

IROS 2019 Grasping and Manipulation Competition: Manufacturing Track - Task Rules

Background

We are entering a new manufacturing era where more and more small and medium sized enterprises (SMEs) are looking to implement robotic solutions into their production operations. SMEs represent the majority of manufacturers worldwide and they most often produce in batches with product variation from batch to batch, often called high-mix, low-volume production. To support production in such an environment where robot expertise is often limited, and cost is always a factor, robot systems must be easy to deploy and reconfigure with minimal retooling.

Assembly is one of the most difficult operations for robots, often relying on specialized tooling or jigs to ensure that a part can be positioned by a robot within the required assembly tolerances. These positioning tolerance requirements can also lead to time consuming robot programming strategies to precisely align a part for assembly. This competition challenges teams to develop robot systems that are easy to deploy and program with the goal of handling small batch assembly operations with part variations between batches. The robot systems will also be tested on their ability to disassemble parts.

Teams will compete with the goal of disassembling and assembling a task board containing a variety of insertion, meshing, screwing, and deformable material routing operations using an autonomous robot system. Less time spent fixturing and programming the system for operation will inevitably lead to more components being disassembled and assembled in the allotted time and possibly time bonus points upon full completion of the process faster than the allotted time. The main system components expected to achieve a truly autonomous system include one or more of the following: vision sensors, force sensors, robots, robot hands, flexible gripper systems and hand tools as well as the use of part and assembly CAD data.

Teams should design and test the operation of their systems prior to the competition using the three task boards and associated parts found at: <https://www.nist.gov/el/intelligent-systems-division-73500/robotic-grasping-and-manipulation-assembly/assembly>. These initial task boards will be used by teams to qualify for the competition. More details on this can be found on the manufacturing track website. All information submitted for review by the competition organizers will be kept confidential. Prior to the competition date, teams will be given designs for a practice task board containing all components that will be used on the actual competition task board.

A new task board and parts to be disassembled and assembled will be used for the competition where part locations on the task boards and kit layout are different from the practice set, but the parts to be disassembled/assembled remain the same. The location of the task components will be randomized as described in the Setup section below. In addition, CAD data for the parts and task board will be supplied at time zero of the competition via a USB thumb drive. These files will contain the new designs of the task board and kit layout in the same formats provided with the practice materials. During the competition, the task boards must first be disassembled and then assembled by the competing robot systems per the following rules.

Overview

The manufacturing track is composed of two sub-tasks: disassembly and assembly. The disassembly subtask 1 starts with a fully assembled task board where components are removed from the task board and placed in a kit. The assembly subtask 2 starts with an empty task board, where components are presented in kit form and assembled onto the task board. Team rankings will be determined by the results of these two sub-tasks. The task board presented with these rules closely resembles the practice and competition task boards. These rules are tentative and subject to change. Figure 1 shows the practice board for which designs were distributed to teams several months before the competition.

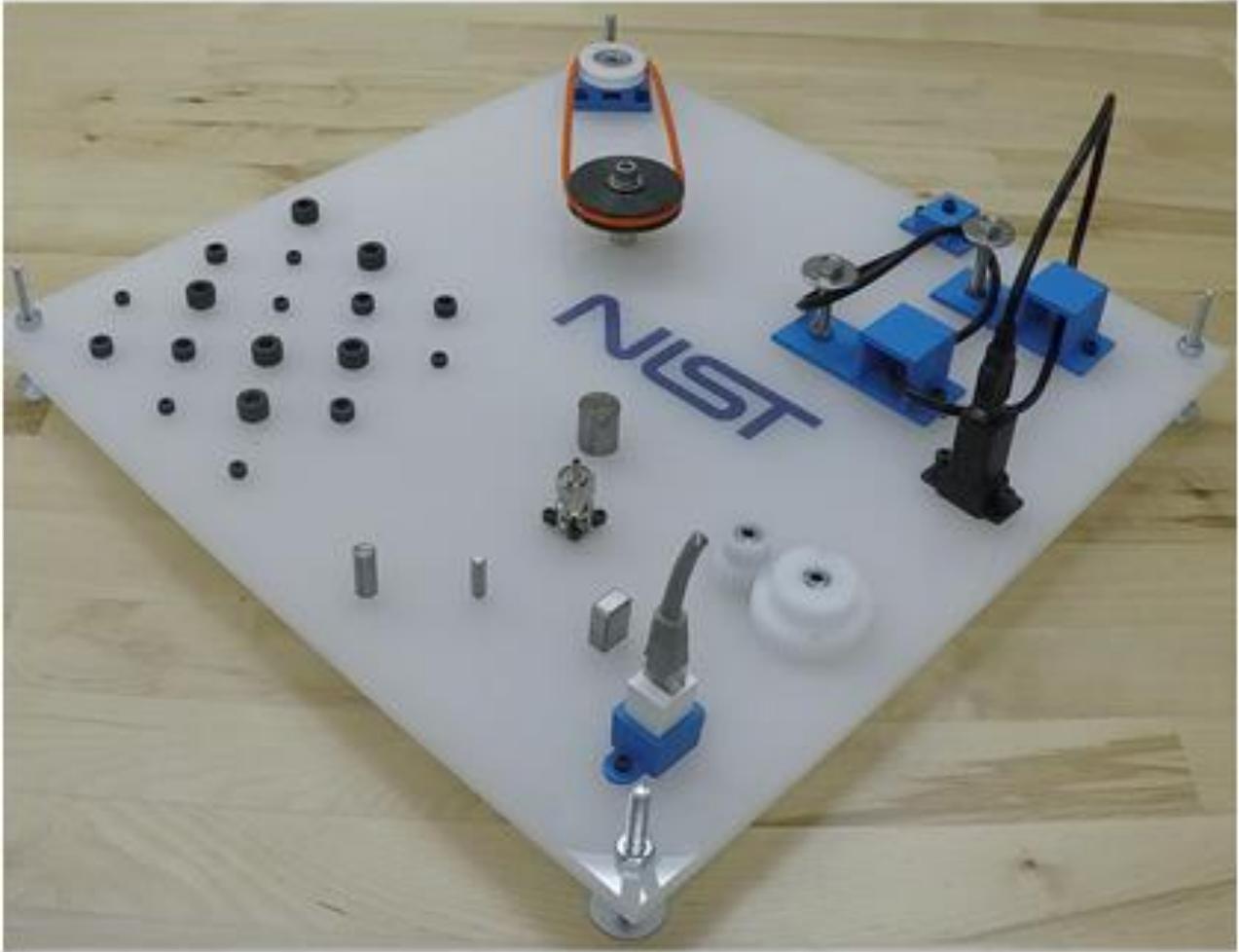


Figure 1: Fully assembled practice task board

Task: Board Disassembly/Assembly

Parts (figure 1a & 1b):

- 1) Board with slip-fit holes, threaded holes, female electrical connectors, cable routing components and initial belt drive components.
- 2) Components (tentative):
 - a. Metric pegs of various diameters and cross-sectional shapes
 - b. Standard Socket Cap Screws (sizes M4, M6, M8) course thread
 - c. Various male electrical connectors
 - d. Gears
 - e. USB cable
 - f. Belt drive assembly components
- 3) Kit mat
- 4) Computer Aided Design (CAD) data for all parts and the task board.

This task consists of the following two subtasks:

Subtask 1: Board Disassembly

Subtask 2: Board Assembly

Setup

Prior to the start of the competition, teams must define the planar workspace of their robot system on the table surface. Teams will be given a roll of black electrical tape to mark this work area that must be at minimum dimensions of 60 cm x 100 cm. They will then be given three stickers to mark the approximate center locations for the task board, kit tray (disassembly subtask) and kit layout (assembly subtask). Competition organizers will then define placement areas for the task board (Velcro), kit tray (Velcro), and kit layout (adhesive tape) and each will be placed randomly about the defined sticker locations. Teams may inform the judges of their preferred general object orientation (i.e. side of task board which faces a robot). Random planar, linear offsets relative to the stickers and object centers will be kept at less than 10 cm in any direction and less than 30 degrees about the axis normal to the table. All objects will be fixed flat to the table surface. Methods for dispensing screws to the robot system for assembly are at the discretion of the teams and this can be done outside of the defined work area. Figure 2 shows the initial setup.

Note: Practice task boards and associated parts must be stored as to not interfere with the competition.

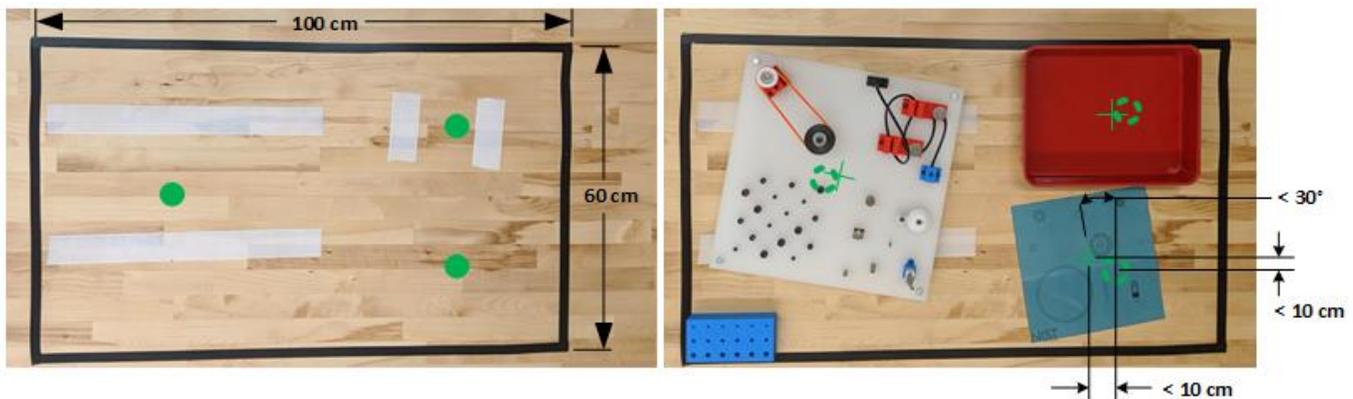


Figure 2: The initial layout as defined through a cooperative effort between teams and judges

Subtask 1: Task Board Disassembly

Description:

Screws, pegs, gears, male electrical connectors, routed cables, and belt drive components are already assembled on the task board. The goal is for the competing robot system to remove all non-permanent components from the board and place them in the predefined kit space. Points are assessed on a per part basis.

Base Time Limit: 40 minutes

Number of disassembly operations: 32

Achievable Points: 92 + Time bonus

Setup:

- 1) No additional setup required

Steps (Judge records start time):

- 1) Expedient teaching methods applied if applicable. (teams cannot change setup)
- 2) The robot system disassembles a part from the task board
- 3) The robot system places the removed part into the associated kit tray
- 4) Repeat 2) and 3) for all parts.

(Team informs judge to record end time and assess)

Scoring:

- 1) 2 points for each part removed from the board (plus 2 points for removal of cable from each router)
- 2) 1 point for each part placed into the kit tray
Note: USB connector cannot contact task board assembly, it is not necessary to place any portion of the USB cable into the kit tray.
- 3) Time Bonus: $Time\ bonus = INT((end\ time[sec] - start\ time[sec]) / 32) \times 1\ point$

Rules:

- 1) Time bonus points are only available if all removable parts are successfully disassembled into the kit tray (maximum points achieved) as shown in Figure 3.
- 2) A part is considered removed from the task board even if it is dropped by the robot system.
- 3) No points for placement in kit tray if part touches the table surface.
- 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 (e.g., wrenches, electric drivers) is allowed provided the robot acquires these tools without human assistance.
- 7) Perception system markers (e.g., reflectors, AR tags, QR codes) may not be placed on the individual parts to be disassembled.
- 8) Perception system markers can be placed on the task board and kit.
- 9) Working area is the area within which the end-effector of the robot can move. The maximum size of the working area is the table top which is estimated to be 150 cm x 75 cm.
- 10) A reset is allowed in order to make program changes or repair/secure a task board. During a reset, teams must reassemble all parts on the task board. All accumulated points are reset to zero. The clock continues to run throughout the reset. Organizers will supply replacement boards or parts to teams as necessary, while supplies last.

