Dec.8th, 2017

# World Robotics Summit
# Disaster Robotics Category
# Plant Disaster Prevention Challenge
# Provisional version Competition Rules
# For 2018 Pre-competition Application Requirements Ver. 0.96

## 1. Competition Scenario and Background

The competition theme is daily inspections, tests and emergency response taken when a fault occurs at plants such as manufacturing, refining and steel making.
Competing tasks and missions are set up in order to correspond to various plants.

### Advantages of introducing robots for plant inspection

[Autonomous inspection] In offshore plants where it is difficult to dispatch workers or facilities (pumps, tanks, boilers) located in dangerous places (environments), if the inspection of structures and health assessment diagnosis is fully automated, then human accidents at the time of inspection can be prevented.

[Early detection of fault] Raising the frequency of periodic inspections by robots, equipment failure and accidents caused by abnormalities due to human error, deterioration of facilities or equipment breakage due to aging, which result accidents (explosion (gas leak), fire (generation of toxic gas, (the outflow of harmful substances) etc., can be prevented. In addition, inspection and analysis can be performed without stopping facilities by introducing a robot, which is also expected to improve the operational rate of facilities.

[Disaster Response] If a section of the piping is damaged due to a disaster, leakage of combustible gas will occurs, and this would results an explosion and fire. As for the countermeasures, it is necessary to open and close the valves of the sprinkler (shower) and foam fire extinguisher in the facility of which environment is filled with combustible gas. For rapid initial fire fighting(gas and oil lines closed / the fire hydrant opened) a robot which can work in areas too dangerous for humans is useful.

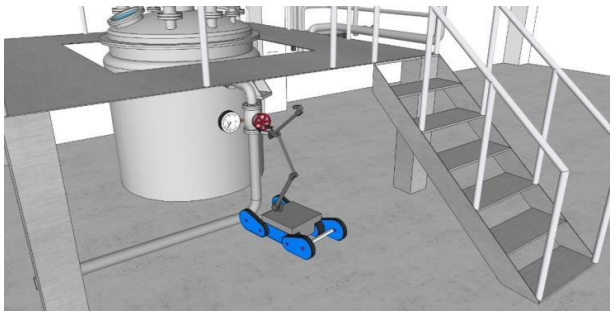
## 2. Competition Mission

Five competition missions have been prepared to evaluate the performance of the plant inspection robot.

Participating teams will continuously perform the competing tasks (inspection investigation, manipulation work) according to the competition mission and will return to the starting point after competing all tasks. The outline of each competition mission is explained below.

Mission P1：Inspection / Maintenance

Competition task: Daily inspections at plants are conducted several times a day by several staff members. We want to reduce the labor of inspection by using tele-operated / autonomous mobile robots.



Therefore, in this mission, the robot checks the operational state of the facility equipment, inspects it, reads the numerical value of the meter etc. in the designated place, and reports the numerical value.

It also adjusts the facility equipment as specified.

Required ability:

[Mobility] The moving space is a passage (partly narrow width 60 cm), stairs, pipe lines, and the material of the road surface is concrete, grating, checker plate, or the like..

The robot is required to move in these spaces.

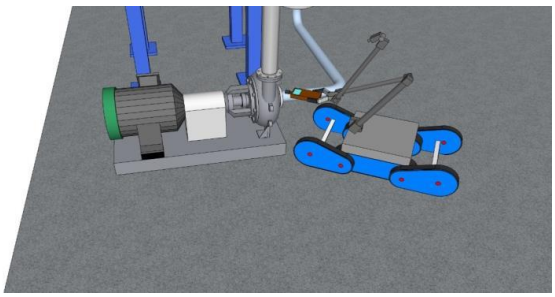
[Observation and Manipulation] The object to be inspected / operated is a meter, a valve handle or the like. The location and shape of these objects are known beforehand. The robot is required to have the ability to inspect and manipulate these objects by using mounted sensors, manipulators and the like.

[Environmental adaptation] The robot is required to adapt to and perform tasks that can be executed in the normal environment of a plant in which pipe lines are complicatedly stretched around a plurality of facility apparatus.

