

# Manufacturing Track

## Task 1: Board Assembly/Disassembly

### *Overview:*

In Task 1, a manufacturing task board is premade and placed on a table alongside a bowl. All CAD models are available and should be leveraged where possible. During the first subtask, nuts, gears, pegs, and male electrical connectors are already inserted on the board. The goal is to remove all nuts, gears, pegs, and male connectors from the board, and place them in a bowl located adjacent to the board. During the next subtask, the same task board and parts will be used where nuts, gears, pegs, and male electrical connectors are placed in a kit. A kit is a collection of parts where parts are often organized in a portable tray. The parts can be fixtured within the tray or randomly placed on the tray. The goal is to remove all nuts, gears, pegs, and male connectors from the kit, and place them in the task board. Basic points are scored for completing the assembly/disassembly operations using an autonomous robot system. Bonus points are awarded based on the following:

- 1) Teams fixture the task board, kit/bowl and individual part locations within the kit (lead through programming technique) – no bonus points
- 2) Teams use a marker based perception system (e.g. reflectors, AR tags, QR codes), where markers are attached to the board/kit/bowl to determine their locations and parts locations within the kit are known to competitors. – partial bonus points (Tier 1)
- 3) Teams use perception system (no markers) to locate board, kit/bowls, and all parts that are placed randomly within the kit. – full bonus points (Tier 2)

### *Parts (figure 1a & 1b):*

- 1) Board with slip-fit holes for pegs, bolts, female connectors, and gear guide rods.
- 2) Standard metric nuts of various sizes
- 3) Standard metric gears of various pitch diameters
- 4) Metric pegs of various diameters and cross-sectional shapes
- 5) Various male electrical connectors
- 6) Bowl from service track
- 7) Randomized kit for placing parts to be picked up (subtask 2 only)

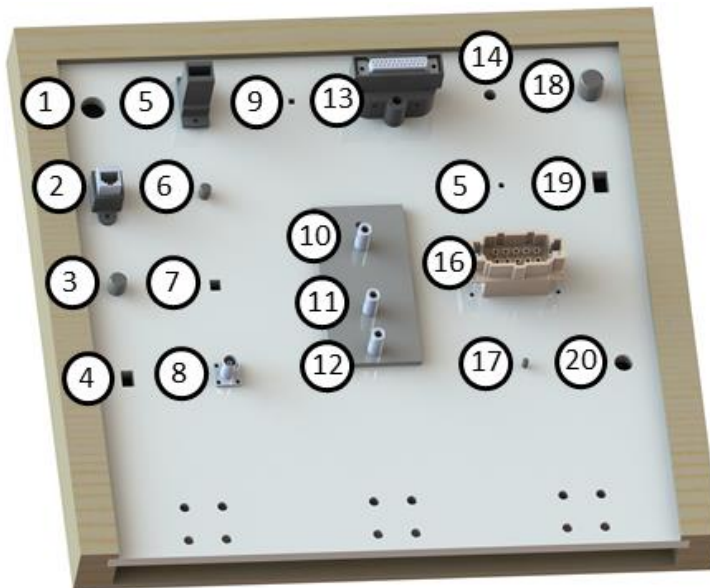
### *Supporting Material:*

<https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-competition-manufacturing>

This task consists of the following two subtasks:

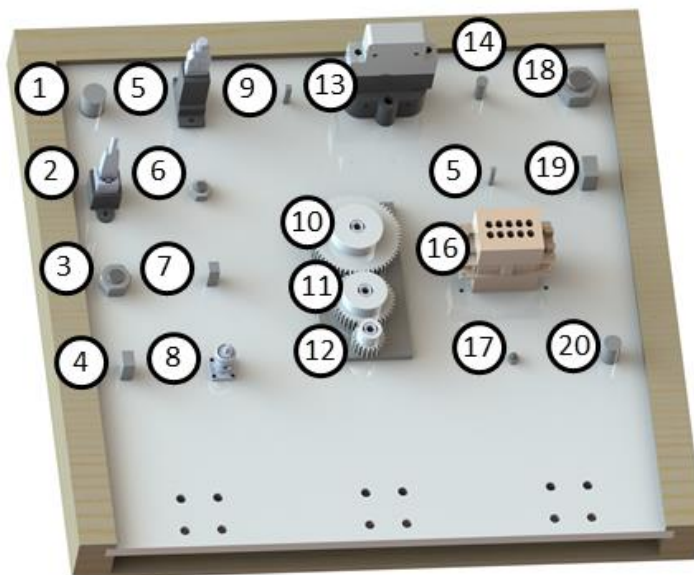
Subtask 1: Board Disassembly

Subtask 2: Board Assembly



(a)

