Industrial Robotics Category

Assembly Challenge

Rules and Regulations for WRS 2020

The Industrial Robotics Competition Committee

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1 Background

George Devol applied for his historic patent, Programmed Article Transfer, in 1954. This patent was approved in 1961, and in the same year, Unimate was released from an American company, Unimation, as the world's first industrial robot. His concept of a programmable transfer machine and operating principles of teaching and playback remain timeless even today, and we could say that it is the fundamental concept behind industrial robots. The fact that most industrial robots today, especially arm-type robots, are operated by the teaching and playback method illustrates the universality of Devol's ideas.

Now, if we look at the cost for implementing standard robot systems, the expense of the robot itself amounts to no more than 20-30% of the total cost, and in many cases peripheral equipment, peripheral devices, and system integration makes up over 50% of the cost. This is the reason why the industrial robot itself is regarded as an "incomplete product". Industrial robots, which were supposed to provide functionality as programmable universal machines are often installed as part of a special purpose system and are not re-programmed once they are installed.

Industrial robots with this teaching and playback method based on Devol's patent may have had a somewhat high initial financial and labor cost to install. In the era of mass production, once the system was configured, they could be used as-is for several years which made up for the initial cost. However, the ever-shortening product life-cycles and diversification of consumer needs is resulting in a demand for high-mix low-volume production that is difficult to meet with this sort of system, and in response, cellular manufacturing using humans (human cell) emerged.

However, labor shortages and increases in labor costs have become problems in recent years in both Japan and elsewhere, and the achievement of a robot system that can handle high-mix low-volume production is in demand. In particular, small- and medium-sized enterprises (SMEs) that operate under strict cost limitations cannot easily implement robots with large integration costs. Therefore, it is essential for us to be able to use industrial robots as programmable universal machines that can be easily and quickly configured and re-configured into systems without paying a high cost for system integration, in order to manufacture different products without waste. This is a necessary requirement for promoting the implementation of robots not only at SMEs but at large-scale enterprises as well.

From the above-mentioned background, the Industrial Robotics Category of the World Robot Summit (WRS) aims to realize the future of manufacturing systems "toward agile one-off manufacturing" as a goal, by building agile and lean production systems that can respond to ever-changing manufacturing requirements (even for a one-off product in an extreme case) in high-mix low-volume production through a competition in this category. Table 1 shows the levels of production systems, where current production systems as Level 1, and the highest objective of next-generation production systems as Level 5. At WRS we are aiming for at least Level 4.

Assembly is one of the most difficult operations for robots. Assembly tasks are often laborious and costly due to the need to prepare peripheral devices such as parts feeders and jigs. In addition, careful teaching is necessary for parts mating, and fine adjustment of the teaching data is also laborious and time-consuming to overcome the temporary stoppages that can occur frequently after introducing a new manufacturing system. Therefore, the WRS Industrial

Robotics Category has set product assembly as the challenge task in this competition from the numerous tasks in the manufacturing domain.

2 Overview of Competition Tasks

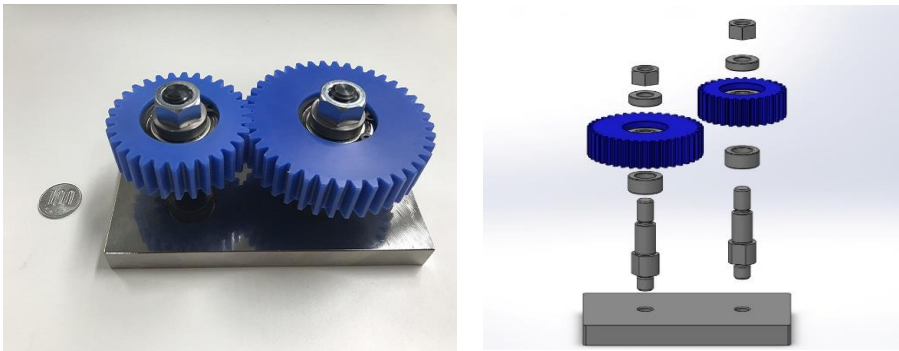
2.1 Changes from Past Competition Tasks

Prior to the WRS 2018 pre-competition, the Industrial Robotics Category had conducted a gear unit assembly competition as a trial task in October 2017 at the IROS site as part of the 2nd Robotic Grasping and Manipulation Competition as shown in Figure 1. The 11 parts used for the gear unit assembly can be seen in Figure 1 (b). All of these parts were easily available from MISUMI around the world. In particular, the shaft and the inner gear bearing were a transition fit which is difficult even for humans if they are not used to it.

At the WRS 2018 pre-competition, the belt drive unit shown in Figure 2 was devised as a more difficult product than the gear unit at the trial-task in 2017. The difficult point of the belt drive unit in comparison to the gear unit was: (1) There were many parts including very small parts such as M3 thread screws. (2) It featured a soft part, namely the belt. (3) Compared to the gear unit, the direction of assembly was not always perpendicular. (4) It included an assembly process that required two arms, namely holding one part while assembling another part. Additionally, some of the parts in the belt drive unit were revealed directly before the competition as surprise parts introducing an element of responding to new production demands in an agile and lean manner in the competition. In the WRS 2018 pre-competition, in addition to the belt drive assembly competition there were also task board and kitting tasks. Please refer to [1] for details of the competition rules of WRS 2018 pre-competition. Also please refer to [2] that summarizes the WRS 2018 pre-competition.

Table 1: Levels of Next-generation Production Systems (Draft Version)

	Factors during setup changes		**Factors during operation**	**Remarks**
	Agility	**Leanness**	**Operation rate improvement**	
Level 5	0 day for new product (Changeover on the same day)	100% continual use (Introduction of universal hands that are able to perform jig-less assembly for multiple products, etc.)	Machine learning (Temporal stoppage prevention/cycle time improvement) Fully automated recovery (Even big stoppages)	Ultimate goal Autonomous motion planning, etc.
Level 4	2 days for new product (Changeover on a weekend or an overnight business trip)	Available for new products only by recombining existing equipment. (Universal hands able to grasp multiple products, etc.)	Automatic recovery from temporal stoppage (Learning through observing human intervention, etc.) Human intervention is required for big stoppages.	Target level at WRS Small number of universal hands
Level 3	1 week for new product (Changeover in a week, e.g. during large consecutive national holidays)	50% or more can be reused (Use of specialized hand library, flexible jig, multi arms, etc.)	Operation rate improvements (Prevention measures against temporal stoppages, etc.) Automated proposals of improvements.	Offline planning Reduction of specialized tools with multi arms, etc.
Level 2	1 month for new product	Reusing only robots	Reduction of temporal stoppage rate by absorbing part variations using sensors.	Levels possible with current technologies
Level 1	For specific products only Changeover is not assumed.	0% (No reuse is assumed.)	Controls parts variations to ensure an enough utilization rate. Human intervention is required for temporal stoppages.	Many robot systems used today.



(a) Overview (b) Parts

Figure 1: Gear unit designed for the WRS trial task

(a) Overview (b) Parts

Figure 2: The belt drive unit used for the Assembly Challenge of the WRS 2018
(The design of the Belt Drive Unit for the WRS 2020 is subject to change.)

2.2 Outline of the Assembly Challenge for WRS 2020

The Assembly Challenge is a competition where teams quickly and accurately assemble model products that contain the technical elements necessary for assembling industrial products. In order to meet new production requirements, robot systems are expected to be able to assemble different products in an agile and lean manner.

The following two tasks will be provided at the 2020 competition.

1. Task-Board task

Teams compete in the task elements necessary to assemble a belt drive unit. In this task, the parts supplied under the same conditions as the next assembly task are to be assembled at designated locations on the task board.

2. Assembly task

A belt drive unit will be assembled using parts from a provided parts tray. Additionally, assembly of a product with different specifications (surprise product) from the pre-announced product will be required to demonstrate the capability of responding to new production demands, and teams will have to perform agile and lean setup changes. However, the parts that make up the surprise product will be announced in advance so that the teams can design robot hands and the other devises for those parts.

As with WRS 2018, the parts used for each task will be available from MISUMI as much as

possible, with the consideration so that the tasks can be used in various locations as benchmarks for assembly work. Additionally, as with WRS 2018, samples of parts to be used in the competition will be sent in advance to participating teams.

2.3 Schedule

See Table 2 for the WRS 2020 Competition schedule. The event is scheduled for one week including setup days. The first two or three days are for setting up, and Day 1-3 will be the scored competition, Day 4 will be exhibitions, technical exchange, and awards ceremony. Team meetings are scheduled in the evening for every day until Day 4, starting with the evening before Day 1. The symposium, which was originally scheduled on Day 5, will be held separately later in an on-line format. Details will be announced after the competition.

The competition is scheduled to do the task-board task on Day 1, to do the assembly task for assembling the normal belt drive units on Day 2, and to do the assembly task for assembling the normal and surprise products on Day 3. Table 3 describes the scoring for the product assembly task.

A detailed competition schedule including dates and start and end times will be announced at a later date. Note that the competition schedule is subject to change.

2.4 Prizes and Awards

2.4.1 Prizes (Grand Prize, Second Prize, Third Prize)

At the competition, the top three teams with the highest scores will be awarded.

2.4.2 Society Awards

There will also be some Society Awards presented to teams that excel from various standpoints. In WRS 2018, the following elements were evaluated for the society awards. Similar awards will be presented at WRS 2020.

・Innovation and originality that will lead to future implementation as a next-generation robot system

・Excellence in software technology, network technology, etc.

・Excellence in hardware technology such as a versatile hand.

・Excellence in the overall system integrated from robots, sensors, peripherals, etc.

2.4.3 Competition Committee Special Prizes

Besides the above mentioned prizes, at WRS 2020, there are the following three prizes based not on an overall score but on specific evaluation axes for each task.

(i) Best Assembling Skill Prize

The team with the highest number of points on the first try of task-board task on Day 1 (if more than one team completes the task and has the same score, then the team that was faster) will win this prize. By looking at the results from the first try in which the teams see the task board layout for

the first time just ten minutes before the task begins, the team with the best assembly skills that can respond quickly to changes in the assembly positions for individual parts will be recognized with this award.

(ii) Best Product Assembly Prize

The team that completely assembled the largest number of normal products in the normal product assembly task in Day 2 afternoon will receive this prize. “Complete assemble” means that it meets the conditions for the completion bonus (which will be outlined below) and passes the product evaluation test. If more than one team completed the same number of products, the team that was able to completely assemble the product(s) in the shorter amount of time will be the winner. The ultimate goal of the assembly task is to completely assemble products, so the team that assembles the largest number of normal products in the completion will be awarded this prize.

If no team manages to “completely” assemble a product, this prize will not be awarded. If there is a team that manages to completely assemble two products, even if another team completely assembles one product faster, the team that has completely assembled two products will be declared the winner.

(iii) Best Agile & Lean System Prize

The team with the most points in the first try of the assembly task, including the assembly of a surprise product on the morning of Day 3, will win this prize. This award will not be awarded if the Robotics Competition Award Committee determines that no team has reached a certain level for agile and lean manufacturing, for example, if the completeness of the surprise products is not satisfactory.

Since teams are informed of the information about the surprise product at the competition venue before the competition of the first try begins[1], the team that can handle production demands of the surprise product in agile and lean manners will win this prize.

Through establishing these special prizes, participating teams are expected to deepen their understanding of the aims of the competition and motivate themselves to build systems that excel not only in overall points but also in the above evaluation axes, which will eventually lead to future social implementation of the developed systems. As is clear from the selection criteria, these special awards do not prevent teams from winning duplicate awards with the top three prizes. The Industrial Robotics Competition Award Committee will select the winners and the Industrial Robotics Competition Committee will present the awards for these prizes.

2.4.4 Safety Award

As described in detail in Chapter 6, safety and health are a top priority in this competition. Based on this, a safety and health policy with specific rules has been formulated, and participating teams are expected to strictly follow these rules set by the Competition Committee.

While each team is obliged to strictly follow the safety and health rules, Safety Award has been established in order to recognize the safety and health activities of each team. The Safety Award will be awarded to the team (or possibly teams) with the best safety and health efforts in total including their efforts for risk assessments submitted in advance and their efforts during the competition including setup at the competition site. The Safety and Health Management Committee of the

[1] Information about surprise product will be provided to the teams after the venue setup has been completed and before the competition of the first try on Day 3 begins. Exact timing will be announced later.

Industrial Robotics Competition Committee will select candidates for this award, and the Safety and Health Management Committee will present the winning team(s) with the award after getting the approval of the Industrial Robotics Competition Committee.

2.5 Differences in Competition Tasks from WRS 2018 and Background of WRS 2020 Competition Rules

The following five points are the major changes between the WRS 2018 and WRS 2020 competitions. Please refer the following sections of the rules for details.

(1) The kitting task has been eliminated, and the assembly task begins with the supplied parts kitted on a tray. The parts tray is brought in with an automated guided vehicle (AGV), and the assembled products are placed on the AGV to be carried out in the same way as bringing in the parts. Additionally, supplying method for only small general-purpose parts like screws will be left up to individual teams.

(2) The contents of the task-board task including the parts supplying method have become more consistent with the assembly task.

Table 2: Competition Schedule of the WRS 2020 Assembly Challenge

Setup Period (2-3 days)		Day 1	Day 2	Day 3	Day 4
Staff only	Staff & team only	Open to the public			
Venue Setup	Team Setup	Assembly Challenge Competition			Presentation competition, etc.
			Assembly task		
Team members kept out	System setup, adjustment, safety inspection after setup is complete	Task Board task	w/o Surprise Product	w/ Surprise Product	Exhibition, technical exchanges, awards ceremony
No Luggage accepted	Luggage loading			(Exchange meeting)	Unloading & Shipping

Table 3: Points Table

Day	Task	Points	Remarks
Day 1	Task-board task	100	Better points from two tries Time bonus awarded separately
Day 2	Assembly task w/o Surprise Product	200	Assemble two normal products Time bonus awarded separately
Day 3	Assembly task w/ Surprise Product	300	Assemble one normal product and one surprise product The best score of two tries will be used. If the more difficult surprise product (surprise-plus) is chosen, it will be possible to get a higher score. Time bonus awarded separately
	Technical Evaluation	50	Based on the submitted technical documents and the actual performance in the competition
	Total	650	

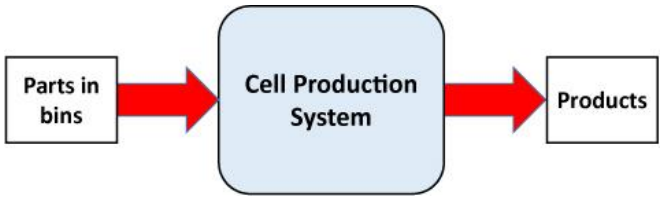
(3) In the assembly task, instead of the surprise parts (new parts information that was supplied directly before the task) that were introduced in WRS 2018 as a surprise element, a new idea of a surprise product will be introduced, where the information about the parts will be supplied in advance to some degree, but the teams will be notified of the way how each part should be assembled directly before the task.

(4) A cable insertion task has been added to the assembly task.

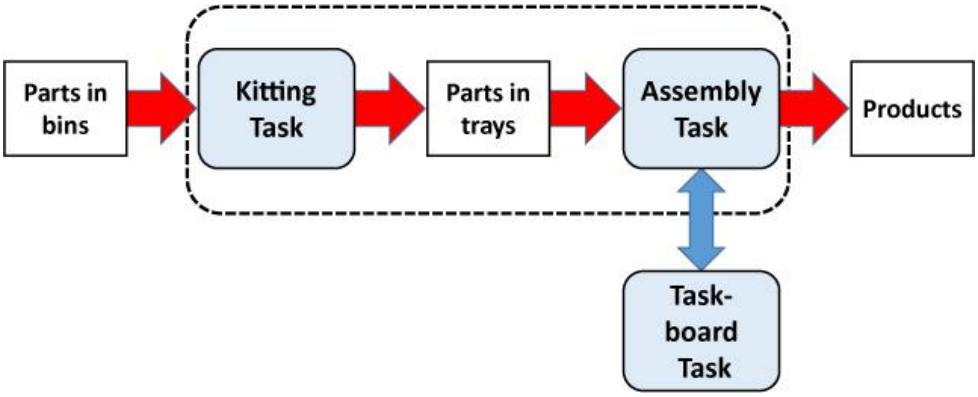
(5) Resets can be done any number of times, but for each reset, the team will not be able to resume the competition for a predetermined length of time (assuming about two minutes). “Pause” can be declared made when carrying out the finished product by AGV and bringing in the parts for the next product, but the number of pauses must match the number of products to be assembled. Making a pause means that the competition time will stop for a certain period of time (assuming about one or two minutes). Additionally, the definition of the ‘phases’ during the competition has been changed.

In the WRS 2018, there were the task-board task and the kitting task in addition to the assembly task. The reason for this was that although the competition committee aimed for the robotization of a human cell as shown in Figure 3 (a), it was considered too difficult for the teams to robotize the current human cell where basically a single human assembles a product by taking out necessary parts from parts bins. Then, as shown in Figure 3 (b), the tasks were broken down into two parts, kitting task and assembly task, where kitting is performed as a pre-assembly stage in order for the assembly to be done with the kitted parts.

The task-board task was developed with inspiration taken from the one developed by Van Wyk et al. at NIST for the IROS 2nd Robotic Grasping and Manipulation Competition [3], and the elements of assembling a belt drive unit were extracted and the teams compete on that basic technology for assembly in the task-board task.



(a) Cell production system



(b) Tasks of the WRS 2018 Assembly Challenge

Figure 3: Design concept for the tasks of the WRS 2018 Assembly Challenge

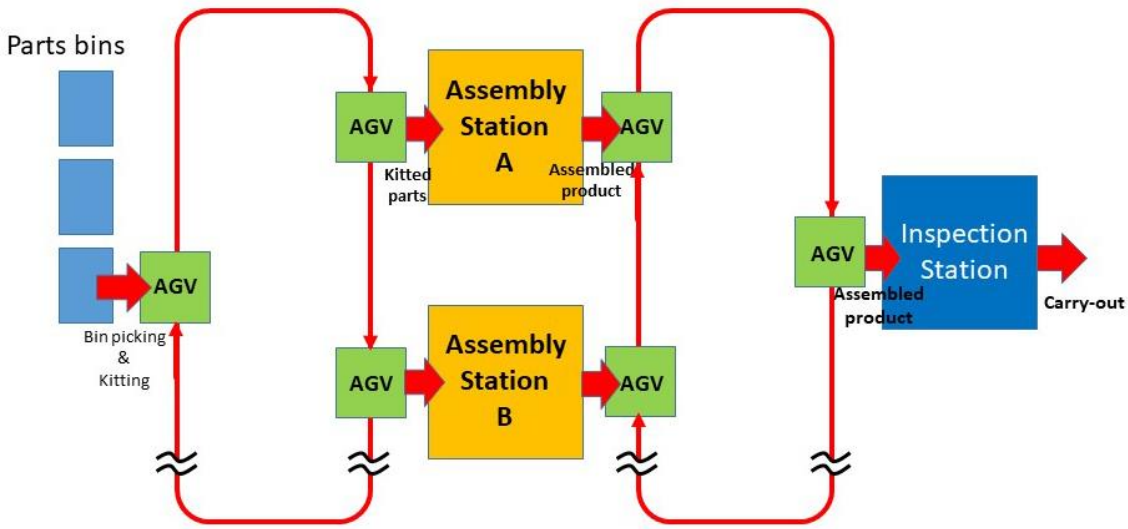


Figure 4: Design concept for the task of the WRS 2020 Assembly Challenge

Figure 5: The AGV to be used

Alternatively, WRS 2020 assumes a system in which parts kitting, assembly, and product inspection are modularized as shown in Figure 4. The parts kitting is performed by mobile picking robots (called “mizusumashi” (whirligig beetle) robots in Japanese) that take out parts from the parts bins as necessary according to production requirements [4] and supplies them to a robot at the assembly station. The assembled products are carried to the product evaluation station by another mobile robot [5]. Under this assumption, the competition committee set the competition to be exclusively specialized for the assembly station. At WRS 2020, an AGV as shown in Figure 5 will be newly introduced for parts supply and product carrying-out. A similar AGV was implemented on an experimental basis at WRS 2019 trial competition[2]. Confirming

[2] The Industrial Robotics Competition Committee has conducted a WRS 2019 industrial robotics trial competition at the International Robot Exhibition (iREX 2019) in December 2019. The purpose of this trial competition was to conduct some parts of the WRS 2020 competition tasks in order to verify their appropriateness, especially for the new elements we have

that there were no problems with its operation and introduction, AGVs will be implemented for the WRS 2020 competition instead of manual carts. These AGVs can follow magnetic tape that has been installed on the floor, and it can be controlled to start and stop with commands from an outside system. For detailed information on AGVs, see Appendix C.

The details of the concept of the surprise products are described in the next section.

2.6 Purpose of the Surprise Products

In the WRS Industrial Robotics Category, we aim to realize a production system that can respond to various production demands (ultimately even one-offs in extreme cases) in agile and lean manner in the high-mix low-volume production. Therefore, the assembly challenge includes surprise products that differ from the product announced in advance in order to compete on making quick setup changes.

At the WRS 2018 in Tokyo, several parts were changed to surprise parts for the belt drive unit on the second day of the assembly task, but since the information about the parts were provided at the competition venue, teams had difficulty to prepare hands and other equipment in advance to fit the surprise parts. With this in mind, the WRS 2020 competition will provide information in advance about the parts that will make up the surprise product (shape and size range, etc.) so that the teams can have enough time for preparing hands and other equipment for those parts. The surprise products will be products of new specifications by changing the combination and arrangement of those parts.

3 Competition Area

3.1 Team Area

Each team will have an area for running their system including robots as shown in Figure 6 (hereinafter referred to as the System Running Area), an area for operating and monitoring the system (hereinafter referred to as the Operation Area-1), an area for placing parts trays containing parts or assembled products and accessing to the AGV in the System Running Area (hereinafter referred to as the Operation Area-2), and an area for storing luggage that will not be used in the competition (hereinafter referred to as the Team Storage Area).

A working table will be provided to the requested teams and can be set in the System Running Area. Other necessary items such as additional tables, parts shelves, tool shelves, etc. may be supplied and installed by each team.

As shown in Figure 6, the AGV will be set to move in a straight line between Operation Area-2 and the System Running Area. The running route will be specified by the long magnetic tape set on the floor. Stopping positions and acceleration/deceleration positions of the AGV are specified by magnetic markers attached beside the long magnetic tape. The locations of the tape and marker will be adjusted depending on the system installation layout of each team. Note that

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introduced. Four teams that participated in WRS 2018 participated in the trial competition, but the competition was just a trial format, and although teams were scored, there were no prizes or prize money. The results of this trial competition will not have any effect on the results or selection of teams for WRS 2020.

areas demarcated by orange diagonal lines in Figure 6 are areas where equipment and any objects cannot be placed. Besides, areas demarcated by red diagonal lines in Figure 6 are areas where no one can be when the AGV is in operation as well as no equipment or objects can be placed.

When installing equipment in the System Running Area, teams must consider the visibility inside the System Running Area for the spectators. For example, teams must not place a parts shelf in the spectator's side of the System Running Area, or cover the System Running Area with a shade. Further, the competition committee may install cameras in the System Running Area and the Operation Area in order to capture the competition scene that may be provided to the spectators. If teams interfere with such shooting, for example by installing a pillar that blocks the camera view, the camera may be attached to that pillar. Spectators will be instructed that flash photography is prohibited.

Care should be taken when installing the ceiling (for example, to install celling lights) in the competition area, especially in the System Running Area. Those teams must contact the competition committee in advance and get permission. Details on height restrictions and conditions for using the ceiling will be provided later, in following with the Fire Service Law.

At the competition venue, four teams will be set up in the competition area as shown in Figure 7, and this will make up a single arena. Four arenas will make up the competition area for 16 teams in total. In this arrangement, all of the team areas will have the same shape and the same layout (location of entrance/exit, positional relationship between the System Running Area Operation Area, Team Storage Area, etc.).

Please note that the layout of the team area including System Running Area, Operation Area, and Team Storage Area may change significantly due to COVID-19 measures.

3.2 Number of Players

There is a limit of ten players that may enter the team area consisting of the Operation Area, System Running Area, and Team Storage Area. However, depending on the actual venue layout and the need for team members to maintain a social distance from one another in order to prevent the spread of COVID-19, the number of people allowed on a team may be further restricted (to about five people). It is permitted to switch out team members for each task, but they may not be switched during the task.

3.3 Power and Air Pressure Sources

A single-phase 100V power supply will be provided. In addition to the 100V power supply, a 3-phase 200V power supply can be made available to the teams who request it. Air pressure sources will also be provided.

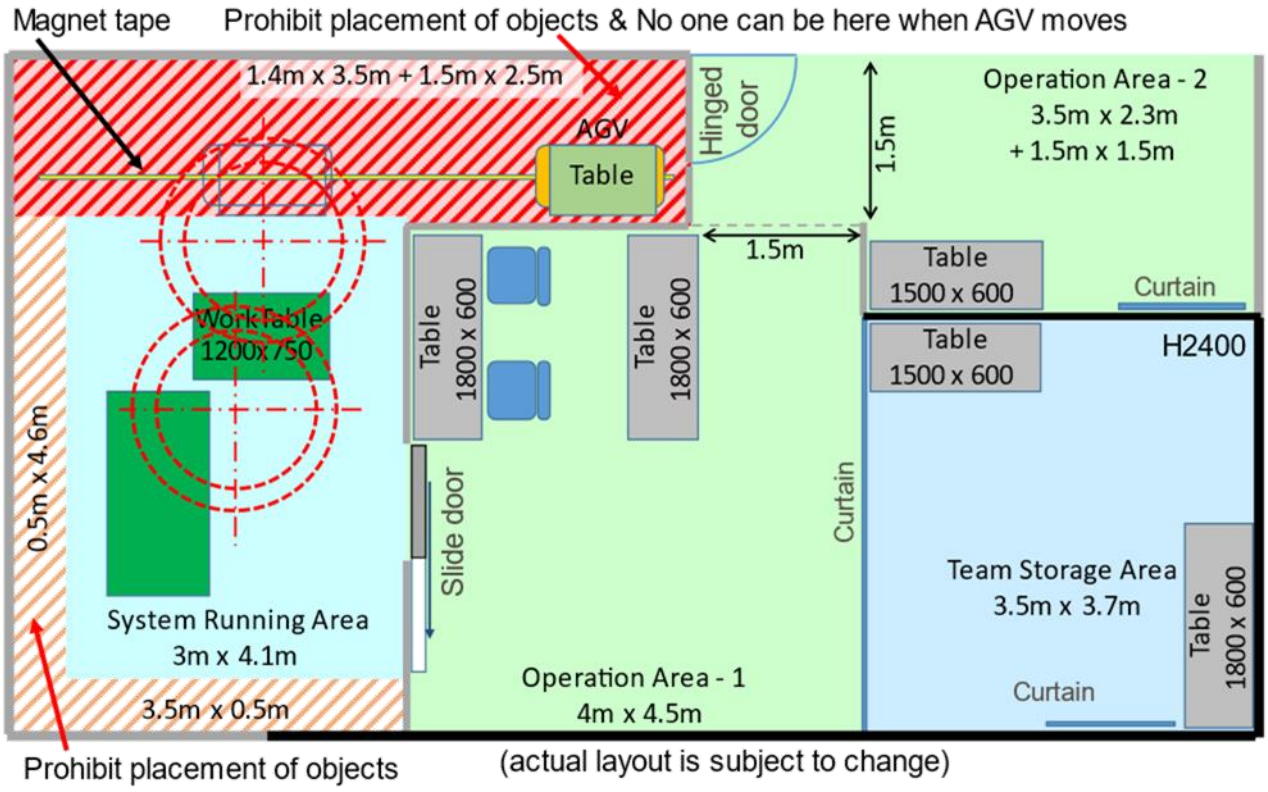


Figure 6: System Running Area, Operation Area and Team Storage Area
(actual layout is subject to change)

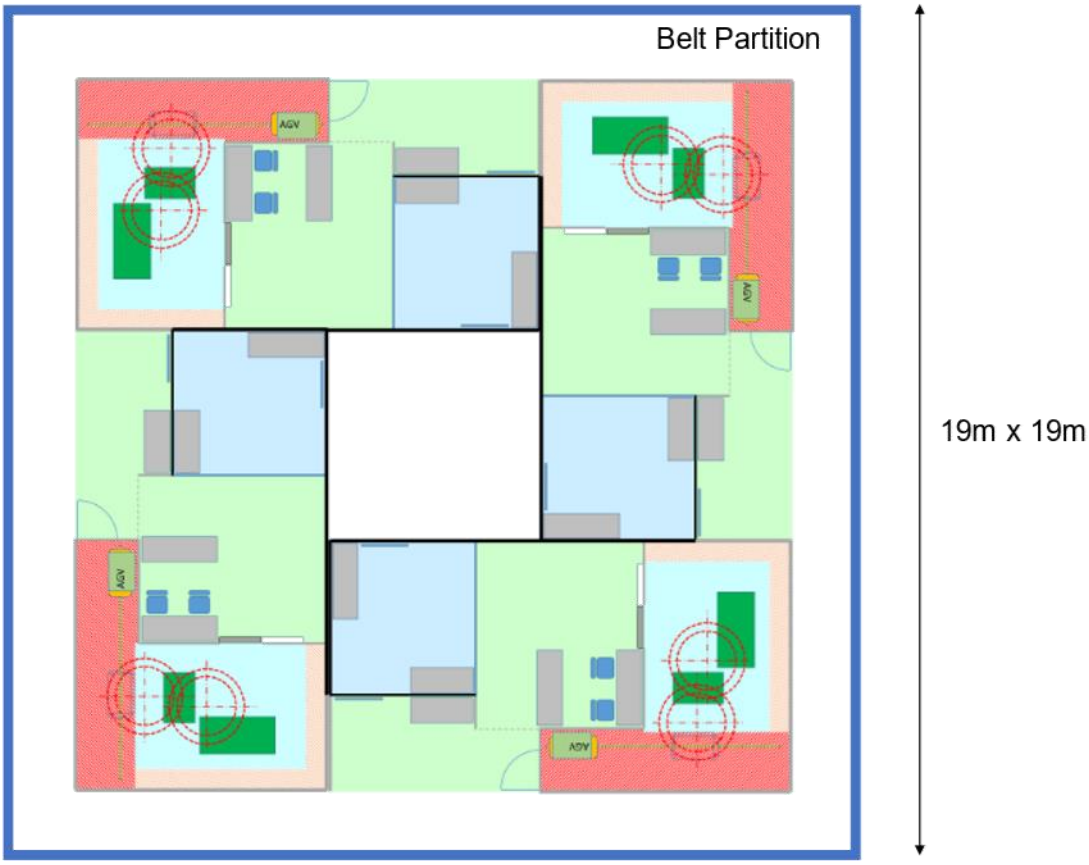


Figure 7: Arena configuration (actual configuration is subject to change)

3.4 Lighting Requirements

Lighting will be provided from the venue lighting. The competition committee will not install any extra lighting for each team area. Due to this, the brightness and color may be different for each team area. Additionally, the windows of the venue will be blocked off with curtains to prevent direct sunlight, but the brightness level may change depending on the presence or absence of sunlight. Each team may bring their own shades and/or lights, but it must be installed within the team area, and may not influence other teams, and it must not interfere with the operation of the referee or obstruct the view of the spectators. Further, details with regard to height restrictions and ceiling conditions related to the Fire Service Law will be supplied later and must be observed.

3.5 Network Infrastructure

An internet connection will be provided to each team area. However, as it is best effort service, network speed is not guaranteed. Additionally, considering the impact on other teams, bandwidth is capped at 64Mbps. As remote control is banned, the internet connections will be disconnected during the competition tasks.

At the WRS 2020 competition, wired LAN connections will be supplied. The use of Wi-fi and other wireless communication in the 2.4GHz or 5GHz bands will not be permitted as it can affect the competition fields of other categories. Further, each team will not be permitted to supply their own internet connection environment.

4 Robot Requirements and Limitations

4.1 Functional Requirements

Robots need accident prevention functionality for safety and health. Emergency stop buttons, safety fences, a door with safety switches, and dead man's devices must operate normally. Any environmental pollution must be prevented. For details on safety and health management, see Section 6.

4.2 Hardware Requirements

4.2.1 Robot

The robots used for the competition can be prepared by each team, borrowed from the competition committee, or, a combination of both may be used. Details on the specification of the lending robots will be announced separately.