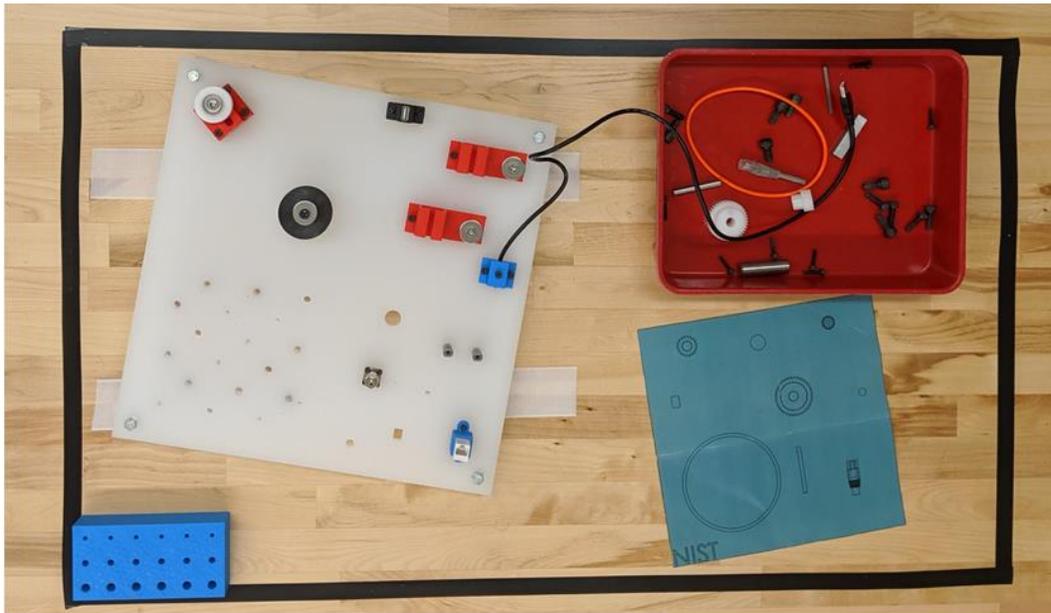


Figure 3: Fully disassembled Task Board

Subtask 2: Task Board Assembly

Base Time Limit: 80 minutes

Number assembly operations: 32

Achievable Points: 181 + Time bonus

Description:

Pegs, male electrical connectors, routed cables, screws and belt drive assembly components are placed on designated locations in the kit area by the team. The goal is for the robot system is to pick all screws, pegs, gears, male electrical connectors, routed cables, and a belt drive assembly from the kit layout/bolt dispenser and assemble them into their defined locations on task board. Points are assessed on a per part basis.

Setup:

- 1) Teams gather all components (from task board, table, and kit tray) and place them on kit layout. Belt is placed on the mat roughly centered on the concentric circle template. Judges ensure that the task board is empty, and the layout is correct. A second set of screws is provided so that teams can have the dispensing system already set up. Teams can remove the kit tray from the work area if desired.