- (1) 16 mm hole
- (2) RJ45 Female Connector
- (3) M12 Bolt
- (4) 12 mm x 8 mm hole
- (5) USB Female Connector
- (6) M8 Bolt
- (7) 8 mm x 7 mm hole
- (8) BNC Female Connector
- (9) 4 mm x 4 mm hole
- (10) Large Gear Shaft
- (11) Medium Gear Shaft
- (12) Small Gear Shaft
- (13) DSUB Female Connector
- (14) 8 mm hole
- (15) 4 mm hole
- (16) Female Waterproof Connector
- (17) M4 bolt
- (18) M16 bolt
- (19) 16 mm x 10 mm hole
- (20) 12 mm hole



(b)

- (1) 16 mm peg
- (2) RJ45 Male Connector
- (3) M12 Nut
- (4) 12 mm x 8 mm peg
- (5) USB Male Connector
- (6) M8 Nut
- (7) 8 mm x 7 mm peg
- (8) BNC Male Connector
- (9) 4 mm x 4 mm peg
- (10) Large Gear
- (11) Medium Gear
- (12) Small Gear
- (13) DSUB Male Connector
- (14) 8 mm peg
- (15) 4 mm peg
- (16) Male Waterproof Connector
- (17) M4 nut
- (18) M16 nut
- (19) 16 mm x 10 mm peg
- (20) 12 mm peg

Figure 1: (a) Task board and base parts prior to assembly, (b) Fully assembled task board

### Subtask 1: Task Board Disassembly

*Difficulty:* Level 4

*Description:*

A fully assembled manufacturing task board is placed on the table alongside a bowl. Its location can be predefined by the team or arbitrarily placed within a defined region by the competition staff to test perception solutions. Perception solutions qualify for bonus points as indicated in the scoring section below. Nuts, gears, pegs, and male electrical connectors are already inserted on the board. The goal is to remove all nuts, gears, pegs, and male connectors from the board, and place them in the bowl. Points are assessed on a per part basis.

*Base Time Limit:* 20 minutes

*Number of parts to disassemble: 20*

*Achievable Points:* 100 (includes maximum perception bonus) + Time bonus

*Setup:*

- 1) Team fixes location or judge randomizes location (for bonus points) of assembled task board on table (see Figure 2)
- 2) Team fixes location or judge randomizes location (for bonus points) of bowl on table

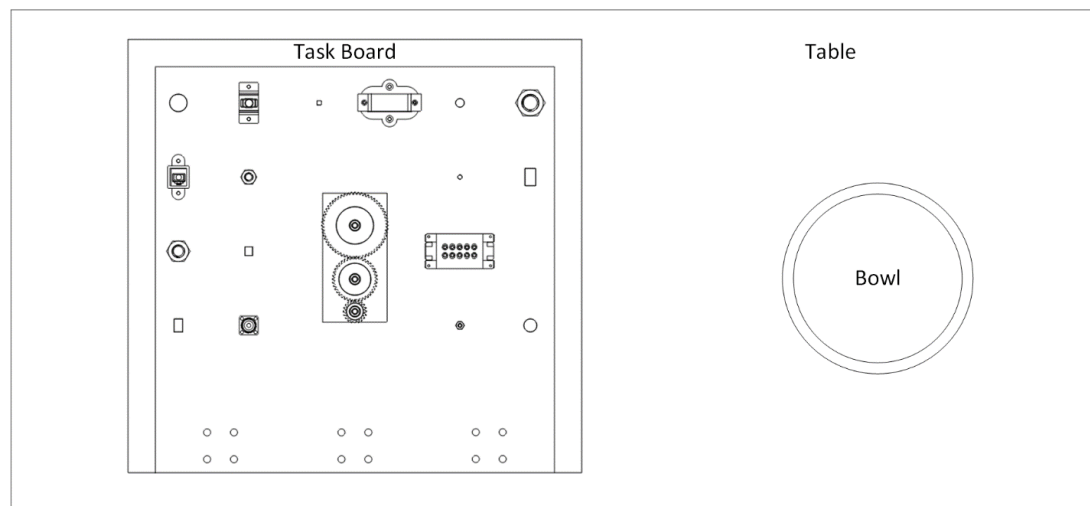


Figure 2: Layout for subtask 1

*Steps:*

- 1) The robot system disassembles a part from the task board
- 2) The robot system places the removed part into the bowl
- 3) Repeat steps 1 and 2 for each part

*Scoring:*

- 1) 2 points for each part removed from the board
- 2) 1 point for each part placed into the bowl
- 3) Perception Bonus:
  - a. 1 bonus point for each part removed from boards that were located using board mounted markers (e.g. reflectors, AR tags, QR codes)
  - or-
  - b. 2 bonus points for each part remove using an independent perception system (no markers attached to board)
- 4) Time Bonus:
  - a. Boards that were located using board mounted markers (e.g. reflectors, AR tags, QR codes)  
 $Time\ bonus = INT((base\ time[sec] - spent\ time[sec]) / 20) \times 1\ point$
  - b. Using an independent perception system (no markers attached to board)  
 $Time\ bonus = INT((base\ time[sec] - spent\ time[sec]) / 10) \times 1\ point$

*Rules:*

- 1) All bonus points are forfeited if manual registration, lead through programming is used, or placement of task board and bowl in team specified locations.
- 2) Time bonus points are only available if all 20 parts are successfully disassembled and placed into the bowl.
- 3) A part is considered removed from the task board even if it is dropped by the robot system.
- 4) No manual or teleoperated intervention by human operator (e.g., no manual tool changes)
- 5) No restriction on number of arms, grippers, sensors used.
- 6) Use of hand tools is allowed provided the robot acquires these tools without human assistance.
- 7) Markers may not be placed on the individual insertion parts
- 8) Working area is the area where the end-effector of the robot is allowed to move. The maximum size of the working area is the table top which is estimated to be 1.5 x 0.75 meters. Judges will work with teams to achieve random placement of board and kits fits within the dexterous work volume of the robot system.
- 9) Multiple resets are allowed within the subtask. The robot system must resume autonomous operation at the point of failure.

## Subtask 2: Task Board Assembly

*Base Time Limit:* 40 minutes

*Number of parts to assemble:* 20

*Achievable Points:* 200 (includes maximum perception bonus) + Time bonus

### *Description:*

The manufacturing task board and kit is placed on the table. Location can be predefined by the team or arbitrarily placed within a defined region by the competition staff to test perception solutions. Perception solutions qualify for bonus points as indicated in the scoring section below. Nuts, gears, pegs, and male electrical connectors are placed on their respective locations on the kit, with optional randomized layout. The goal is to pick all nuts, gears, pegs, and male connectors from the kit, and assemble them into their defined locations on task board. Points are assessed on a per part basis.

### *Setup:*

- 1) Team fixes location or judge randomizes location (for bonus points) of disassembled (empty) task board on table (see Figure 3)
- 2) Team fixes location or judge randomizes location (for bonus points) of kit on table
- 3) Parts to be assembled are placed in respective locations on kit fixed by teams or randomized by judges (for bonus points)

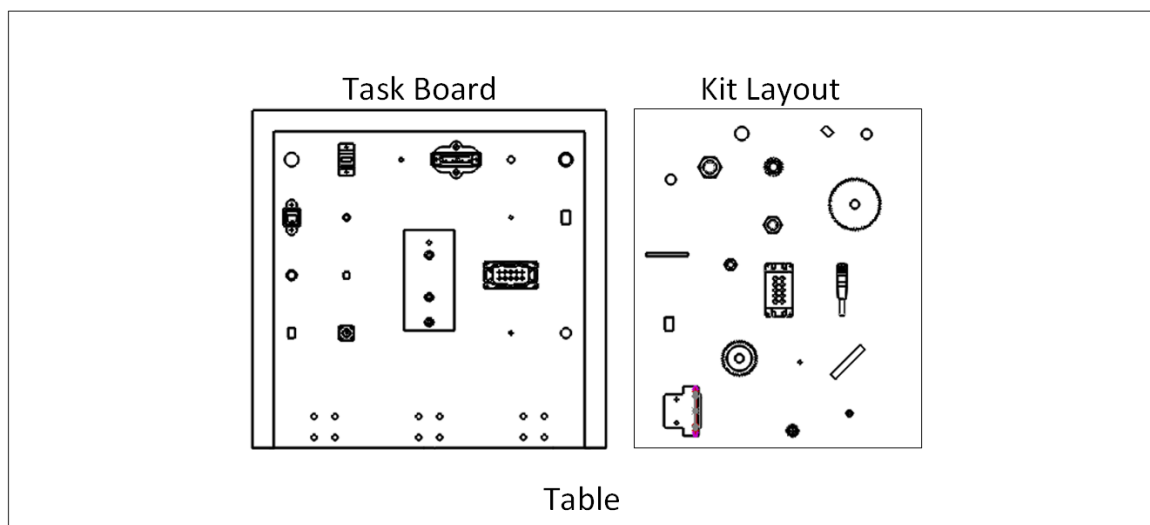


Figure 3: Layout for subtask 2

*Steps:*

- 1) The robot system picks up a part from the kit
- 2) The robot system assembles the part into its location on the board.
- 3) Repeat steps 1 and 2 for each part.

*Scoring:*

- 1) 2 points for each part that is picked up from the kit layout.
- 2) 1 points if the part contacts the assembly board surface before the grasp is removed, including drops onto this surface.
- 3) Up to 3 points for each part assembled using the following criteria

Part Type	Points	Description
nuts	2	Nut cannot be lifted off bolt and freely turns to tighten
	1	Nut is fully threaded and seated against board
gears	2	Insert gear onto shaft seated against board
	1	Gear mesh (1st gets a point when 2 <sup>nd</sup> gear is meshed with it)
pegs	2	Insertion into hole
	1	Constrain bottom of peg against underlying surface to board
connectors	2	Insertion into corresponding connector
	1	Fully seated or snapped connection

4) Perception Bonus:

- a. 1 bonus point for each part that is picked up from the kit layout using kit mounted perception markers (e.g. retro-reflectors, AR tags, QR codes). In this case, the teams can fix markers to the kit. Teams can use any method to secure the parts location in the kit.

-or-

- b. 2 bonus points for each part that is picked up from the kit layout using an independent perception system (no markers attached to kit). Part locations with the kit are set by competition staff and are **unknown** to the teams.

-and-

- c. 1 bonus point for each part assembled that receives at least 2 assembly points per the above table using board mounted perception sensors (e.g. retro-reflectors, AR tags, QR codes)

-or-

- d. 2 bonus points for each part assembled that receives at least 2 assembly points per the above table using an independent perception system (no markers attached to board)

5) Time Bonus:

- a. Completed boards that were located using board mounted markers (e.g. reflectors, AR tags, QR codes)

*Time bonus =  $INT((base\ time[sec] - completion\ time[sec]) / 20) \times 1\ point$*

- b. Completed boards that used an independent perception system (no markers attached to board)

*Time bonus =  $INT((base\ time[sec] - completion\ time[sec]) / 10) \times 1\ point$*

*Rules:*

- 1) All bonus points are forfeited if manual registration, lead through programming is used, or placement of task board and bowl in team specified locations
- 2) Time bonus points are only available if all 20 parts are successfully assembled onto the board.
- 3) No manual or teleoperated intervention by human operator (e.g., no manual tool changes)
- 4) No restriction on number of arms, grippers, sensors used
- 5) Use of hand tools is allowed provided the robot acquires these tools without human assistance
- 6) Points only awarded for assembly of a part into its designated location. (e.g. no points for inserting 8mm peg into 16 mm hole)
- 7) Markers may not be placed on the individual parts to be assembled
- 8) Randomized locations may require reorientation of parts to be assembled
- 9) Working area is the area where the end-effector of the robot can move. The maximum size of the working area is the table top which is estimated to be 1.5 x 0.75 meters. Prior to the competition, competitors must mark the dexterous work volume of the robot system using tape.
- 10) Multiple resets are allowed within the subtask. The robot system must resume autonomous operation at the point of failure.

## **Time Shift**

60 (=20 + 40) minutes are allotted to each team including setup time for completing subtask 1 and subtask 2. A team can stop subtask 1 and move on to subtask 2 anytime. Subtask 1 may not be worked once subtask 2 is started. A team can divide the time between subtasks as desired. After 60 minutes, Task 1 activities must be stopped.

Note: Time for placing the parts and tray at arbitrary location by competition staffs will be excluded from 60 minutes allotted time.

**The information contained within this document is subject to change.**