the large-scale demo to assemble a part with an overhang, such as the part shown in Figure 1(b), certain adjustments need to be made to the workspace to ensure that the overhanging particle will connect to the correct particle or first particle it encounters. Due to the gravitational forces involved in the large scale demonstration there are instances where a slider could miss its initial connection point and slide into a connection with another particle along the assembly. In order to prevent this error, the workspace of the large-scale demonstration was redesigned from the original computer simulation by a trial and error process. This redesign ensured that sliders connecting to one another in a horizontal fashion during a “go down” command remained on the same row of the workspace by placing stop blocks below each slider’s destination. Similarly, when moving an assembled row of three sliders, at least two of these sliders must come to rest against a stop block to ensure the assembled piece retains its shape and proper position.

**what is the maximum size you can make?**

While the workspace of the current large-scale demo is two by one foot, a two by two feet workspace would be the largest workspace that could be made and easily demonstrated in a similar manner. In order to make this size board another two by one foot workspace would have to be made as well as a bottom layer to fasten the two workspaces together without disrupting the surface of the workspace. As far as scaling, the maximum achievable size of the demonstration would realistically depend on the size availability of magnets to use within the sliders.

**what is the repeatability of the system?**

Due to the size of the part hoppers being a four by four grid, when there are one to three sliders in each part hopper the demonstration is highly repeatable with the only issues occurring if the board is not tilted evenly or tilted too quickly. With four sliders in each part hopper the demonstration is only moderately repeatable as the initial movements of the sliders within the part hoppers is more restricted. A large part of this issue is that the sliders must be properly aligned to neutralize their repulsive forces and upon the initial tilt up command a slider could be repelled and prevented from moving completely down the track. When the number of sliders in the part hoppers is increased above four, this affect increases exponentially to the point that a successful demonstration with eight sliders in each part hopper could not be produced. Due to the fact that each slider has eight magnets, when there are eight sliders in such close contact with one another the magnetic field becomes highly complex and a simple group translation is impeded.