Technical Challenge: Ability to automatically determine the value of the meter and to operate the valve in a feedback manner corresponding to a dynamic change of the numerical value. Practical level processing capacity (speed and accuracy). Inspection ability by autonomous movement.

Mission P2：Fault Detection

Competition task: Discover an abnormality (fault) at an early stage by utilizing sensor

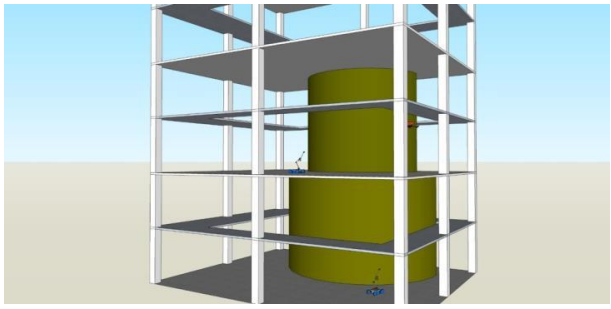


technology and analysis technology. Therefore, in this mission, the robot quickly finds the abnormality (fault) caused by aged deterioration of equipment, artificial mistake, etc. Follows instructions for periodic inspection and reports place and contents.

Required ability:
[Mobility] Same as Mission P1
[Observation and Manipulation] Inspection task is abnormality (fault) detection of an abnormal heat source presence / absence of each facility, gas leakage (concentration), abnormal sound, presence / absence of vibration, loose bolt fastening, water leak etc. The robot detects the abnormality (fault) by using mounted sensors, cameras, etc. The location of the abnormality (fault) occurrence is unknown, but abnormal events are prescribed and known in advance specified by the competition organizers. For the abnormal event measurement, each team can use a device prepared by the competition organizers, or team's own device.
[Environmental adaptation] Same as Mission P1

Technical Challenge: Fault detection in an unknown environment. Utilization of existing measuring instruments and integration of the measuring equipment to robot (integration technology). Practical level processing capacity (speed and accuracy). Inspection ability by autonomous movement.

Mission P3 : Diagnosis



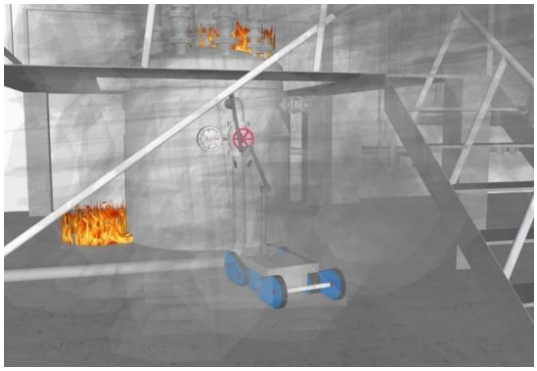
Competition task: In the plant, large-scale inspections are conducted every several years, assuming repair and refurbishment. In addition, there are cases where the plant operation is stopped and cleaning work is performed. For this reason, we would like to use robots to shorten plant shutdown periods and to check dangerous places such as high places. Therefore, in this mission, the robot evaluates and diagnoses the health of the facility for large-scale structures such as piping (including flange), tanks and chimneys, and reports the state of aging and deterioration.

Required ability:
[Mobility] Same as Mission P1
[Observation and Manipulation] The diagnostic objects are pipes / ducts, large scale structures. The robot detects the abnormality (fault) by using mounted sensors, cameras, etc. The location of the abnormality (fault) occurrence is unknown, but abnormal events are prescribed and known in advance specified by the competition organizers.
[Environmental adaptation] Same as Mission P1
Technical Challenge: Investigate work in a complicated pipe lines, in a wide area like a large tank, and a high place like a chimney. Integration of diagnostic equipment to robot (integration technology).

Autonomous control performance is not indispensable, but advanced human-robot interaction and data processing ability that can cope with complicated / large scale objects and practical level processing capacity (speed and accuracy) are required. In reporting, it is desirable to have the ability to create 3D models on site in real time and map survey results in order to identify inspection location.

Mission P4 : Disaster Response: Initial fire extinction

Competition task: An explosive sound is generated while the robot is on routine inspection. It is caused by a gas leakage due to aging piping. Fire occurs around the relevant facility equipment and smoke is emitted. Also, other equipment is in a dangerous situation, there is a possibility of a gas leak and further explosions, people cannot approach. In order to prevent the disaster from spreading, the initial fire must be extinguished by robot. Therefore, in this mission, the robot opens and closes valves of various pipes around the relevant facility equipment and other facility equipment appropriately (opens fire extinguishing equipment piping (sprinkler and foam fire extinguishers ), closes combustible gas and oil piping).



Required ability:

[Mobility] Same as Mission P1

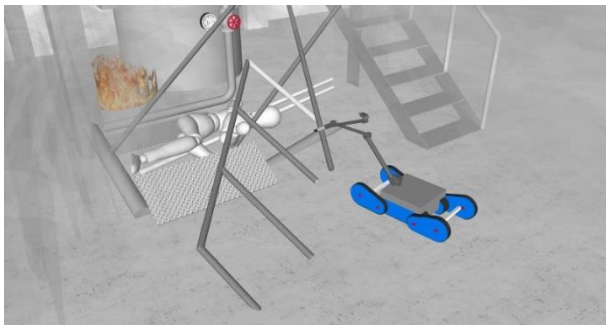
[Observation and Manipulation] In addition to mission P1 + P2, tasks include initial firefighting and removal of debris.

[Environmental adaptation] At the time of the disaster (unknown environment without prior information with smoke, water, oil, debris etc.)

Technical Challenge: Realization of comprehensive and practical ability. In particular, aim to realize work in an unknown environment with external interference. In addition, aim to combine the ability of each competition task P1 to P3 and execute at the time of the disaster.

Mission P5 : Disaster Response: Search

Competition task: After the disaster (explosion), there is one missing person at the time of mustering the workers. It is known that the missing person was in the office on the second floor when the accident occurred. Therefore, in this mission, the robot also searches for the rescuee to prevent secondary disasters.



Required ability:

[Mobility] Environment with debris

[Observation and Manipulation] Work on debris removal and search for necessary rescuee

[Environmental adaptation] Application to disaster environment (nonstructural environment without prior information with smoke, water, oil, debris, etc.)
Technical Challenge: Realization of comprehensive and practical ability. In particular, aim to realize work in a nonstructural environment with disturbance (unknown environment). In addition, aim to combine the ability of each competition task P1 to P3 and execute at the time of the disaster.

## 3. Field of competition

The competition field shall be the reproduction of an actual plant. The plant layout, layout of various targets and details thereof are planned to be released as technical data, e.g., in 3D CAD, in advance.

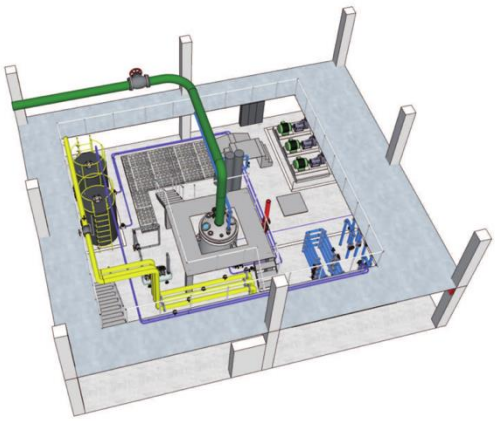
### 3.1 Outline of simulated plant

The main event of 2020 is scheduled to be carried out in a 6-story building of W 10 m × D 12 m × H 30 m which is to be constructed in the Fukushima Robot Test Field in Minamisoma City, Fukushima Prefecture. Each floor has the following structure, and the height of each floor is 5 m.
1st floor: basic equipment (pump, boiler, small tank, pipe lines)
2nd floor: Pipe lines
3 / 4th floor: Medium and large tank
5 / 6th floor: Chimney

Conceptual drawing of simulated plant

At the 2018 pre-competition, we plan to construct a small prototype at Tokyo Big Sight, mainly with the basic equipment and pipe lines.

3.2 Field of competition (1st floor: basic equipment) Outline



3.3 Outline of equipment / structure

3.3.1 Small tank

Equipment specification:

JIS-SS Steel plate welded assembly structure ( φ1,200×H1,900mm )

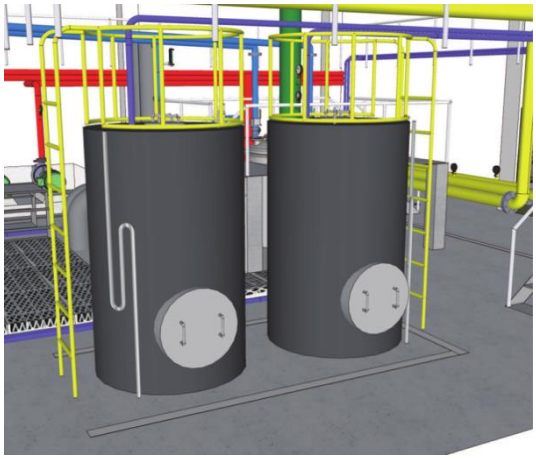
Ladder (No safety fence, effective width 450 mm, step interval 300 mm, 7 steps)

Inspection hatch (ceiling, diameter φ 300 mm, swing bolt fixed detachable hatch)

Inspection hatch (bottom, diameter φ 600 mm, bolt fixed detachable hatch)

Tank side surface water level gauge (tubular type liquid level gauge)

Discharge part 50A Ball valve



Inspection / Maintenance item:

(1) Tank side: Check water level

(2) Ceiling hatch: Measure oxygen concentration in tank.

(3) Opening and Closing the Ceiling Hatch, Handle Operation

Report content (judgment criteria):

(1) Water level

(2) Presence / absence of abnormal concentration .

The criteria will comply with the standards issued by the National Petroleum Association (JPI-8S-2-2016 equipment maintenance standard) and the American Petroleum Institute (API) and others.

Details will be provided separately by WEB etc.

3.3.2 Boiler

Equipment specification:

Small boiler ( φ1,300×H1,550mm )

JIS-300A Flange joint ( 10K ) x 1 , JIS-80A Flange joint ( 10K ) x 2

Pressure gauge 4 or more, temperature gauge 1, 50A ball valve (handle) x 2, 50A ball valve (lever) x 2

Inspection Deck:

Walkway width 1,000 mm

Skeleton staircase (full width 700 mm (effective width 600 mm), step depth 240 mm, riser height 227 mm, inclination about 40 deg.)

Foam fire extinguishing facilities available

Inspection / Maintenance items:

(1) Pressure / temperature measurement
(2) health (presence / absence of abnormal heat source, presence of gas leak (concentration measurement))
(3) Handle operation (water and fuel flow rate / pressure adjustment)

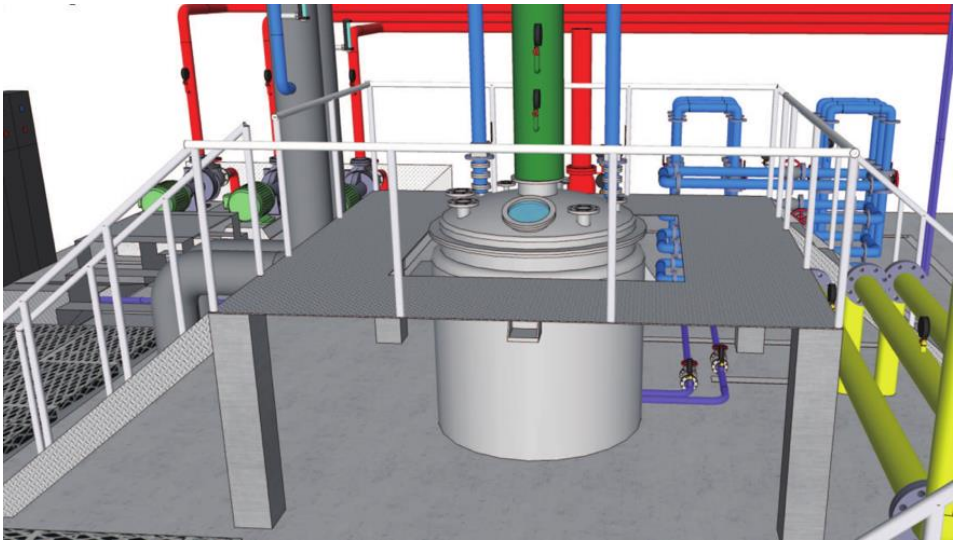
Report content (judgment criteria):

(1) Pressure / temperature

(2) Presence of abnormality (fault) .

The criteria will comply with the standard issued by ASME (American Society of Mechanical Engineers) etc.

Details will be provided separately by WEB etc.



### 3.3.3 Pump

Equipment specification:

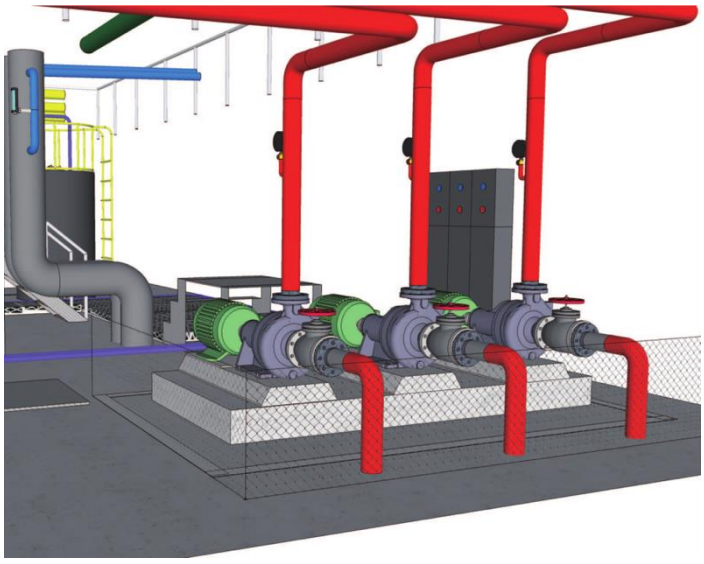
Kawamoto Pump company's fully-enclosed external fan indoor type spiral pump
(GDFM 1005 M 4 E 11, bore size 100 × 80, 11 kW)
JIS - 100 A flange (10 K, suction side), JIS - 80 A flange (10 K, discharge side)
Pressure gauge, 100 A ball valve
Set on a base with a height of 200 mm

Inspection / Maintenance item:

(1) Pressure measurement
(2) Health (abnormal sound / vibration (bearing deterioration), water leakage, loose fastening part of base bolt
(3) Handle operation

Report content (judgment criteria):

Presence of abnormality (fault). The criteria will comply with the ISO Evaluation of machine vibration standard (ISO 10816-3).
Details will be provided separately by WEB etc.



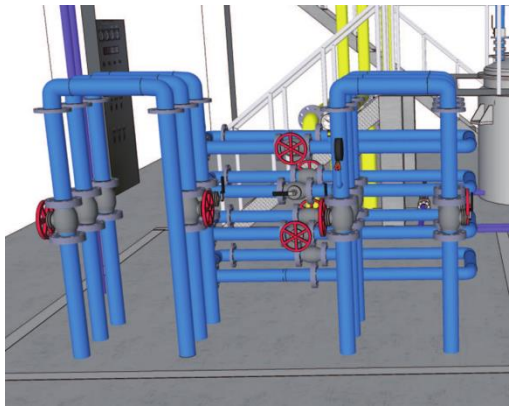
### 3.3.4 Pipe lines

Equipment specification:

JIS - SGP pipe (50 A, 80 A, 100 A, 300 A), JIS - SS (10 K) flange, JIS - SS welded elbow (bend)
Pressure gauge, gate valve (150 A, 300 A), ball valve (80 A), butterfly valve (80 A)

Inspection item:

(1) Pressure measurement
(2) Health assessment (deformation, fracture, crack, corrosion, water leakage, loose bolt, abnormal sound etc.)



Report content (judgment criteria):

Presence of abnormality (fault). Judgment criteria will be in compliance with infrastructure inspection method

Details will be provided separately by WEB etc.

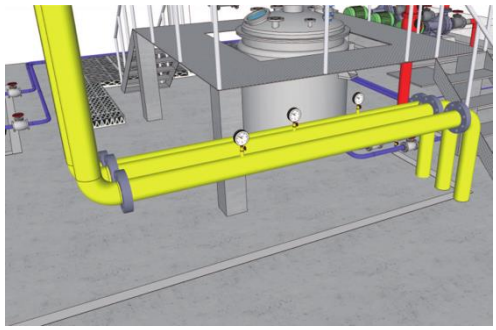
Duct

Structure specification:

Cross-section 500 mm × 300 mm

Inspection items:

Health assessment (deformation, fracture, crack, corrosion, water leakage, loose bolt, abnormal sound etc.)



Report content (judgment criteria):

Presence of abnormality (fault). Judgment criteria will be in compliance with infrastructure inspection method

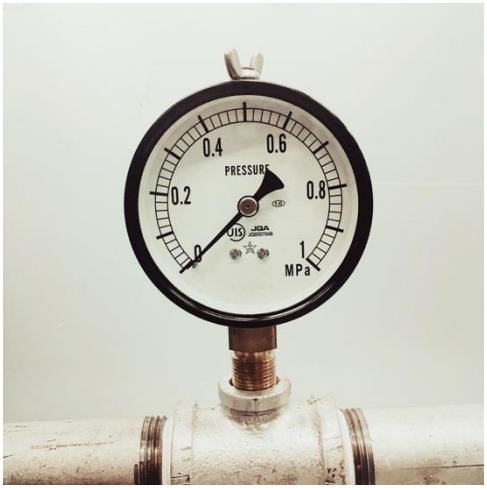
Details will be provided separately by WEB etc.

### 3,4 Outline of inspection / adjustment target

Plan to prepare standard products according to piping system

#### 3.4.1 Pressure gauge

The pressure gauge to be prepared JIS B 7505-1 "Bourdon tube pressure gauge" .




Ex. Made by MIGISHITA SEIKI MFG.co., LTD
General purpose pressure gauge S - 31 - 1 MP (A frame standing type · φ

#### 3.4.2 Valve (handle, lever)

Plan to prepare gate valves and ball valves as shown in the picture below.

Reference: Torque required for rotation
(1) Handle Approximately 0.8 Nm
Class 125 Brass Gate Valve FR 1 B (25 A) manufactured by KITZ Corporation
(2) Lever about 2.0 Nm
Type 600 Brass Ball Valve manufactured by KITZ Co., Ltd. TK 1 B (25 A)
KITZ Corp.
http://www.kitz.co.jp/english/

### 3.5 Types of road surface

Concrete, grating, checker plate, liquid (water) pool, step

Skeleton stairs
Step depth 250 mm, riser height 192.3 mm (number of steps: 13), width 1000 mm, gradient 37.34 deg.
Step depth 150 mm, riser height 227.3 mm (number of steps: 3), width 900 mm, gradient 56.6 deg.
Step depth 200 mm, riser height 227.3 mm (number of steps: 3), width 900 mm, gradient 48.7 deg.

Slope
Slope 15 deg.

### 3.6 Debris

Debris are scheduled to be prepared assuming things that the inspection robot can deal with.

## 4. Competition schedule

Setup (robot inspection) 2 days, preliminary competition 4 days, final contest 1 day
Competition time: 1 mission 30 minutes
The teams that will participate in the finals will be selected based on the result of the preliminary competition

## 5. Scoring method

The score is decided according to the points below.

5.1 Mission Point: Evaluation of Mission Achievement Level

The number of tasks cleared each (inspection investigation / temporary measures) for the checkpoint installed in each mission is taken as the mission point.

5.2 Technical points: Evaluation of Robot Technology Level

The following tasks (i) to (iii) are accrue points in order of difficulty from (1) to (3). Task (iv) adds points according to environmental resistance.

(i) The robot can reach the checkpoint
- (1) The robot can reach the checkpoint by the tele-operation of the operator
- (2) The robot can reach the checkpoint by semi-autonomous control with the assistance of the operator.
- (3) The robot can automatically identify the surrounding environment and can reach the checkpoint by autonomous control

(ii) The robot can report the status of the checkpoint (inspection check result)
- (1) The operator can visually check the status and location of the checkpoint and submit handwritten reports.
- (2) The robot can automatically identify the checkpoint status, automatically generate a report showing its contents and location on a map (2D map), and submit it as an electronic file.
- (3) The robot can automatically identify the checkpoint status, automatically generate a report showing its contents and location on a map (3D map), and submit it as an electronic file.

(iii) Appropriate temporary measures can be done
- (1) The robot can deal with temporary measures by tele-operation of the operator.
- (2) The robot can deal with temporary measures by semi-autonomous control with the assistance of the operator.
- (3) The robot can recognize the surrounding environment automatically and respond to temporary measures by autonomous control

(iv) It is compatible with environmental resistance (waterproof and dustproof (IP), explosion-proof)

Judged by the presence or absence of correspondence by presenting certificates (certification etc.) of the relevant performance

5.3 Time point: Evaluation of speed
Points are added according to the speed of each mission.

5.4 Evaluation for performance of the energy saving
Points are added depending on high battery efficiency

## 6 . Team members

Team members shall apply in advance by TDP (Team Description Paper) and shall be limited to a maximum of 10 people. Only team members can enter the paddock area (team waiting room).
The role of team members is determined as follows.

· Team leader (one person): Organize team. Only the team leader can file a complaint against the competition results.
· Robot operator (2 people): Those who operate the robot. Those qualified to enter the operator area.
· Network administrator: Person who manages the team network.
· Safety manager: Watch over the robot during robot operation to ensure the safety of the surrounding area (1 person / unit).
· Helper: Transport robot from start point or restart point.

Operators and safety managers must be different. Concurrent roles are possible for the remaining roles. Except for the team leader, the roles may be changed for each mission.

## 7 . Robot

· Robots in the competition can be in any form, such as crawler type, drone type, humanoid type, leg type, snake type and the like.
· The number of robots used for competition shall be unlimited.
  - At the start of the competition, the total bottom area of the robots shall not exceed 4 square meters.
  - The height is unlimited.
  - After the start of the competition, the bottom area may exceed 4 square meters.
· Maximum weight of the robot is 100 kg / unit.
· The robot and the operation system are limited to those described in the TDP(Team Description Paper) submitted in advance.
· The robots and the operation system are subjected to tests in advance and are limited to those that pass.
· Robots can be exchanged for each mission. However, it is not allowed to exchange during the mission.

- Use batteries that are guaranteed to be safe to use.
- Prepare for emergencies, consider team responses to robot malfunction such as fire etc.
- Comply with the laws of the competition country (Japan) such as Radio Act etc.

## 8. About the mission

Definition of words

Restart: Respond to technical problems, imposing a penalty of 5 minutes.

Abstention: In case the mission cannot be carried out.

Implementation of dangerous acts: The team will be disqualified

· When carrying out the mission, safety managers must accompany the robot to act in anticipation of unforeseen circumstances.

· For arbitrating the mission results, team can appeal to the judges through the team leader. Appeals must be lodged by the start of the next competition.

## 9. Communication network

For communication between the operator's computer and the robot, either wireless or wired communication may be used. Regarding the conditions of the communication network, it must comply with the regulations concerning communication, separately specified for the entire WRS (World Robot Summit).

## 10. Award

The ranking is determined according to the score calculated based on Chapter 5.

## 11. Other

During the competition, follow the instructions of the organizers.