There is no restriction on the number of robots, but teams must take into account the limited installation space for robots. There is also no regulation about the weight of a robot, but each team needs to prepare a worktable if the weight exceeds the bearing load of the table provided by the competition committee.

Furthermore, equipment such as devices that generate a loud noise may be prohibited to use if the referees deem that device inappropriate.

4.2.2 Power and Number of Actuators

There are no limitations for the type, number, or power of actuators (motors) used in the

robots. However, if the competition committee determines that there is a safety and health issue, there may be the cases where use is restricted. See Section 6.2.1 "Hardware Requirements."

4.2.3 CPU, Memory Storage, etc.

There are no limitations regarding computing ability.

4.2.4 Costs

There is no upper cost limit for robots and peripherals.

4.3 Software Requirements

4.3.1 Network Utilization

During team setup, teams may use the Internet to access, for example, cloud computing, but must be prepared for network trouble. Use of Wi-fi is not permitted. The internet connection will be terminated during the competition tasks. For details, see Section 3.4, “Network Infrastructure.”

4.3.2 Remote Control

Remote control by personnel is not assumed in this competition because it is an assembly challenge intended for the automation of production sites. Therefore, robots may not be operated remotely in the Operation Phase. This refers not only to the direct control by a device like a joystick but also the control through voice or gestures. In order to prevent remote control via the Internet, the Internet connection will be terminated during the competition tasks.

4.4 Placement of Markers

In the competition, only the product parts and parts trays supplied on site by the competition committee will be used, and no markers are allowed to be attached to these parts. In addition, colored markers will be attached to the upper four corners of the parts trays in order to assist in detecting its position and orientation (See Figures 8 and 9). Teams may affix markers to the work environment except the product parts and parts trays. Based on the result of the WRS 2019 trial competition, in WRS 2020, the markers with the same color may be used to mark the four corners of the parts trays. For details on markers, see Appendix D.

5 General Rules for Competition

5.1 Definitions of Phases during Competition

The tasks (the task-board task and assembly task) are made up of a Preparation Phase, an Operation Phase, and a Reset Phase including Skip Phase (Figure 8). The Preparation Phase is the time when the referee supplies each team with the parts that will be used in the task, the team checks them, and sets the necessary parts in the System Running Area. For both the task-board task and the assembly task, the Preparation Phase will have a designated minimum time period (assuming 10 minutes). Teams must confirm the parts provided, and ask for trades if necessary, during this phase. After that, the referee will set the parts in the parts tray using a designated method. During the assembly task, AGV will be used to bring the parts trays in the

System Running Area and set them in their initial position. For the task-board task, teams will use this phase to place the task board in the System Running Area. Teams may not touch the robots or robot systems during the Preparation Phase. Meanwhile, the referees will check whether there are any problems in the Operation Area or the System Running Area during this phase.

After preparation is done, the team leader will tell the referee that they are ready to start the Operation Phase. If the minimum required time for the Preparation Phase has not yet elapsed, the team must wait until the required time has elapsed, and then the Operation Phase (Running State) will begin. If the required time has already elapsed, the Operation Phase will begin immediately. During the Operation Phase (Running State), since the robots and other equipment will be working, people are prohibited from entering the System Running Area. Therefore, team members cannot touch the robot, the working environment for the robot, the parts, the tools, etc. during the Operation Phase (Running State). Additionally, since remote control is prohibited, a paper or something must be placed on the keyboard or any other similar devices, and it must be clear that no one is touching any input devices. There is no specific order of assembling the parts and the robot(s) can assemble the parts in any order.

In the assembly task, the assembled products must be unloaded and carried out, and if necessary, the product can be carried out and new parts for the subsequent product can be brought in even during the competition (i.e. during the Operation Phase). During the Operation Phase, a team may declare “Pause” and when it is approved, they can change the state from Running State to Bring-in/Carry-out State. Once the state has been changed to Bring-in/Carry-out State, the team members can open the door leading to the System Running Area from the Operation Area-2 (see Figure 6) and remove the tray containing assembled products from the top of the AGV and/or place the parts tray(s) containing the parts on it. During the Bring-in/Carry-out State, all other robots except the AGV must be stopped. During this state, team members can access only the AGV, and cannot enter the System Running Area or touch any robot other than the AGV. After the door has been closed followed by a declaration and approval of “Run”, the state can be returned from the Bring-in/Carry-out State to the Running State. After “Pause” was declared and approved and entering the Bring-in/Carry-out State, the progression of the task time will be suspended for a predetermined time (assuming about 1 or 2 minutes). Note that the AGV can be operated manually either in the Running State or the Bring-in/Carry-out State.

The Reset Phase is a time to recover the system from an error and restore the parts to their initial position. After “Reset” has been declared and the referee has confirmed that the robots have entered a safety mode described later (Emergency Stop Mode or Manual Mode), team members may enter the System Running Area and restore the robot system.The competition ends when the prescribed competition time ends or the team declares "Finish". When the competition ends with the "Finish" declaration or the end of the competition time, the referee will record the end time and start scoring. Team members must not touch the products or operate the robot until the referee finishes scoring and gives permission to the team.

The time bonus, which will be described later, will be awarded based on the remaining time of the competition, which is calculated by subtracting the spent time from the allotted competition time. The spend time is the total time spent for the Preparation Phase (at least 10 minutes), for the Operation Phase (excluding the time suspended during the Bring-in/Carry-out State), and for the Reset Phase (at least 2 minutes for each time).

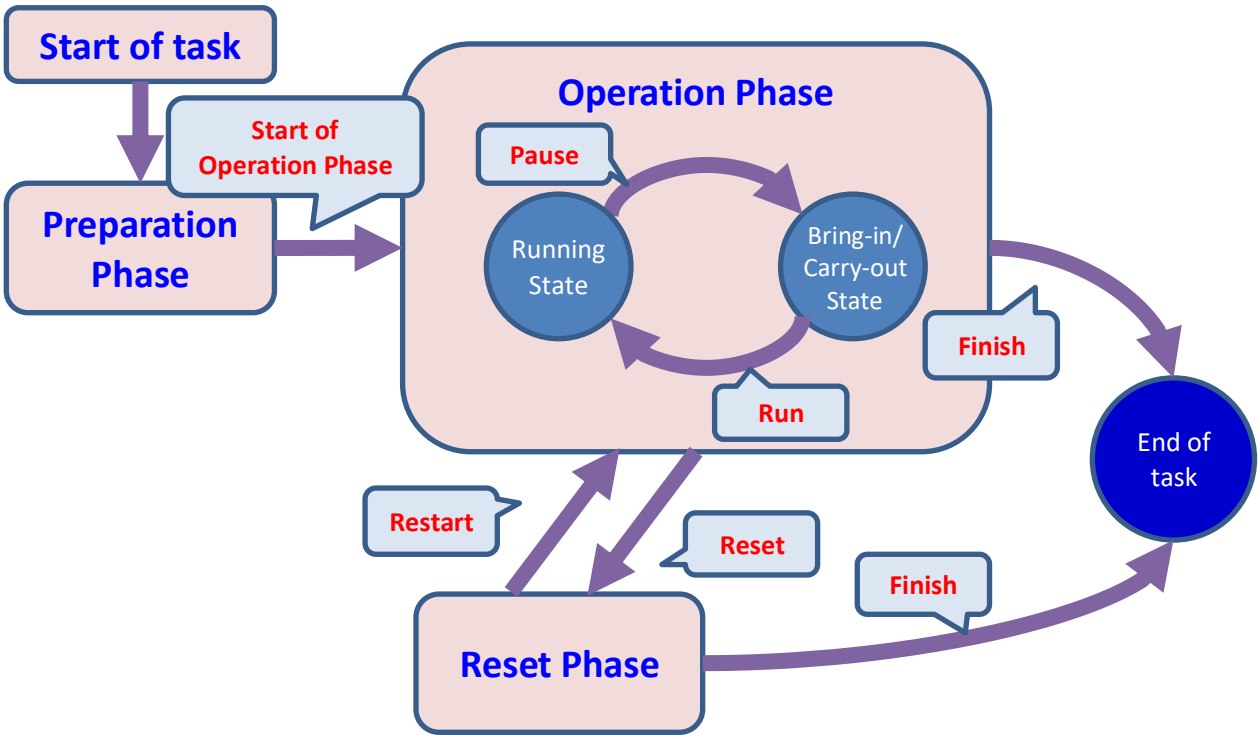


Figure 8: Transitions between phases and states by declaration and approval

5.2 Method of Supplying Parts to Robot Systems

The way to supply the parts are supplied to the robot systems has been changed significantly, compared to the WRS 2018 pre-competition in Tokyo. The parts used in the task-board task and the parts for a single belt drive unit used in the assembly tasks will be supplied by laying them on a single parts tray (Figure 9), except common small parts like screws, washers, and nuts. A black cushion will be placed on the bottom of the parts tray. There will be no partition plates inside the tray, and in principle the parts will be set without overlapping. Refer to Appendix D for detailed specifications of the parts tray.

Before the Preparation Phase starts, the tray containing the parts should be placed on the table in Operation Area-2 by the referee (see Figure 6). When the Preparation Phase begins, the referee hands over the tray containing the parts to the team, and the team confirms that the supplied parts are not defective. In the assembly task, if the team wants to adjust the state of the parts described later, they can do such adjustments at this timing.

After checking and adjusting, the final placement of the parts on the tray will be done by the referees during the Preparation Phase, and the placement positions and orientations of the parts may change each task (Figure 10). Information about the parts layout on the tray will not be announced in advance, so the robot must be able to correctly pick up the parts from the tray regardless of where the parts are located in the tray. Further, as will be explained later, when transporting the trays to the top of the AGV manually and carrying in the parts tray to the System Running Area with the AGV, the vibrations may cause parts to overlap, but teams may not alter the positions of the parts.

The method for carrying the parts tray into the System Running Area is planned to use an AGV. Each team will be supplied with an AGV at the competition venue. First, the team

members manually place the parts tray from the table in Operation Area-2 to the top of the AGV staying in the System Running Area just behind the door. When a team member opens the door, the team must declare “Pause” and the robot system must transit to the proper mode, as shown in Section 5.1. Once the team members have placed the parts tray(s) on top of the AGV, the only actions that each team is permitted to do later is to carry the tray in to the System Running Area by the AGV. This means that the teams may not touch the parts tray or the parts in the parts tray when bringing in the parts tray. Picking up parts from the parts tray on the AGV must be done by robots only. Those parts will include the base plate as well in the case of assembly task (Figure 10). In other words, please be aware that although the base plate was permitted to be placed manually by the team members during the Preparation Phase in the WRS 2018 competition, this action will be prohibited in the WRS 2020. If team member touches a part on the parts tray, the referee must place it again. When bringing in or carrying out (explained later) the parts tray, it is permitted to bring in and carry out the parts trays one at a time or all them together. Please note that parts trays will be stackable even with parts inside.

For small parts (screws, washers, and nuts), based on the assumption that a supply device for those parts would be used in real sites, each team will be permitted to use a screw holder or a screw supplying device as long as they prepare themselves (Figure 11). It is permitted to place those devices on the worktable in the System Running Area beforehand. Those small parts (about 100 pieces for each part) will be provided at once during the team setup period and will not be provided separately at the beginning of each try. Note that teams should not use other small parts than those provided ones.

When bringing in or carrying out the parts tray, teams must follow the safety procedures described in Section 6 (Safety and Health) and safely stop the robot system. It is permitted to bring in and carry out the parts trays one at a time or all them together. Please note that parts trays will be stackable even with parts inside.

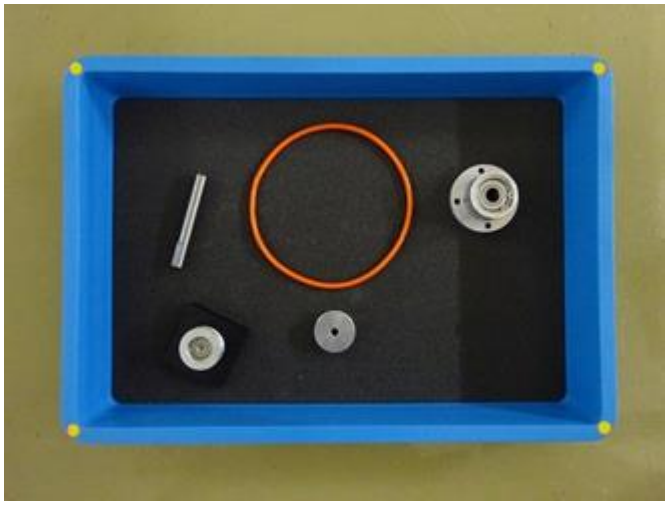


Figure 9: An example of supplied parts laid out on a parts tray for the task-board task

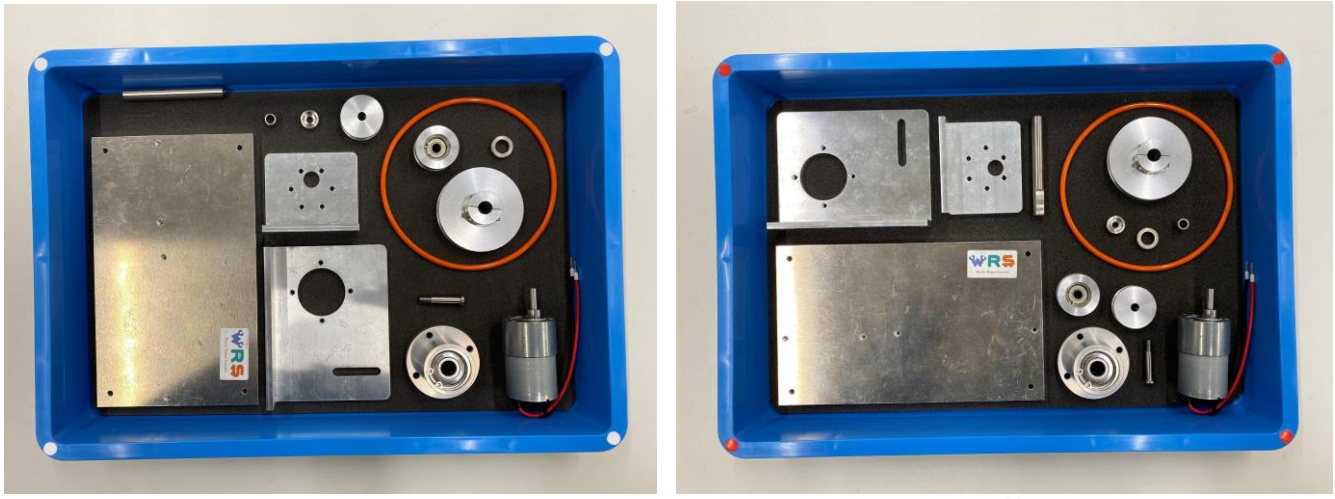


Figure 10: Example of supplied parts laid out on a parts tray for the ``assembly task:
Parts placement pattern A(left) and pattern B(right)
(The parts shown here were the ones used in the WRS 2019 trial competition)
(The colors of the markers at the four corners may differ from tray to tray in WRS 2020)

Figure 11: Example of parts holder for screws, washers, and nuts
(The parts shown here were the ones used in the WRS 2018 pre-competition)

5.3 Carrying-out of Assembled Products

In the assembly task, carrying out the completed products is the reverse procedure of bringing in the parts tray by the AGV. The robot must place the finished product(s) on the parts tray and then place the tray on the AGV. Next, the team members can operate the AGV to transport the parts tray near the door leading to Operation Area-2. The team members then manually carry the parts tray and place it on the top of the table in the Operation Area-2. As with the case of bringing-in, when the team members open the door, they must declare “Pause” as shown in Section 5.1 and the robot system must transit to the proper mode. The team members should not touch the parts tray(s) as well as the products or parts inside directly until the AGV completes the transportation of the parts tray (i.e. until the AGV arrives back to the starting position in front of the door leading to Operation Area-2). The team members cannot touch the assembled product(s) on the parts tray(s) until the referee has completed the product evaluation and scoring.

Note that only products that have been transported to the designated area outside the System Running Area (namely on the table in Operation Area-2 shown in Figure 6) within the allotted competition time will be subject to product evaluation and scoring in the case of assembly task. In the case of the task-board task, the task ends when all parts are assembled on the task board, so it is not necessary to carry out the task board or the parts tray.

Even if all parts are not assembled, the product can be carried out for scoring. However, even if the product is not completed, for example the half-completed product, it must be carried out by the AGV. In other words, the product must be placed on the parts tray by the robot. Products may be carried out one at a time or all them together. Once “Pause” has been declared and approved in order to carry out a product and the state has been changed from the Running State to the Bring-in/Carry-out State, the progress of the competition time is suspended for a fixed period (assuming 1 or 2 minutes). Each team should bring in/carry out the parts trays without rushing for their safety.

In order to carry out a product that the robot cannot place on the parts tray (including partially finished products), “Skip” must be declared so that parts and/or the parts tray can be moved manually. Skip will be explained in detail in Section 5.5. Although, parts are normally returned to their initial state by a “Reset”, team members may place a product in the parts tray and put the tray on the AGV only when they want to carry it out. After placing the product in the tray on the AGV manually by “Skip”, the team must return to the Operation Phase once and then declare “Pause” to move into the Bring-in/Carry-out State and carry out the parts tray by the AGV in the same way as normal bringing-in/carrying-out.

5.4 Reset

Teams may choose to reset their systems including the robots if their system does not operate as intended during the Operation Phase. In the event of using a reset, it will be possible to transition from the Operation Phase to the Reset Phase by setting the robot to Emergency Stop Mode or Manual Mode that satisfies the safety conditions described later. After recovering the system, teams must return the robots and task objects, etc. to their initial state as defined elsewhere, and restart the task. Restart of the task is prohibited until a certain time has passed (assuming two minutes) since the reset was started, in order to prevent frequent reset and restart. If the resetting took longer than the predetermined time, the task can be restarted at any time. However, if the parts on the parts tray must be restored to their original locations, be aware that the referee will restore the parts layout on the parts tray during the Reset Phase.

Refer to Section 5.1 for actions permitted and prohibited during a reset. No point deductions will be taken for using a reset. Note that even if a team uses a reset, their competition time will not be extended.

5.5 Skip

In the assembly task, the robot must place the product on the parts tray in order to carry out a completed product. If a team wants to carry out a product (or a half-finished product) that the robot was unable to place on the parts tray for some reason, or if the robot was unable to return the parts tray to the AGV, a team can declare “Skip”, and manually return the product to the parts tray and manually place the tray on the AGV if necessary. Be aware that once “Skip” is declared and approved, the robot cannot be used until the product has been carried out. In other words, team

members must manually place the product on the parts tray, and then put the parts tray on the AGV. If there are several half-completed products to be carried out, they may all be placed on the parts tray at once.

When “Skip” is declared and approved, a penalty will be imposed, as described below. Declaration of “Skip” can be done only once per product. Be aware that even if a team takes “Skip”, the competition time will not be extended.

Once “Skip” is declared and approved, team members can enter the System Running Area. Therefore, just as when “Reset” is declared, the robot must be safely stopped in Emergency Stop or Manual Mode, which will be described below in further detail. Once “Skip” is declared and approved, the timekeeping is continued but the team must stay in “Skip” for at least a certain period of time (assuming one minute).

When the parts tray containing the product is manually placed on the AGV by “Skip”, it is assumed that the next step is to declare “Pause” in order to carry out the product by the AGV. Therefore, after completing the manual work by “Skip”, it won’t be possible to start the robot operation immediately. If “Skip” is declared and approved but the product is not carried out, that product will not be included in the scoring. In other words, be aware that even if “Skip” is declared, only products that are carried out by the AGV in the parts tray and delivered to the designated place outside the System Operating Area will be eligible for scoring.

The only items that may be touched by team members during Skip Phase are the products (including half-finished products) and the parts tray. If the product or parts tray cannot be removed because the robot is touching the product or parts tray, it is necessary to declare "Reset" to evacuate the robot to a safe position even during the Skip Phase. In this case, the progress of the competition is suspended at least for three minutes, two minutes due to “Reset” and another one minute for “Skip” (note that timekeeping is continued). If a team decides to unload the product (which is likely to be a half-finished product) instead of starting over the subtask that they are currently working on, they can declare "Skip" even during Reset Phase. Again, the progress of the competition will be suspended for at least 3 minutes.

Teams can also cancel "Skip" and change to "Reset", i.e. they can change the strategy from unloading the product (which is likely to be a half-finished product) to starting over the current subtask. Note that two minutes suspension is applied in this case and the team cannot declare "Skip" again for that product.

The following penalties will be imposed on products carried out by a Skip. First, even if a product is determined to be completed, a complete bonus will not be given, and the eligibility for a time bonus for that task will be cancelled. Second, if a product is not completed, it will be awarded only half the original points (rounding down) that the product is eligible for.

From the viewpoint of task phases and robot modes, “Skip” is treated equivalently as “Reset”. Therefore, Skip Phase is not specifically shown in Figures 8 and 13.

5.6 Dealing with AGV Errors

If the AGV becomes inoperable for any reason, the following measures will be taken. All time used to resolve the AGV error will be excluded from the competition time.

5.6.1 Dealing with Errors during Bringing-in

If the AGV becomes inoperable during bring-in, the progress of the competition time should be immediately stopped, and the team should safely stop the robot system by setting the robot in Emergency Stop Mode or Manual Mode which will be described later. Next, they should remove the part tray from the AGV and move the AGV by hand to the planned location inside the System Running Area where it is supposed to stop, and then place the parts tray containing parts again on the AGV. Once all people have exited the System Running Area and safety has been confirmed, the robot is brought back to a state of operation, and the competition begins. If the AGV cannot be pushed by hand, the competition will be cancelled and a re-competition will be scheduled.

The AGV that becomes malfunction during bringing-in will not work for the following carrying-out either, so the guidelines for dealing with errors during carrying-out shown next will also be applied.

5.6.2 Dealing with Errors during Carrying-out

If the AGV becomes inoperable during carrying-out, the progress of the competition time should be immediately stopped, and the team should safely stop the robot system by setting the robot in Emergency Stop Mode or Manual mode which will be described later. Next, they should manually carry out the parts tray on the AGV from the System Running Area. If the AGV becomes inoperable during the carry-out process, the team should move it back by hand to the location inside the System Running Area where it is expected to stay during the assembly task.

If an AGV error occurs when carrying out the product not at the end of competition but in the middle of it, parts for the next product must be brought in manually. In such a case, the team must follow the guidelines for dealing with errors during bringing-in shown in 5.6.1.

5.6.3 Restoring a Broken AGV

If the AGV becomes inoperable during the competition, a person in charge asked by the competition committee will repair and restore it. If it cannot be restored, it will be changed out with a spare AGV. If several AGVs become inoperable and there aren't enough spares, that team may be asked to use a manual pushcart instead of an AGV. If that occurs, the time necessary to transition the robot to Safety Mode and back again, which was not necessary with the AGV, will not be counted as part of the competition time.

5.7 Time Extensions due to Trouble

Each team is responsible for any trouble that occurs in their team area during the competition and no time extensions will be given for any of the tasks. This would include, for example, communication failure with a robot. Note that the competition can be suspended according to judgment by the referees. In the event of issues that influence every team, such as problems with the AGVs (except mistakes of operations, settings, etc. made by a team) and a power outage, the competition committee may allow an extension of time after deliberation.

5.8 Task Completion and Scoring

Referees will score in accordance with the scoring criteria of each task. Referees will evaluate the state of the completed task board in the case of the task-board task, and the state of assembled products which are carried out in the case of the assembly task. For incomplete products, partial points will be added in accordance with the scoring criteria. When the required

task has been completed earlier than the time limit of the task, extra points will be added as the time bonus based on the remaining time.

5.9 Penalties

This section describes actions when teams breach rules and regulations. Referees will determine the penalties after deliberation if an issue not addressed in this section occurs.

5.9.1 Withdrawal or Suspension from the Competition

If a participating team withdraws from a part of the competition, or if the referees judge that the content of the competition by a team is equivalent to withdrawal, the team may be excluded from the ranking evaluation. The team may also be removed from consideration for various awards. Teams will also be withdrawn if they do not satisfy the safety and health regulation or do not follow the directions of the Safety and Health Management Committee. The Safety and Health Management Committee is described in Section 5.8, and the safety and health regulation are described in Section 6.

5.9.2 Damage to the Field

Teams must not bump into or damage any materials at the competition venue. Any team that causes serious damage that cannot be repaired immediately will be disqualified until that is repaired. This rule applies to damage caused not only by robots but also by team members.

5.9.3 Interference to Other Teams

The team areas are quite close together, and teams must not cause problems to neighboring teams. This policy applies to not only baggage protruding from their own team area, but also to acoustic or electromagnetic noise, vibration, heat, exhaust, smell, lighting disturbances, and so on.

5.9.4 Damage to Parts

Points shall be deducted if referees determine that a part distributed to a team has been damaged and may no longer be used in the competition. A part deemed necessary to change shall be replaced with a spare part, but a spare part may not be available in some cases, because the number of spare parts is limited. Further, teams may not add markers to the parts provided by the competition committee.

5.9.5 No Show

Teams shall be withdrawn from a task if no team member is present in the team area at the time to start a session or if the team is clearly not ready to start a task.

5.9.6 Number of Players

As outlined in Section 3.2, there is a limit to the number of players that may enter their team area consisting of the Operation Area, the System Running Area, and Team Storage Area. If the number of team members allowed in the area at one time is exceeded, points will be deducted. This may be confirmed not only by the referee but also by the Safety and Health Management Committee as outlined in the following section. The limit of ten people is not only for during the

task-board task and the assembly task but also during the time period when the team is making adjustments of their system. However, in the event that the limit is reduced to five players due to COVID-19 prevention measures, the area and period of limitation will be designated separately.

In either case, the limit of the number of people does not include the referee, Safety and Health Management Committee members, the competition committee members, and so on. As this section is written with the goal of ensuring a safe competition, the first violation confirmed by the referee or Safety and Health Management Committee will result in a warning and points will not be deducted. If the same team makes a second violation, points will be deducted. If another team points out a violation, the referee and/or Safety and Health Management Committee will intensify their patrols. However, the Competition Committee is expecting that pointing out violations by other teams will lead to increasing safety awareness of the teams.

5.10 Referees & Safety and Health Management Committee

At least two referees will be assigned to each team during the competition. The team members must obey the instructions of the referees. In the WRS Industrial Robotics Category, the referee group will consist of non-team members and will not be selected from the team members. The referees' decisions are final. However, if an obvious mistake has been made, the decision may be revoked at the discretion of the competition committee chairperson.

The Safety and Health Committee will carry out safety patrols as needed, and point out any unsafe behaviors and/or safety issues. The Committee may stop a competition task and require safety and health improvements depending on the situations. Team members must always obey the instructions of the Safety and Health Management Committee. The Safety and Health Management Committee conducts safety and health inspections during the team setup period.

6 Safety and Health

Needless to say, the management of this competition puts safety and health at top priority. Concrete rules are formulated under the Safety and Health Management Policy. Any inconsistencies related to the protection of safety and health shall be rectified immediately.

6.1 Safety and Health Management Policy

6.1.1 Compliance Standards

Teams shall adhere to the ISO10218 series and higher international standards. However, durability and reliability may be dealt with in consideration of the short competition period.

6.1.2 Safety due to Separation Principle and Functional Safety

We aim to prevent accidents that occur as a result of physical contact between participants and objects including items used in the competition and scattered objects from those items. It is essential to introduce measures such as safety fences as a way to prevent this physical contact. The System Running Areas where the competition systems operate and the Operation Areas where participating teams and referees stay are the restricted areas called Team Area, and they are completely separated from the space where spectators are present by either safety fences (System Running Area) or partitions (Operation Areas). Even inside the Team Area, a safety fence is installed between the System Running Area and the Operation Area, and functional

safety is implemented and operated based on risk assessment in the area where humans and robots exist side by side. Safety fences and basic parts for safety circuits are provided by the competition committee. Participating teams must submit risk assessment results in advance. At the competition venue, they are required to connect their competition systems to the safety circuits, and pass a safety and health inspection before they may participate in the competition.

6.1.3 Obligation to Adhere to Safety and Health Management Regulations

All participants are obligated to protect the safety and health of everyone each other. For example, participating teams must strictly adhere to the Safety and Health Regulations stipulated by the competition committee. Spectators must cooperate with the competition committee by not entering restricted areas and recognizing the dangerous part of the competition tasks. If participating teams do not follow the Safety and Health Regulations and are found to be endangering participants, proper measures will be taken. These measures can range from asking participants to follow safety rules, to stopping of competition tasks, or even disqualification from the competition.

6.1.4 Safety and Health Management Committee

A Safety and Health Management Committee will be formed. This committee members will perform inspections for submitted document, Safety and Health Inspection before starting the competition at the venue, safety patrols during the competition, and point out unsafe acts, conditions, systems, and areas. Depending on the situation, competition may be suspended until improvements are made, and teams may be asked to stop their operations or even be disqualified. Teams must follow the instructions by the organization member.

6.1.5 Safety and Health Advisory Organization

An organization that advises on safety and health measures will be deployed in advance of the competition. Participating teams can seek advice from the organization for their safety measures and submitted materials described in below section, if necessary.

6.2 Safety and Health Regulations

6.2.1 Hardware Requirements

See Section 4.2 for hardware requirements. However, the Safety and Health Management Committee may restrict on use of the hardware if they are harmful to safety and health.

6.2.2 Safety and Health Requirements of Competition Systems

Competition systems must have accident prevention functionality installed. There must be emergency stop buttons, safety fences, a door with a safety switch, and an input from motion sensors. If there is a teaching device, there must be a properly working 3-posision enabling switch (so-called dead man’s switch). All of these must work properly, otherwise permission to participating in the competition will not be given.

All environmental pollution must be prevented. Acoustic noise, vibration, heat, smell, electromagnetic noise, harmful rays, air pollution, exhaust gas, waste liquid, toxic substances and any other harmful substances are prohibited from use without proper control or management. Please be especially aware of the output power of laser lights. This information

must be included in the risk assessment. If such items are installed without being reported by the team, it will result in ineligibility, even if they do not work.

If such as roofs, shades, towers, highly raised stages will be used to control natural light and artificial lightings or to install bird eye cameras, lightings, vision sensor system, please make an application in advance as the fire extinguisher must be reinstalled. Failure to apply can result in a starting delay or, worst, disqualify the competition.

As necessary, competition systems including robots may be fixed to the floor with anchor bolts. If using anchor bolts, please apply in advance to ensure the availability of installation operation. Failure to apply in advance can result in a starting delay or suspension.

Electricity and air will be supplied for each team system, but any changes in the supply lines must be made by a special person who has qualifications indicated by the venue. Thus, the construction will be done by the management side. Due to the danger involved, teams are never allowed to do this work. Any teams that do such work will be disqualified. Please notify the organizer if any work is required.

Any action that disables the safety and health equipment of the competition system or deviates from the operational rules for risk reduction or other unsafe actions are strictly prohibited and such actions will result in disqualification from the competition.

6.2.3 Materials for Advance Submission

Each team should submit following documents as an evidence for the risk assessment clarifying the team name, its representative person and the risk assessment implementation date by the prescribed date before the competition;

1. Overall description of the robot system

2. Operation manual of the system including prohibited matters

3. Risk assessment sheet including risk assessment and risk reduction measures

   The risk assessment sheet must also contain the followings;

   (1) Description of safety systems including emergency stop switches and door interlock switches and their safety performance

   (2) Mode switching circuit and its explanation

4. Residual risks list

Required materials are subject to change. Failure to submit them will result in disqualification.

Personal clothing and protective equipment to be worn by people working within the safety fence are defined in Table 4, and all members of the team must comply with it. Include this issue in the submitted materials.

Table 4: Clothing and Protective Gear for Work Inside the Safety Fence

Hair	Make sure to bundle long hair
Work clothing	Make sure to wear long sleeves and long pants that are not baggy
Helmet	Make sure to wear the proper type of helmet in the expiration date to mitigate head injuries
Protective goggles	Always protect your eyes. Make sure to wear the proper goggles, such can protect the eyes from scattering objects and hazardous rays.
Gloves	Make sure to wear the proper type gloves for electric shock and cut resistance for each object. However, gloves are strictly prohibited to wear when using rotation tools because they can become entangled.
Ear plugs	Make sure to wear the proper ear plugs for impulsive sound and steady noise to protect your hearing ability.
Safety shoes	Always protect your feet. Make sure to wear the proper type of shoes as necessary, for example, protection for heavy objects falling onto your toe.

6.2.4 Preparation before Starting Competition at the Venue

Each team will be provided safety fence and door switches etc. forming a safety circuit with open ended contact points. Each team will install their competition systems within and only within the safety fence (i.e. inside the System Running Area), and the competition systems must be connected to the safety circuit. However, computers and controllers whose housing shape does not change may be set up within the Operation Area. The equipment may not protrude from these areas regardless of where they are set up. The safety circuit consists of a door switch for the safety fence, an emergency stop button, signal lights, motion sensors, and more. Detailed specifications for the safety circuit will be provided separately.

6.2.5 Requirements to Pass Safety and Health Inspection before Starting Competition at the Venue

The Safety and Health Management Committee will examine the safety and health aspects of the team systems. Inspections will be held individually for each team. Safety and health inspections determine whether each team satisfies the regulations. Teams that do not meet the criteria will receive a request for improvement.

Teams may not participate in the competition until they pass the inspection.

6.2.6 Execution of Safety Patrols at the Venue

Safety and health patrols will be carried out as- needed. Corrective action will be recommended with regards to any safety and health concerns. Detection of undeclared items, competition systems with safety and health problems, non-use of necessary protective equipment, deactivation of safety equipment, electrical live-line working, team member running in the team area and other unsafe acts, exceeding the number of allowed competition participants, etc. will be pointed out. Depending on the situation, the competition may be cancelled, the applicable team(s) may be ordered to stop the competition, or the applicable team(s) may be disqualified.

6.3 Operation Modes

6.3.1 Mode Definition

The following operation modes are defined for robots and/or the robot systems in order for the systems to run safely. Using different operation modes for the Preparation Phase, Operation Phase, and Reset Phase aims for safe operations, and keeps people from harm.

The following three modes must be implemented;

- Automatic Mode
- Emergency Stop Mode
- Manual Mode (Reduced Speed)

The following mode is optionally allowed in order to perform teaching tasks more conveniently.

- Manual (High Speed) Mode

Each mode will be explained as follows.

(i) Automatic Mode:

This is the operation mode for ordinary work, corresponding to the Automatic Mode in the ISO standard, and there is no restriction on robot operation. During Automatic Mode, any person must never enter the System Running Area. The door between the System Running Area and the Operation Area must be closed.

(ii) Emergency Stop Mode:

When entering this mode, the robot stops and the power must be shut off. In the event of a system problem, the system should be immediately switched to this mode either automatically or manually. It corresponds to the Emergency Stop (Category 1 or 0) in the ISO standard. During Emergency Stop Mode, people can enter the System Running Area (including the Robot Working Area). The door between the System Running Area and the Operation Area may be opened.

(iii) Manual Reduced Speed Mode:

It corresponds to Manual Mode (Reduced Speed) in the ISO standard. In this mode, power is supplied to the robot and the servo is on. The speed of the robot is limited to 250mm/second. The human operator can use a teaching pendant or a similar device to control the robot manually. The safety door between the System Running Area and the Operation Area may be opened. Human are allowed to enter the System Running Area (including the Robot Working Area). However, in this competition, as shown in Section 5.1, the human operator is not allowed to control the robot when the task is in Operation Phase, especially in Bring-in/Carry-out State of this competition that uses these Manual Mode (iii) and (iv).

(iv) Manual High Speed Mode (Optional):

This mode is equivalent to Manual Mode (High Speed) in the ISO standard. Power is supplied to the robot, and the servo is on. The speed of the robot can exceed 250mm/sec. Be aware that this mode should only be used for program verification, must not use instead of automatic mode. See (iii) for other caution for this competition.

6.3.2 Mode Implementation

Robots with three operational modes (Automatic Mode, Emergency Stop Mode, and Manual Mode) are as illustrated in Figure 12.

Figure 13 shows the relationship between the robot operation modes and task phases, and the conditions allowed in each operation mode.

At present, we are considering the use of the items shown in Figure 14 for safe operations.

The signal tower is a display device used to notify the operator, the referees, and others about the current operating mode of the robot. The mode select switches are selector switches that are used to allow the operator to manually change the operating mode of the robot. When the emergency stop switch, safety door switch, or enabling switch is activated, the robot should transition to the emergency stop mode immediately.

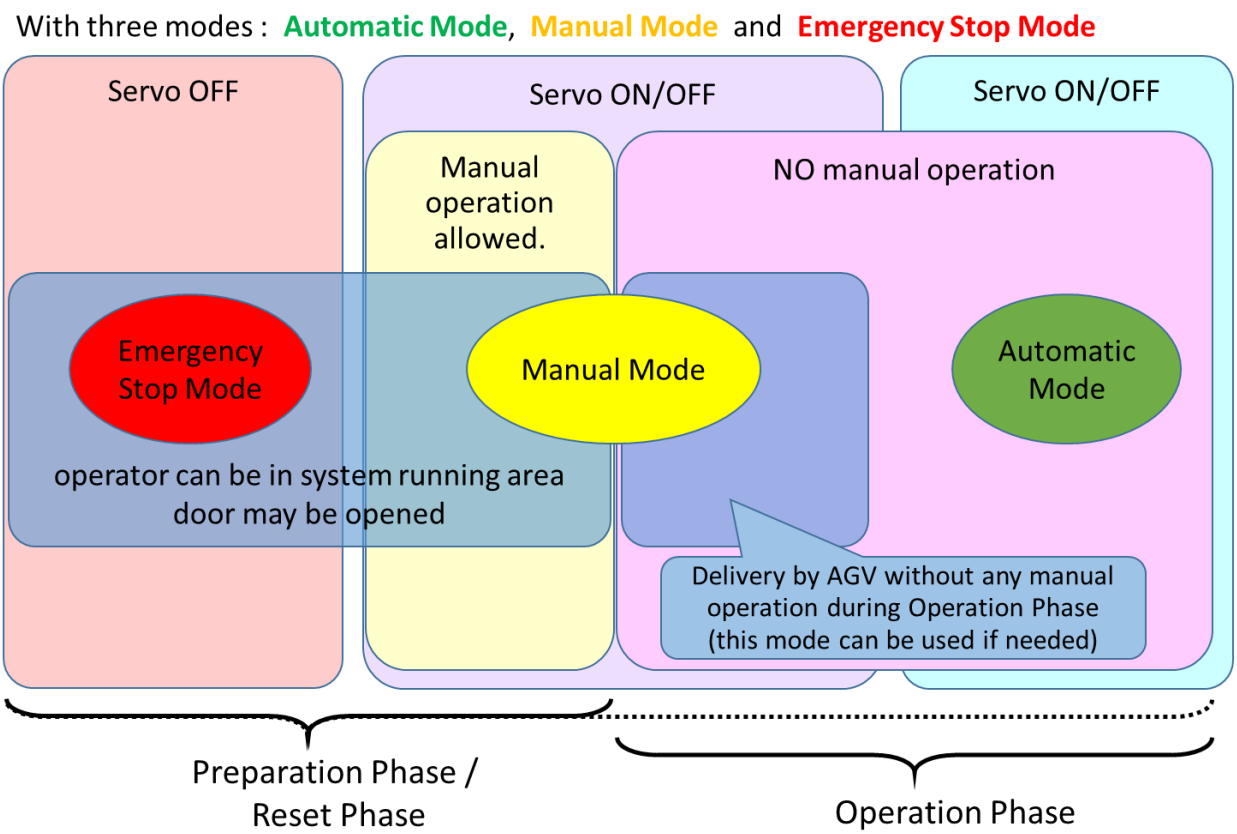


Figure 12: Implementation case with three robot operational modes

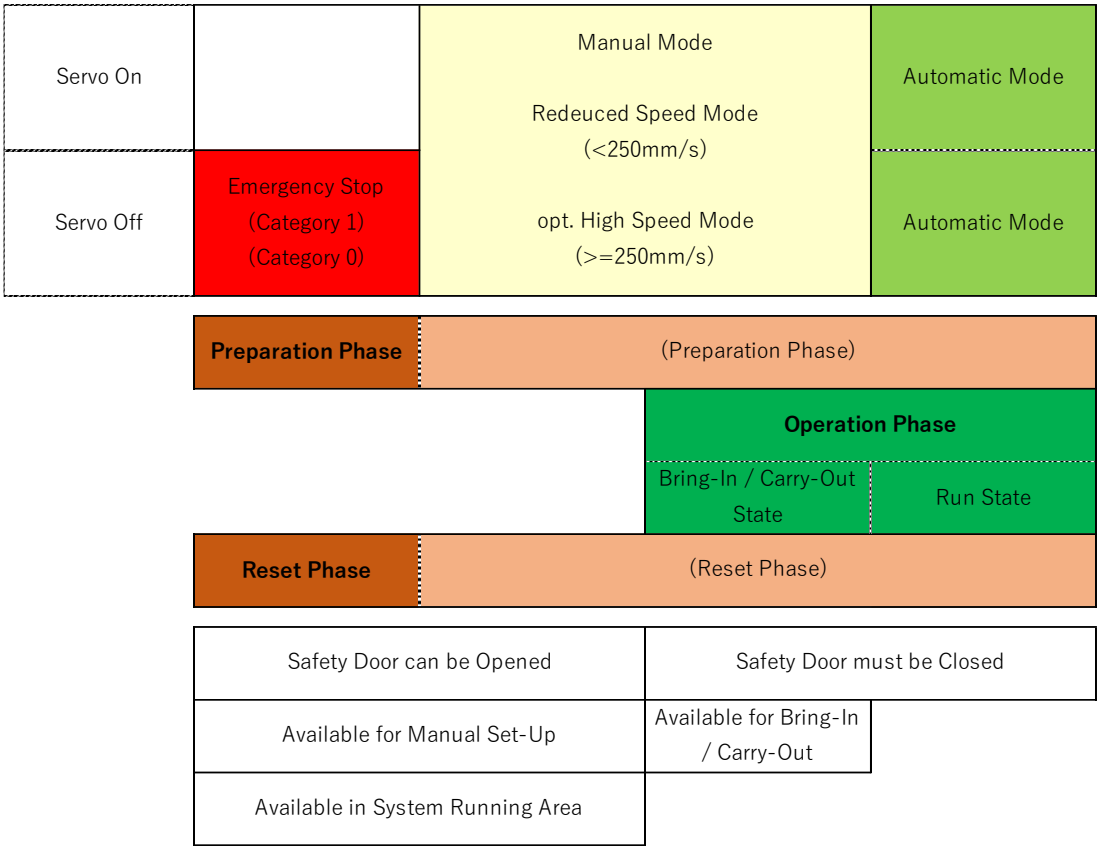


Figure 13: Relationship between robot operation modes and task phases (subject to change)

Excluding some of them, it is not necessary for the teams to use all of those switches and devices. However, if some of them are not used, there must be some alternative way to ensure a safe mode transitions, and the team must pass the safety inspection.

Various examples of operation transitions are shown in Figures 15.

Switches and Signal Towers

Figure 14: Items planned to use for safe operations

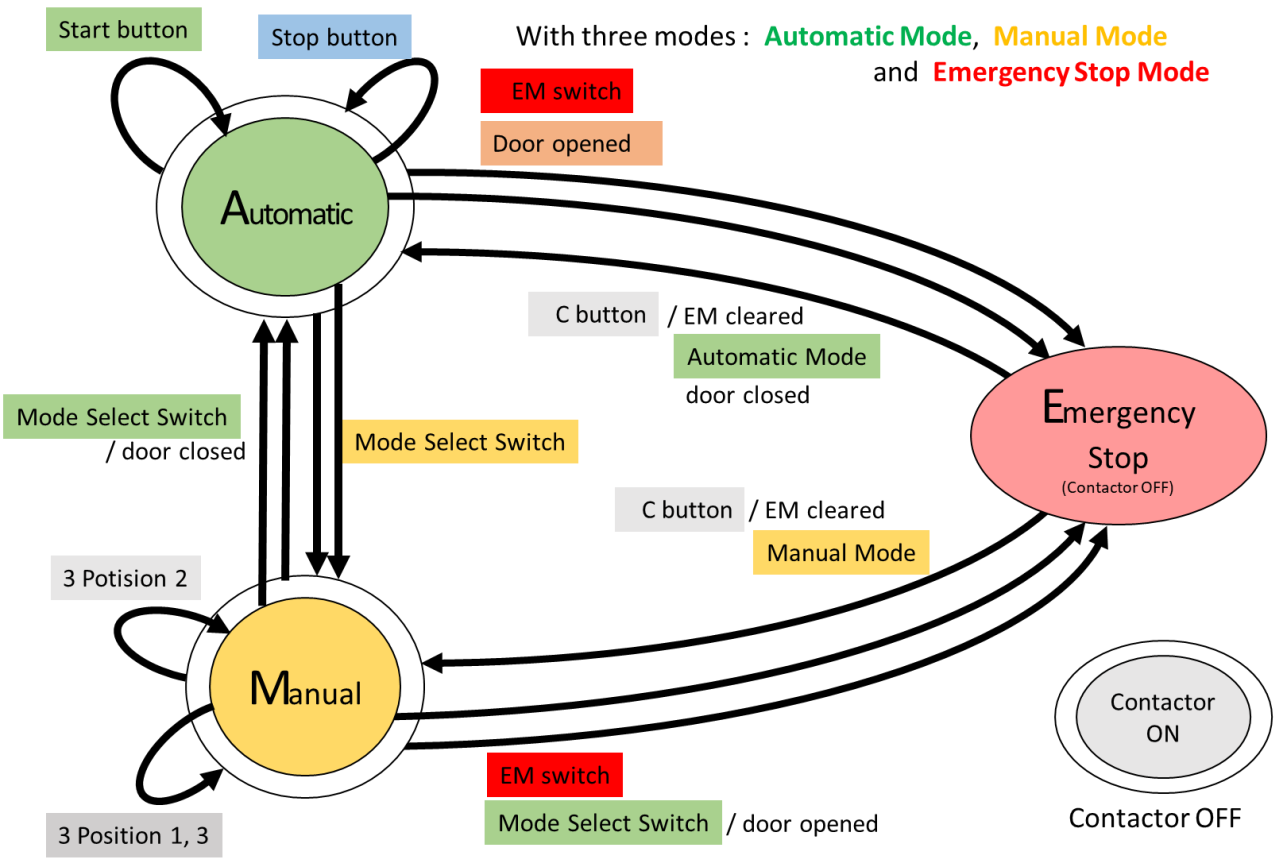


Figure 15: Example of mode transition between three operational modes

7 Task-Specific Rules

7.1 Task-Board Task

7.1.1 Outline

In this task the elemental technologies for assembling a belt drive unit are evaluated using the task board[3], on which the extracted elemental technologies are arranged.

In this task, the robot must pick up the parts placed on the parts tray and small parts on the parts holder, and assemble them to the designated locations on the task board. The robot may use appropriate tools as necessary. Figure 16 shows the parts arranged on the parts tray, Figure 17 (a) shows the task board with assembled parts, and Figure 17 (b) shows its side view. Figure 18 shows the task board in its initial state before the parts have been assembled. The plate and parts shown here are still preliminary version. So, the parts and arrangement in the competition may be different. Please refer to the upcoming rules.

In this task, teams compete for the superiority of the elemental technologies required to assemble a belt drive unit, such as recognition of parts, alignment of parts, insertion of parts, fitting of parts, fastening of parts, and attachment of flexible parts. In some operations, it will be necessary to consider the order of the work, for example first fitting the bearing housing in to the hole of the L-shaped plate then fastening it with bolts. Technical challenges in the task-board task are (1) part recognition and grasping, (2) fitting parts with very small clearances, (3) nut screwing, (4) flexible part (e.g., a belt) and tiny part grasping and assembly, and (5) simultaneous 3-part assembly.

Figure 16: Parts on the parts tray for the task-board task
(Parts layout shown here is just an example and actual layout may differ from it.)

[3] The idea and design for the task-board task was strongly inspired by the task board designed by NIST, which was used in the 2nd Robotic Grasping and Manipulation Competition [3] held at IROS2017 [6].

Figure 17: (a) Assembled task board (front view) (b) Assembled task board (side view)

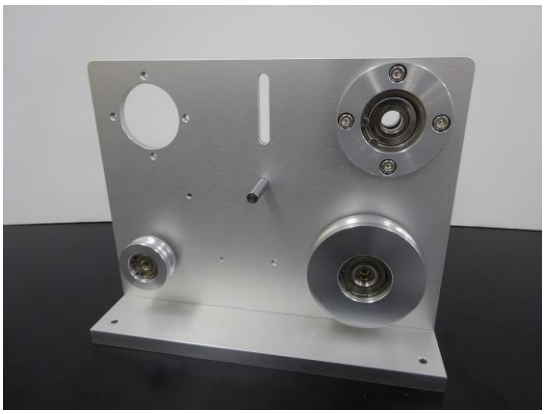


Figure 18: Task board before assembly (initial state)

7.1.2 Rule Details

(1) Parts supply method and task board

This task will use the same parts used in the assembly task. See Appendix A.1 for details on the parts to be assembled. There will be several parts already assembled on the task board. These parts are detailed in Appendix A.2 The parts listed in Appendices A.1 and A.2 are all products made by MISUMI. Details about individual parts can be found on the MISUMI website. 3D-CAD data files for the parts are available to download from the MISUMI website. Unlike WRS 2018, the material of the task board will be metal (Aluminum A5052: White anodized) so that the difficulty in fitting parts with tight clearance would be the same as the assembly task. Additionally, in order to match the working direction with the assembly task, the plate on which the parts are to be assembled stands upright on the base plate. The sizes of the two plates will be detailed in Appendices A.3 and A.4. Markers may not be placed on the task board or the parts. Finally, note that the layout of the task board which will be used in the actual task-board task in the WRS 2020 may be different from that shown in Appendix A.4.

After the Preparation Phase is completed, the Operation Phase begins, and the robot assembles the parts on the task board. During the Operation Phase, the teams may not touch the robot, parts, tools, task board, parts tray, or parts holder for small parts.

During the Operation Phase, the robot system will do the following operations with the parts:

(i) The robot system picks up parts from the parts tray or the parts holder.

(ii) The robot system assembles the parts on the board in predetermined positions.

The above procedure is repeated for each of the parts. However, the set screw is already assembled on the task board (see Appendices A.2 and A.5). Teams must assemble as many parts as possible accurately within the allotted task time. The order in which the parts are assembled may be decided by the team. As the parts will stay on the task board after they are placed, the placed parts may interfere with the operations of the robot system that come after.

If a “Reset” is declared and approved, teams must return all parts to their initial positions except the set screws.

(2) Preparation Phase

Before the Preparation Phase begins, teams should move the AGV to the starting position at the end of the pathway for the AGV after the referee approves it, right next to the door leading to the Operation Area-2 shown in Figure 6.

When the Preparation Phase starts, the referee will supply teams with a task board and the parts tray containing the parts. Once the teams receive the task board and the parts tray from the referee, they can check the conditions of the parts. As shown in Figure 16, the idler pulley will be provided in the upright position with a jig. Figure 19 shows a jig for the idler pulley. This jig will be made out of aluminum, and there will be black anodizing on the surface. The size will be 50mm x 50mm x 10mm and there will be a through hole in the center of 6.3mm in diameter. The task board will be supplied to the teams in the state shown in Figure 18.

Next, the referee will use a template to arrange the parts in the parts tray on the table of the Operation Area-2. Details about the template will not be made public. While parts arrangement by the referee, teams can place the task board anywhere within the System Running Area during the Preparation Phase. Teams will be able to fix the task board on the working table with a clamp, place a non-slip mat beneath the task board, and place necessary tools during the Preparation Phase as needed. Teams must prepare the needed tools by themselves. Teams may modify tools as necessary. Tools used may be installed into the robot hand in advance.

Once the referee has completed the arrangement of parts in the parts tray, teams must transport the tray to the top of the AGV by hand, and then operate the AGV after the referee approves it and bring in the parts tray into the planned location in the System Running Area by the AGV. In case of an emergency stop of the AGV, the AGV is returned to the original starting position. Then, the referee will use a template to arrange the parts in the parts tray on the table in the Operation Area-2 again. Details of parts supply are outlined in Section 5.2.

The Preparation Phase is scheduled to take at least ten minutes.

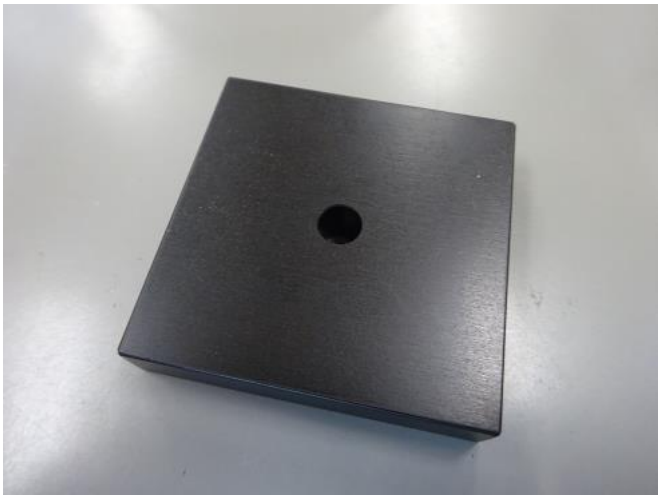


Figure 19: The jig for placing the idler pulley

Table 5: Points of Task-Board Task

Subtask	Target part(s)	Task Description	Points		
			Completion Level		Max
			Level 0	Level 1	
1	Bearings with housing, 4 x M4 Bolt	Insertion into a hole, Screwing into a tapped hole	0	14	14
2	Idler pulley, M6 Nut	Fastening a nut and a bolt	0	14	14
3	Drive shaft	Insertion into a hole	0	14	14
4	M3 Set screw	Screwing into a tapped hole	0	14	14
5	4mm Round belt	Looping over pulleys	0	14	14
6	Pulley	Placing onto a shaft	0	10	10
7	M3 Bolt	Screwing into a tapped hole	0	10	10
8	M4 Bolt	Screwing into a tapped hole	0	10	10
				Total	100

(3) Evaluation method and point allocation

After the end of the time period of the task or the Finish is declared, the task board will be evaluated as it sits in the System Running Area. If the robot is touching any parts or the assembled product at the end of the task, those parts will not be scored. Points are added based on the number of completed parts. Points are allocated based on the completion level of assembly. The completion level will be set for each part. See Table 5 for the scoring based on the completion levels. A chart of these levels can be found in Appendix A.5. Assembling of flexible parts, tiny parts, and three parts assembled simultaneously with multiple arms will be scored higher.

In the event that all parts are completely assembled, points for a time bonus will be awarded

based on the amount of time remaining for the task. In order to get a time bonus, all parts must be completed at level 1. One point will be awarded for every 20 seconds of remaining time for a maximum of 50 points. The maximum of 50 points corresponds to completing the task board in 3 minutes and 20 seconds after the start of the competition.

Teams can try the competition of the task-board task as twice, and better score of the two tries will be applied. The competition time is planned to be 20 minutes. The order of the start time for each team will be determined by the competition committee.

7.2 Assembly Task

7.2.1 Outline

The purpose of this task is to quickly and accurately assemble a model product that contains the elemental technologies necessary for the assembly of industrial products. At the WRS 2020 competition, teams will assemble the belt drive unit similar to the one used at the WRS 2018 competition (Figure 20). Note that the model product for WRS 2020 is not exactly the same as the model product for WRS 2018. Refer to Appendix B for details on the parts to be assembled and the sizes of the plates. Note that, unlike WRS2018, the plates are anodized white.

In this task, the robots of each team must pick up parts directly from the provided parts tray, and assemble a belt drive unit from those parts. Also, in order to evaluate the ability to respond quickly to new production demands, the robot system will be required to assemble a new product (surprise product) that will be announced for the first time just before the competition begins. This means that teams will have to make quick setup changes. However, information on parts that will constitute the surprise product will be announced in advance so that hands and other devices can be designed and prepared in advance. If necessary, the robots may use appropriate tools.

The assembly task will be held over the series of two days. The first day of the assembly task (Day 2) will be for assembling pre-announced normal products. The second day of the assembly task (Day 3) will be an assembly task that includes a surprise product.

In addition to the items mentioned in the task-board task, technical challenges in the assembly task are recognizing and grasping various sizes of parts, motion planning of multiple arms, jig-less assembly, and agile response to surprise products. In order to utilize these technologies, teams must be able to include force sensors, vision sensors, and robot hand systems (multiple hands may be used) that can grasp a variety of parts, using robots with appropriate movable range. All should be able to be set up within a short time.

In this competition, we aim to realize the future of manufacturing through construction of production systems that can respond to variable production requirements in agile and lean manners (ultimately even for one-off production requirements) in high-mix low-volume production or variety and variable production. We expect teams to realize a system that can be changed over quickly as well as performing rapid production.

In the following subsections, overall competition schedule is shown in Section 7.2.2, competition time is shown in Section 7.2.3, competition time-line is given in section 7.2.4, “Reset” in the assembly task is described in Section 7.2.5, definition of subtasks is given in Sections 7.2.6 and 7.2.7, and surprise product is explained in Section 7.2.8. Finally, product evaluation, scoring, and time bonus are explained in Sections 7.2.9, 7.2.10, and 7.2.11, respectively.

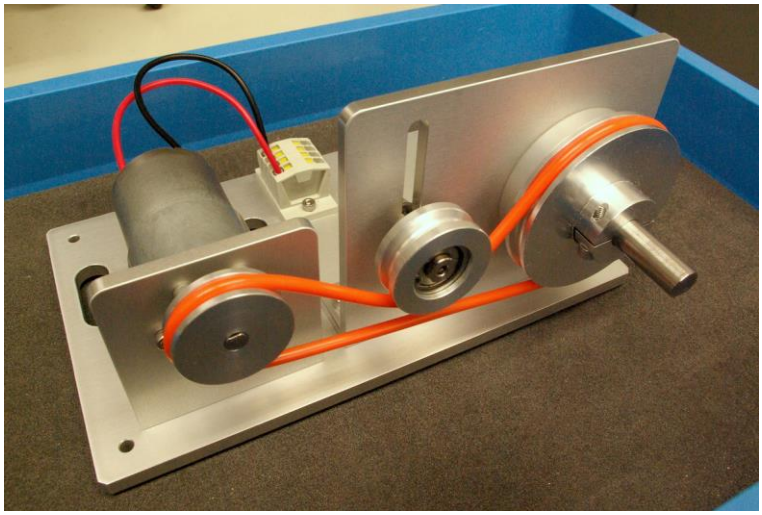


Figure 20: Belt drive unit; A sample photograph of the model product in the assembly task.

7.2.2 Overall Competition Schedule

The first day of the assembly task (Day 2) will be the day when teams assemble the normal product for which all design information has been released in advance. In the morning, each team will join a rehearsal competition where teams can check their system and referees can check the way of scoring in the same environment as the actual competition. On the afternoon of the same day, each team will try an actual competition, where two normal products should be assembled. The score will be a total of the scores for the two products. On the second day of the assembly task (Day 3), teams will assemble one each of both the normal and surprise products within the allotted competition time. This competition is designed to assemble normal and surprise products in a mixed production style. On Day 3, tries will only be conducted twice for each team, and the better score will be the one that is counted.

7.2.3 Competition time

Day 2 Morning: A rehearsal will be held in the same environment as the competition of Day 2 afternoon, and with the same task time (namely 30 minutes).

Day 2 Afternoon: Assemble two normal products. Task time is scheduled to be 30 minutes. The order of the start time for each team will be determined by the competition committee.

Day 3: Assemble one normal product and one surprise product. Each team will have two tries. Task time is scheduled to be 40 minutes in the morning, and the second try in the afternoon will be 30 minutes. It is not yet decided when the information about the surprise product will be disclosed, but it will be after the system setup at the venue. The order of the start time for each team will be determined by the competition committee. Note that the schedule of Days 2 and 3 is subject to change.

7.2.4 Competition Time-line

(1) Preparation Phase

Before the Preparation Phase begins, teams should move the AGV to the starting position at

the end of the pathway for the AGV after the referee approves it, right next to the door leading to the Operation Area-2 shown in Figure 6.

When the Preparation Phase starts, the referee will supply teams with a set of parts trays. First, the team will receive the trays from the referee, and can check the conditions of the parts. If teams want to adjust the parts conditions related to Subtask B, they can do these adjustments at this timing (see Subtask B in Section 7.2.5). Next, the referee will use a template to arrange the parts to be assembled in the parts tray on the table of the Operation Area-2. Details about the template will not be made public.

Once the referee has completed the arrangement of parts in the parts tray, teams must transport the tray(s) to the top of the AGV by hand, and then operate the AGV after the referee approves it and bring in the parts tray into the planned location in the System Running Area by the AGV. In case of an emergency stop of the AGV, the AGV is returned to the original starting position. Then, the referee will use a template to arrange the parts in the parts tray on the table in the Operation Area-2 again. Details of parts supply are outlined in Section 5.2.

(2) Operation Phase

If a team completes the preparation within 10 minutes, it can move to the Operation Phase 10 minutes after the start of the Preparation Phase. If it takes more than 10 minutes, the team can move to the Operation Phase as soon as it is ready.

The assembled product should be returned to the parts tray and this tray should be returned on top of the AGV by robots or other systems without intervention by team members. Then the parts tray with the assembled product should be carried out by the AGV. Once the AGV has returned to the original starting position, then team members can take the parts tray and move it to the designated location (namely on the table in the Operation Area-2). If the assembled product cannot be moved to the parts tray by robots for some reason, teams can declare “Skip” and move the product to the tray manually. Details about carrying out the assembled product are outlined in sections 5.3. See also section 5.5 for details about “Skip”.

Note that only products that have been transported to the designated area outside the System Running Area within the allotted competition time will be subject to product evaluation and scoring.

(3) Product evaluation and scoring

After the end of the time period of the task or the Finish is declared, teams can ask the referee to evaluate their assembled products. Product evaluation will involve checking whether the belt drive unit functions correctly, and points will be assigned based on the level of achievement.

See Section 7.2.8 for details about the product evaluation.

After the product evaluation or right after the competition if teams do not ask the product evaluation, the referee will score the assembled product based on the completion level of each subtask. See Section 7.2.9 for details of scoring.

In the event that all parts are completely assembled, points for a time bonus will be awarded based on the amount of time remaining for the task. See Section 7.2.10 for details about time bonus.

7.2.5 Reset in Assembly Task

When a "Reset" is declared and approved, the subtask currently undertaken should be reset to their initial state. The definition of subtasks will be given in Section 7.2.6.

When several subtasks are being undertaken simultaneously, the team can choose at least one subtask to be returned to the initial state. If the team wishes, more than one subtask currently undertaken can be reset. This rule can also be applied when multiple robots execute several subtasks simultaneously or two products are assembled simultaneously.

7.2.6 Definition of Subtasks

The assembly tasks can be done in any order, but the level of completion of the product will be evaluated through the following subtasks. The subtasks for the belt drive unit assembly are listed below

- Subtask A – Attach the motor to the motor fixing plate with screws.
  - Related parts numbers (refer to the parts list in Appendix B.6): 3, 4, 18
  - Conditions for task completion: All of the screws must be attached without any gaps. The referee will make a visual check.
- Subtask B – Attach the pulley to the motor shaft.
  - Related parts numbers: 4, 5, 19
  - Conditions for task completion: The motor-shaft-pulley must be correctly attached to the motor shaft. Conditions for this are: 1) The face of the pulley and the face of the tip of the shaft are aligned (the degree of alignment will be confirmed visually). 2) The rotation axis of the set screw is nearly perpendicular to the D-cut surface of the motor shaft. Please note that whether or not the pulley is attached to the shaft by the set screw with sufficient torque will be evaluated at the final product evaluation stage.
  - When the parts are supplied to the team before the competition, the set screw (part # 19) has been installed in either of the two screw holes of the pulley (part # 5). Teams can adjust the depth of the set screw in the Preparation Phase before bringing in the parts in the System Running Area. Teams can also adjust the direction of the D-cut surface of the output shaft of the motor.
- Subtask C1 – Attach the bearing holder to the output shaft fixing plate with screws.
  - Related parts numbers: 2, 7, 17
  - Conditions for task completion: The bearing holder must be attached to the output shaft fixing plate in the right direction, and be affixed with four screws.
- Subtask C2 - Insert the output shaft into the bearing holder, and attach the end cap to the output shaft with a screw.

- Related parts numbers: 7, 8, 9, 17
- Conditions for task completion: The output shaft must be inserted into the bearing holder in the right direction, and the end cap must be fixed with a screw.

- Subtask D – Attach the output shaft pulley to the output shaft.
  - Related parts numbers: 7, 8, 9, 10, 11
  - Conditions for task completion: The pulley clamp is facing out and attached to the output shaft. The fixed position must be in contact with the inner ring of the bearing with a spacer in-between (but since it is difficult to evaluate the fixed location through a visual inspection, it will be done by checking the distance between the pulley face and the plate face). Additionally, the end cap and inner ring of the bearing must be in contact.
- Subtask E - Assemble the tension pulley with the output shaft fixing plate
  - Related parts numbers: 2, 12, 13, 14, 15, 16
  - Conditions for task completion: The tension pulley and the related parts are fixed in the correct order on the output shaft fixing plate as specified in the design drawing.
- Subtask F – Assemble the motor fixing plate and the base plate with screws
  - Related parts numbers: 1, 3, 17
  - Conditions for task completion: The motor fixing plate and the base plate must be affixed with two screws. Plates at the correct angle that do not wobble will be evaluated favorably.
- Subtask G – Assemble the output shaft fixing plate and the base plate with screws.
  - Related parts numbers: 1, 2, 17
  - Conditions for task completion: The output shaft fixing plate is fixed to the base plate with two screws. Plates should be fixed with the correct angle and should not wobble.
- Subtask H – Assemble the belt
  - Related parts numbers: 6 and the parts assembled in the previous subtasks
  - Conditions for task completion: The belt is correctly fitted in the grooves of the two pulleys, and it has sufficient belt tension through being pushed by the tension pulley.
- Subtasks I1 and I2 – The Connecter is inserted into the terminal (Subtask I1 is to insert the black cable (part #22), into the designated terminal, and Subtask I2 is to insert the red cable (part #23) into the designated terminal).
  - Related parts numbers: 4, 20, 21, 22, 23
  - Conditions for task completion: The power cable should be inserted into the terminal block without any protrusion of the terminal cover of the power cable from the top face of the terminal block.
  - The terminal block is supplied together with the base plate where the terminal block is already attached.

The conditions for task completion are detailed in Appendix A.5.

Please note the above subtasks are defined for the normal product, and the surprise product will have different definitions.

7.2.7 Details of Subtask I1 and I2

This subsection describes the connecter insertion process which is required by Subtask I1 and I2. The motor used in the task will be provided with power cables that have rod-type crimp terminals as shown in Figure 21. The cable insertion task involves inserting the rod-type crimp terminals at the end of the power cables into the designated locations on a clutch lock terminal block which has already been affixed to the base plate (see Figure 22). Parts information about the terminal block and rod-type crimp terminals to be used can be found in the appendix. The cables are red and black wires equivalent to AWG No.22 wire cut to about 14cm. The covering at both ends is removed by about 1cm, and performed soldering to the motor and crimping of the terminals, respectively. The type and length of the power cable are subject to change. Note that picking up a base plate or an assembled belt-drive unit by grasping the terminal block is prohibited. If a team does so, it is regarded that the terminal block was damaged and certain points will be deducted.

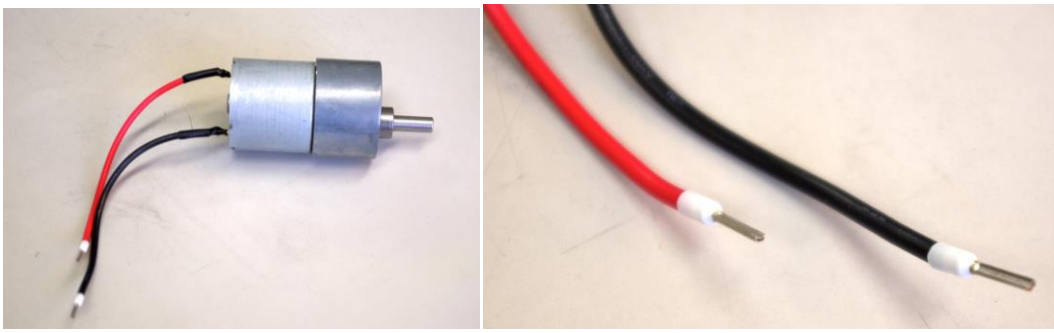


Figure 21: The appearance of the motor to be provided for the assembly task, and a close-up view of the rod-type crimp terminals

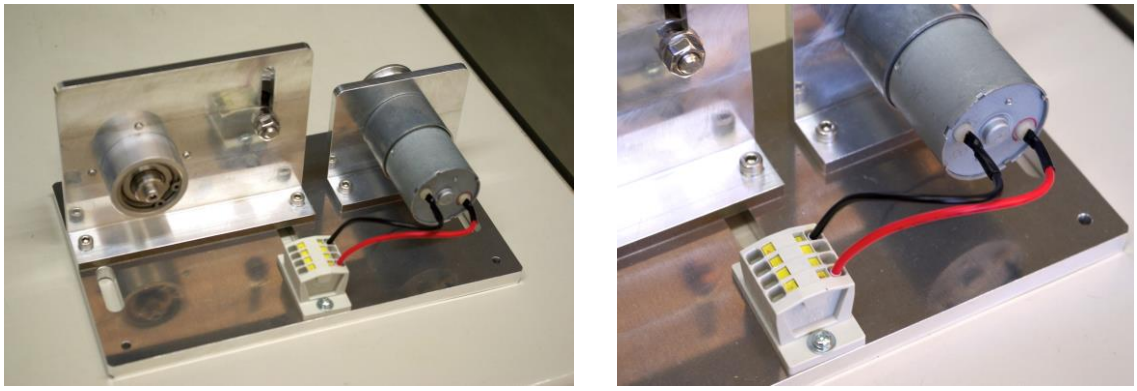


Figure 22: A snapshot when cable insertion task (Subtask I1 and I2) is successfully completed

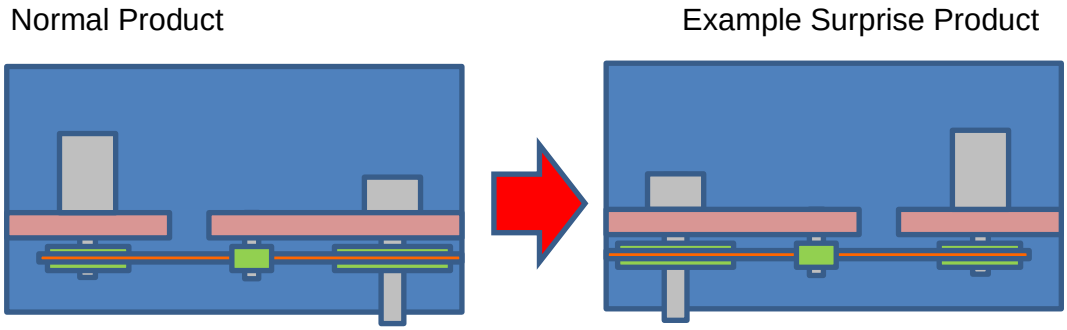


Figure 23: Conceptual diagram of the surprise product actually used at the WRS 2019 trial competition

7.2.8 Surprise Product and Surprise-plus Product

The surprise product for WRS 2020 will have the same winding function as the normal product. Information about the parts used for the surprise product (the approximate shape and size, etc.) will be released in advance with enough time for the teams to prepare hands and other necessary devices for those parts. Information about the surprise product, namely how to assemble the parts announced earlier, will be provided to the teams after the venue setup has been completed.

Figure 23 is a conceptual diagram of the surprise product planned for the WRS 2019 trial competition. Note that Figure 23 is just an example of the surprise product and in the WRS 2020 other types of surprise product may be introduced.

Further, if a team chooses to assemble the surprise-plus product, the team will be asked to assemble a product that is more difficult to be assembled than the above surprise product, for example, a product using parts newly specified just before the competition starts.

Teams that choose the surprise-plus product will have additional points added to their score for the related sub-tasks, as explained in Section 7.2.9. There are several parts that may be used in the surprise-plus products. Information about all parts for the surprise-plus, including several ones that will not be used at all, will be released at the same time as the surprise (no-plus) product information. The parts that will be actually used for assembling the surprise-plus product will be announced directly before the competition begins. It is optional to choose the surprise-plus product assembly, so it is fine for teams to choose to assemble the surprise (no-plus) product.

7.2.9 Product Evaluation

Only products that have been transported to the designated area outside the System Running Area within the allotted competition time will be subject to product evaluation. Product evaluation consists of functional evaluation and visual evaluation. Functional evaluation is performed by connecting a hoisting pulley to the output shaft, supplying a rated voltage to the motor, and lifting a load hanging from the hoisting pulley. The function of the product is evaluated whether it can lift the load up to the specified height within a certain period of time.

Visual evaluation includes checking new scratches made on the product and the degree of alignment of the grooves of the motor pulley and the output pulley.

Note that even if the product breaks, parts loosen, or come off when taking this product

evaluation, the team cannot fix it. This means that those parts may be evaluated as incompletely assembled in the subsequent scoring Therefore, teams can choose whether or not to take this product evaluation. However, in order to earn the time bonus described later, it is necessary to take this product evaluation.

The product evaluation method will be explained in detail in Appendix B.

Table 6: Points Table of Assembly Task

Points allocation for each belt drive unit (Day 2)

Description		Points		Notes
Subtasks	F, G	2 (each)	40	4 points in total
	B, C1, C2, D	3 (each)		12 points in total
	A	4		
	E, H, I1, I2	5 (each)		20 points in total
All subtasks (excluding subtask 11 and 12) are completed		30		completion bonus
Product evaluation (visual and function)		30		
Total		100 (normal)		

Points of Day 2

Description	Points	Notes
Belt Drive Assembly (Max. 2)	100 (each)	200 points in total
Total	200	Not including time bonus
The time bonus is as follows: Time bonus = INT(remaining time [sec]) / 10[sec]) x 1 point (The upper limit of the time bonus points is 100 points.)		

Points allocation for each belt drive unit (Day 3, Normal)

Description		Points		Notes
Subtasks	F, G	1 to 2 (each)	40	*Points will be adjusted depending on the surprise product *The score may be even higher if surprise-plus is selected
	B, C1, C2, D	1 to 3 (each)		
	A	1 to 4		
	E, H, I1, I2	1 to 5 (each)		
All sub-tasks completed (except sub-tasks I1 and I2)		30		completion bonus
Product evaluation (visual and function)		30		
Total		100		(Maximum score for surprise plus is 116)

Points allocation for each belt drive unit (Day 3, Surprise)

Description		Points		Notes
Subtasks	F, G	3 (each)	50	6 points in total
	B, C1, C2, D	4 (each)		16 points in total
	A, I1, I2	5 (each)		15 points in total
	E	6		
	H	7		
All subtasks completed (except I1, I2)		120		completion bonus
Product evaluation (visual and function)		30		
Total		200		

Points allocation for each belt drive unit (Day 3, Surprise-plus)

Description		Points		Notes
Subtasks	F, G	3 (each)	65	6 points in total
	C1, C2	4 (each)		8 points in total
	A, I1, I2	5 (each)		15 points in total
	E	6		
	B, D	8		16 points in total
	H	14		
All subtasks completed (except I1, I2)		175		completion bonus
Product evaluation (visual and function)		30		
Total		270		

Points of Day 3

Description	Points	Notes
Belt Drive Assembly (One Normal Products)	100	(In the case when surprise-plus is not selected)
Belt Drive Assembly (One Surprise Product)	200	(In the case when surprise-plus is not selected)
Total	300	(If surprise-plus is selected, the maximum score is 386)

The time bonus is as follows:

Time bonus = INT(remaining time [sec]* / 10) x 1 point

(The upper limit of the time bonus points is 130 points.)

*In the afternoon try on Day 3, the remaining time shall be the actual remaining time plus 10 minutes.

7.2.10 Scoring

Only products that have been transported to the designated area outside the System Running Area within the allotted competition time will be subject to scoring. If the team wants the product they assembled to be evaluated, the product evaluation will be made prior to this scoring. Scoring is done by adding points according to the completeness of each subtask. The completeness of each subtask is evaluated by the referee by checking the condition of the assembled parts related to the corresponding subtask. If all subtasks (except I1 and I2) are completed, completion bonus points will be added. Table 6 shows the points for the assembly task.

Since the purpose of the competition on Day 3 is to see how quickly the teams can handle the surprise product, it is not enough that teams work only on the assembly of the normal product. Therefore, in order to clarify in scoring that it is necessary to work on the surprise product, the points of the normal product are adjusted according to the points obtained from assembling the surprise product by the following formula:

Adjusted points for each subtask of the normal product = ROUNDUP (original points of each subtask * Degree of completion of the surprise product assembly),

where Degree of completion of the surprise product assembly is defined as follows:

Degree of completion of the surprise product assembly = (Total points for subtasks of the surprise product assembly + ε) / (Maximum total points for subtasks of the surprise product assembly (50 points)).

Here, ε in the numerator of the fraction in the above formula is a small dummy variable so that teams can get at least 1 point by ROUNDUP operation if they have earned some points for the subtask of the normal product even if their total points of the surprise subtasks is 0. If teams earned some points for the subtasks of the surprise product, it is regarded as ε = 0.

Note that as can be seen from the formula for adjusting the subtask points of the normal product shown above, if the degree of completion of the surprise product is low, teams may earn only one point for each subtask of the normal product, even if it is completed. Also, note that if a surprise-plus product is selected, the degree of completion of the surprise product assembly may exceed 1. In such a case, points for each subtask of the normal product will be increased; for example, points for subtask A become 6 points in maximum (addition of 2 points), and points for subtasks E, H, I1, and I2 become 7 points in maximum (2 points added).

7.2.11 Time bonus

If all "complete products" required by the competition are assembled before the end of the competition time limit, a time bonus will be awarded based on the amount of the remaining time. Here "complete product" means a product that has all completed subtasks except subtasks I1 and I2 and has passed the product evaluation test.

For the competition on Day 2, if two complete normal products have been assembled within the competition time, one point will be awarded for every 10 seconds of the remaining time up to a maximum of 100 points. The maximum of 100 points corresponds to completing two normal units in 6 minutes and 40 seconds per each unit.

For the competition in the morning of Day 3, if one complete normal product and one complete surprise (or surprise-plus) product have been assembled within the competition time, one point will be awarded for every 10 seconds of the remaining time up to a maximum of 130 points. The maximum of 130 points corresponds to completing two units (one of them is the surprise product) in 9 minutes and 10 seconds per each unit.

For the Day3 afternoon competition, the time bonus is calculated after adding 10 minutes to the remaining time of the actual competition, considering that the competition time in the afternoon is shortened by 10 minutes from the morning competition. Namely, for the competition in the afternoon of Day 3, if a complete normal product and a complete surprise product have been assembled within the competition time of 30 minutes, 10 minutes will be added to the actual remaining time and one point will be awarded for every 10 seconds of the adjusted remaining time up to a maximum of 130 points. Therefore, as in the morning competition, the maximum of 130 points corresponds to completing two units (one of them is the surprise product) in 9 minutes and 10 seconds per each unit.

8 Documents for submission

Besides the documents that every team must submit to the WRS secretariat regardless of the competition category, such as the team introduction documents, there are also documents specific to the Industrial Robotics Competition (the submission deadline is scheduled to be about two weeks before the competition. Exact dates will be released later), which will be indicated in Table 7. However, the documents listed here are preliminary, and there may be additions or removals from the list of documents for submission. Details about each document for submission will be announced to the teams.

The contents determined at this moment are shown as follows. Please note it may change in the future.

(A) Technical Document

Teams should prepare the following six pages of technical documentation in a PowerPoint format that includes the content that would be difficult to understand from the competition alone. In particular, the slide of 5, Summary should indicate what level the team's system is, based on Table 1, and include the basis for that evaluation, as well as the appeal points and efforts of the team towards social implementation in the future.

The technical documentation will be used in determining the winners of various society prizes, and they will also be referred to when scoring the technical points. See Table 8 for the basic points distribution.

1. Team Introduction

   This should reflect the contents of the team introduction document, which is to be submitted to the WRS secretariat separately.

2. Overall Outline of the System

   An overall outline of the team's entire robot system using a system configuration diagram.

3. Recognition and Picking (parts and products) Technology

Efforts (hardware and software) in picking a target part from the parts tray in the task-board task and assembly task and returning the completed product back onto the tray in the assembly task.

4. Assembly Technology Efforts (hardware and software) related to motion generation and control of robots for assembly in the task-board task and the assembly task.

5. Changeover

Efforts (hardware and software) to changeover from the setup for task board to that for belt drive assembly and for handling the surprise product.

6. Summary: Summary of the team appeal points (in the viewpoint of agility and leanness) and team's view on social implementation of their technology.

The technical documentation will be used for evaluating each team for academic awards and it will also be referred to for scoring technical points. Scoring standards and points allocations are shown in Table 8.

(B) Video clip introducing the team and system

A video clip introducing the team, team members, and the robot system that the team has built. Overall length should be approx. 2 minutes. This video clip will be shown to the audience during the Preparation Phase.

(C) Risk Assessment Sheet

See section 6.2.3 for details.

(D) Exhibition Presentation File

Teams asked by the judging committee to join an exhibition must prepare their exhibition presentation file and submit it to the committee after the exhibition. The presentation file submitted will be kept by the competition committee. Teams will be notified about their participation in the exhibition after the points are all finalized on Day 3. Exhibition presentation files can be based on the (A) technical documentation, with edits and additions made as necessary.

Table 7: List of Materials for Submission

Required?	Item	Format	Submission Deadline	Notes
✓	Technical Documentation	PowerPoint File	About 2 weeks prior to the competition	
✓	Team and System Introduction Video	Mpeg File	About 2 weeks prior to the competition	
✓	Risk Assessment Sheet	pdf	About 2 weeks prior to the competition	
	Exhibition Presentation File	PowerPoint File	After the exhibition (Only for exhibition teams)	Modified file based on the technical documentation

Table 8 - Scoring standards and points allocations for technical assessment based on technical documents

		Points	Pages of the submitted documents where the required contents should be described
Evaluation Points for Agility & Leanness	Are attempts being made for jig-less and teaching-less assembly?	10	②④
	Are attempts being made to handle the surprise product?	10	②④
	Notable efforts for parts recognition and picking	10	③
	Notable efforts for parts grasping and assembly	10	④
Evaluation Points for Social Implementation	Is there a cost-consciousness that takes social implementation into account?	5	⑤
	Is there a consideration for the impact of society and the well-being of people when the team's technology is implemented into society?	5	⑤
Total		50	

9 Symposium

A symposium of the WRS Industrial Robotics Category was originally scheduled to be held on Day 5, the next day of the final day of the WRS 2020 competition. However, the symposium will be held online at a later date to prevent infection with the new coronavirus.

The goals of this symposium are:

- Technical exchange between participating teams,

- Feedback from teams about reflection points of the WRS 2020,

- Opinions from teams regarding future competitions.

Details about the symposium will be announced later. Participation in the symposium will only be opened to involved parties (teams, committee, sponsors and secretariat), but the press will be allowed to listen-in.

Participation in the symposium is voluntary. Considering the purpose of the symposium, however, teams are strongly encouraged (at least one member per team) to participate in this symposium. Further, top winning teams are strongly encouraged to present at the symposium.

10 Schedule

The schedule leading up to the WRS 2020 competition is as follows, but in order to prevent the spread of COVID-19, or other similar issues it may change without prior notice.

Year 2019

June	Outline of competition rules released for recruitment purposes. (finished)
June to August	Participating team recruitment period (finished)
September to November	Team selection (finished)
December	Trial competition (at iREX 2019) (finished)
	*the trial competition is unrelated to team selection and results for WRS 2020
	Decision and notification of teams that passed the first review (finished)

Year 2020

January	Release of task rules for participating teams (finished)
	Teams who wish to be provided rending robots for the competition will be notified their robot specifications and when the robots will be provided at this point (finished).
	Announcement of the contents of the Final Examination (Stage gate) (finished)
	* Announcement has been done only to the teams that pass the first review.
March	Rule revision has been postponed due to COVID-19
April～	Submission of the materials for the Final Examination (Stage gate)
	* Submission deadline has been extended due to COVID-19
April～	Final review (Stage-gate)
May～	Final screening notifications (teams are notified at any time as they are accepted)

Year 2021

March	Release of task rules (final version) for participating teams (this version)
??	Team site visit (tentative)
??	WRS 2020 Competition

11 Conclusion (Robotics for Happiness)

The underlying theme of the WRS is “Robotics for Happiness.” Before concluding the rules, we would like to consider what “Happiness” means for the WRS Industrial Robotics Category.

In order to achieve the goal of the Industrial Robotics Category, ‘agile one-off manufacturing,’ it is necessary to use industrial robots as ‘programmable universal machines’ that are able to respond to different purposes. Ultimately, we, the Industrial Robotics Category, aim at realizing the circulation-based production society as shown in Figure 24. Looking at this figure from the production system side, not only the reuse of production assets such as robots but also the reuse of production software is expected in this type of circulation-based production society. On the product side, this society would of course reuse/recycle materials and components as well as reflect the product demand immediately in production plans. Besides that, information about how and where products are used would be leveraged in the subsequent product designs. Further, it should be pointed out that the circulation of entities and software in industrial assets and products is related to the concept of Cyber Physical System (CPS) which has recently attracted attention in INDUSTRIE 4.0 [7] and so on.

If circulation-based production systems can be established in this way, the burden on the environment could be reduced and we could also achieve a society where desired products can be obtained in an appropriate timing at an appropriate price. We believe that this is the “Happiness” that the WRS Industrial Category can bring to the world.

We are looking forward to having many participations not only from the teams that participated in the WRS 2018 pre-competition, but also from all other teams who agree with the concept of this competition. And we also look forward that they show off the technology that will lead to the next generation of production systems in the Assembly Challenge of the WRS 2020.

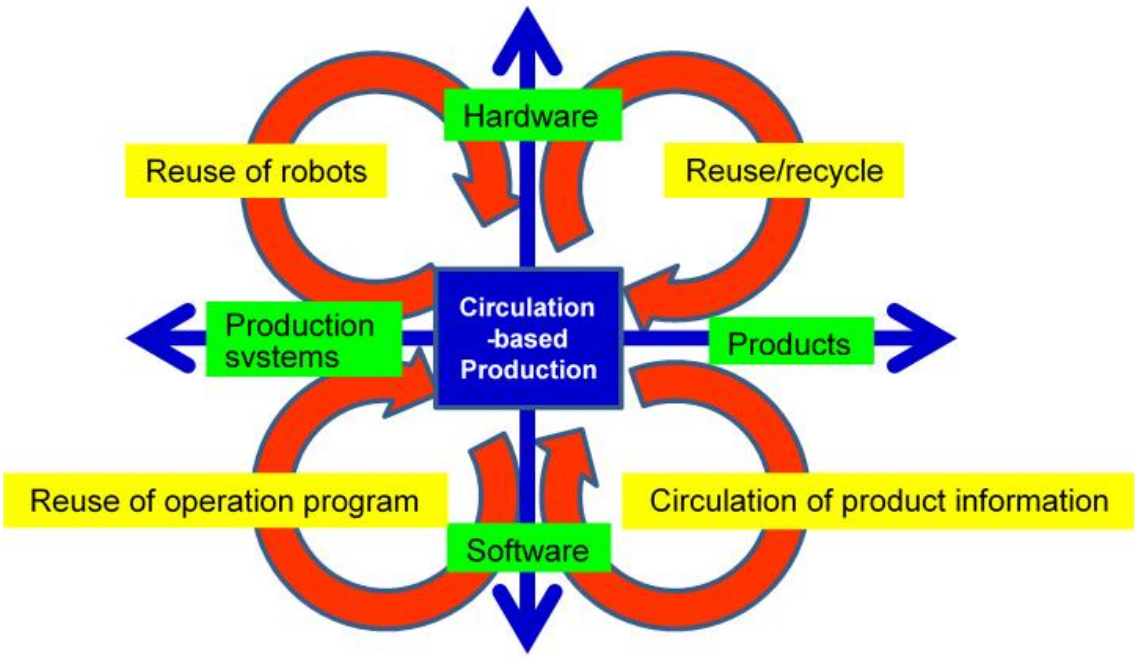


Figure 24: Circulation-based Production Society

References

[1] The Industrial Robotics Competition Committee, *Industrial Robotics Category Assembly Challenge – Rules and Regulations 2018*.
http://worldrobotsummit.org/download/rulebook-en/rulebook-Assembly_Challenge.pdf, 2018.

[2] Yasuyoshi Yokokohji et al., "Assembly Challenge: a robot competition of the Industrial Robotics Category, World Robot Summit - summary of the pre-competition in 2018,", Advanced Robotics, Vol.37, No.3, 2019. https://doi.org/10.1080/01691864.2019.1663609

[3] Yu Sun et.al. *2ND ROBOTIC GRASPING AND MANIPULATION COMPETITION*.
http://www.rhgm.org/activities/competition_iros2017/. 2017.

[4] *RoboCup @Work*.
http://www.robocupatwork.org/index.html

[5] *RoboCup Logistics league*.
https://ll.robocup.org/

[6] *The 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems*.
https://www.iros2017.org/. 2017.

[7] Recommendations for implementing the strategic initiative INDUSTRIE 4.0,
https://www.din.de/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-for-implementing-industry-4-0-data.pdf

Appendix A.

A1_TaskBoard_assmbled
Completion configuration of WRS 2020 Task-Board.

A2_TaskBoard_Setup
Setup configuration of WRS 2020 Task-Board

A3_01-base-01
Geometric feature, dimension and tolerance of the base plate of WRS 2020 Task-Board

A4_02-plate-01
Geometric feature, dimension and tolerance of the 02-plate of WRS 2020 Task-Board

A5_Completion_Level
Completion level of WRS 2020 Task-Board.

Appendix B.

B1-decomposition_state
Exploded view of assembled product unit of WRS2020.

B2_01-base-01
Geometric feature, dimension and tolerance of the base plate of WRS 2020 Assembly Task

B3_02-plate-01
Geometric feature, dimension and tolerance of the motor fixing plate of WRS 2020 Assembly Task.

B4_03-plate2
Geometric feature, dimension and tolerance of the output shaft fixing plate of WRS 2020 Assembly Task.

B5_PartsListAssemblyTask_WRS2020
Detailed parts list of WRS2020.

B6_Completion_level
Completion level of WRS 2020 Assembly Subtasks.

Appendix C.

C1-Specifications_of_AGV
The specifications of the AGV and the top palel.
Operation of the AGV
Human flow line at each team area (tentative)
Examples of AGV use
Specifications of manual pushcart

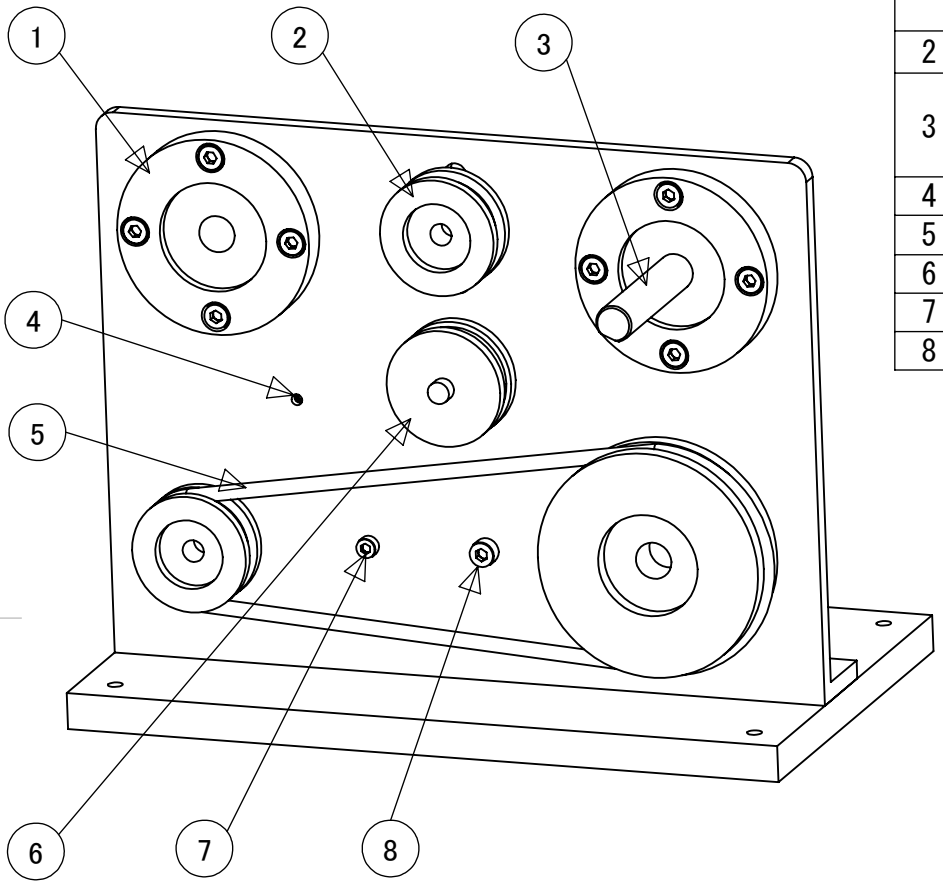
Appendix D.

D1-Specification for Parts Tray
 Specification for Parts Tray of WRS2020.

D2-Specification for Markers
 Specification for Markers of WRS2020.

Industrial Robotics Competition Committee
World Robot Summit

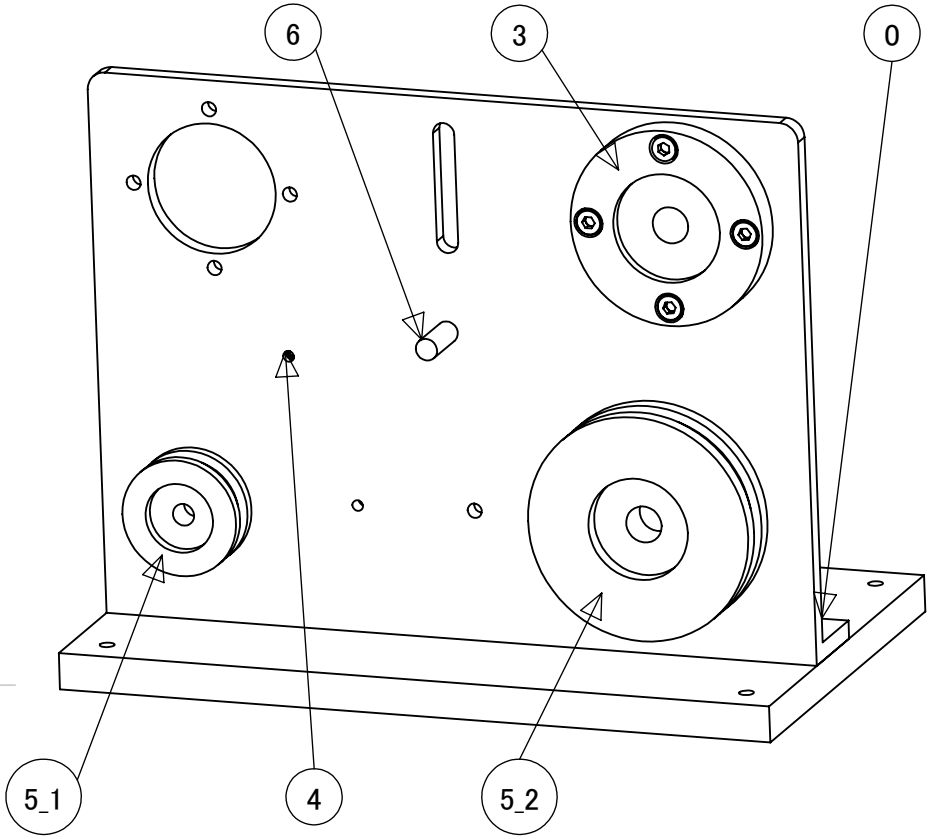
* 16th January, 2020
  publish the first version.
* 10th April, 2021
  update the model number for 6mm Shaft at TaskBoard_Assembled.
  add the 2xΦ10 holes at 01-base-01.
  the treatment of A5052 is white alumite at 01-base-01 and 02-plate-01.
  plates of photo for completion level are changed to white alumite
  add B6_Completion_level
* 25th May, 2021
  change the belt length at B5_PartsListAssemblyTask_WRS2020 from 400mm to 380mm.
* 18th July, 2021
  add the condition of the top board and the Human flow lines for AGV
  change the parts number to ``MBGNA30-2, SLBNR6'' at TaskBoard
* 9th August, 2021
  replace the overview for belt drive Unit.
  change the conditions for Subtask A and C1.
* 27th August, 2021
  marked the changes in purple.
  add the photo to Completion Level (Parts #1) in TaskBoard Task.
  change the part name from ``6mm shaft'' to ``drive shaft'' at SubTask #3 in Table 5 and Appendix A1.



No.	Model number*	Part name	Task
1	SBARB6200ZZ-30, 4 x SCB4-10	Bearings with housing, M4 Bolts	Insertion into a hole, Screwing into a tapped hole
2	MBGNA30-2, SLBNR6	Idler pulley, M6 Nut	Fastening a nut and a bolt
3	SSFHRT10-75-M4-FC55-G20	Drive shaft	Insertion into a hole
4	MSSFS3-3	M3 Set screw	Screwing into a tapped hole
5	MBT4-400	4mm Round belt	Looping over pulleys
6	MBRFA30-2-P6	Pulley	Placing onto a shaft
7	SCB3-10	M3 Bolt	Screwing into a tapped hole
8	SCB4-10	M4 Bolt	Screwing into a tapped hole

* Products by MISUMI

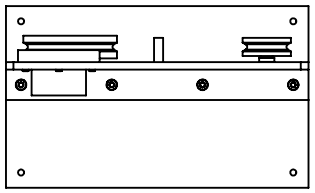
Part No.	Part name	Last update 2021-Aug.-22	
		Scale	Proj. method
010	TaskBoard_Assembled	0.500	3rd. angle projection
Designed by M. Shibata	World Robot Challenge 2020		
Checked by H. Dobashi			



No.	Model number*	Part name	QTY
0	SCB4-10	M4 Bolts	4
3	SBARB6200ZZ-30, SCB4-10	Bearings with housing, M4 Bolts	1 4
4	MSSFS3-3 **	M3 Set screw	1
5_1	MBGNA30-2, TWASS10-6-3	Idler pulley, Washer	1 1
5_1	MBGNA60-2, TWASS14-10-1	Idler pulley, Washer	1 1
6	PSSFAQ6-25-B5	6mm Shaft	1

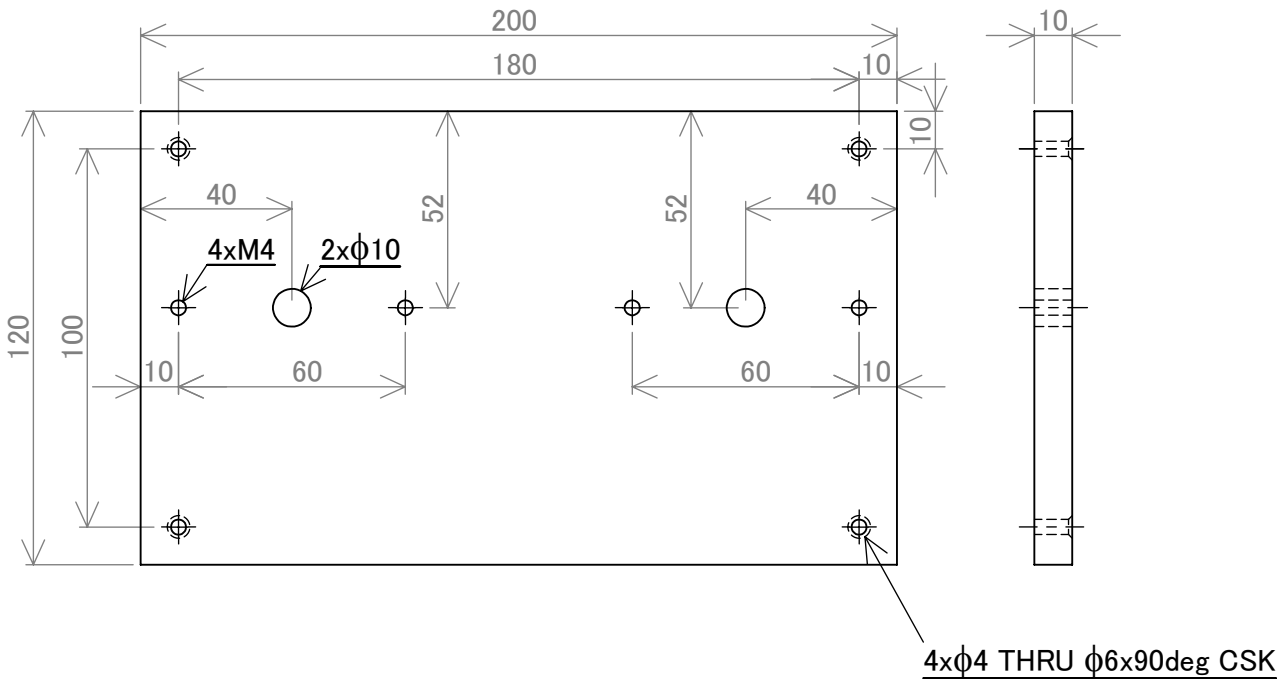
* Products by MISUMI

** This part is screwed into the L-plate in advance (Offset 2mm).



Top view (1:5)

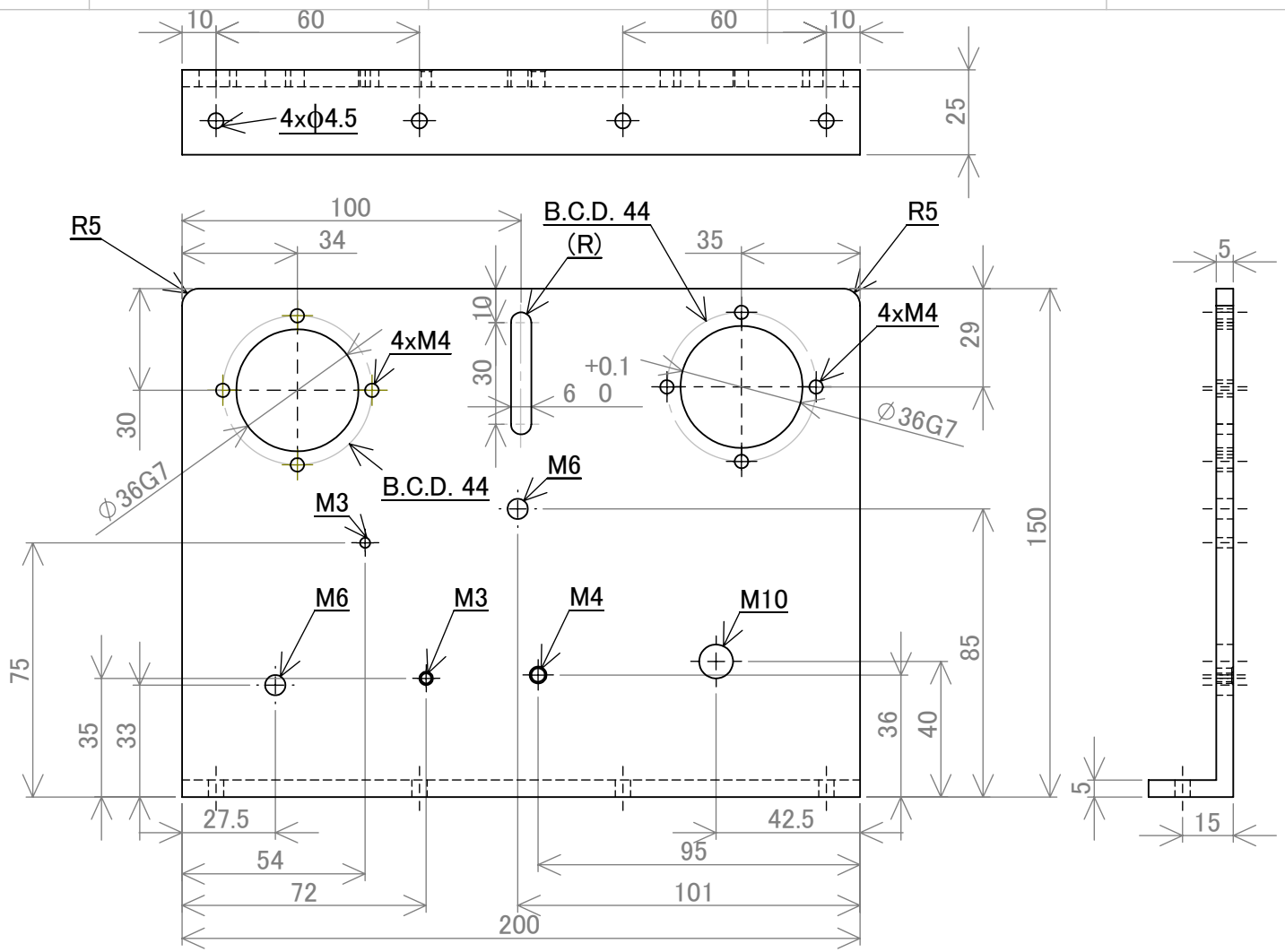
Part No.	Part name	Last update 2021-Feb.-05	
		Scale	Proj. method
010	TaskBoard_Setup	0.500	3rd. angle projection
Designed by M. Shibata	World Robot Challenge 2020		
Checked by H. Dobashi			



* A5052 (White alumite treatment) is used.

* Unless otherwise specified, dimensional tolerances are according to JIS B0405 Medium grade.

Part No.	Part name	Last update 2021-Feb.-05	
		Scale	Proj. method
000	01-base-01	0.500	3rd. angle projection
Designed by M. Shibata	World Robot Challenge 2020		
Checked by H. Dobashi			



* A5052 (White alumite treatment) is used.

* Unless otherwise specified, dimensional tolerances are according to JIS B0405 Medium grade.

Part No.	Part name	Last update 2021-Feb.-05	
		Scale	Proj. method
000	02-plate-01	0.500	3rd. angle projection
Designed by M. Shibata	World Robot Challenge 2020		
Checked by H. Dobashi			

Completion Level (1/2)

Definitions

- Contact: X_Y: Contact with X and Y (e.g. “Contact: bolt_plate” means that the bolt contacts the main plate).
- NoContact: X_Y: No contact with X and Y (e.g. “NoContact: bolt_plate” means that the bolt does not contact the main plate).
- Screw: X_Y: Screwing with X and Y (e.g. “Screw: bolt_nut” means that the bolt is screwing with the nut).

Level 2

Contact: cylindrical surface (part)_cylindrical surface (hole)

Contact: flange surface (part)_plate surface

In case that all conditions are satisfied, the completion level is given for the part.

Checkpoint by referees

Check by thickness gauge (0.3mm)

*** The gap is less than the gauge.**

Completion Level (2/2)

Definitions

- Contact: X1_X2 ..._Xn:
  = Contact: X1_X2 & Contact: X2_X3 & ... & Contact: Xn-1_Xn

- NoContact: X1_X2 ..._Xn:
  = NoContact X1_X2 or NoContact X2_X3 or ... or NoContact Xn-1_Xn

- NoScrew: X_Y: No screw exists where screw should exist between X & Y

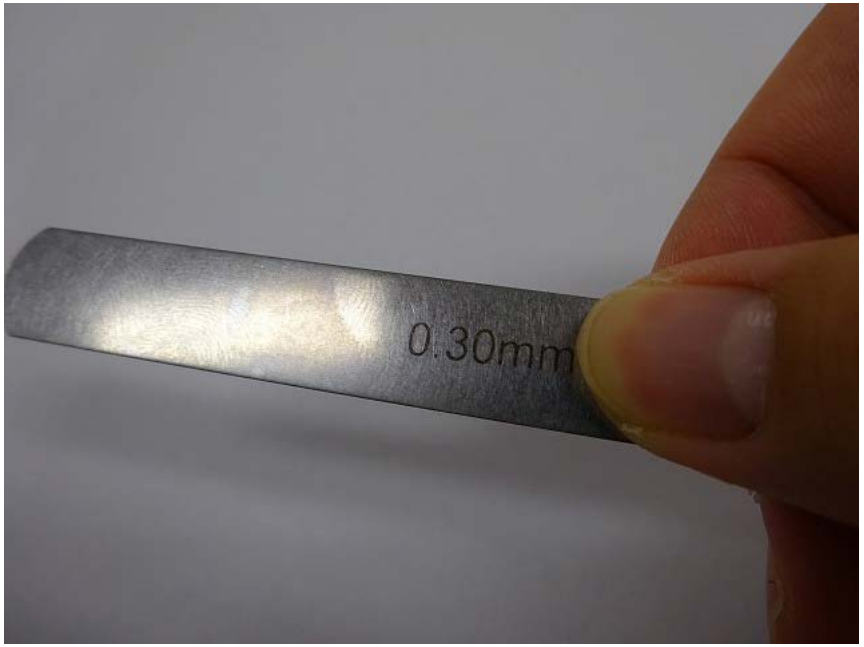
- Screw: X1_X2 ... _Xn: Screwing with X1, ... and Xn

- Flat: X_Y: Two surfaces X & Y are nearly aligned

- NoFlat: X_Y: Two surfaces X & Y are not nearly aligned

Thickness gauge

To check the completeness, referees use a thickness gauge.



The referees pinch at the end of the word “0.30mm” when using the gauge.

Completion Level (Parts #1)

Level 0

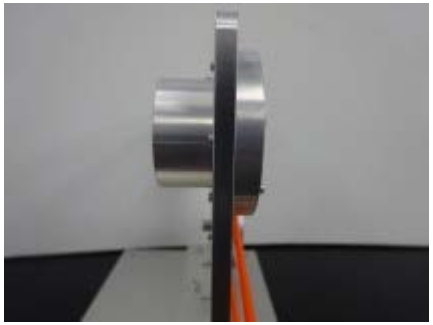
Contact: housing flange_L plate

Screw: bolts_thread

Contact: housing flange_bolt_head

Contact: housing flange_L plate

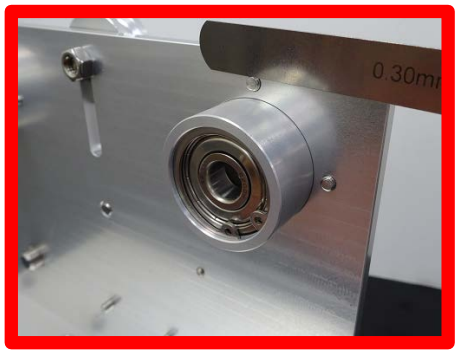
Level 1



Screw: bolts_4 threads

Contact: housing flange_4 bolt_heads

Contact: housing flange_L plate



Check by thickness gauge (0.3mm)

Completion Level (Parts #2)

Level 0

Screw: bolt_nut

Level 1

Screw: bolt_nut

Contact: Ider pulley_L plate

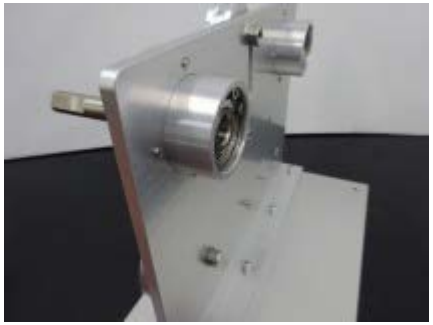
Contact: nut_L plate

Placement is not related to this level.

Check by thickness gauge (0.3mm)

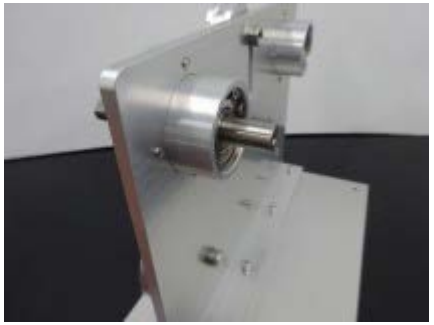
Completion Level (Part #3)

Level 0

Contact: shaft_bearing

Level 1

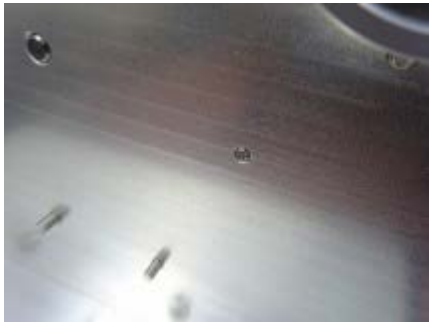



Contact: shaft_bearings

Referees check whether the part contacts the bearings with eyes.

Completion Level (Part #4)

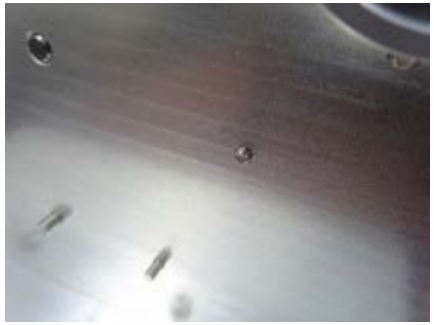
(Initial condition)



Flat: screw bottom_L plate

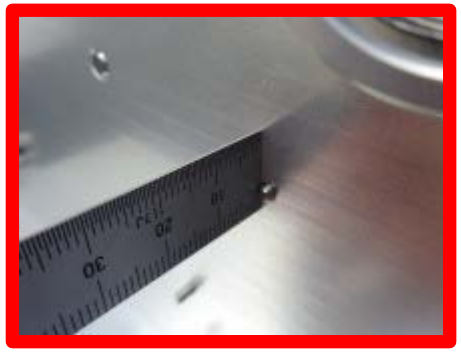
The set screw is pre-assembled into the L plate in advance.

Level 1



Screw: screw_thread

NoFlat: screw bottom_L plate



Check by ruler

(The height h: 1mm < h < 3mm)

Completion Level (Part #5)

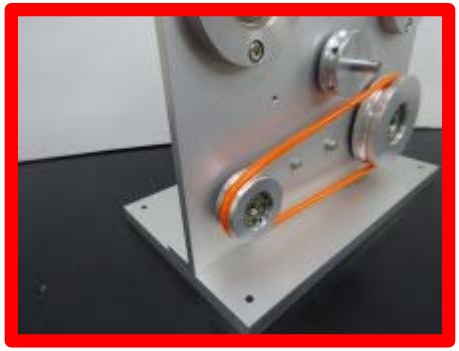
Level 0

Contact: round belt_pulley groove

Level 1

Contact: round belt_pulley grooves

***The belt should work as a transmission mechanism.**



Check whether the belt loops the grooves

Completion Level (Part #6)

Level 0

Contact: cylindrical surface (part)_shaft edge

Level 1

Contact: cylindrical surface (part)_cylindrical surface (shaft)

Referees check whether the part contacts the shaft with eyes.

Completion Level (Part #7)

Level 0

Screw: bolt_thread

NoContact: bolt head_L plate

Level 1

Screw: bolt_thread

Contact: bolt head_L plate

Check by thickness gauge (0.3mm)

Completion Level (Part #8)

Level 0

Screw: bolt_thread

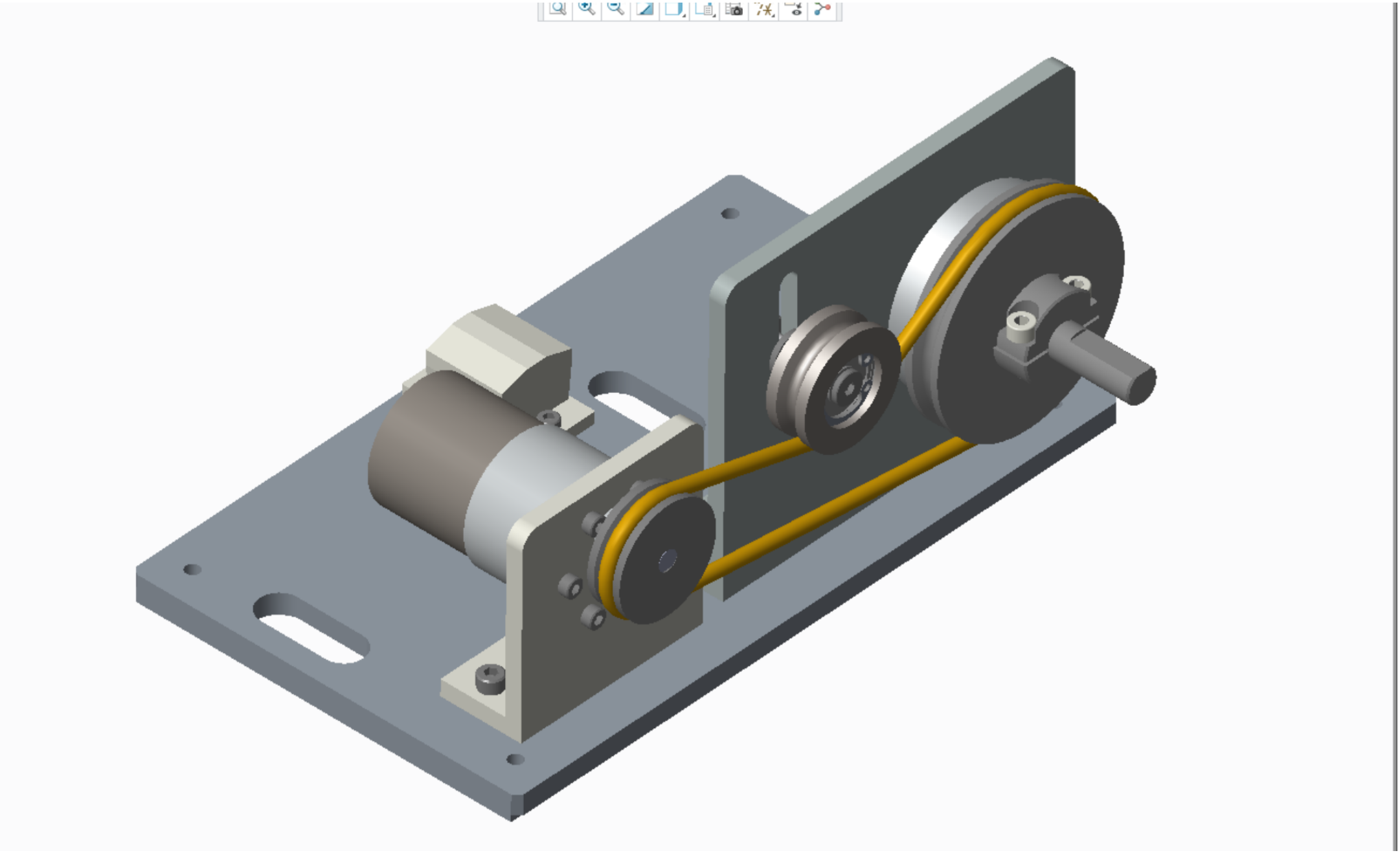
NoContact: bolt head_L plate

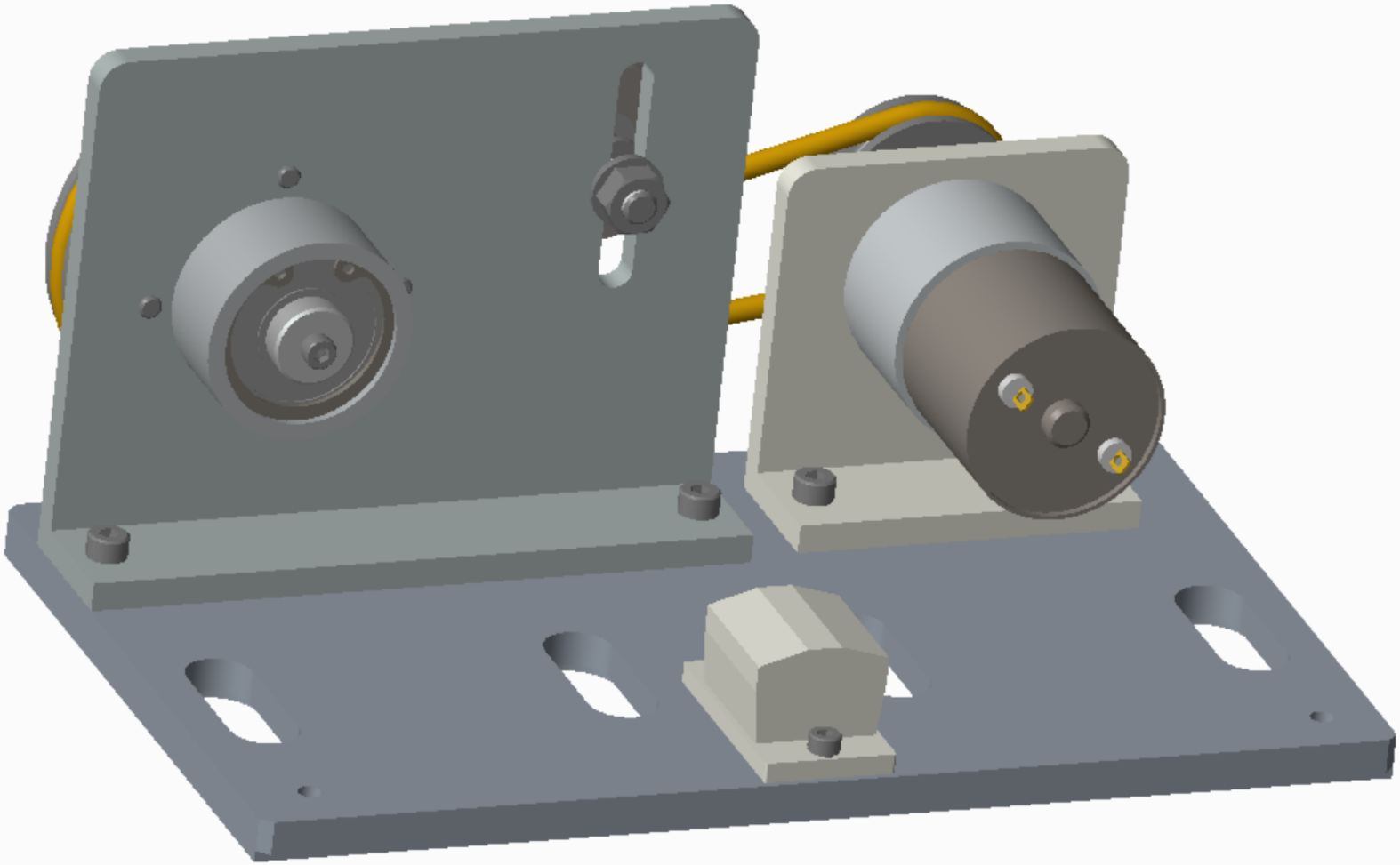
Level 1

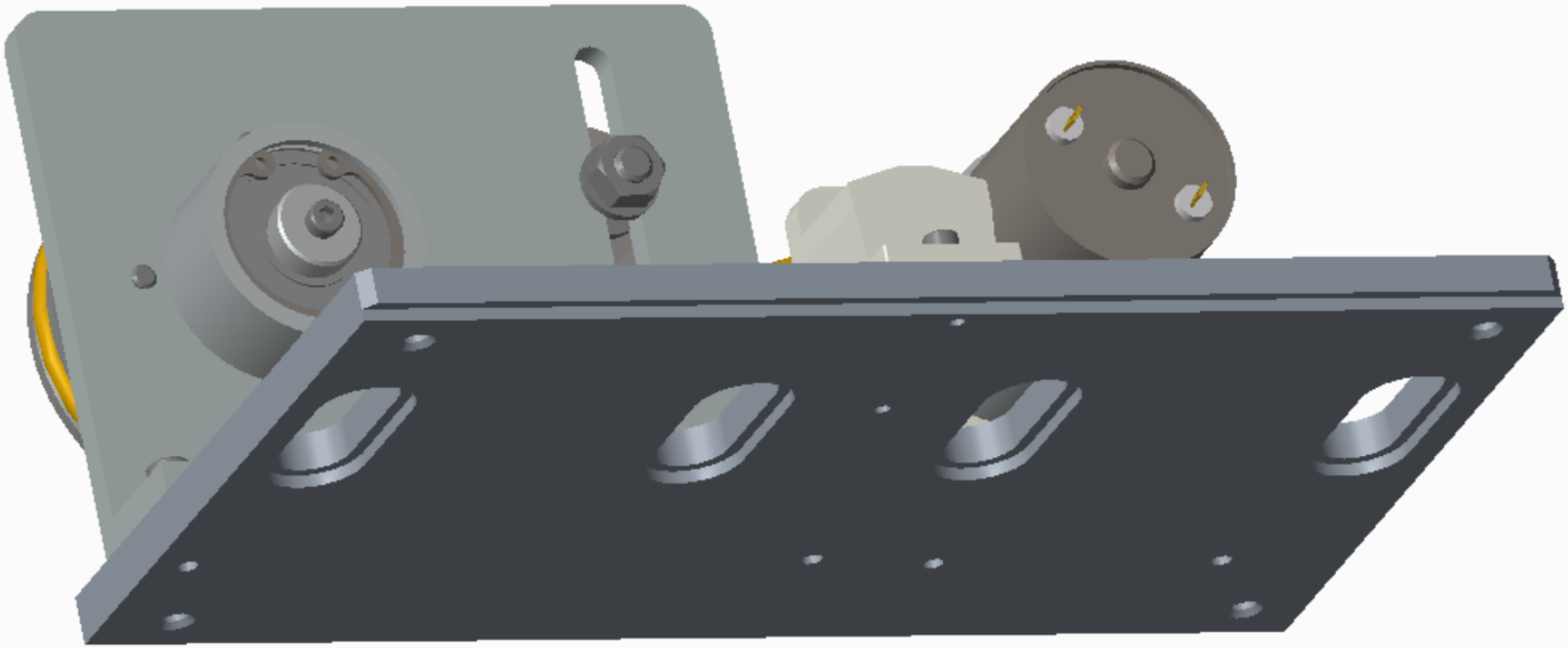
Screw: bolt_thread

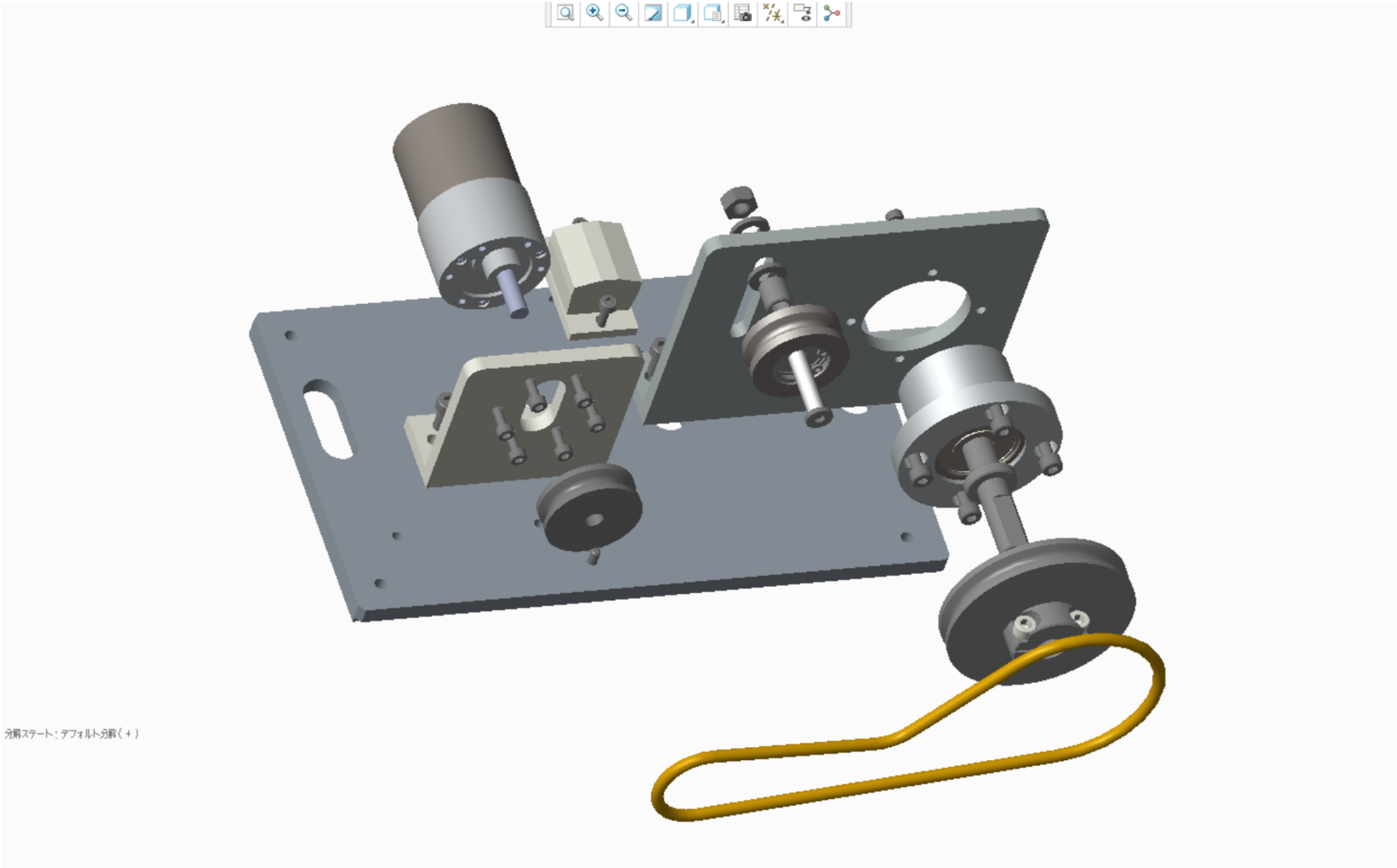
Contact: bolt head_L plate

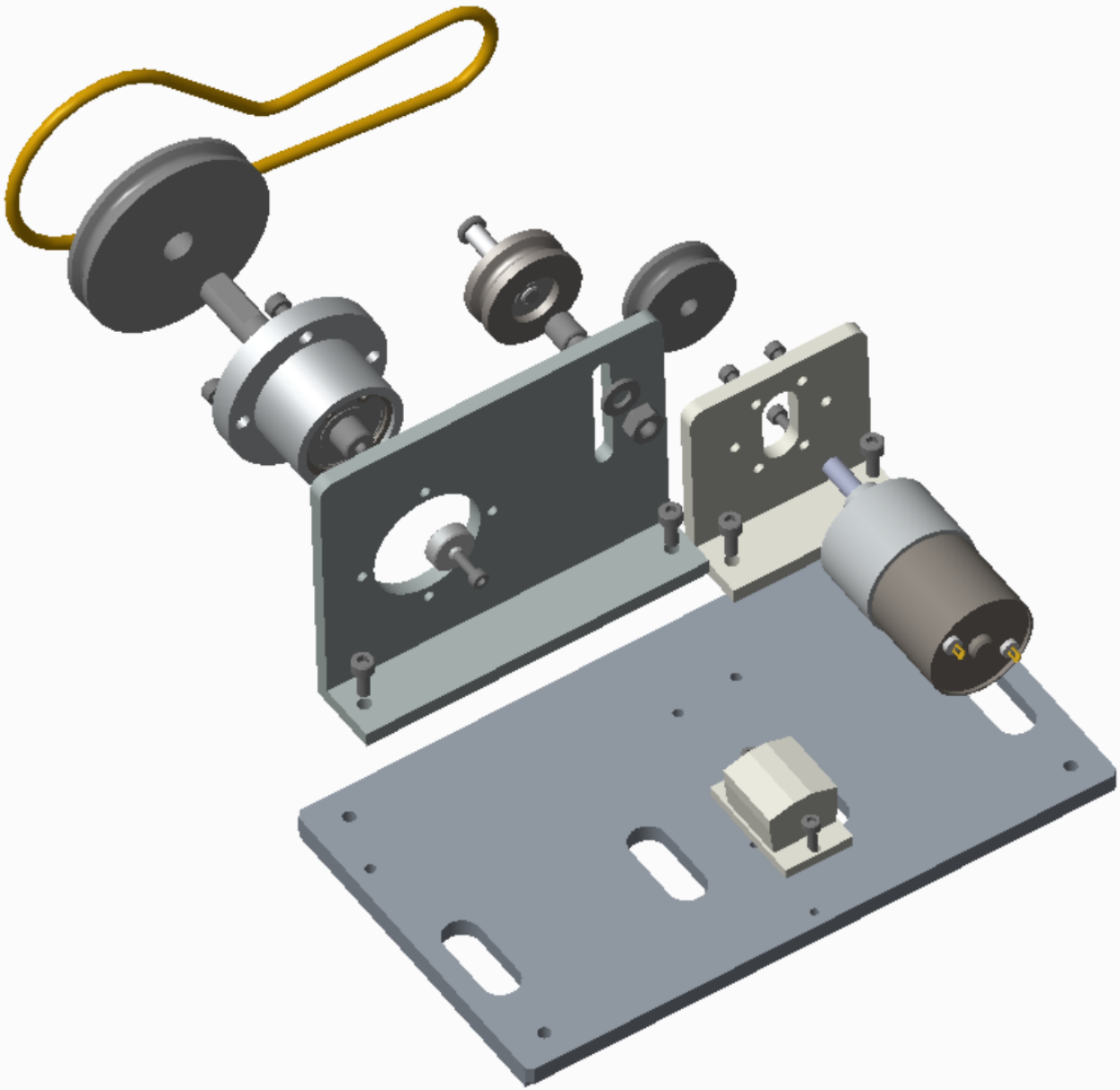
Check by thickness gauge (0.3mm)



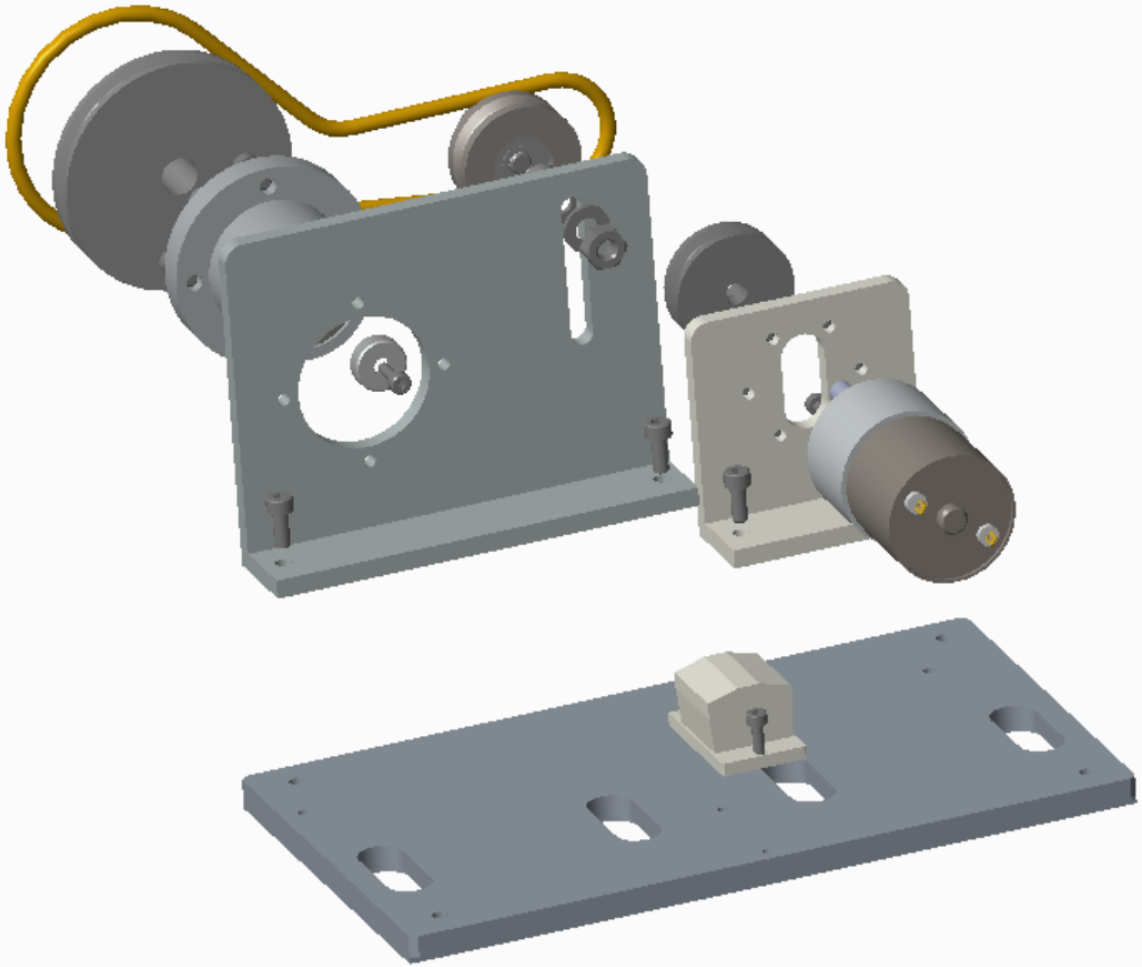




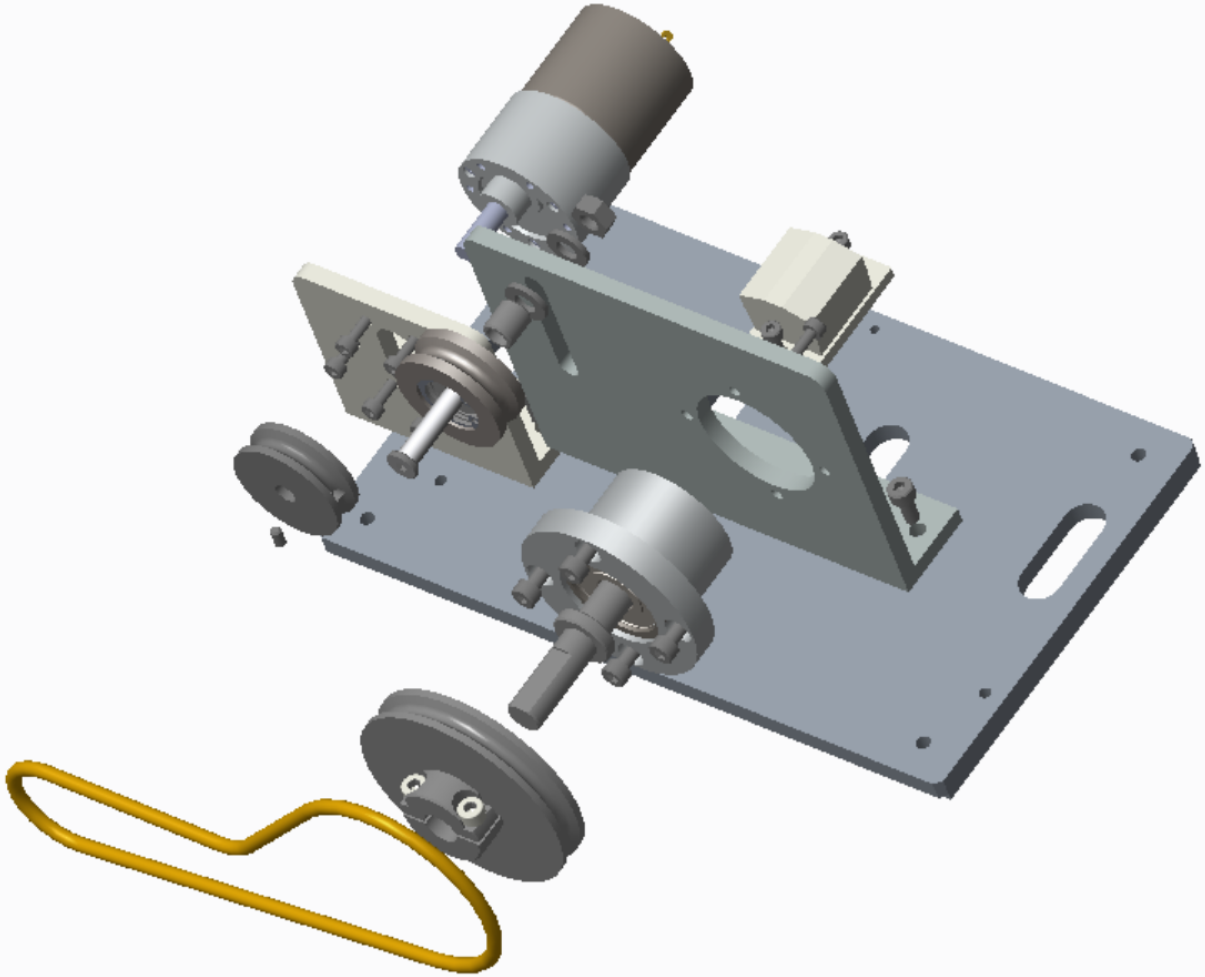

分解ステート：デフォルト分解（＋）



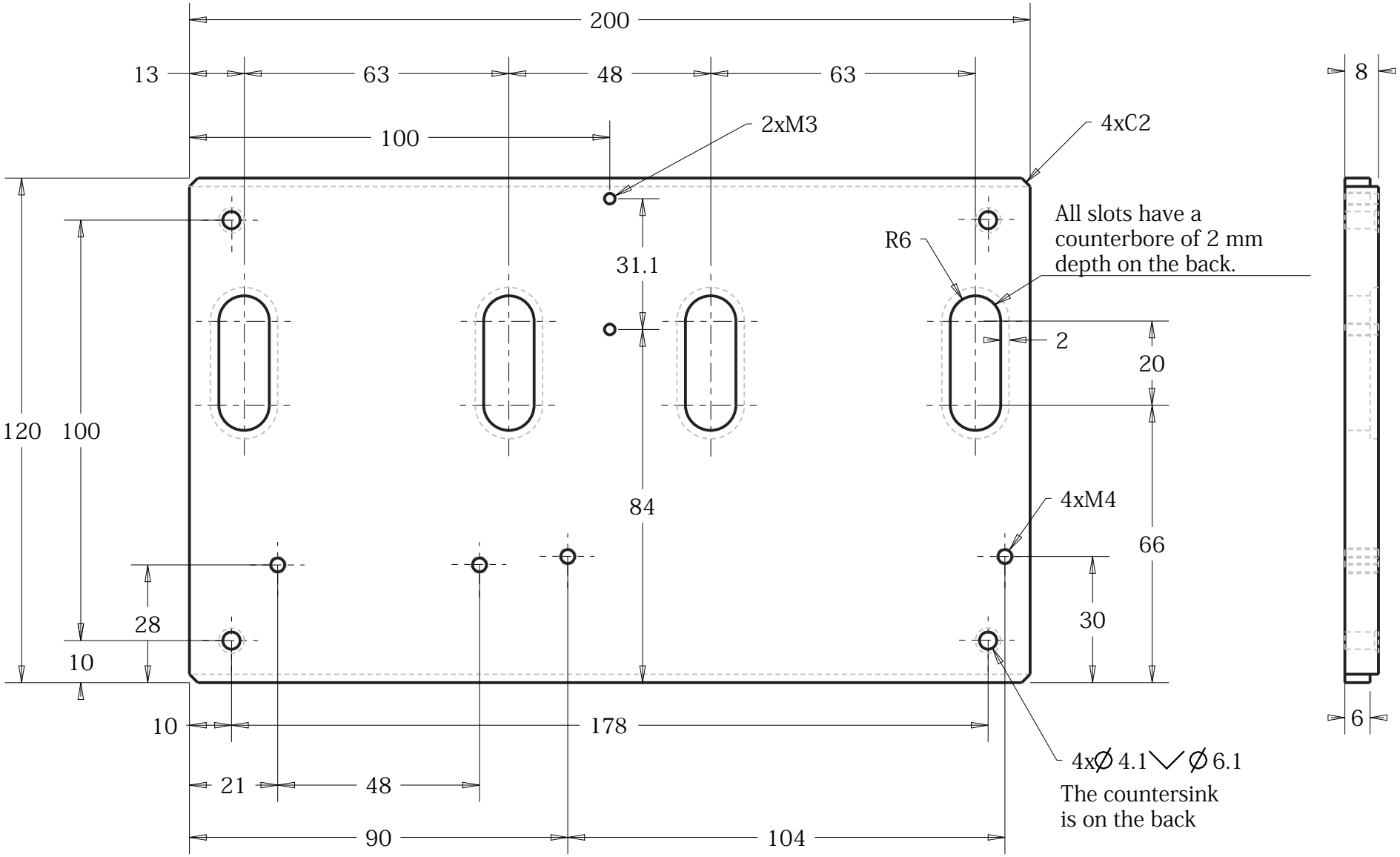
)解ステート：デフォルト分解（＋）



分解ステート：デフォルト分解（＋）

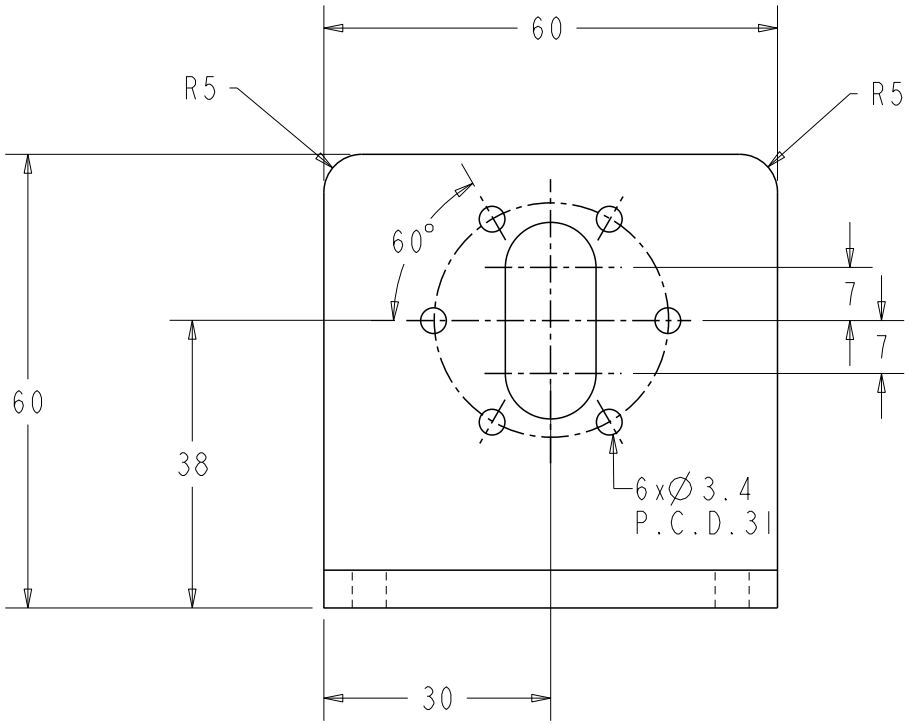


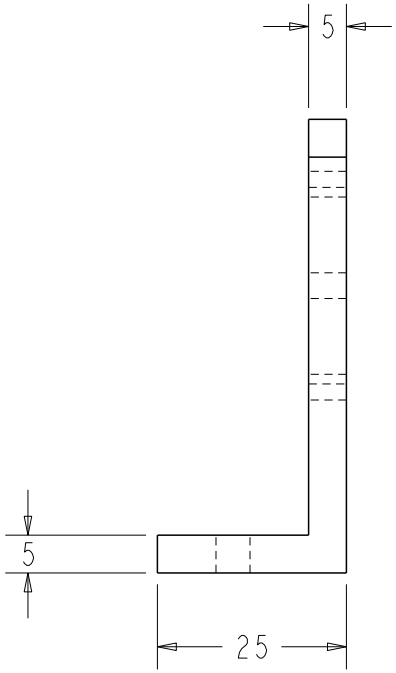
分解ステート：デフォルト分解（＋）

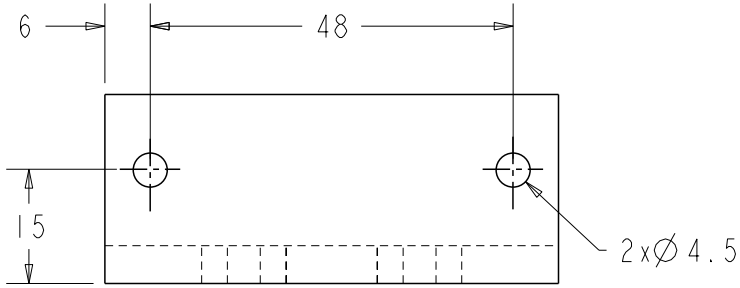


Anodic Oxide Coating

Part No.	Part name	Last update Aug.-28-21	
		Scale	Proj. method
01	01-BASE	0.750	3rd. angle projection
Designer S.Kotosaka		World Robot Summit 2021 Assembly Task	
01-BASE			

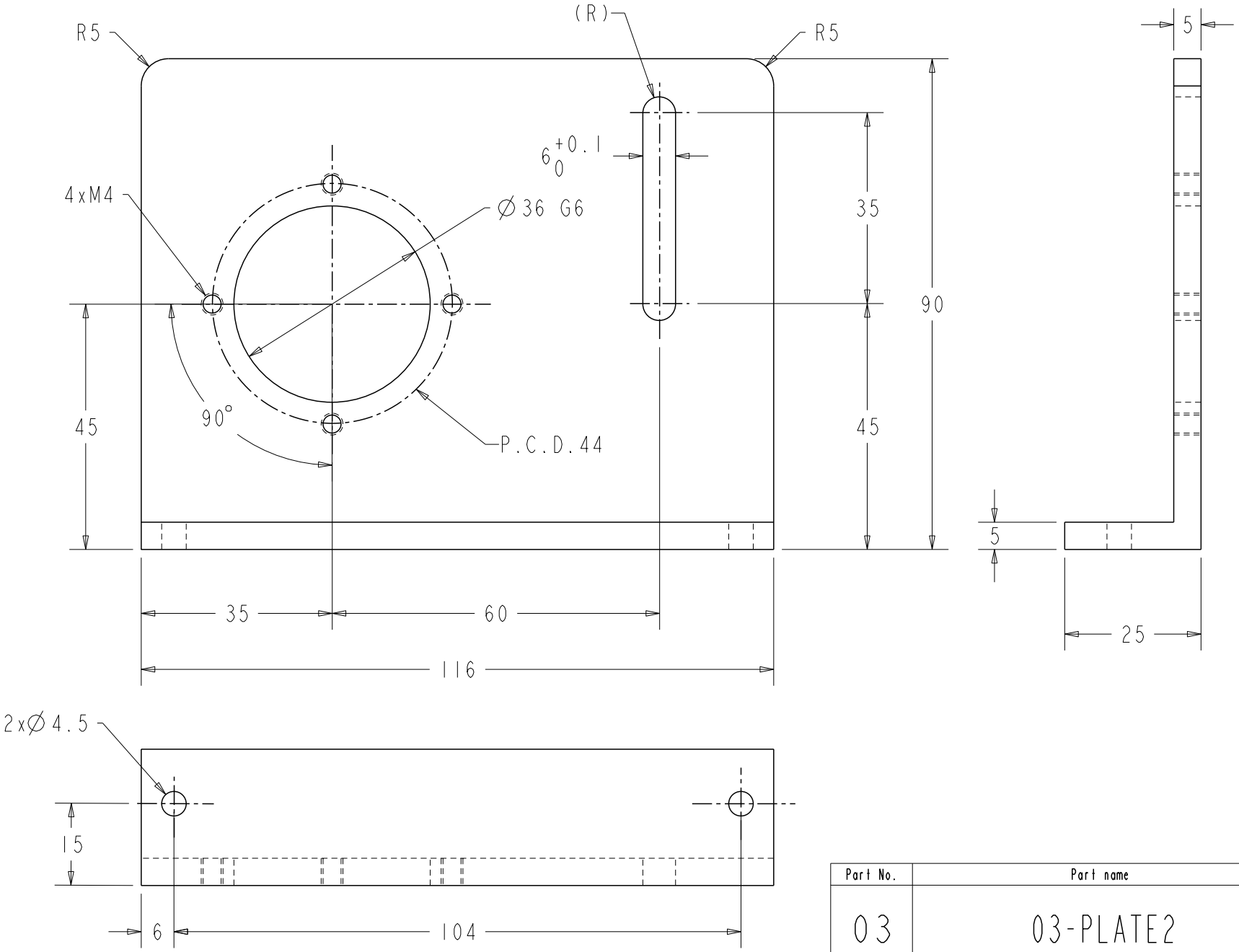






Anodic Oxide Coating

Part No.	Part name	Last update Mar-08-21	
		Scale	Proj. method
02	02-PLATE	1.000	3rd. angle projection
Designer S.Kotosaka		World Robot Summit 2020 Assembly Task	
02-Plate			



Anodic Oxide Coating

Part No.	Part name	Last update Mar-08-21	
		Scale	Proj. method
03	03-PLATE2	1.000	3rd. angle projection
Designer S.Kotosaka		World Robot Summit 2020 Assembly Task	
03-PLATE2			

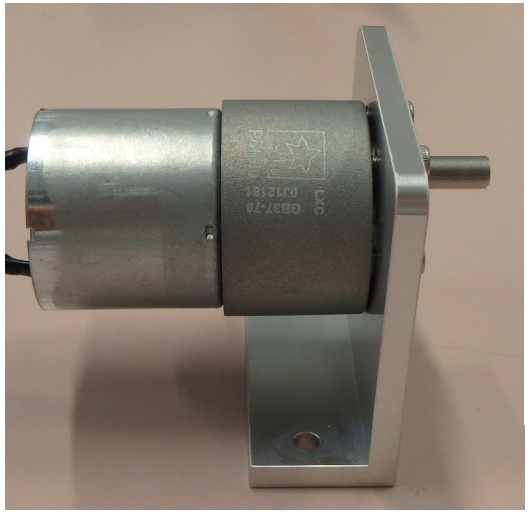
Assembly Task

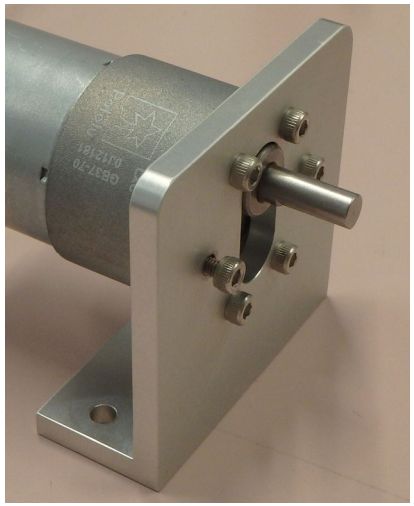
Parts list for WRS2020 Assembly Task (without suprize task) 2021.May.19

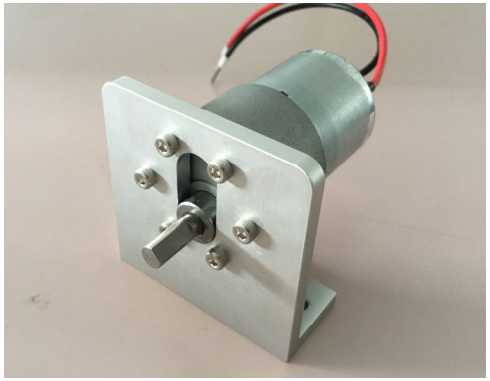
No.	Name of part	Note.	Qty.	Retailer	MISUMI order number	Remarks
1	01-BASE	Base plate	1	manufactured		
2	02-PLATE	Output shaft fixing plate	1	manufactured		
3	03-PLATE2	Motor fixing plate	1	manufactured		
4	04_37D-GEARMOTOR-50-70	70:1 Metal Gearmotor 37Dx54L mm 12V (Helical Pinion)	1	Pololu	https://www.pololu.com/product/4744	with power cable No. 22, No. 23.
5	05_MBRFA30-2-P6	Pulley for Round Belt (4mm) - Setscrew P.D. 30mm	1	MISUMI	MBRFA30-2-P6	
6	06_MBT4-380	Polyurethane roundbelt (weldedjoint product) P.D. 4mm L=380mm	1	MISUMI	MBT4-380	
7	07_SBARB6200ZZ_30	Bearings with Housings (Double Bearings)	1	MISUMI	SBARB6200ZZ-30	
8	08_SSFHRT10-75-M4-FC55-G20	Drive shaft (Straight) D10h7	1	MISUMI	SSFHRT10-75-M4-FC55-G20	
9	09_EDCS10	End Cap for Shaft	1	MISUMI	EDCS10	
10	10_CLBPS10_17_4	Bearing Spacers For Inner Ring (output pulley)	1	MISUMI	CLBPS10-17-4	
11	11_MBRAC60-2-10	Pulley for Round Belts Clamping Type P.D. 60mm	1	MISUMI	MBRAC60-2-10	
12	12_CLBUS6-9-9.5	Bearing Spacers For Inner Ring (tension pulley)	1	MISUMI	CLBUS6-9-9.5	
13	13_MBGA30-2	Idler for Round Belt - Wide	1	MISUMI	MBGA30-2	
14	14_BGPSL6-9-L30-F7	Bearing Shaft Screw	1	MISUMI	BGPSL6-9-L30-F7	
15	15_SLBNR6	M6 Hex Nut (Fixing for idler shaft)	1	MISUMI	SLBNR6	
16	16_SPWF6	M6 Flat Washer (Fixing for idler shaft)	2	MISUMI	SPWF6	
17	17_SCB4-10	10mm M4 Socket Head Cap Screw (metric coarse thread)	9	MISUMI	SCB4-10	
18	18_SCB3-10	10mm M3 Socket Head Cap Screw (metric coarse thread)	6	MISUMI	SCB3-10	
19	19_MSSFS3-6	6mm M3 Hex Socket Set Screw (metric coarse thread)	1	MISUMI	MSSFS3-6	
20	20_TW1004	Clutch lock terminal block (compact)	1	MISUMI	TW1004	Supplied with part number 1 (base panel) attached with screw.
21	21_H0.5/14D	Weidmuller Wire-end ferrule	2	MISUMI	H0.5/14D	Crimped on the ends of the wires of part numbers 22 and 23.
22	22_NAUL1015_22_BK	NAUL1015 UL compliant wire (black)	1	MISUMI	NAUL1015-22-BK-10	Motor power line. Supplied with soldered to motor.
23	23_NAUL1015_22_R	NAUL1015 UL compliant wire (red)	1	MISUMI	NAUL1015-22-R-10	Motor power line. Supplied with soldered to motor.

Completion (Subtask A)

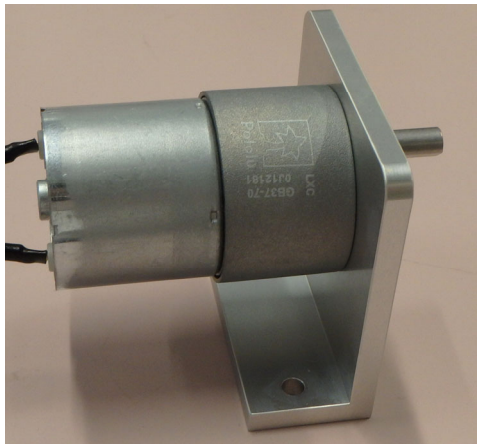
Not Complete

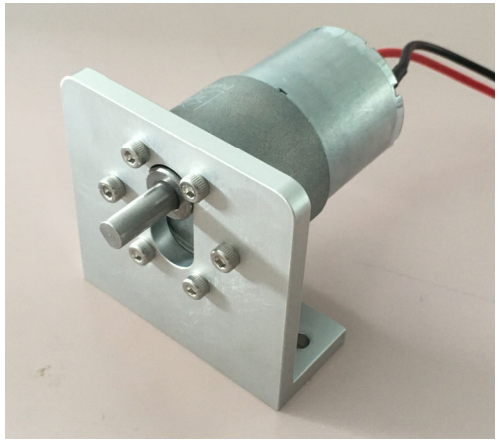






Complete





Motor shaft is located at the top side of the plate hole

AND

Contact: surface(motor)_surface(plate)
[check by 0.3mm gauge]

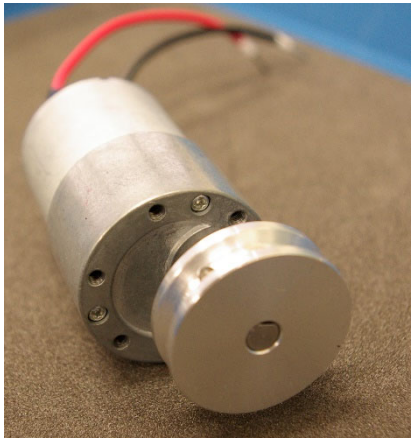
AND

Screw: (all six)bolt_plate
[check by 0.3mm gauge]

Completion (Subtask B)

Not Complete

Complete



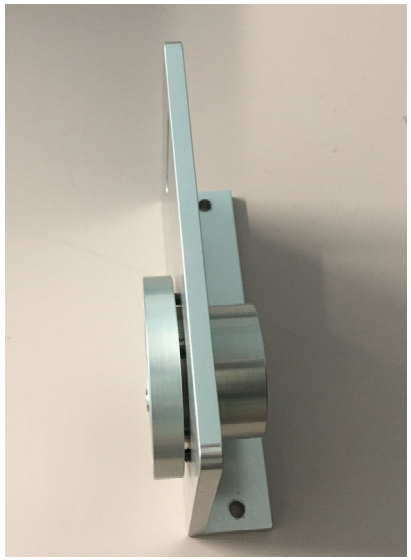
Contact:
surface(motorShaftDcut)_setscrew
[check by eye and touch]

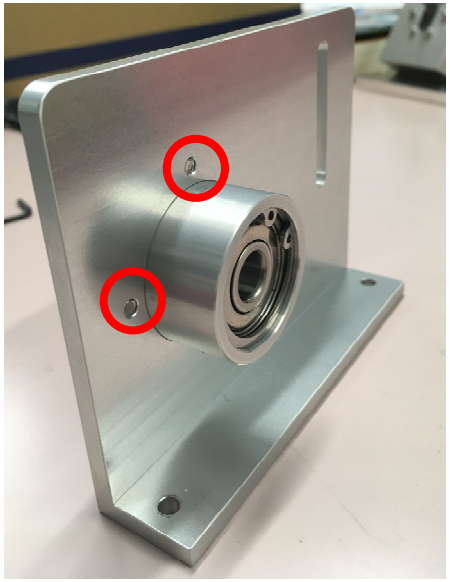
AND

Flat:
surface(motorShaft)_surface(pulley)
[check by eye as less than 1mm]

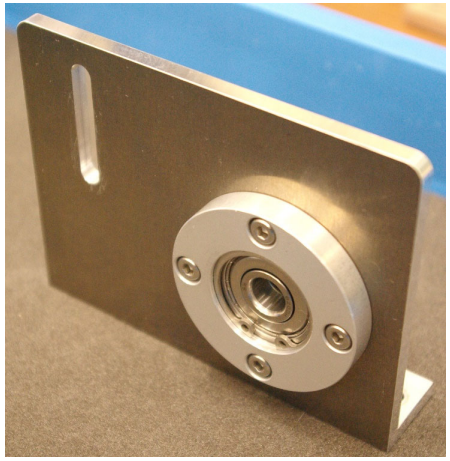
Completion (Subtask C1)

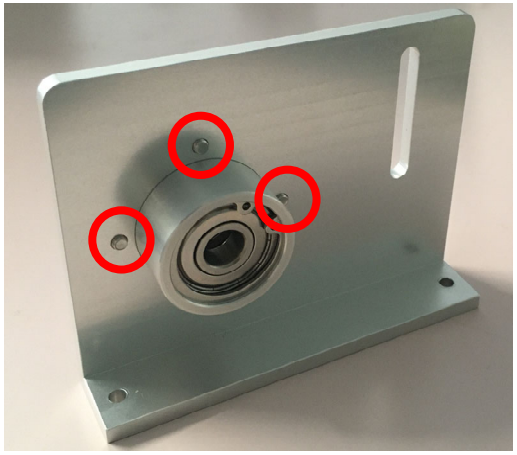
Not complete





Complete





Contact: surface(holder)_surface(plate)
[check by 0.3mm gauge]

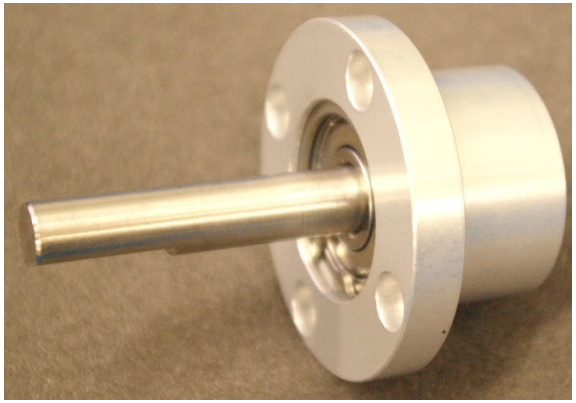
AND

Screw: (all four)bolt_holderPlate
[check by eye and touch for sticking out of bolt end]

Completion (Subtask C2)

Not complete

Complete



Contact: cylindricalSurface(shaft)_ cylindricalSurface(holder) [check by eye]

AND

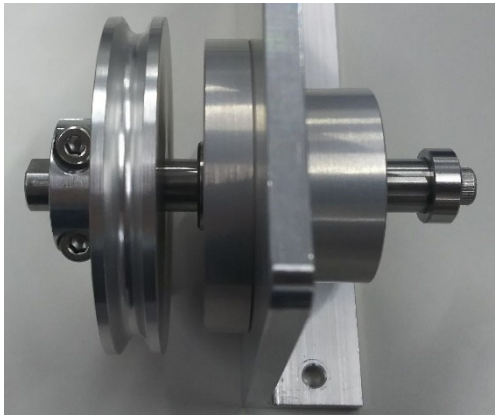
Contact: surface(endcap)_surface(shaftEnd) [check by eye and touch]

AND

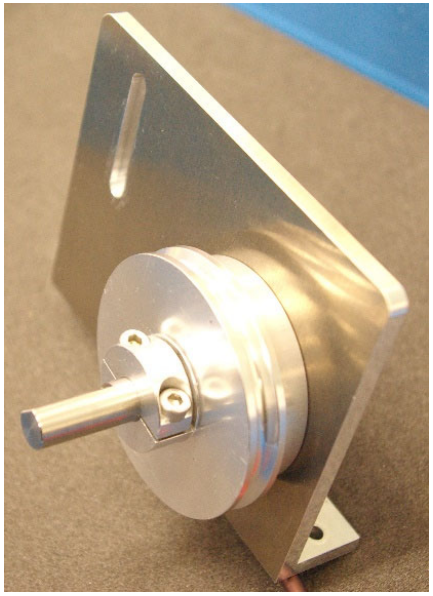
Screw: bolt_endcap_shaft [check by 0.3mm gauge]

Completion (Subtask D)

Not Complete



Complete



Contact: cylindricalSurface(shaft)_cylindricalSurface(pulley Clump) [check by eye and touch]

AND

Screw: clumpbolt_clump_shaft [check by eye and touch]

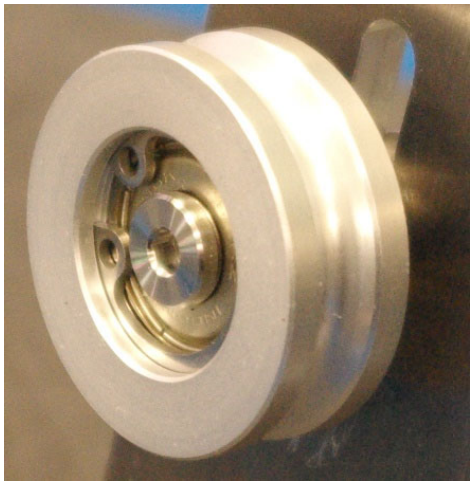
AND

Contact: surface(pulley)_surface (spacer)_surface(bearing)_ surface(endcap) [check by touch and 0.3mm gauge]

Completion (Subtask E)

Not Complete

Complete



Contact: cylindricalSurface(shaftScrew)_cyrindrialSurface(bearing) [check by eye]

AND

Contact: shaftScrew_ bearingSpacer_washer [check by eye]

AND

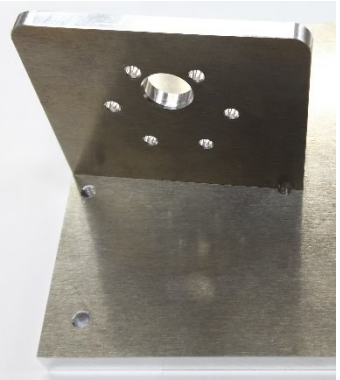
Contact: shaftScrew_ plateHole [check by eye]

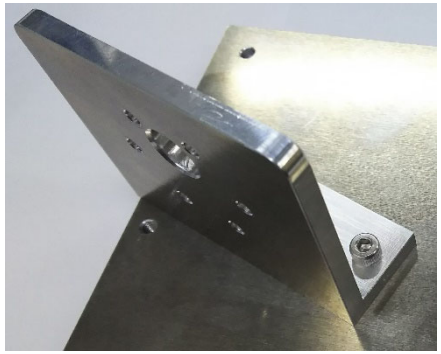
AND

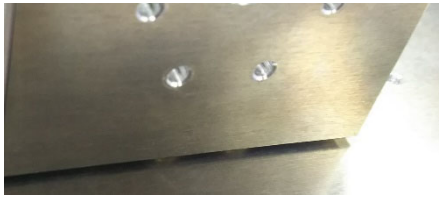
Screw: shaftScrew_nut [check by eye]

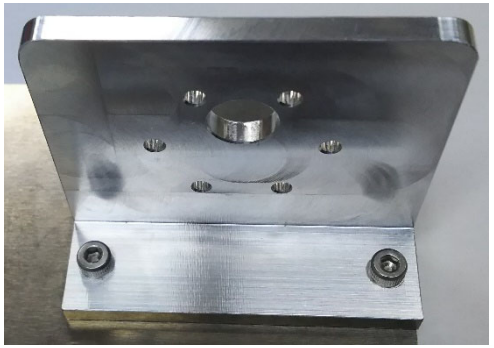
Completion (Subtask F)

Not Complete









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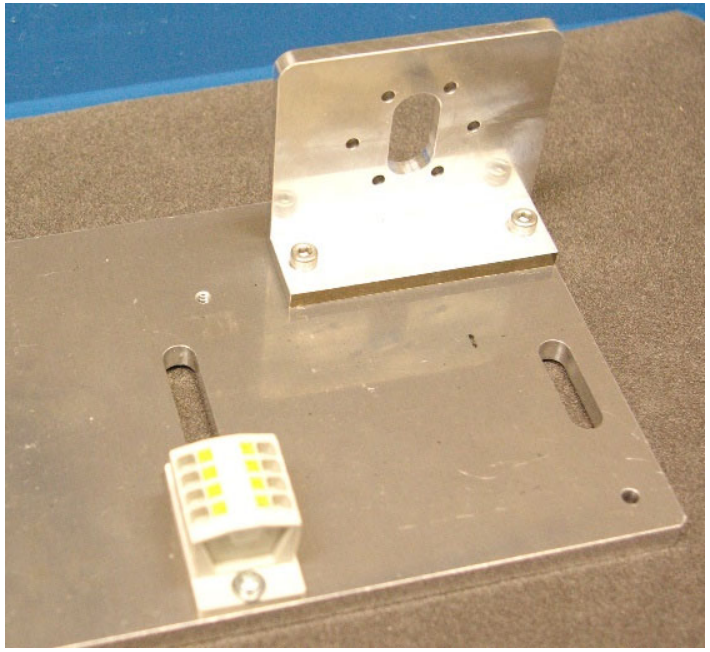


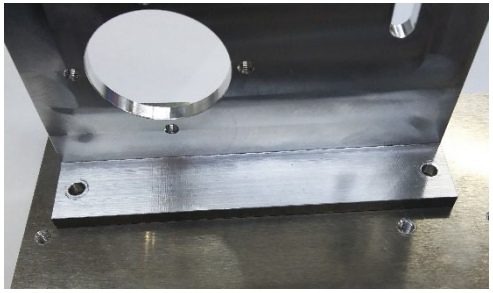
Screw: (all two)bolt_ motorplate_baseplate
[check by eye and 0.3mm gauge]

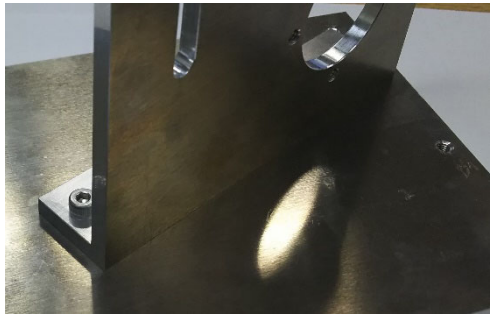
AND

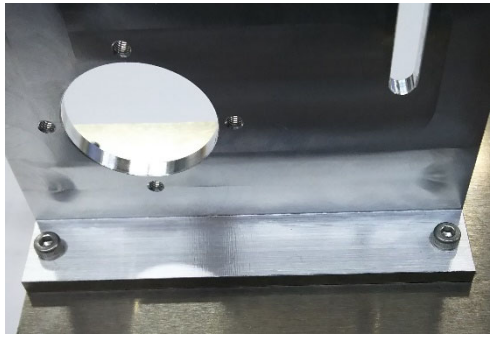
Correct plate direction [check by eye]

Completion (Subtask G)

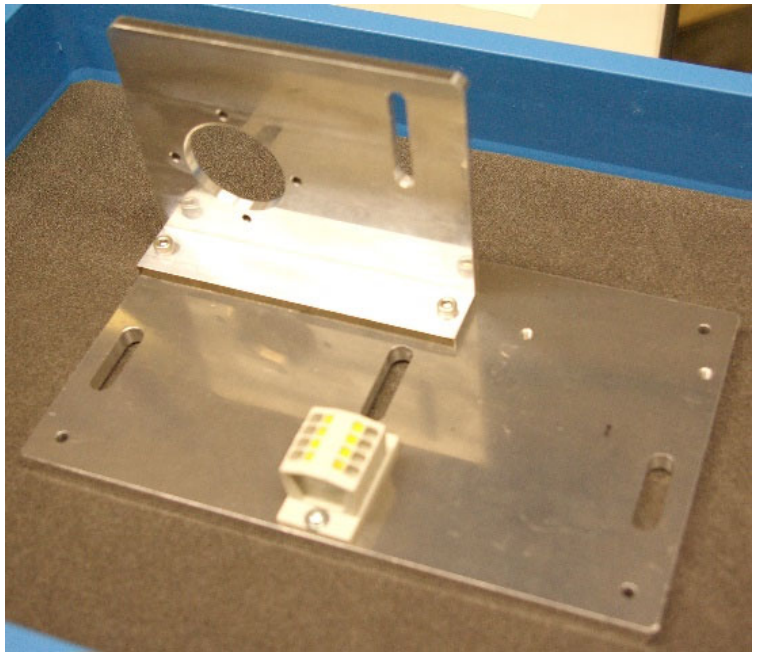
Not Complete







Complete



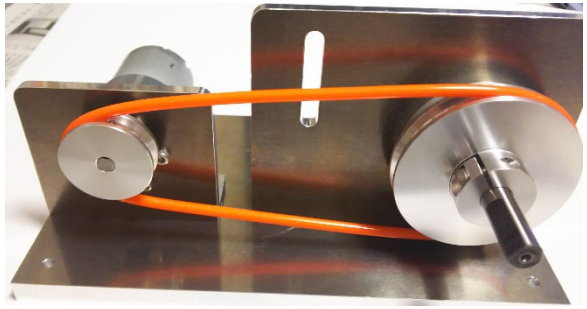
Screw: (all two)bolt_ outputplate_baseplate [check by eye and 0.3mm gauge]

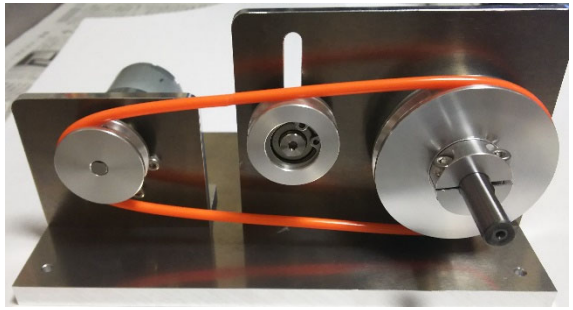
AND

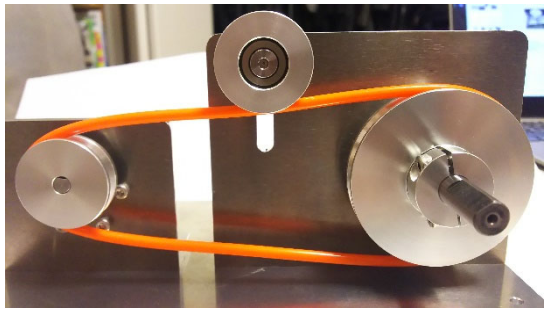
Correct plate direction [check by eye]

Completion (Subtask H)

Not Complete







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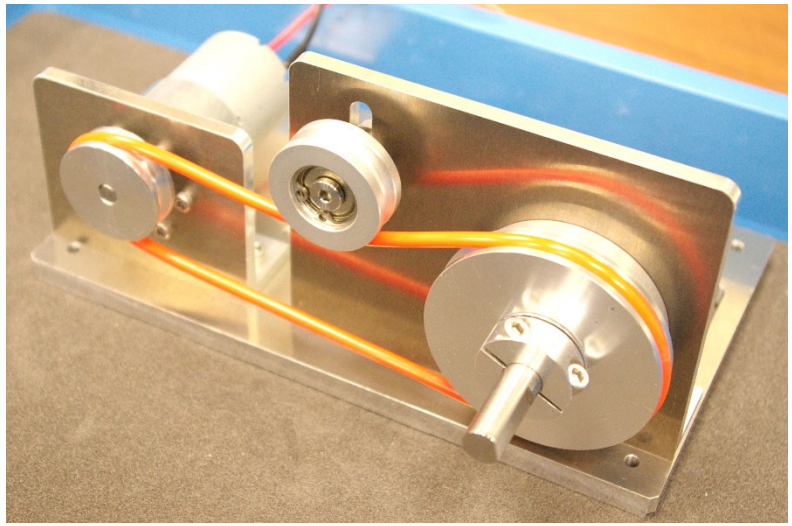


Two shafts (motor shaft & output shaft) are inside the loop of the belt. The shafts go through the loop.

AND

Contact: UshapeSurface(motorPulley)_belt

AND

Contact: UshapeSurface(outputPulley)_belt

AND

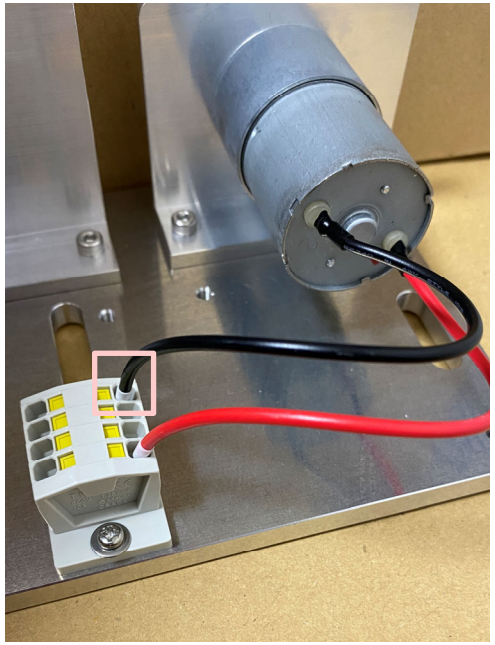
Contact: UshapeSurface(idlerLowerpart)_belt

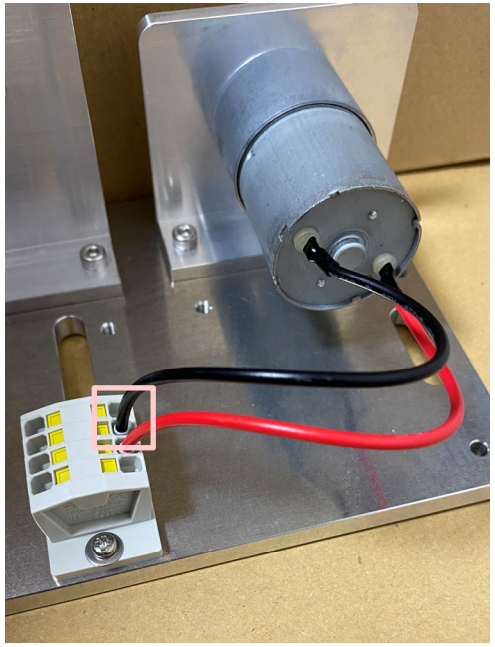
AND

Slit can be seen above idler [check by eye]

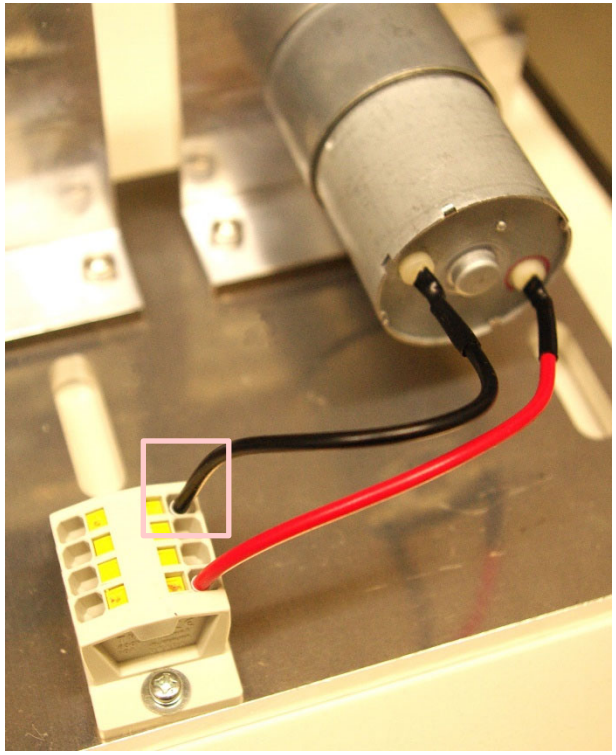
Completion (Subtask I1)

Not complete





Complete



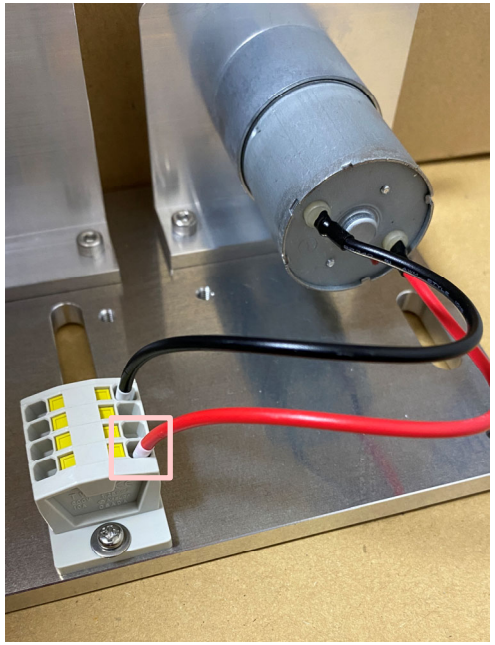
White collar is inserted under the end surface of terminal block [check by eye]

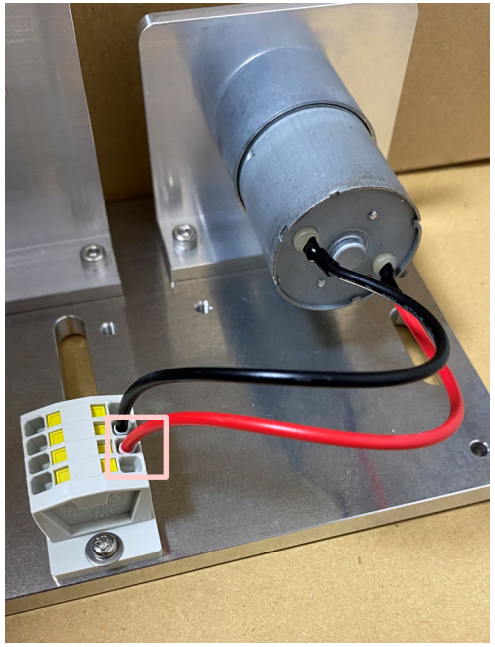
AND

Correct slot [check by eye]

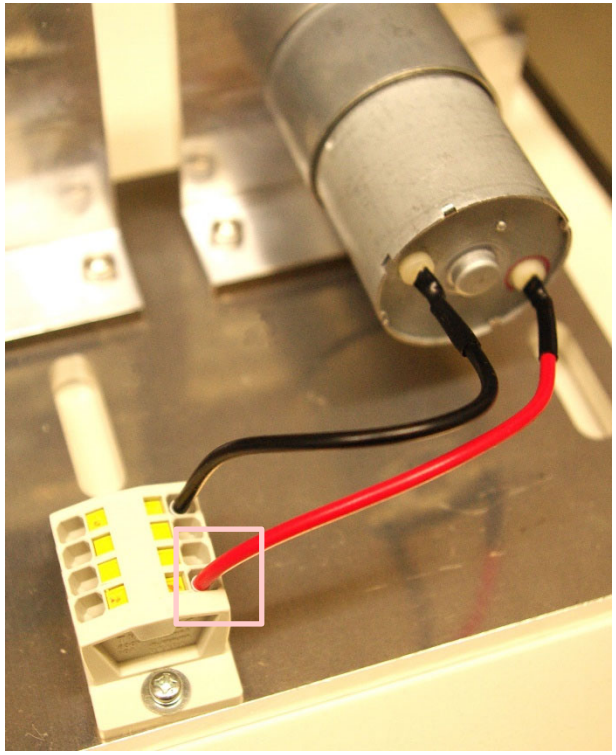
Completion (Subtask I2)

Not complete





Complete



White collar is inserted under the end surface of terminal block [check by eye]

AND

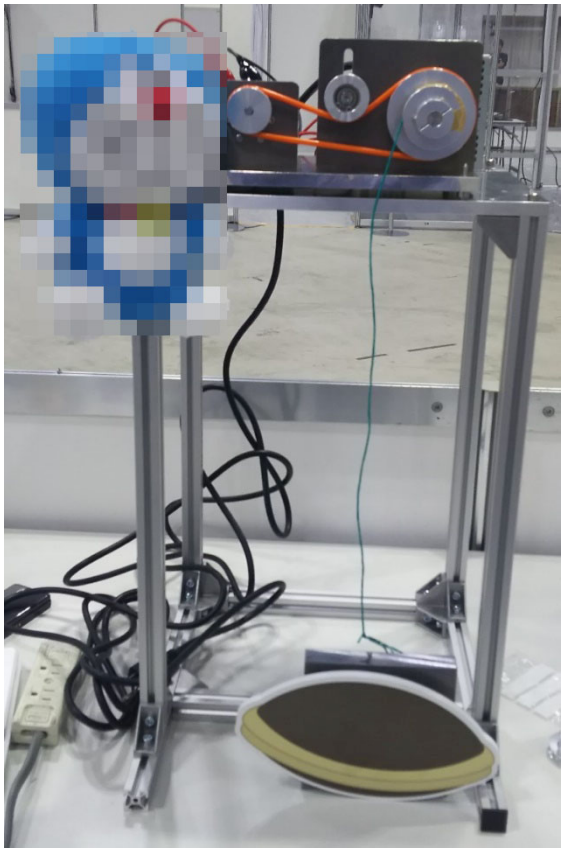
Correct slot [check by eye]

Product evaluation (Function)

Level 0

(0pts)

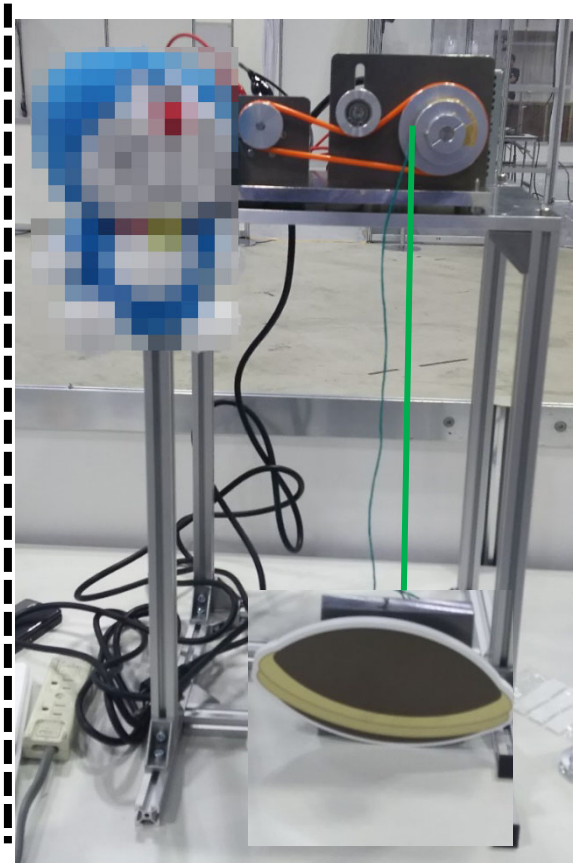
the sinker does not go up [check by eye]



Level 1

(10pts)

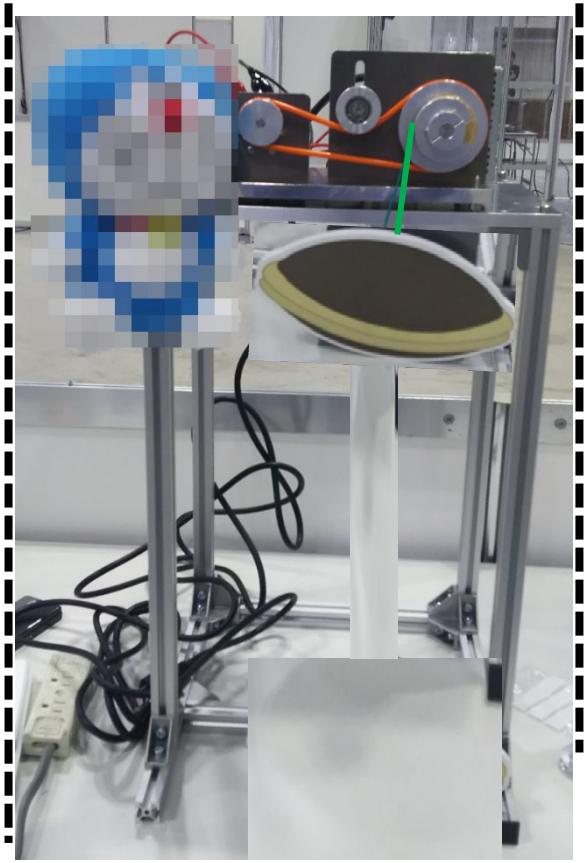
the sinker goes up to float but does not reach defined height [check by eye]



Level 2

(25pts)

The sinker goes up to defined height [check by eye]



Product evaluation (Visual)

Level 0 (0pts)	Level 1 (3pts)	Level 2 (5pts)
New scratch with 5mm or more in width or 1mm or more in depth [check by eye]	New scratch with 2mm to 5mm in width or 0.3mm to 1mm in depth [check by eye] OR Groove of pulleys and idler has disalignment with 1mm or more [check by eye]	No scratch with 2mm or more in width or 0.3mm or more in depth [check by eye] AND Pulleys and idler are assembled within 1mm disalignment [check by eye]

To get Level 1 or Level2 for product evaluation (visual), it is required that all subtasks except for I1 and I2 are completed.

Appendix C.

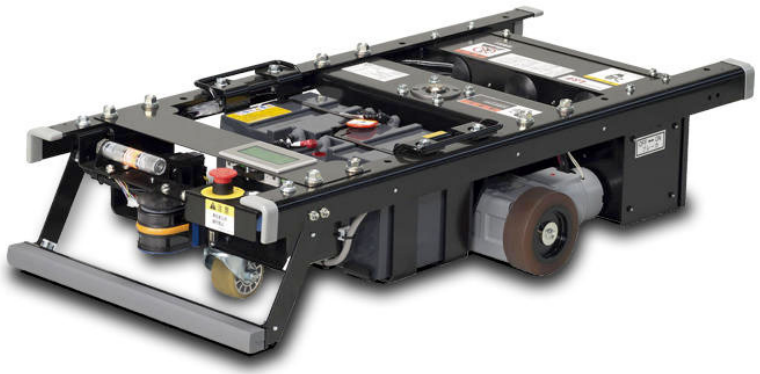
Specifications of AGV

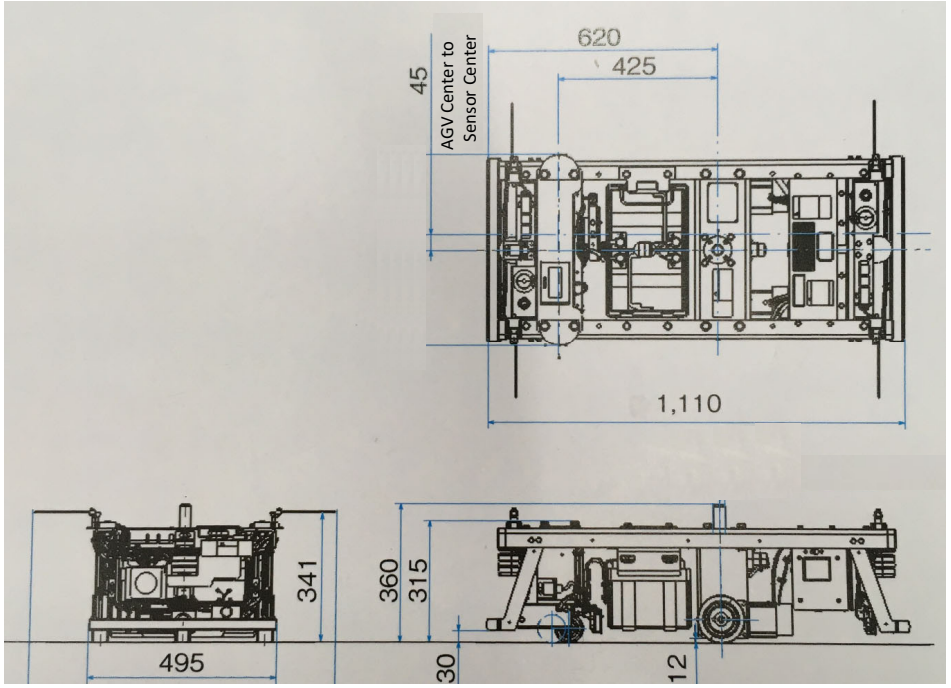
April 15, 2021

About AGV

- TOYOTA Industries Corporation – TOYOTA L&F

https://www.toyota-industries.com/products/industrial_vehicles/toyota/conveying_equipment/index.html



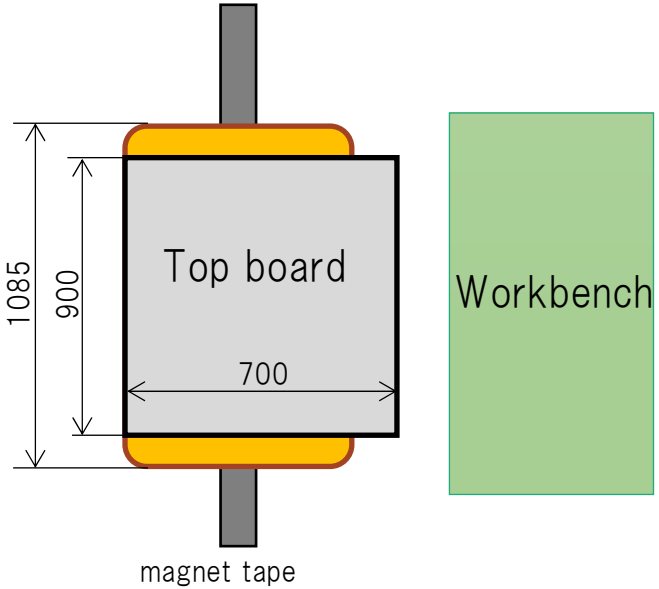


[Caution] Do not modify the AGV!

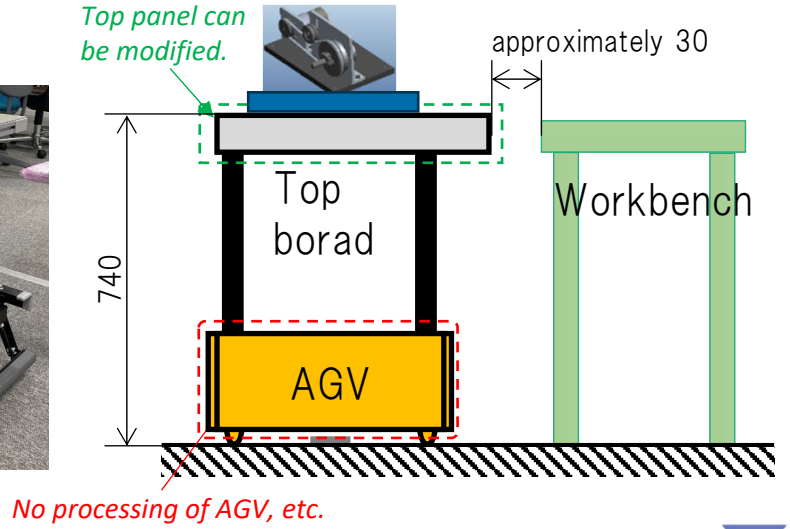
Because this AGV is a rental listing from a sponsor company.

Specifications of the top board

- The board on the top of the AGV is installed in order to transport the trays with parts and assembled products.
- The size of the top board is 900 x 700 mm, and its height is 740mm from the ground.
- The material of the top board is aluminum which is white anodized.
- In order to align the height of the top board with the height of the workbench prepared by your team, you are allowed to attach platforms or objects to the top board. However, the installation of power equipment is not allowed.
- The installation of cameras on the top board is not allowed.
- After the competition, please restore the top board to the original state as much as possible.

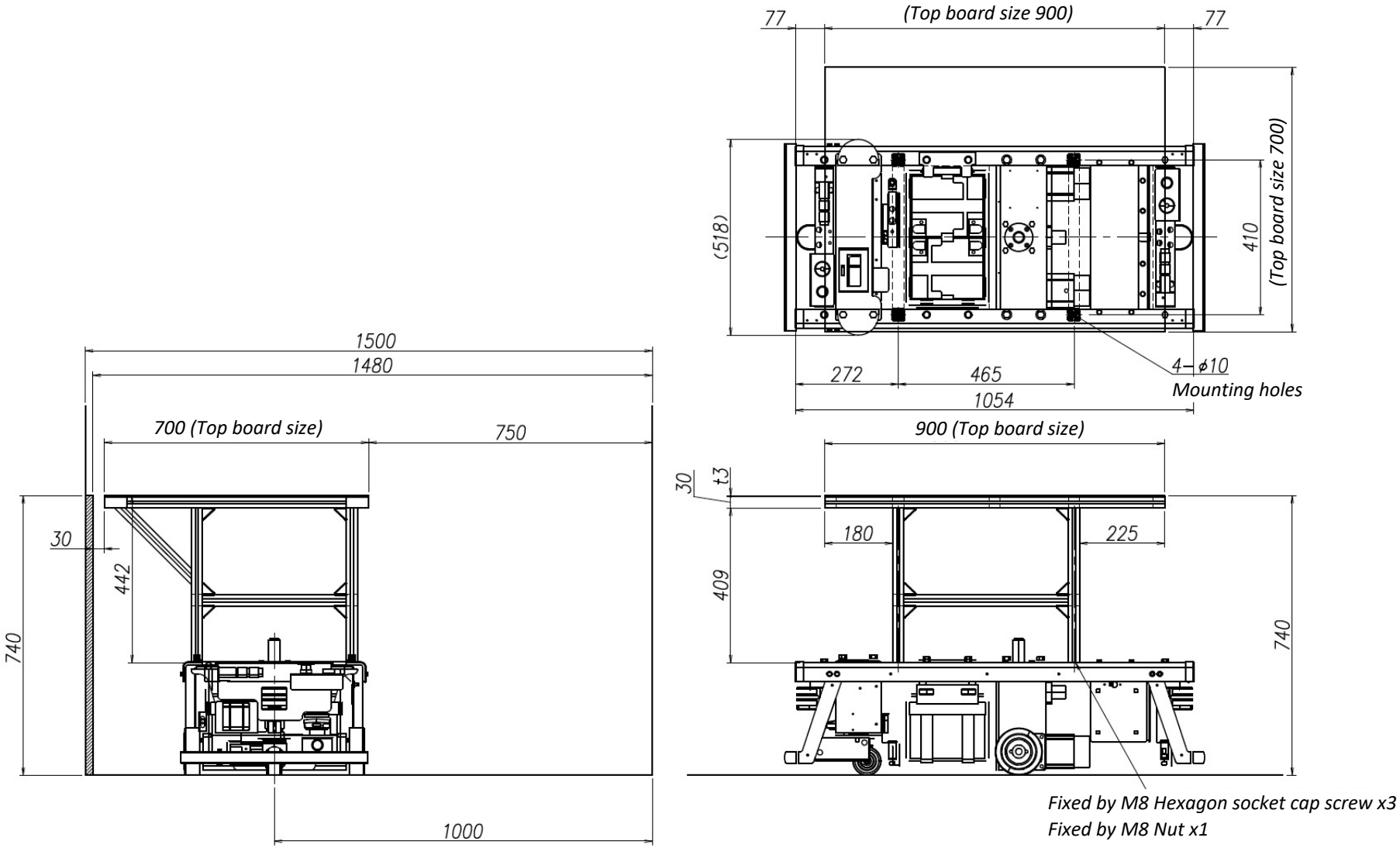


(a) Top view



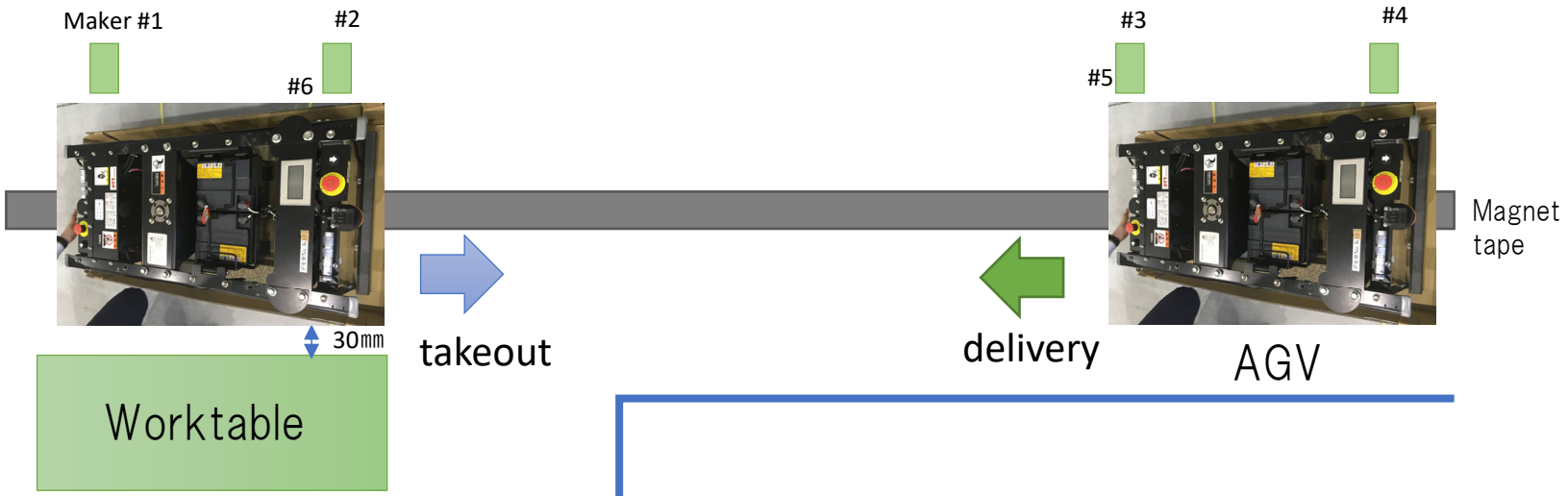
(b) Back view

Drawings of AGV



Path setting of AGV

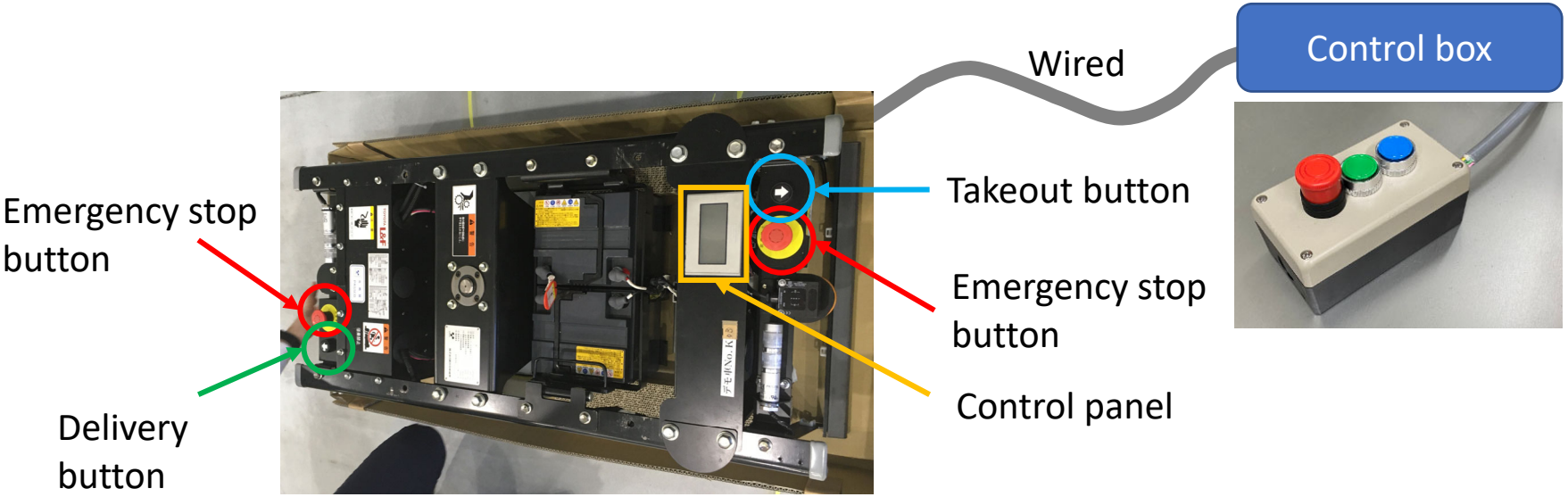
- The AGV runs along the magnetic tape.
  - In the competition, the AGV travels approximately 4meters one way in a straight line.
- Markers will be used for stopping and changing speed.
  - Markers #1 and #4 are the stop positions.
  - Markers #2 and #3 (address No. for takeout movement, #5 and #6 for delivery movement) are used to change the speed.
  - The purpose of deceleration is to improve the accuracy of stopping position.
- The stopping position accuracy in relation to the traveling direction is ±10 to 20 mm.
  - This accuracy depends on the speed of the AGV.
- The distance between the workbench and the AGV should be approximately 30mm to allow for lateral movement during AGV travel.
- Magnet tape and markers are laid out on the floor on the preparation day.



Example

How to operate the AGV

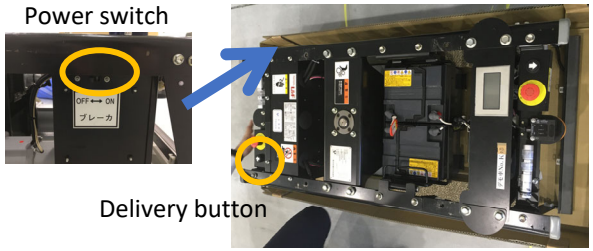
- The AGV is basically operated by the operation remote control.
  - There are three buttons: delivery, takeout, and emergency stop.
  - You only need to press the delivery or takeout button once. You don't have to keep pressing it.
  - The AGV will automatically stop at the target stop position.
- If you press the delivery button while delivery, it will pause, and if you want to move again, press the delivery button again. The same applies to takeout movement.
- If the emergency stop button is pressed, 1) release the emergency stop button, 2) set the release on the control panel, and 3) press the button for the same direction of travel as before.
- The remote control cannot be used to move in the reverse direction until the AGV has reached the target stop position.
  - To move in the reverse direction, it is necessary to change the address on the control panel of the AGV.
  - For example, if you are moving position #1 -> #4 and stop the AGV between #2 and #3 (the display on the control panel shows "2“), and you want to return to position #1, you need to change the address #2 to #5.



How to operate the AGV

Status of AGV	Color of Back light
Normal	Green
Warning	Orange
Emergency	Red

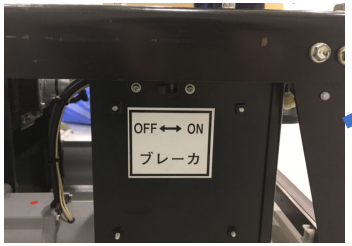
- Control panel on the AGV
  - Task setting
  - Address display and setting
  - Error state display
  - Reset
  - Electromagnetic brake: lock or free
    - MENU -> Manual -> E/M Brake -> Lock or Free



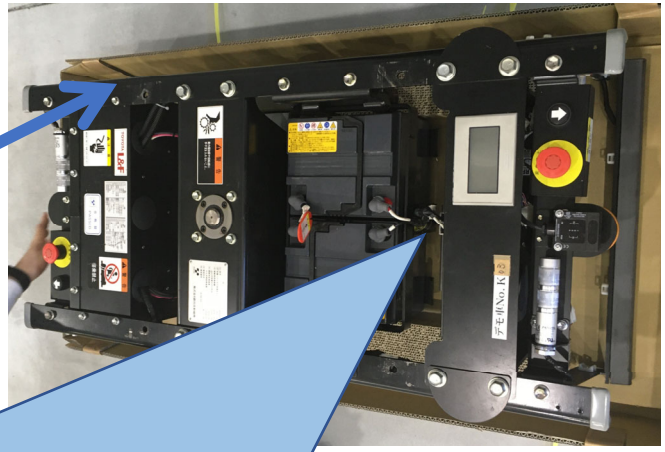
- To move the AGV manually
  - When the power is off,
    - Turn on the power switch while pressing the delivery button
    - After movement, turn off the power switch
  - When the power is on,
    - Release the electromagnetic brake on the control panel
    - After movement, activate the electromagnetic brake

Operation of the AGV

- One AGV will be provided per team.
  - In principle, each team can use the provided AGV exclusively during the competition.
- Under normal use, the AGV will run all day.
  - The AGV should be connected to the charger and charged every night, if power capacity becomes low.



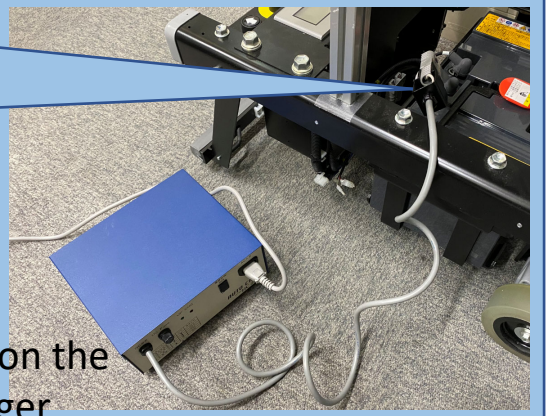
Power switch



【Transportation】
Remove the connector

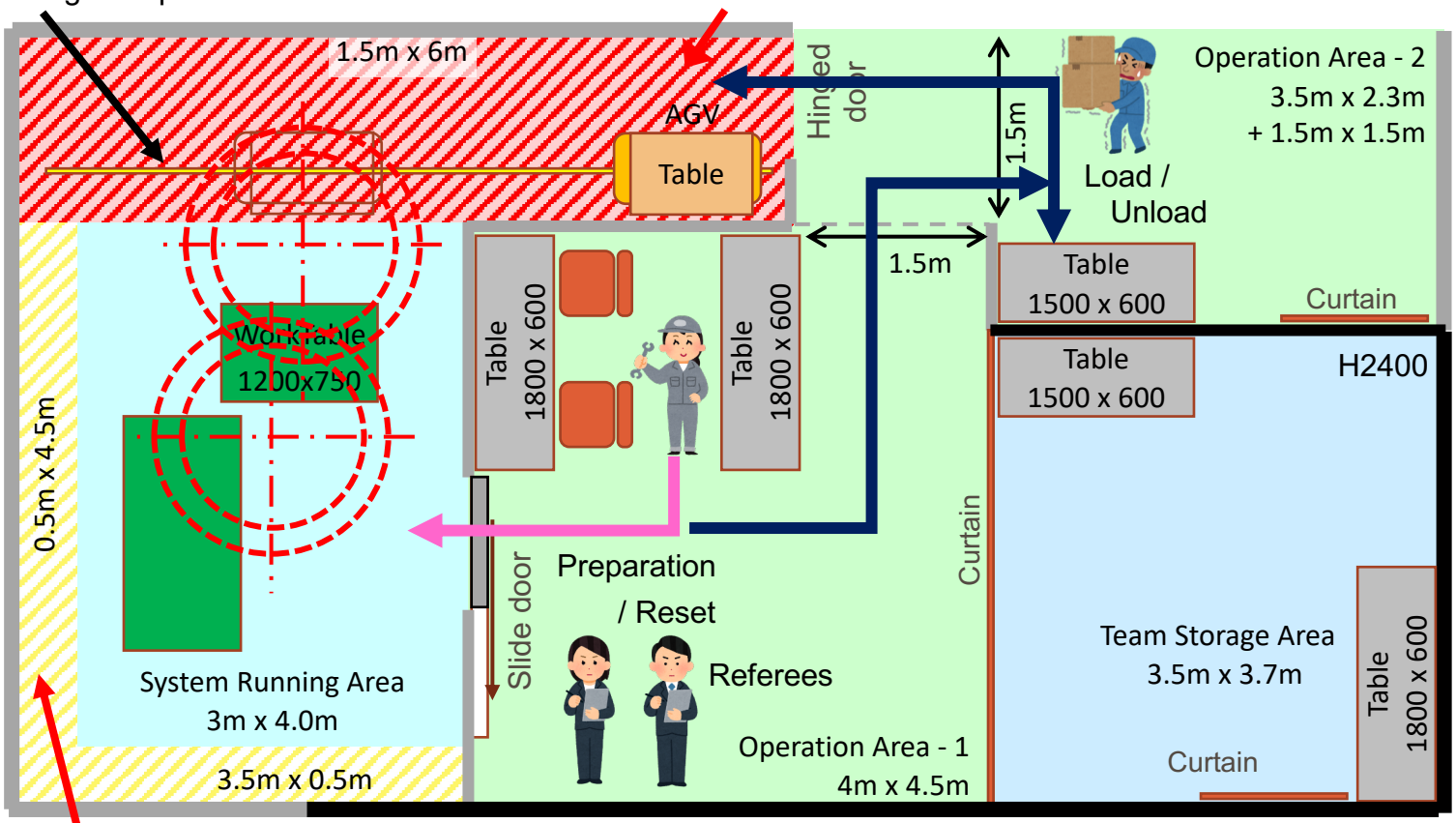
【Using】
Connect the connector

【Charge】
Connect the connector on the battery side to the charger



Human flow lines at the team area (tentative)

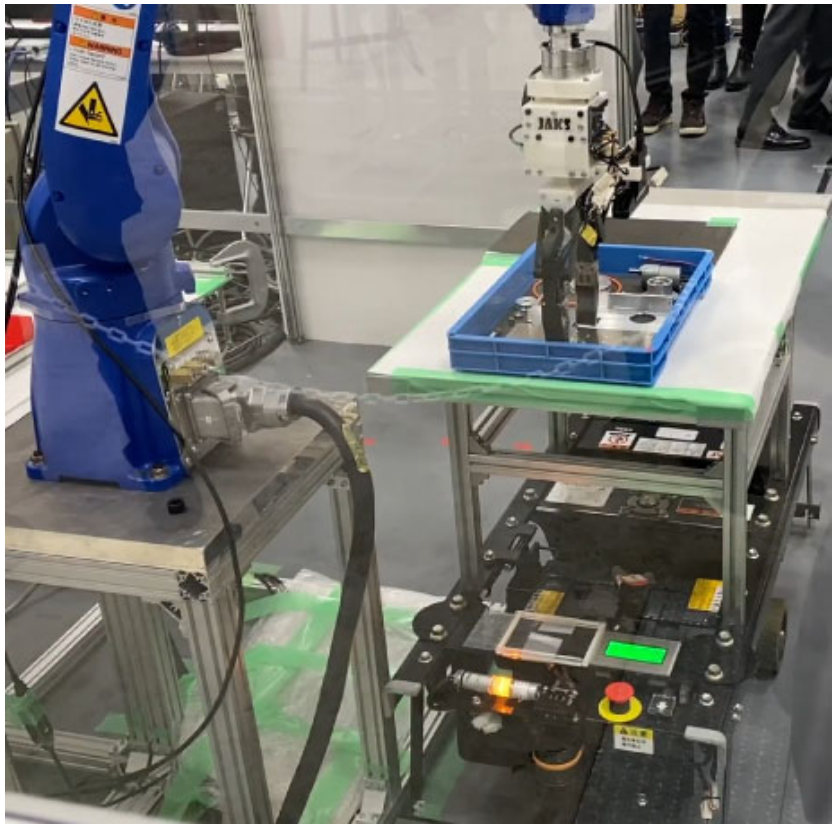
Prohibit placement of objects & No one can be here when AGV moves
However, a vision camera, RealSense and so on are allowed to protrude
from System Running Area at a height of 2 m or more from the floor.

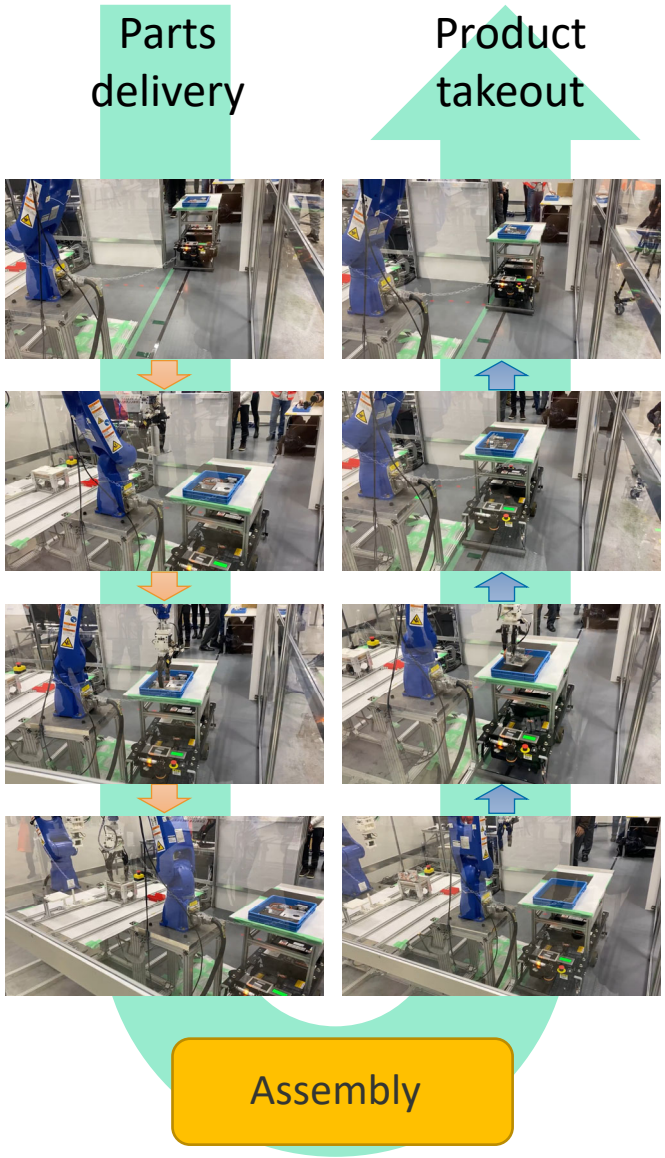


Prohibit placement of objects

(actual layout is subject to change)

Examples of AGV use

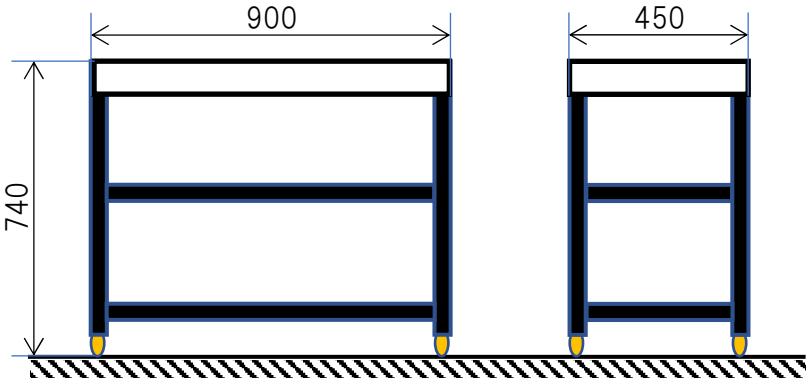




The Assembly task for the belt drive unit
at WRS 2019 trial competition

【F.Y.I.】Specifications of pushcart

- If the AGV becomes inoperable, it will be changed out with a spare AGV.
- If more than one AGV becomes inoperable and there are not enough spares, some teams may be asked to use a pushcart instead of the AGV.
- In order to align the height of the top panel with the height of the worktable, you are allowed to attach platforms or objects to the top panel. However, the installation of power equipment is not allowed.
- Specifications of manual pushcart
  - Maker : Trusco Nakayama
  - Name : Workbench Auxiliary Tables/Trolleys
  - Part Number : WHT-4590
  - Hight x Width x Depth : 740 x 900 x 450 mm
  - Top Plate Material : Polyester decoration
  - https://us.misumi-ec.com/vona2/detail/223000815450/



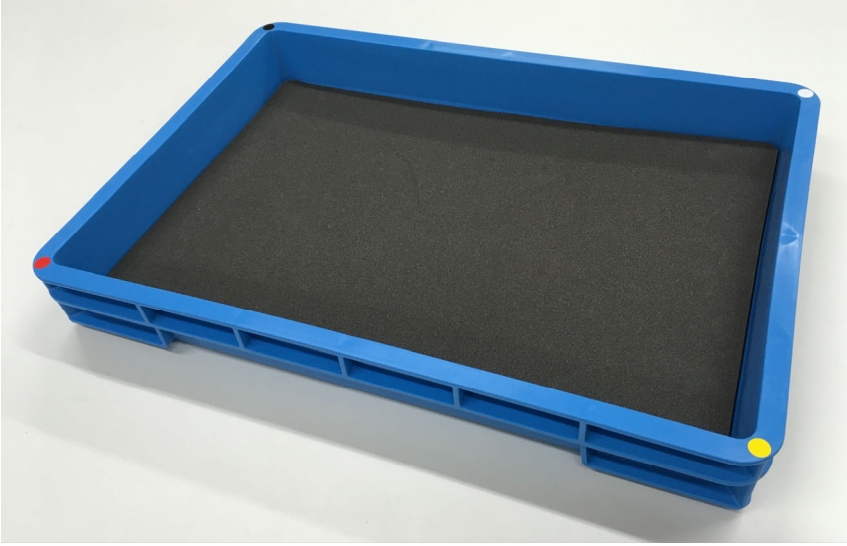
[Caution] The size of the top panel is different from the AGV (500mm → 450mm)

Appendix D.

Specification for Parts Tray.

Specification for Parts Tray

World Robot Summit



Tray

Maker : Sekisui Techno Molding
Name : TC型コンテナ TC-3 青
Part Number: **TC-3-B**
Capacity(L) : 4
Major Diameter(mm)Frontage, Depth, Height : 400×280×53
Effective Inner Dimensions(mm)Frontage, Depth, Height: 366×245×41
Weight : 0.53kg
Material : Polypropylene
MISUMI : https://jp.misumi-ec.com/vona2/detail/223010137324/

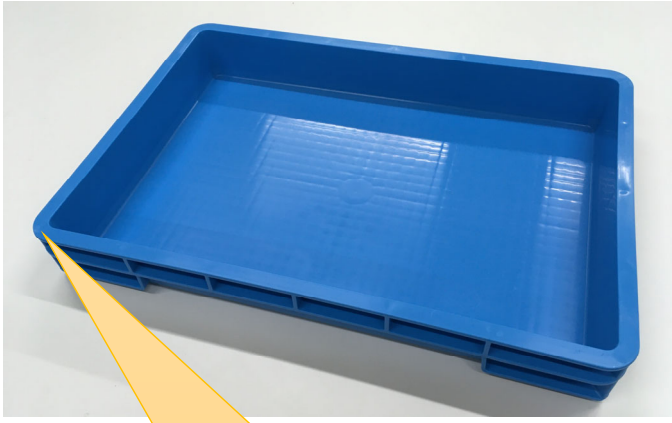
Foam Sheet

Maker : Trusco Nakayama
Name : Polyethylene Foam Sheet
Part Number : **TPEH-0510BK**
Materia : [Sponge]
Foamed Polyethylene
Thickness (mm) : 5
Specifications : Hard type
Color : Black
Density : 65kg/m^3
MISUMI:
https://jp.misumi-ec.com/vona2/detail/221005496975/
https://us.misumi-ec.com/vona2/detail/221005496975/

Marker

HEIKO
Tacklabel
ϕ9mm Black (35601912)
ϕ9mm White (35601921)
ϕ9mm Red (35601842)
ϕ9mm Yellow(35601876)
monotaro:
https://www.monotaro.sg/g/1000274980.html

Specification for Markers



A tack label which diameter is about 9 mm is attached there.

Black

White

Red

Yellow

The markers with the same color may be used to mark the four corners of the parts trays.

There are machining marks which diameter is about 10 mm at the four corners of the 11 mm wide edge