1. *Experimental setup:* The Gravity-Based model utilizes a white workspace to represent available movement space, red sliders to represent positively charged particles, blue sliders to represent negatively charged particles and black stop blocks to represent obstacles in the workspace. This model uses gravity as a global input to manipulate the red and blue sliders through the workspace and assemble parts in a very similar manner to the simulation.
2. *Construction and assembly:* The large-scale, reconfigurable, Gravity-Based model used to demonstrate parallel assembly was manufactured from laser cut acrylic, plastic dowel rods, and 3.175 by 3.175 by 1.5875 mm neodymium magnets. The workspace was made from a 0.61 by 0.305 meter sheet of 6.35 mm thick white acrylic. A laser cutter was used to make a grid of slider tracks 3.25 mm deep and 3.25 mm wide in the workspace as well as four holes with a diameter of 3.2 mm 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 25 mm in diameter. The sliders have eight laser cut slots to house the neodymium magnets 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 sanded to remove sharp edges, allowing smooth travel through the workspace tracks. The placement of the magnets within the sliders was designed to prevent sliders of the same charge from repelling each other out of their tracks while still maintaining the ability to connect with oppositely charged sliders.
3. *Forces Involved:* 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 if not 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 high tilt angle needed to break static friction.
4. *Modifications for real world model:* 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. 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.
5. *Repeatability:* 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 unless 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 “go 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 rapidly from the high number of magnetic fields interacting with one other. Due to this issue, a fully successful demonstration with eight sliders in each part hopper could not be produced.
6. *Scaling:* A larger scale model of this demonstration could be built, although some limitations include the size availability of magnets to use within the sliders and a person’s ability to properly handle the size and weight of a larger workspace. To circumvent this second issue a mechanism could be built specifically to 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.