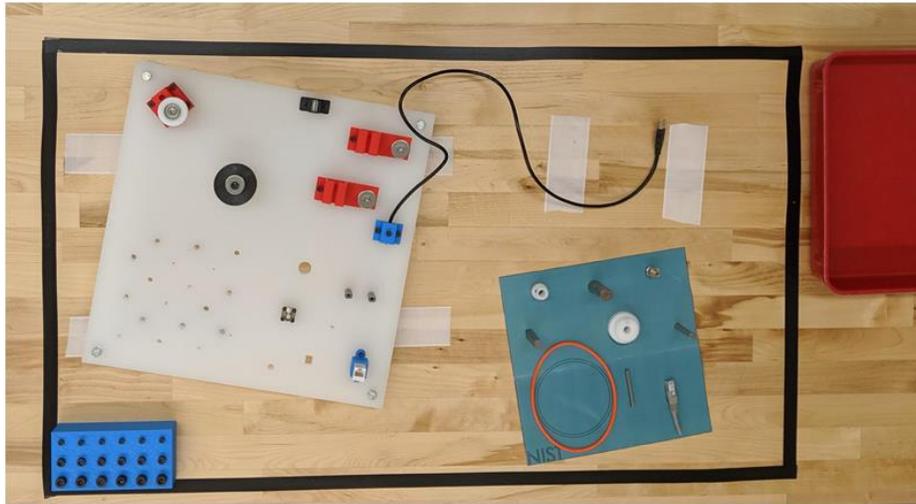


Figure 4: Layout for assembly-subtask 2 showing task board and kit layout with a method of dispensing screws.

Steps (start time = end time from subtask 1):

- 1) Expedient lead through programming methods applied if applicable.
Note: teams cannot change setup
- 2) The robot picks a part from the kit layout.
- 3) The robot system assembles the part into its location on the board.
- 4) Repeat 2) and 3) for all parts.

(Team informs judge to record end time and assess)

Scoring:

- 1) 1 point for each part that contacts the task board surface before the grasp is released or if the part is dropped and remains on the task board (total: 28 points)
- 2) Assembly points are based on the following criteria:
 - a. 18 fastener screwing operations (total: 54 points)
 - b. 9 insertion operations (total: 45 points)
 - c. 4 wire routing operations (total: 40 points)
 - d. 2 thread belt / 1 tensioning operation (total: 42 points)

Assembly Points:

Operation	Points	Success measure
Fastener screwing	2	Screw cannot be lifted from hole and freely turns to tighten (threaded)
	1	Head of screw fully seated on board (washer test)
Insertion	3	Insertion into mating counterpart
	2	Fully seated and locked into place
Belt threading	14	Belt sits in a pulley groove
Tensioning	14	Belt tensioned/screw seated (seated in both pulley grooves)
Wire routing	10	Cable is properly routed in plastic component or between plastic and bolt

- 3) Time Bonus: $Time\ bonus = INT((end\ time[sec] - start\ time[sec]) / 32) \times 1\ point$

Rules:

- 1) Time bonus points are only available if all parts are successfully assembled onto the task board (maximum points achieved) as shown in Figure 5.
- 2) Points are only awarded for assembly of a part into its designated location. (e.g. no points for inserting 8mm peg into 16 mm hole)

- 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 (e.g., wrenches, electric drivers) is allowed provided the robot acquires these tools without human assistance.
- 6) Perception system markers (e.g., reflectors, AR tags, QR codes) may not be placed on the individual parts to be assembled.
- 7) Perception system markers can be placed on the task board and kit.
- 8) Working area is the area within which the end-effector of the robot can move. The maximum size of the working area is the table top which is estimated to be 150 cm x 75 cm.
- 9) A reset is allowed in order to make program changes or repair/secure a task board. During a reset, teams must disassemble all parts from the task board and reset in kit area. All accumulated points are reset to zero. The clock continues to run throughout the reset. Organizers will supply replacement boards or parts to teams as necessary while supplies last.

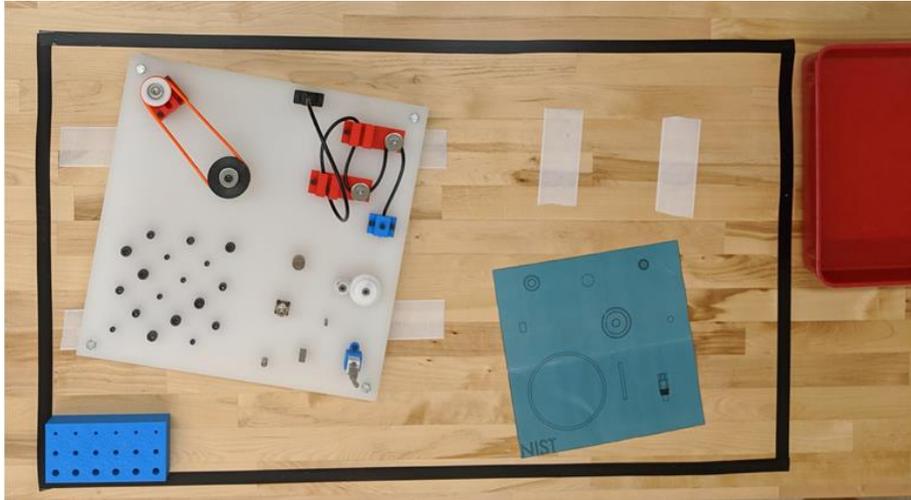


Figure 5: The practice task board will all parts successfully assembled.

Time Shift

120 (= 40 + 80) 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 on once subtask 2 is started. A team can divide the time between subtasks as desired. After 120 minutes, all task activities must be stopped.

Note: Time for teams to setup up kit layout for assembly subtask 2 is included in the 120 minutes.

Scoring Guidance – IROS 2019 – Robotic Grasping and Manipulation Challenge – Manufacturing Track

Threaded Fasteners:



Cross threaded screw cannot advance thread by hand (no points)



Threaded – can be advanced by hand (2 points)



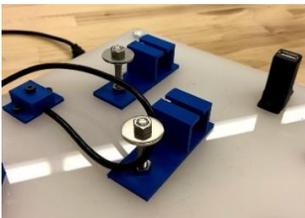
Not fully threaded – can insert washer under head (2 points)



Fully successful fastener operation. Washer cannot be inserted under head. (3 points)

Note: In all four cases above, cross threading and destruction of threads receives not points. Judges check this by screwing/unscrewing fastener with ease.

Cable routing/USB insertion:



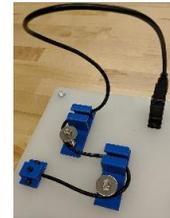
One successful routing (10 points)



Two successful routings (20 points)



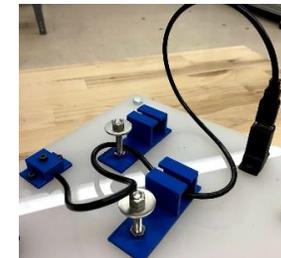
Three successful routings (30 Points)



Four wrong direction routings
Successful USB Insertion/fully seat (5 points USB)



Four successful routings (40 Points) and fully seat



Two successful routings (20 points)



Four successful routings
Successful USB insertion (+5 Points x 4) + 3 Points = total of 23 Points



(a) USB insertion (3 Points)



(b) Insert & seat (5 Points)

Belt Threading and Tensioning:



Threaded on one pulley only (14 points)



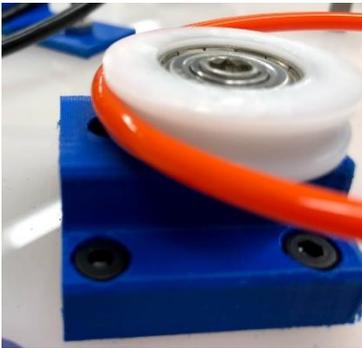
Threaded on one pulley only (14 points)



Fully threaded (28 points)



Fully threaded and tensioned (42 points)



Lack of tension (no points)



(a)



(b)

Belt outer diameter aligns or protrudes back surface of slide tensioner bracket as shown in (a) and (b) - (14 points)

Ethernet Connector:



Insertion into mating counter part
but no snap fit of locking mechanism
(3 points)



Insertion into mating counterpart
and snap fit of locking mechanism
(5 points)

BNC Connector:



Insertion only
(3 points)



Insertion only
(3 points)



Insertion, partial
(3 points)



Insertion and full lock
(5 points)

Pegs:



All edges not below task board top surface (no points)



All edges below task board top surface (3 points)



(a)



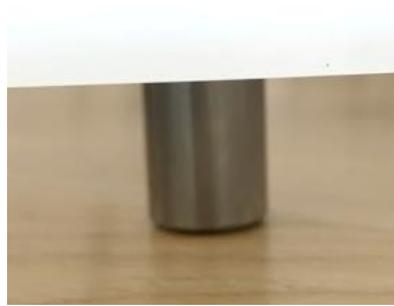
(b)



Full insertion with peg seated on surface that supports the task board (5 points)



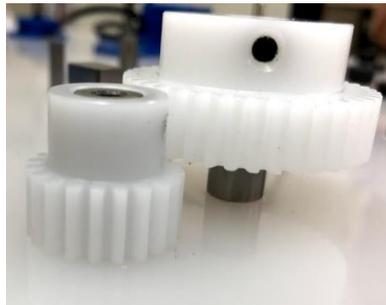
All edges below task board Top surface (3 points)



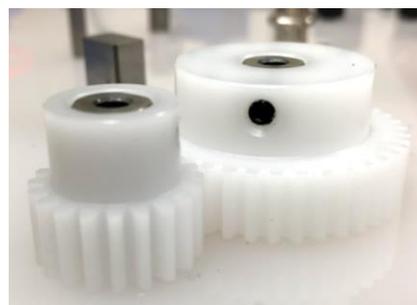
Full insertion with peg seated on surface that supports the task board (5 points)



Inserted but not Seated on task board (3 points)



Small gear inserted and seated for (5 points). Large gear inserted but not seated (3 points)



Both gears inserted and fully seated (5 points) for each.

SubTask1: Disassembly

Team Name: _____

Team Leader: _____

_____ *Team Leader Signature*

Judge: _____

_____ *Judge Signature*

Start Time: _____

End Time: _____

SubTask1: Disassembly

Class	Component	Number Removed	SubTotal	Number in Kit Tray	SubTotal	Total
Threading Fasteners	M8 Fasteners (out of 6)	_____ x 2 = _____		_____ x 1 = _____		
	M6 Fasteners (out of 6)	_____ x 2 = _____		_____ x 1 = _____		
	M4 Fasteners (out of 6)	_____ x 2 = _____		_____ x 1 = _____		
Class	Component	Removed (2 points)		In Kit Tray (1 point)		
Insertions	Small Gear					
	Large Gear					
	16 mm Round Peg					
	8 mm Round Peg					
	12 mm x 8 mm Peg					
	4 mm Square Peg					
	BNC Connector					
	RJ45 Connector					
USB Connector						
Class	Component	Removed (2 points)				
Wire Routing	Route 1 – Bolt					
	Route 2 – Channel 1					
	Route 3 – Bolt					
	Route 4 – Channel 2					
Class	Component	Removed (2 points)		In Kit Tray (1 point)		
	Belt					
Time Bonus: $Time\ bonus = INT((end\ time[sec] - start\ time[sec]) / 32) \times 1\ point$						

Total:

SubTask2: Assembly

Team Name: _____

Team Leader: _____

Team Leader Signature

Judge: _____

Judge Signature

Start Time: _____

End Time: _____

SubTask2: Assembly

Class	Component	Contact Task board (1 point)	Number Threaded	SubTotal	Number Seated (Washer Test)	SubTotal	Total
Threading Fasteners	M8 Fasteners (out of 6)		_____ x 2 = _____		_____ x 1 = _____		
	M6 Fasteners (out of 6)		_____ x 2 = _____		_____ x 1 = _____		
	M4 Fasteners (out of 6)		_____ x 2 = _____		_____ x 1 = _____		
Class	Component		Inserted (3 points ea.)		Seated (2 points ea.)		
Insertions	Small Gear						
	Large Gear						
	16 mm Round Peg						
	8 mm Round Peg						
	12 mm x 8 mm Peg						
	4 mm Square Peg						
	BNC Connector						
	RJ45 Connector						
USB Connector							
Class	Component		Routed (10 points ea.)				
Wire Routing	Route 1						
	Route 2						
	Route 2						
	Route 4						
Class	Component	Belt Only	Threaded/Tensioned (14 points ea.)				
	Large Pulley threaded						
	Small Pulley threaded						
	Tensioning						
Time Bonus: $Time\ bonus = INT((end\ time[sec] - start\ time[sec]) / 32) \times 1\ point$							

Total: