IROS 2020 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 practice task board provided. While we will attempt to ship practice boards to all registered teams, if you wish to purchase the components to build your own task boards, all details can be found at: https://www.nist.gov/el/intelligent-systems-division-73500/iros-2020-robotic-grasping-and-manipulation-competition

A new task board and parts to be disassembled and assembled will be distributed for final competition runs 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 task board and kit layout in the same format provided with the practice materials will be supplied at competition start time. 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.

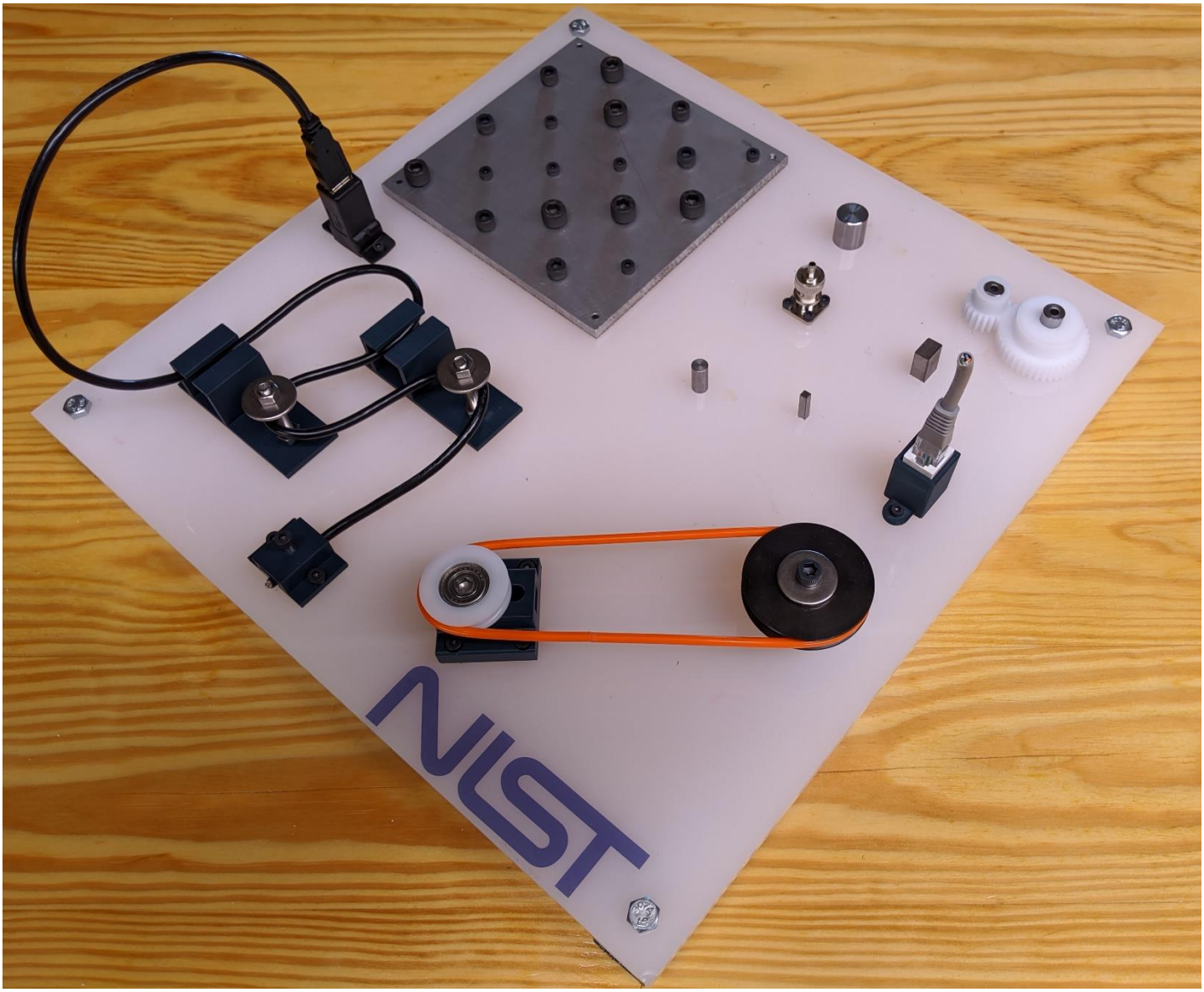


Figure 1: Fully assembled IROS 2020 task board. Note that parts will remain the same however, component locations and orientations are different on the practice and competition boards to be distributed.

Task: Board Disassembly/Assembly

Parts (See Figure 1):

1) Board with slip-fit holes, threaded holes, female electrical connectors, cable routing components and initial belt drive components.
2) Components:
   a. Metric pegs of various diameters and cross-sectional shapes
   b. Standard Socket Cap Screws (sizes M4-0.7, M6-1.0, M8-1.25)
   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. Approximate locations for the task board, kit tray and kit mat are shown in Figure 2. Teams may set their preferred general object orientation (i.e. side of task board which faces a robot). Remote judges will then communicate to the teams as they place the task board and kit mat withing the workspace to insure random placement. The kit tray locations will be set by the teams. 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.

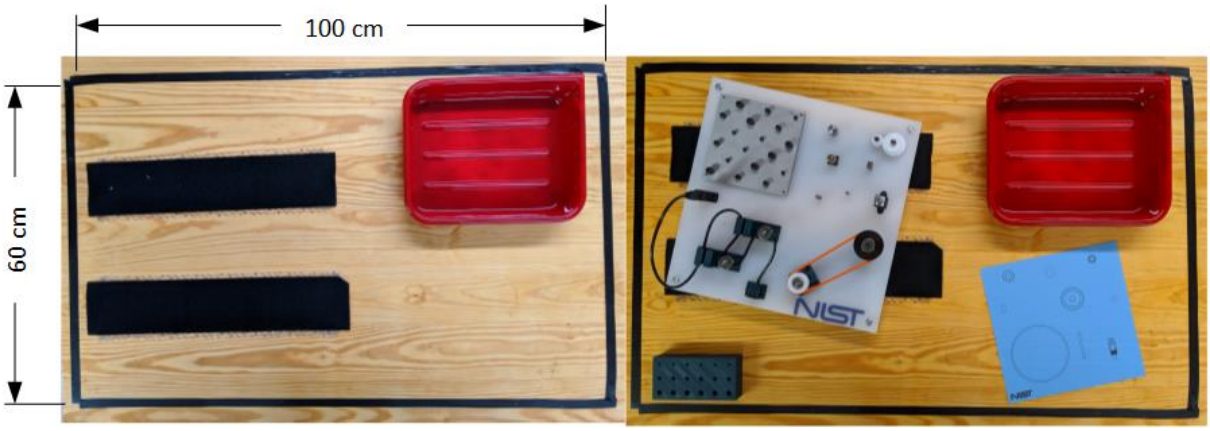


Figure 2: The initial layout where task board and kit layout are randomized. Teams use the electrical tape supplied to mark a 60 cm x 100 cm work area on a surface. General orientation of the task board and kit layout are specified by the teams and the judge ensures that final placement is random.

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. See Figure 3(a) for an example task board before disassembly and Figure 3(b) for an example task board after disassembly.

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) x 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 a typical 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.

(a) (b)

(b)

Figure 3: Subtask 1 – Disassembly. This subtask starts with a fully assembled task board (a). Completion results in a fully disassembled task board with all loose components placed in tray and the cable fully unrouted with the USB connector placed on the table surface (b).

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. Figure 4 (a) shows an example setup before assembly and Figure 4 (b) shows the setup after assembly.

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.

(a) (b)

Figure 4: Subtask 2 – Assembly. This subtask starts with a fully disassembled task board with parts placed on kit layout template and fasteners placed in a bolt rack (a). showing task board and kit layout with a method of dispensing screws. Completion results in a fully assembled task board (b).

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) x 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 1 and Figure 4(b).
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.

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. At the 40 minute mark, all teams must start subtask 2 (assembly). 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.

Remote Judging

Teams will reserve a competition date and time with the competition organizers. Teams must provide three camera feeds to a remotely connected judge for real-time for observation of the competition. The first camera must be positioned so that a judge can observe the entire workstation in operation including all computer systems and robot controllers. The second camera will be focused on the robot work area and positioned to minimize occlusions from the manipulator(s). A third camera will be positioned by the team to provide better detailed views during the scoring process. Prior to the competition date, an organizer will connect via teleconferencing software and ensure that cameras are properly positioned and functional via video conferencing. All three video feeds should be recorded by the teams and submitted. The process for uploading these video files will be provided.

Scoring Guidance – IROS 2020 – Robotic Grasping and Manipulation Challenge – Manufacturing Track

Threaded Fasteners:

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

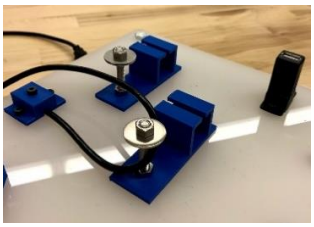
Threaded – can be advanced by hand (2 points)

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

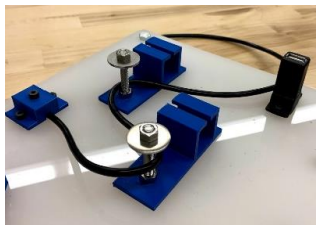
Fully successful fastener operation. Washer cannot be inserted under head. (3 points)

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

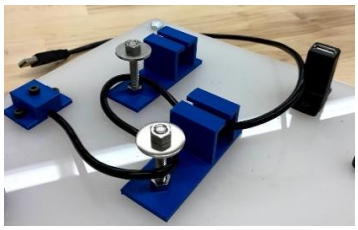
Cable routing/USB insertion:



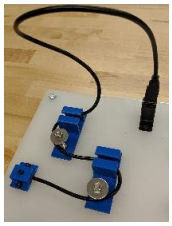
One successful routing (10 points)



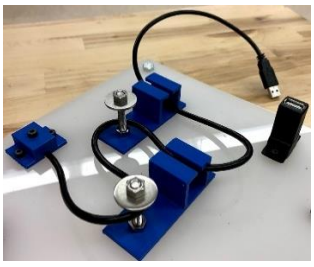
Two successful routings (20 points)



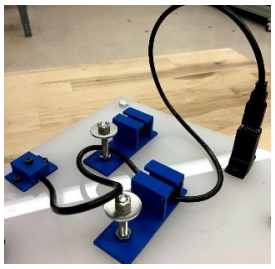
Three successful routings (30 Points)



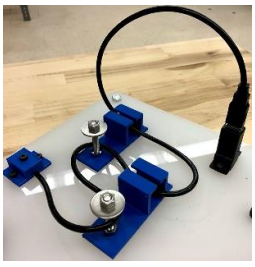
Four wrong direction routings Successful USB Insertion/fully seat (5 points USB)



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)

(b)

(a) USB insertion (3 Points)
(b) Insert & seat (5 Points)

Belt Threading and Tensioning:

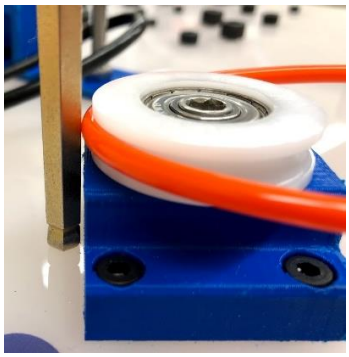
Threaded on one pulley only (14 points)

Threaded on one pulley only (14 points)

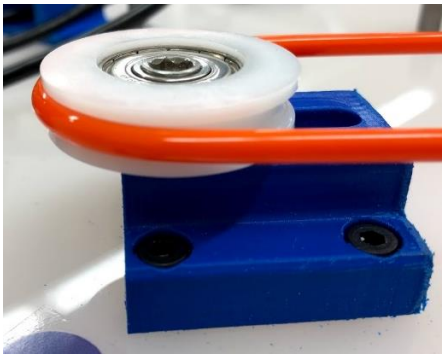
Fully threaded (28 points)

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)

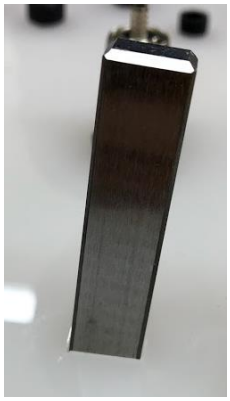
Insertion only
(3 points)

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)

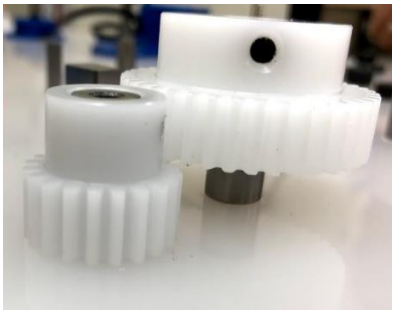
(b)

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

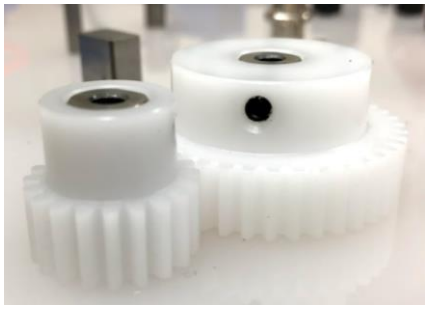
All edges below task board Top surface (3 points)

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.

Scoring Sheet: IROS 2020 Robotic Grasping and Manipulation Competition – Manufacturing Track

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) x 1 point*				

Total:

Scoring Sheet: IROS 2020 Robotic Grasping and Manipulation Competition – Manufacturing Track

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) x 1 point*					

Total: