CYBATHLON

ETH zürich

RACE TASK DESCRIPTION CYBATHLON 2020

V_2019-03-22

CYBATHLON 2020 – RACE TASK DESCRIPTION

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PREAMBLE

CYBATHLON is a unique competition for people with disabilities that promotes inclusion and drives the development of assistive technologies.

The present document defines the tasks and rules of each of the six disciplines constituting the competition at CYBATHLON 2020:

- Brain-Computer Interface Race (BCI)
- Functional Electrical Stimulation Bike Race (FES)
- Powered Arm Prosthesis Race (ARM)
- Powered Leg Prosthesis Race (LEG)
- Powered Exoskeleton Race (EXO)
- Powered Wheelchair Race (WHL)

The tasks were selected and designed to represent typical situations that people with physical disabilities encounter in their everyday life. While some of the tasks were left unchanged as compared to CYBATHLON 2016, others were slightly modified or even developed from scratch. Feedback from the teams and other experts has been considered and incorporated wherever possible.

- As far as indicated all dimensions are in millimetres and weights in kilograms, if not otherwise stated.
- All ramps and the bars of the rough terrain will be coated with a colour containing quartz sand (mixing ratio is 1:0.13).
- Whenever possible, standard furniture and objects available at IKEA are used in the competition tasks. If available by 2020, currently presented furniture and objects will be used in the competition. IKEA furniture and objects, as well as associated dimensions are subject to change.
- On the day of the competition, additional objects might be placed on the furniture for decoration purposes. It will be made sure that these objects do not interfere with the task as described in this document.
- The indicated width of the competition tracks for ARM, LEG, EXO and WHL may vary by ±50mm.
- The blades of the artificial grass used in the tilted path obstacle are 100% polyamide/polyethylene monofilaments. They have a length of 30mm. Density of blades is 2610g/m^2.

Any changes to the tasks will be communicated to the teams.

If you have any comments or questions regarding the present document, we are happy to receive your message at competition@cybathlon.com.

APPLICABILITY TO CYBATHLON SERIES

At the CYBATHLON Series individual races will be organised in cooperation with universities and other partners worldwide. The ground rules and discipline-specific sections of the present document are also applicable to the CYBATHLON Series events.

CYBATHLON Series Name	Location	Date	Applicable sections
CYBATHLON WHL Series	Kawasaki City, Japan	5 – 6 May 2019	1 & 7
CYBATHLON ARM Series	REHAB, the trade fair for improved quality of life Karlsruhe, Germany	16 – 18 May 2019	1 & 4
CYBATHLON LEG Series	REHAB, the trade fair for improved quality of life Karlsruhe, Germany	16 – 18 May 2019	1 & 5
CYBATHLON BCI Series	8th Graz Brain-Computer Interface Conference 2019 Graz, Austria	17 September 2019	1 & 2

Comment

The layout of the competition field (e.g. number of tracks) at the individual CYBATHLON Series events may vary from the one described in paragraph 1.4.1.

CHANGE LOG

Section	*Change*	*Version*
Title page	Applicability of rules to CYBATHLON Series added	*V_2018-02-26*
Section 1	*Team leader* replaced by *team manager*	*V_2018-02-26*
Entire document	*Names of IKEA furniture and objects added*	V_2018-12-19
Entire document	*'course' replaced by 'track'*	V_2018-12-19
Section 2.2.2	*Rule re. use of external stimulation adapted: TMS as an example of external stimulation added.*	V_2018-12-19
Section 3.3	*Rule FES-3re. comparison of lap times* ***removed.***	V_2018-12-19
Section 7.4.6	*Amendment of Ramp & Door Task applicable to WHL Series Japan added*	V_2018-12-19
Sections 4, 5, 6, 7	*Order of tasks and allocation of points*	V_2018-12-19
Section 7.4.4	*Rules re. controlled descending of stairs added.*	V_2018-12-19
Section 7.4.6	*Rules re. use of technical support adapted and clarified.*	V_2018-12-19
Sections 1, 2, 4, 5, 6, 7	*Definition of tasks and rules adapted and revised drawings inserted*	V_2018-12-19
Entire document	*Minor revisions of wording for clarification and unification.*	V_2018-12-19
Entire document	*Definitions of terms added.*	V_2018-12-19
Preamble	*Properties of artificial grass added*	V_2019-03-22
Section 1.1	*GR-7 re. active implanted medical devices removed*	V_2019-03-22
Section 4.4.4	*Lamp model replaced*	V_2019-03-22
Section 4.4.5	*Objects changed*	V_2019-03-22
Section 5.4.5	*Type of objects to be carried changed*	V_2019-03-22
Section 7	*Wording of rules re. technical support to open/close door clarified and new rule WHL-RAMP-5 inserted*	V_2019-03-22

Section 7.4.2	*Amendment for WHL Series Japan inserted*	V_2019-03-22
Section 7.4.6	*Amendment for WHL Series Japan updated with net drawing*	V_2019-03-22
Entire document	*Drawings updated*	V_2019-03-22
Handrails	*Handrails of Stairs and Ramp & Door obstacles were redesigned according to current standards and norms.*	V_2019-03-22

CONTENTS

1. General Rules

The CYBATHLON 2020 competition consists of the following six disciplines:

- Brain-Computer Interface Race (BCI)
- Functional Electrical Stimulation Bike Race (FES)
- Powered Arm Prosthesis Race (ARM)
- Powered Leg Prosthesis Race (LEG)
- Powered Exoskeleton Race (EXO)
- Powered Wheelchair Race (WHL)

Even though many of the disciplines include the term "powered", it is also allowed to use unpowered, passive systems.

A team consists of team officials that include the team manager (team contact person), pilot(s), backup pilot(s), care person(s), discipline manager(s), and support person(s).

1.1 General Rules for Teams and Pilots

The following general rules (GR) apply to all six CYBATHLON disciplines.

GR-1 Several teams participate in the competition. A team consists of at least one technology provider (at least one person from a research laboratory or a company, or a private individual) and one pilot (person with a physical disability). The technology provider is usually the developer of the device, who tunes and adapts the technology and provides technical support at the competition. In exceptional cases, when the pilot develops and brings his or her own technology, the provider and pilot can be the same person.

GR-2 Each team can participate in several disciplines. Only one pilot can participate per team per discipline.[1] Pilots need their dedicated device (i.e. pilots need to have their personal devices that must not be used by anyone else during their participation in the competition).

GR-3 Pilots must be at least 18 years of age on the first day of the competition.

GR-4 In the pilots' inclusion criteria for each discipline the minimal required level of the pilots' lesion or amputation is defined. Pilots who have more severe handicaps than those defined in the inclusion criteria may participate, although they might have a disadvantage in comparison to those pilots who more closely match the inclusion criteria. Each case is individually checked by the organising committee to ensure that the difference, i.e. disadvantage, is not too distinct and that participation is deemed safe for the pilot.

GR-5 Pilots must have sufficient cognitive and communicative abilities to understand the races and rules.

GR-6 The teams shall provide the pilots with sufficient training of the tasks prior to the competition.

Please find further information on the conditions of participation in the CYBATHLON registration forms.

[1] In case of free starting slots in a later registration phase or withdrawal of teams, more than one pilot of the same team will be allowed to start in the same discipline.

1.2 General Rules for Technology and Devices

GR-7 The technical devices and their use must be safe for the pilots, their environment and other people involved prior to, during and after the races. Safety documentation must be provided by the teams several months prior to the race in accordance with registration and submission deadlines (pre-event TecCheck, see CYBATHLON registration form and TecCheck protocols). The descriptions and documentation of the devices are reviewed by neutral matter experts (technical examiners) selected by the CYBATHLON organising committee. CYBATHLON staff members who prevent pilots from falling, help to stand up or to leave the track (spotters) further supplement the safety precautions during the race.

GR-8 One or two days before the competition, the hardware and software are checked on-site by the technical examiners. After this safety and function check (on-site TecCheck), no changes may be made to the device. Inspections of the applied technology and devices by the technical experts can occur at any time during the competition day(s). Teams who refuse the inspection will be disqualified.

GR-9 It is allowed to use commercially available devices. Competitors are permitted to modify them to optimise function. Alternatively, prototypes and research devices are also eligible.

GR-10 All components (e.g. batteries, control units, tools, spare parts, etc.) that are used during a race run must be carried by the pilots from the start to the end of the race run. All of these components must be listed in the description of the device handed in for the TecCheck. During the race run, only the pilots are allowed to maintain or replace components of the device.

GR-11 Between race runs, any team official is allowed to maintain or replace components of the device. If components are replaced, only identical replacement parts may be used.

GR-12 One support person, who is a registered team official, is allowed to travel alongside the pilot on the competition field in a dedicated area. A support person is only allowed to interact with the pilot in case of a technical defect or emergency. In case of any communication between the pilot and the support person (e.g. an external intervention or coaching), the race run is finished for that pilot. Finished means that the race run is terminated for that pilot. The pilot's current score is then taken as her/his score for that race run.

GR-13 Communication (wired or wireless) between the device and any third-party stationary site is not allowed, i.e. remote connection to control the device by any person other than the pilot is forbidden, except for emergency stop and data monitoring.

GR-14 Combustion engines are not allowed.

GR-15 Radio communication between the pilot and a team officials or any other person is not allowed during any race run.

1.2.1.1 Comment

- Spotters are trained to only intervene in case of an imminent risk of injury to the pilot.
- Please find further information on the required documentation of devices in the CYBATHLON registration form.

1.3 General Regulations on the Competition Mode

In each discipline, teams compete for three medals: gold, silver and bronze. All winning teams (first, second, third place) are given two awards, one for to the pilot and one for to the technology provider. The competition in each discipline is split into preceding qualification

races followed by finals. It is not allowed to exchange pilots or modify technical equipment (device or components thereof) between race runs, i.e. only the pilot who enters the qualification race is allowed to start in subsequent final races using the same technical equipment.

1.3.1 QUALIFICATION RACES

Each pilot first competes in a qualification race. Based on the ranking of all pilots of a given discipline, it will be determined, which pilots will compete in the final races. A maximum of 16 pilots will compete in the qualification races in each discipline. Four or fewer pilots compete in each of the qualification race runs.

1.3.2 FINALS

The pilots ranked 1st to 8th in the qualification races of a given discipline will advance to the final races.

The pilots ranked 1st to 4th (pilots ranked 1st and 2nd in the case of the FES Bike Race, where only two pilots compete in each race run) in the qualification races advance to the A-final. The pilots ranked 5th to 8th in the qualification races (ranked 3rd and 4th in case of the FES Bike Races) advance to the B-Final. In the case of the FES Bike Race, the pilots ranked 5th and 6th in the qualification races advance to the C-Final and the pilots ranked 7th and 8th in the qualification races advance to the D-Final.

The pilots and teams who rank 1st to 3rd of the A-Final are awarded the medals. The four pilots in a B-Final compete for the ranks 5 to 8. In case of the FES Bike Race, the two pilots in the A-final compete for the gold and the silver medal. The two pilots in the B-final compete for the bronze medal.

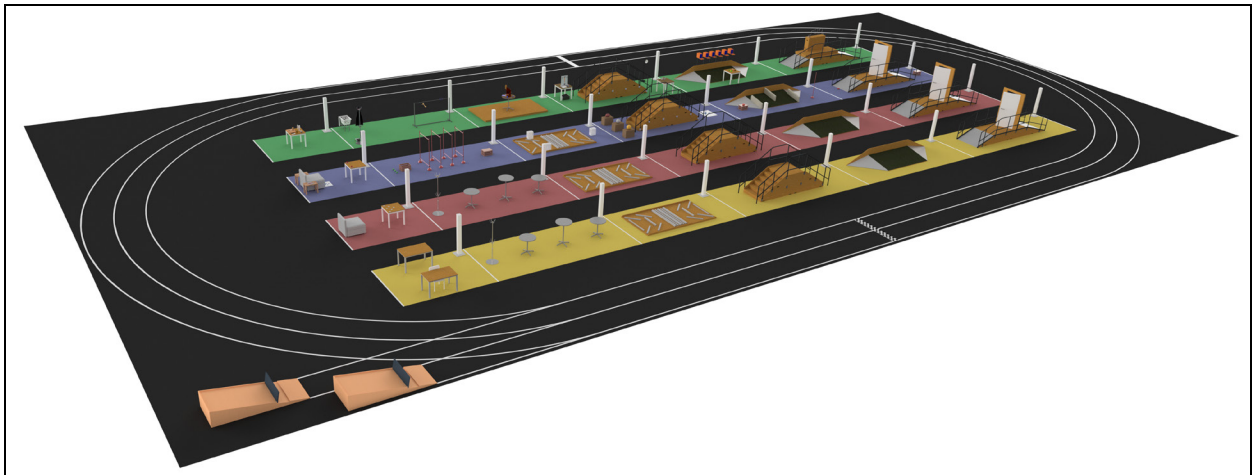
<table>
<tr><th>Disc.</th><th>Max.# Pilots in each race run</th><th>Race end</th><th>Time limit [min]</th><th>Scoring key</th><th>Qualification ranking
Relative to all pilots of the discipline; Allocation to:</th><th>Final ranking
Relative to pilots of the same final</th></tr>
<tr><td>ARM</td><td rowspan="4">4</td><td rowspan="4">1. Finish line reached

2 Time limit reached</td><td>8</td><td rowspan="4">1. Number of points
2. Total time taken for completed tasks (uncompleted or failed tasks are not included)</td><td rowspan="4">A-Final: 1st - 4th
B-Final: 5th - 8th</td><td rowspan="4">A-Final: 1st - 4th
B-Final: 5th - 8th</td></tr>
<tr><td>LEG</td><td>4</td></tr>
<tr><td>EXO</td><td>10</td></tr>
<tr><td>WHL</td><td>8</td></tr>
<tr><td>BCI</td><td rowspan="2">2</td><td>4</td><td rowspan="2">1. Distance covered
2. Total time taken for the distance covered</td><td rowspan="2">A-Final: 1st & 2nd
B-Final: 3rd & 4th
C-Final: …</td><td rowspan="2">A-Final: 1st & 2nd
B-Final: 3rd & 4th
C-Final: …</td></tr>
<tr><td>FES</td><td>8</td></tr>
</table>

1.4 Scoring System, Ranking, and General Race Rules

1.4.1 Overview

There are four parallel race tracks built up in the stadium for BCI, ARM, LEG, EXO and WHL and two for FES.



Overview of the competition field. Two FES tracks run around the four parallel tracks for ARM, LEG, EXO, WHL which are located at the centre. One track of each discipline is shown above for visualization purposes.

1.4.2 BCI and FES Bike Race

The general goal of the races is to, firstly, cover the race distance, and secondly, to cover it as fast as possible within a given race time limit. A countdown is displayed in the arena that shows the remaining time.

The race is finished for the pilot if the pilot passes the finish line or if the time limit is reached. To rank the pilots, in the first instance, the distance covered since the start of the race is determinative. In the second instance, i.e. if more than one pilot covers the same distance, the time taken to cover the distance is determinative. The tasks, the points, and the time limit for the race are the same for the qualification races and the finals.

Example 1

All pilots in the FES Bike Race final reached the finish line within the time limit, i.e. all pilots covered the same distance.

➔ The first pilot to reach the finish line wins the race, i.e. the fastest pilot/time wins the race.

Example 2

No pilot reached the finish line of the FES Bike Race within the time limit.

➔ The pilot who covered the longest distance within the time limit wins the race.

GR-BCI/FES-1 A race run is failed if it is terminated by the pilot, by the referee due to an infringement, or by a physical intervention by a third person, e.g. a CYBATHLON *race assistant* (CYBATHLON staff member who supports the race management) or a support person.

1.4.3 ARM, LEG, EXO AND WHL RACE

The general goal of the races is to, firstly, solve as many tasks as possible on the race track, and, secondly, to solve them as fast as possible within a given race time limit. A countdown is displayed in the arena that shows the remaining time.

The race is finished for a pilot if the pilot has solved (or failed) each of the six tasks, if the time limit is reached, or if a violation of another race rule mandates termination of the race run. For each task, the time to complete the task is measured and points can be scored if the task is completed successfully. More difficult and/or tasks that are more relevant in daily life offer higher scores. The scores for the six tasks are:

101, 102, 104, 108, 115, 130 points

The hundreds represent a task, the tens and units the difficulty/relevance of the task.

To rank the pilots, in the first instance the total number of scored points is determinative. In the second instance, time needed to complete the solved task(s) is determinative. If more than one pilot has solved the same task(s) and, thus, obtained the same total number of points, the time needed to complete the solved task(s) (sum of the time taken to complete all solved tasks) is determinative. The tasks, the points, and the time limit for the race are the same for the qualification races and the finals.

Example 1

One pilot in a Wheelchair Race solved five tasks (e.g. 545 points); another pilot solved four tasks (e.g. 457 points).

➔ The pilots are ranked by the sum of the scored points. The pilot who solved five tasks is ranked higher than the pilot who solved four tasks.

Example 2

Two pilots in an Arm Prosthesis Race both solved two tasks, but not the same two tasks.

➔ The pilots are ranked by the sum of the scored points. I.e. the pilot who scored 231 points is ranked higher than the pilot who has scored 223 points.

Example 3

Two pilots of a Leg Prosthesis Race both solved the same three tasks; consequently, they also scored the same number of points (e.g. both 307 points).

➔ The pilot who solved the three tasks in the least time (sum of the time of the three solved tasks) is ranked higher.

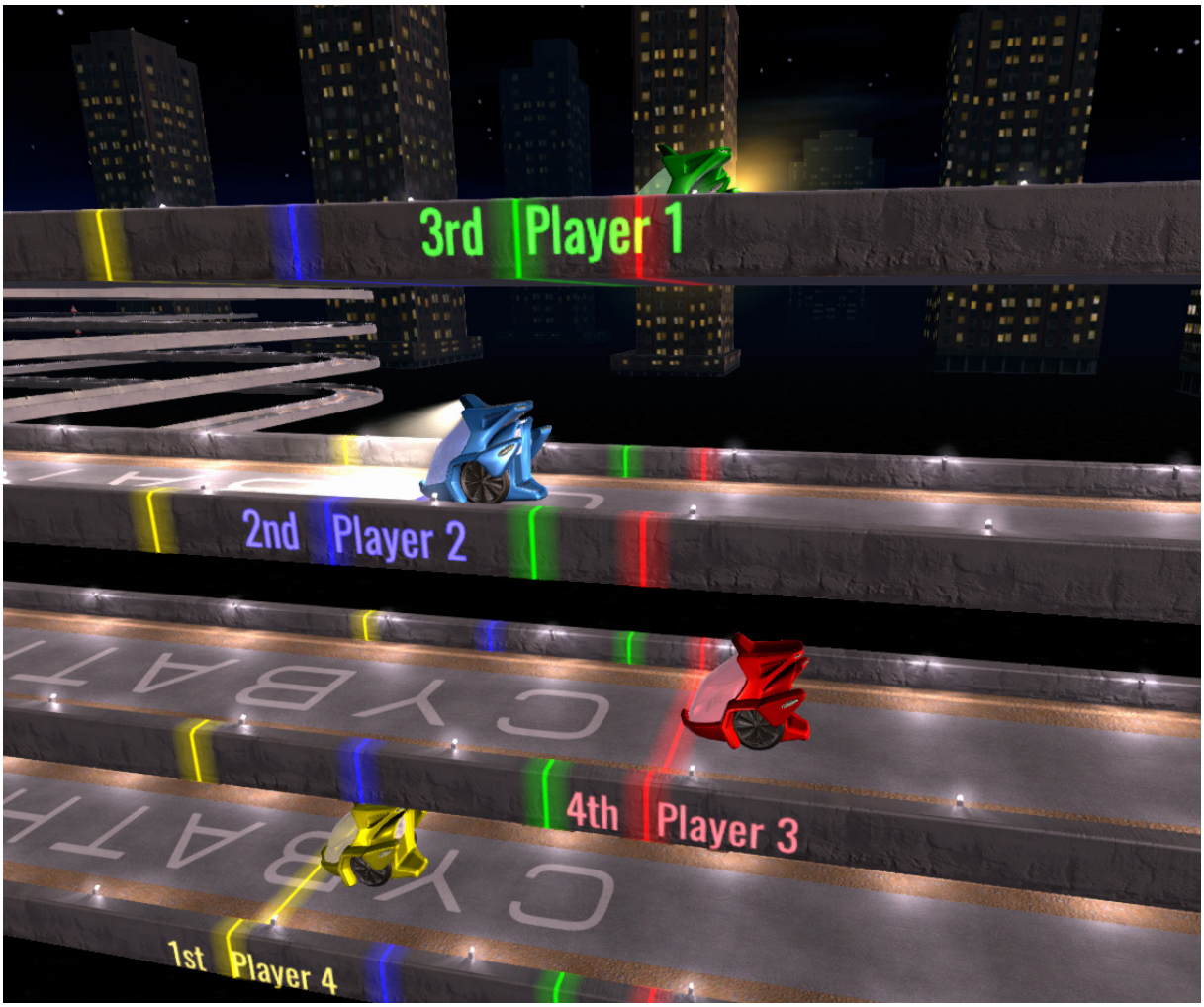
GR-ARM/LEG/EXO/WHL-1 A task ends when the start line of the next task (or finish line of the race) is passed. If not otherwise stated, each obstacle (e.g. ramp, staircase) in a task has to be crossed once in direction of the race track.

GR-ARM/LEG/EXO/WHL-2	A task is failed if it is terminated by the pilot, by the referee due to an infringement, or by a physical intervention from a third person, i.e. a *race assistant* or a *spotter*.
GR-ARM/LEG/EXO/WHL-3	In the case of task termination, the pilots must proceed to the start line of the next task (or finish line of the race). If required, spotters may be asked to intervene and to help the pilot to reach the start line of the next task.
GR-ARM/LEG/EXO/WHL-4	It is permitted to skip tasks and continue with the next task. In this case, the task element must be passed on the right-hand side (in race direction).
GR-ARM/LEG/EXO/WHL-5	The tasks need to be solved in the order of appearance on the race track. It is not allowed to reattempt a task after having passed the finish line of the task, after skipping the task or after the task is failed.
GR-ARM/LEG/EXO/WHL-6	If a side line (marking the boarder of the race track) on either of the sides of the track is crossed, i.e. if any part of the device (e.g. including crutches) or pilot touches the ground beyond the side line, the task is failed. Furthermore, the task is failed if any object of the competition is moved beyond the side lines, start or finish line of the task by an action of the pilot. The width of a race track is approx. 3 m.
GR-ARM/LEG/EXO/WHL-7	An interim time is taken every time a task is completed. If a task is completed correctly, a green lamp located next to the task element on the competition field lights up. The lamp lights up red if a task is failed, i.e. because the task is not overcome, a rule is infringed or the race time limit is reached. The lamp is off if the task is still to be solved within the current race.
GR-ARM/LEG/EXO/WHL-8	A jump start leads to disqualification of the pilot.
GR-ARM/LEG/EXO/WHL-9	Obstacles and objects that are not asked to be moved by the rules per se, must not be displaced. Otherwise, the task is failed.

1.5 Case of Ambiguous Ranking Or Decisions

If after the qualification races, it cannot be determined which pilot is allocated to a certain race of a final (very unlikely), the allocation will be determined by lot. If after the finals, it cannot be determined which pilot is ranked better, the results of the qualification are determinative.
In case of any inconclusive occurrence or situation beyond the referee's decision, rules or regulations, the competition director will be the supreme authority.

2. Brain-Computer Interface Race



Screenshot of the Brain-Computer Interface Race game showing the avatars of the four pilots.

2.1 Introduction

Pilots with quadriplegia use a Brain-Computer Interface (BCI) to control a vehicle (avatar) in a computer game. Commands to control the computer game are triggered by the BCI after the appropriate brain signals were detected. The reliability and precision of BCIs are challenged in the competition in order to stimulate the development of BCIs with various applications suitable for daily life. For example, for people with limited ability to move (e.g. quadriplegia), BCIs could be used to control different types of devices, e.g. a computer, a robotic arm or a wheelchair.

The computer game is a multiplayer racing game developed for the Brain-Computer Interface (BCI) Race. Up to four pilots in each race are equipped with BCIs that enable them to control the behaviour of their avatar in the game.

Each pilot's avatar drives on an individual road (track). During the race, pilots sit in front of their individual screen and see their avatar as well as the positions of the competing avatars. The first pilot to cross the finish line wins the race.

2.2 Inclusion Criteria

2.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Pilots with a complete or a severely affected incomplete tetraparesis, i.e. corresponding to spinal cord injury with impairment at and below the neck (lesion typically C5 and above), AIS A to C (http://www.sci-info-pages.com/levels.html), due to any kind of central nervous system disease or injury or any systemic neural or muscular disease.
- Pilots are not vulnerable to cyber-sickness, epilepsy or similar problems.

2.2.2 Technology

In addition to the general rules described in section 1.2, the following criteria apply to the BCI hardware:

- While the primary envisioned BCI type is electroencephalography (EEG), other brain activity measurements such as functional near infrared spectroscopy (fNIRS) are also permitted as long as they primarily measure brain activity.
- Electrodes can be wired or wireless, and the BCI amplifier can be powered by any means as long as the technology is safe.
- Skin-piercing electrodes or any other invasive technologies are not permitted. Other than that, the choice of electrode type, cap and gel (if any) are at the discretion of the participating team.
- Pilots have to watch the race screen during the race. It is not allowed to provide any additional (artificial) stimulation (e.g. transcranial magnetic stimulation) or feedback in any modality to the pilot via the BCI system. Thus, visually evoked potentials (SSVEPs, P300, etc.) may not be used as the source of the input signal for the race unless they are elicited by the race animation provided by the organisers and not by an additional display. In addition, it is not allowed to provide feedback on the current state of the analysis, e.g. the current state of the signal (how close the pilot is to sending a command).
- During the mandatory on-site TecCheck prior to the competition, judges may attach EOG electrodes to check for the presence of eye artefacts (if not used anyway for artefact removal).

- During each race, each pilot is recorded by video. In case of any doubt, the video material is used for review by the CYBATHLON competition management. In addition, the teams must record all signals that are used to process and control the game. After each race, the teams must be prepared to provide the software together with the raw signals (e.g. by using an external drive) for spot checks by the CYBATHLON competition management. In case of infringement, the team can be disqualified after the race.

The following criteria apply for the BCI software:

- Ocular control, control by facial muscles or the use of any other muscular activity is not permitted.
- Artefact removal is crucial. Teams have to confirm in writing prior to the event that muscle and eye movement artefacts and other artefacts are removed or otherwise do not affect the command process, or that the classifier is blocked by artefact detection and not misused as commands to control the game. For example, the pilot should not be able to send commands by blinking with the eyes repeatedly, but should also not be able to prevent commands from being sent by blinking repeatedly.
- Before the event, teams are required to send a description of the artefact removal procedure and examples of the signals to be checked by external judges who are experts on signal processing. All submitted documents are treated confidentially. The documentation will be requested from registered teams by the CYBATHLON organising committee well in advance to allow ample time for corrections, if necessary.
- Once artefacts are removed, any signal feature and classification procedure can be used in the BCI as long as it primarily reflects volitional brain activity, not automatic subconscious processes (e.g. alpha blockade). Teams have to send the description of the inference process to be checked by external judges before the race.
- Using brain signals associated with attempted movements of partially paralysed and non-paralysed limbs, which result in some residual actual movement, are not allowed.
- Communication regulations and communication protocols for the teams' computers to the competition system will be communicated at a later stage. It is the responsibility of the teams to implement and follow the instructions provided by CYBATHLON organising committee.

2.3 Specific Rules

BCI-1 It is not allowed to turn the BCI system off during the race. The BCI must be on during the race.

BCI-2 Pilots are not allowed to intentionally use eye or muscle activity to control their BCI. Referees will be somewhat permissive regarding this rule as it is understood that perfect artefact removal is not possible. Extensive eye or muscle activity will lead to a warning. If a pilot is issued three warnings within the same race run, the race is finished for that pilot.

BCI-3 Pilots who are not able to connect with or send a command to the game in the preparation phase right before the start of the race will not be allowed to start in the race and will be ranked last, i.e. the race is failed for these pilots.

BCI-4 In the race, pilots always see their corresponding avatar. It is permitted to remove the background, i.e. change to a black background.

2.4 Task Description

Pilots have to send appropriate commands using their BCIs within the correct time frame while virtually driving on a race track that is divided into dedicated zones (tasks), indicated by road

signs or lines on the ground. After the race is started, each avatar moves forward by itself, and thus, reaches the finish line of the race even without receiving any input signals from the pilot or if constantly receiving wrong input signals. Pilots can send up to three different commands to control their avatar. The higher the number of independently controlled commands increases the chances of winning the race.

Sending the appropriate command at the right time is required to maintain the avatar's speed, while wrong input or no input (if input is required) slows down the avatar. Pilots can trigger their avatar to turn left (LEFT) or right (RIGHT). There will also be sudden changes in the environment, i.e. streetlights turning off, upon which the avatar is slowed down until the pilot reacts with the appropriate BCI input (HEADLIGHT). In certain parts of the game, no signals must be sent (NOINPUT) and avatars decelerate if they send any command by accident.

LEFT, RIGHT and NOINPUT commands can be anticipated by the pilot, whereas the HEADLIGHT signal must be generated in response to a changing environment.

Actions	*Description*
LEFT/RIGHT	As soon as the avatar is in the LEFT/RIGHT task ahead of a turn (i.e. between the two white lines ahead of the turn), the LEFT/RIGHT command should be sent to indicate turning left or right. This will maintain the avatar's speed and will turn it left or right. The avatar will remain in the LEFT/RIGHT state until it has finished the turn or until it receives another command. Thus, a correct action may be aborted by sending an incorrect command or an incorrect action may be corrected by subsequently sending the correct command. The goal is to send the correct command as early as possible after having reached the zone. The earlier it is received, the bigger the advantage for the pilot's avatar.
HEADLIGHT	While the avatar is driving through a HEADLIGHT zone, the streetlights will flicker and then turn off at a random time. Since driving in the dark without headlights is dangerous, the avatar will slow down. In order to regain the avatar's initial speed, the headlights must be turned on by sending the HEADLIGHT command. The earlier the HEADLIGHT command is received once the street lights have turned off, the bigger is the advantage for the pilot's avatar. If pilots fail to send the HEADLIGHT command, or trigger the LEFT or RIGHT command by accident, their avatar will remain at the slower velocity up until the next zone is reached.
NOINPUT	In the NOINPUT zone, no command should be sent to benefit from the maximum velocity. Any command registered during the NOINPUT zone slows down the avatar for a certain duration or until the next zone is reached.
Incorrect commands	Triggering incorrect actions slow down the avatar. Triggering actions where none are required is considered incorrect.
Transition to the subsequent NOINPUT task	Every time the avatar transitions to a subsequent NOINPUT task, all commands/actions are cleared. The avatar will travel at the base velocity of the NOINPUT task until a new command is received.

The order of tasks appearing along the race track is not known to the pilots prior to the race and is different for every race. The total number of zones remains constant. The number of each type of zone (LEFT/RIGHT/HEADLIGHT) in each race will be defined and communicated at a later date.

The BCI game and a game manual describing the details of the game will be available to registered teams once the programming of the game is finalized. It can be used for testing and practicing at the labs. Registered teams can get a copy of the game as soon as it is ready. Please contact bci@cybathlon.com.

2.5 Competition Mode and Scoring System

See section *1.3* and *1.4.*

Time limit:	4 min
Race distance (virtual):	500m

3. Functional Electrical Stimulation Bike Race

Overview of Functional Electrical Stimulation Bike Race track. Race direction is counter-clockwise.

3.1 Introduction

Pilots with complete spinal cord injury (SCI) are equipped with Functional Electrical Stimulation (FES) devices, enabling them to perform a pedalling movement on a recumbent bicycle.

Regular FES cycling exercise after SCI has been shown to lead to physiological adaptations, such as improvements in bone density, cardiovascular as well as respiratory fitness, and increase of muscle mass. Besides the application of FES cycling in rehabilitation, it can be of high recreational value to the people with SCI.

In order to successfully participate in the race, the pilots build up their fitness by specific FES training regimens prior to the event. During the race, besides absolute muscular strength and endurance, the temporal activation of muscles also plays a crucial role in minimising muscle fatigue effects. Any stimulation pattern can be applied to any leg muscle, as long as the stimulation technology and pattern are safe. In the race, two pilots start at the same time on a circular race track. They ride eight laps on a circular race track which results in a total race distance of about 1200 m.

3.2 Inclusion Criteria

3.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Spinal cord injured pilots with paraplegia (AIS A or B, with a complete loss of motor function in the lower limbs (http://www.sci-info-pages.com/levels.html) are included.
- Pilots with lesions affecting the control of trunk, arm and/or neck must be checked individually, as pilots must have sufficient voluntary control to steer the bike and stabilise the upper body while riding down the start ramp and navigating through turns.

3.2.2 Technology

In addition to the general rules described in section 1.2, the following criteria apply for the FES bike technology:

- The cycling device can be commercially available or custom-made. The cycling device structure and function are allowed to be optimised for better mechanical efficiency.
- Only passive cycling devices without actuation are allowed. The only actuation is provided through the FES-stimulated legs of the pilot.
- Any number and any size of wheels are allowed
- The maximum width of the cycling device is limited to 900 mm to enable proper use on the ramps and in the lanes of the race track. The cycling device must fit on the start ramp behind the start gate (total length 2000 mm).
- Cycling devices must be able to turn with a radius of approx. 13 m.
- The FES stimulator can be commercially available or custom-made. In any case, the stimulator has to fulfil the standard regulations for electrical safety, including the latest IEC standards 60601-1 and 60601-2-10 (or similar regulations applied in the country of development), which describe particular requirements for the basic safety and essential performance of transcutaneous nerve and muscle stimulators.
- Surface and implanted stimulation technologies are allowed. The implants must be medically stable for at least six months and free of complications (e.g. infections) prior to the competition.

- FES stimulation intensity may be adjusted by the pilots during the race so that they can apply their own strategy to minimise effects of muscle fatigue.
- Any control strategy or stimulation pattern is allowed to stimulate muscles of the lower extremities such as quadriceps, hamstrings, gluteal and calf muscle groups. It is not mandatory to stimulate all of these muscles.
- Any number of stimulation channels is allowed.
- The FES stimulators may apply closed-loop control strategies using sensors applied to the pilots or the bike. It is also allowed to manually trigger the stimulator.

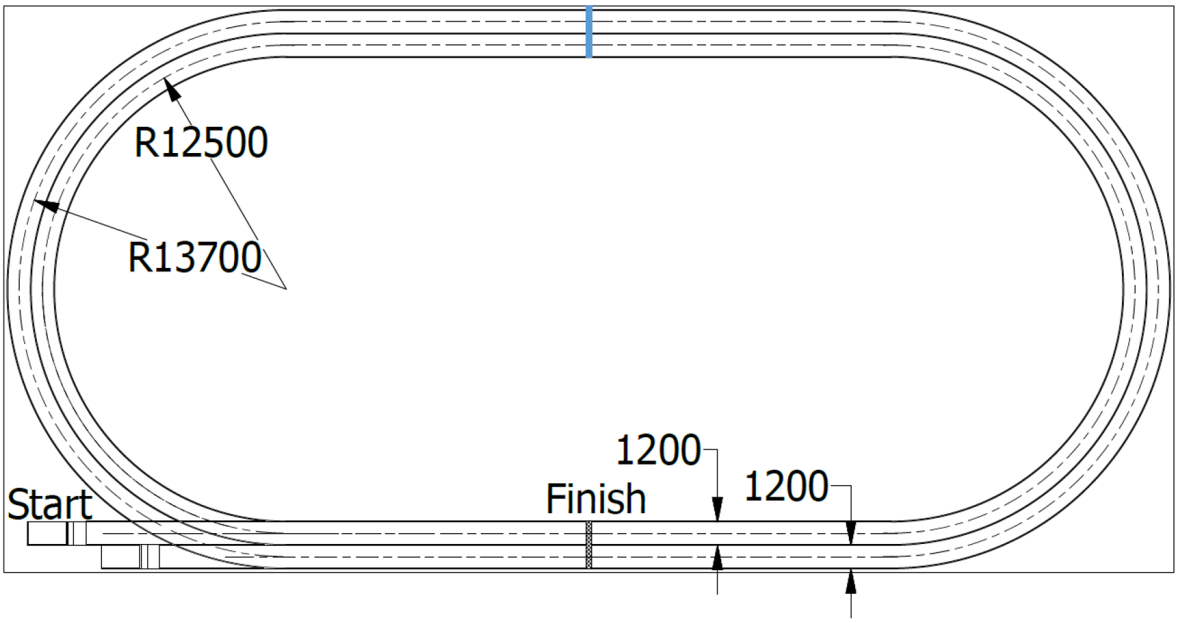
3.3 Specific Rules

FES-1	Wearing a helmet is mandatory. The teams are required to bring their own helmet.
FES-2	Two pilots start simultaneously, one on the inner and one on the outer lane. The pilot starting on the outer lane is allowed to move to the inner lane after having passed the blue line (see illustration below). Staggered starting positions compensate for the additional distance the pilot starting on the outer lane has to cover in the first turn.
FES-3	If a faster pilot is able to lap his/her competitor, she or he is only allowed to overtake the slower pilot in the outer lane. After overtaking, at least 2 m distance between the two bikes must be obtained before the leading pilot is permitted to move from the outer lane back to the inner lane. In case of disregard of this rule, a warning is issued to the overtaking pilot.
FES-4	If a pilot gets stuck in the race (e.g. due to reduced muscle force or malfunction of the stimulator or bike), the race is finished for that pilot.
FES-5	If a pilot crosses the inner line of the inner lane with any wheel, a warning is issued to this pilot. If a pilot crosses the inner or outer lane with all wheels (e.g. to take a shortcut) the race is finished for that pilot.
FES-6	Hands or arms are allowed to be used to push on the legs to overcome pedalling dead points, but not to support on-going propulsion. Extensive use of hand pushes or any other misuse of hand pushes lead to a warning.
FES-7	The starting lanes (i.e. inner or outer lane) for the qualification races are allotted by the competition management. Pilots ranked higher after the qualification races have priority to start in the inner lane in the finals.
FES-8	In case the pilots collide during the race, the race will be finished for the causer of the collision. The other pilot is allowed to go back on the race track (if necessary by the help of race assistants) and continue the race.
FES-9	If a pilot is issued three warnings within the same race run, the race is finished for that pilot.

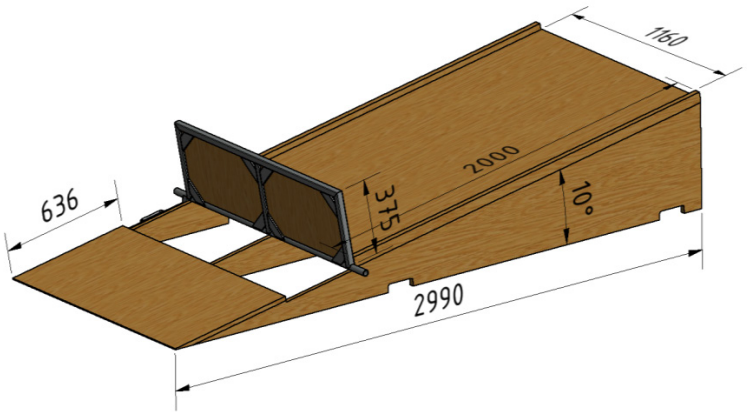
3.4 Task Description

The start ramps allow the pilots to accelerate at the beginning of the race. A short gate is used to prevent jump starts. While waiting for the start, no part of the bike is allowed to touch the gate and no part is allowed to be beyond the gate. The pilots are asked to use their brakes until the gate drops. The race begins (i.e. the clock starts) once the start gate drops.

The exact surface type of the circular race track will be communicated at a later date. It will be of low compliance (i.e. hard surface) to minimise energy dissipation due to rolling.



Top: Illustration of track set up. Pilots ride on the race track counter-clockwise. Eight laps on the race track correspond to 1200 m. At the chequered line, split times of full laps are measured. This line also serves as the finish line. Split times of half laps are taken at the blue line. After having passed the blue line for the first time after the start of the race, pilots starting on the outer lane are allowed to move to the inner lane. The dimensions of the race track are subject to change.



Left: Start ramp with start gate. To initiate the start of the race, the start gate drops and allows the pilots to accelerate.

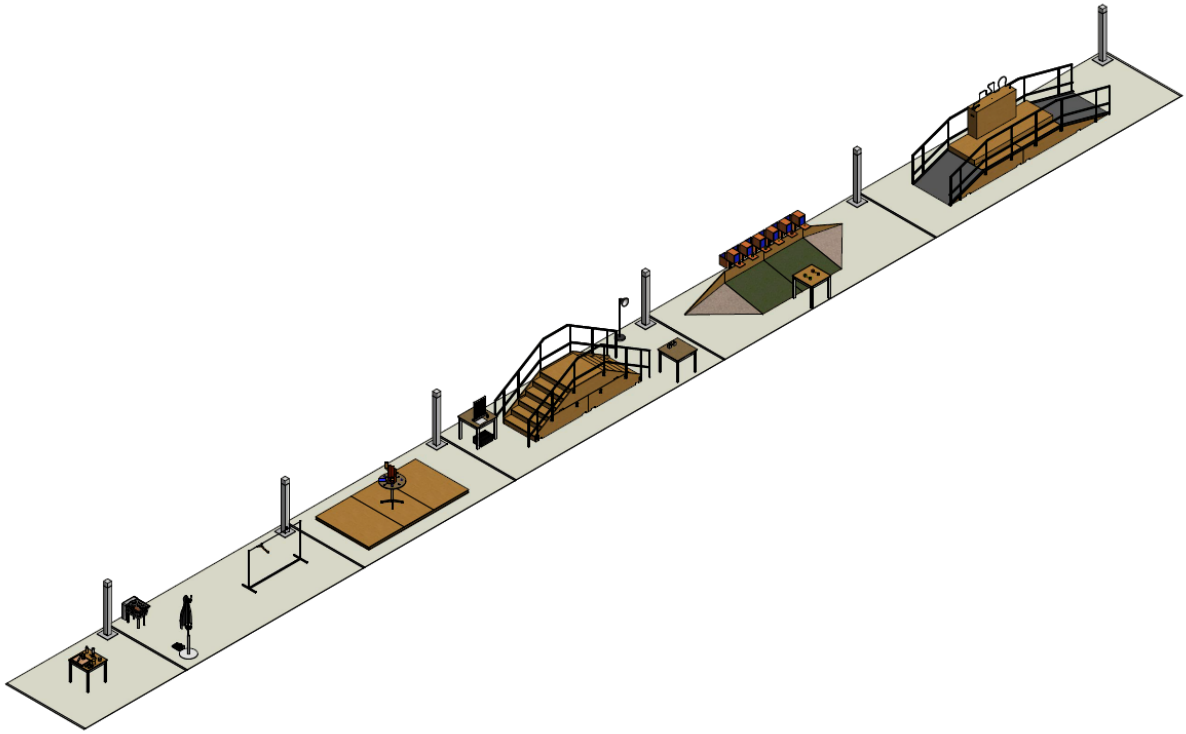
3.5 Competition Mode and Scoring System

See also sections *1.3* and *1.4*.

Time limit: 8 min
Race distance: 1200 m (8 laps)

Split times are taken every half lap. If pilots have completed the same number of laps within the time limit, due to withdrawal by the pilot, or due to an enforced finish of the race by the referee in case of infringement or three warnings, the last split time is considered to rank these pilots. If the pilots completed the same number of half laps within the same time, the pilot with less warnings scores better.

4. Powered Arm Prosthesis Race



Overview of Powered Arm Prosthesis Race track. Race direction is bottom left to top right.

4.1 Introduction

Pilots with transradial or more proximal arm amputations or dysmelia are equipped with exoprosthetic devices (arm prostheses). The pilots are challenged by a wide range of tasks related to daily life activities. In some tasks, the pilots are allowed to use both hands and arms, as well as any other part of the body to manipulate objects. In other tasks, pilots are faced with situations that explicitly challenge the performance of their prosthesis, i.e. the synergy between the pilot and the technology. In these tasks, the pilots are only allowed to manipulate certain objects or parts of the object with the prosthetic hand. These objects/parts are always coloured blue. In a third type of task, pilots are challenged to identify objects without being able to see them, i.e. they have to rely on sensory information provided by the arm prosthesis. Pilots are asked to solve as many tasks as possible in a given time.

4.2 Inclusion Criteria

4.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Transradial or more proximal amputation or dysmelia of at least one arm.

4.2.2 Technology

In addition to the general rules described in section 1.2, the following criteria apply for the powered arm prosthesis technology:

- Passive and active prostheses are allowed.
- The prosthetic device is allowed to have any number of actively driven (powered) joints (e.g. for hand opening/closing or wrist pronation/supination). The prosthetic device can have several passive or mechanically coupled joints (e.g. at the fingers). Any kind of body powered (e.g. cable driven) system is also allowed.
- Surface or implanted electrode systems can be used to access sensory or motor nerves.
- Osseointegration is allowed if pilots are in a clinically stable condition and any health risks (e.g. infections) can be excluded.
- There is no weight limitation for the prosthesis.

4.3 Specific Rules

ARM-1 Pilots are not allowed to use trailers, backpacks, bags, pockets, ropes or similar items or to use the clothes to carry objects on the race track (e.g. tools, plates, and bags of the tasks), but it is allowed to use such aids to carry components of the device (e.g. batteries, control units, tools, replacement equipment, etc.).

ARM-2 Any object on the race track that has blue parts is only allowed to be manipulated or touched with the prosthesis. Blue objects are only allowed to be manipulated or touched at the blue parts with the prosthesis, i.e. with the prosthetic hand (not including wrist, lower or upper arm). If a pilot uses two prostheses, a blue object is only allowed to be manipulated or touched with one prosthesis at a time.

ARM-3 While manipulating or holding a blue object, it is not allowed to physically support or guide the movement of the prosthesis with the other (non-prosthetic) arm or hand (or any other part of the body).

ARM-4 While manipulating or holding a blue object, it is not allowed to physically change prosthetic hand or finger configurations with the other hand. However, it

is allowed to change a mode of the prosthesis with the non-prosthetic hand, e.g. by pushing a button on the prosthesis.

ARM-5 Objects falling on the floor are allowed to be picked up. If an object breaks into pieces, one of the pieces must be used to continue the task.

ARM-6 It is allowed to grasp objects of the race track that are not blue with the prosthetic hand to manipulate blue objects (e.g. to use it as a tool), but not with the non-prosthetic hand.

ARM-7 It is allowed to use the handrails.

4.4 Task Description

Each task is described in the following sections. If not otherwise mentioned, the direction of the race is (bottom) left to (top) right in all of the following figures.

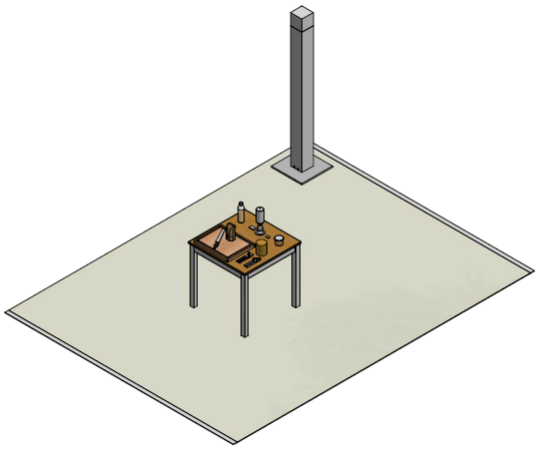
4.4.1 Breakfast

4.4.1.1 Introduction

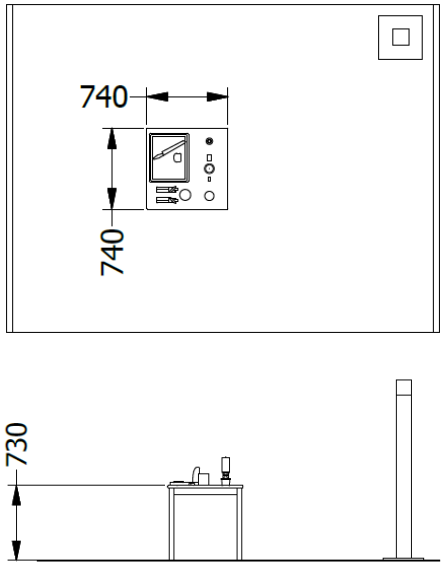
The ability to use kitchen utensils (e.g. cutlery, can opener etc.) is critical for self-sustained living and involves countless tasks which are typically performed by a dexterous bimanual interaction. Also some objects in the kitchen are very delicate to handle and require a very precise control of grip force.

In this task, a breakfast table must be prepared. The task includes cutting bread, unwrapping a sugar cube and opening a bottle, a jam jar and a can. Furthermore, a candle must be lit.

4.4.1.2 Elements



Top: Illustration of task set up. Breakfast must be prepared at the table.
Bottom: Dimensions of task set up.



# Object	*Photo*	*Colour Material*	*Weight [kg]*	*Size [mm]*	*Brand/Link Model*
1 Bread (half loaf)		natural bread	~0.300	l: ~150	- -
1 Breadboard		natural wood/bamboo	3.400	l: 450 w: 360 h: 30	IKEA APTITLIG
1 Breadknife		grey-black steel-synthetic		blade: 230	IKEA VARDAGEN
1 Package with a pair of sugar cubes		white sugar-paper	0.008	l: 35 w: 20 h: 10	-
1 Jam jar with lid		glass-white glass-aluminium fastening moment: ~4.0 Nm	0.154	Ø: 85 h: 68 230 cl	agrimarkt.info -
1 Plastic bottle with lid		transparent plastic fastening moment: ~1.2 Nm	0.030	Ø: 60 h: 220 330cl cap Ø: 30	bottleshop.ch -
1 Can		golden aluminium	0.072	Ø: 100 h: 120	- -
2 Can openers		brown-metal metal-synthetic	0.157	l: 190 w: 45 h: 50	WEST “Sieger”, one for left (black) and one for right (white) hand use
1 candle holder		white wood	0.270	$Ø_{top}$: 70 h: 130	IKEA Ersätta
1 Candle		white wax	0.370	h: 140 Ø: 70	IKEA Sinnlig

# Object	Photo	Colour Material	Weight [kg]	Size [mm]	Brand/Link Model
1 box of matchsticks		cardboard	0.005	l: 58 w: 31 h: 12	- -
Objects that must be manipulated in this task. The depicted objects are not proportional in size.					

4.4.1.3 Task Rules

ARM-BREAK-1 One slice of bread must be cut with the knife so that it is separated from the bread by falling off the loaf. Half a loaf is provided. A slice of approximately 20 mm of width needs to be cut on the cut side of the bread.

ARM-BREAK-2 The paper of the sugar cube has to be separated completely from the sugar.

ARM-BREAK-3 The lid of the jam jar has to be separated completely from the glass. If the glass breaks into pieces, the task is failed.

ARM-BREAK-4 The lid of the plastic bottle has to be separated completely from the bottle.

ARM-BREAK-5 The can top has to be completely removed from the can by using the can opener for left or for right hand use.

ARM-BREAK-6 The candle must be lit using a matchstick. Three matchsticks are provided.

ARM-BREAK-7 All objects must be placed on the table, i.e. if an object has fallen off the table before passing the start line of the next task, the task is failed.

ARM-BREAK-8 The order in which these sub-tasks are completed is not defined.

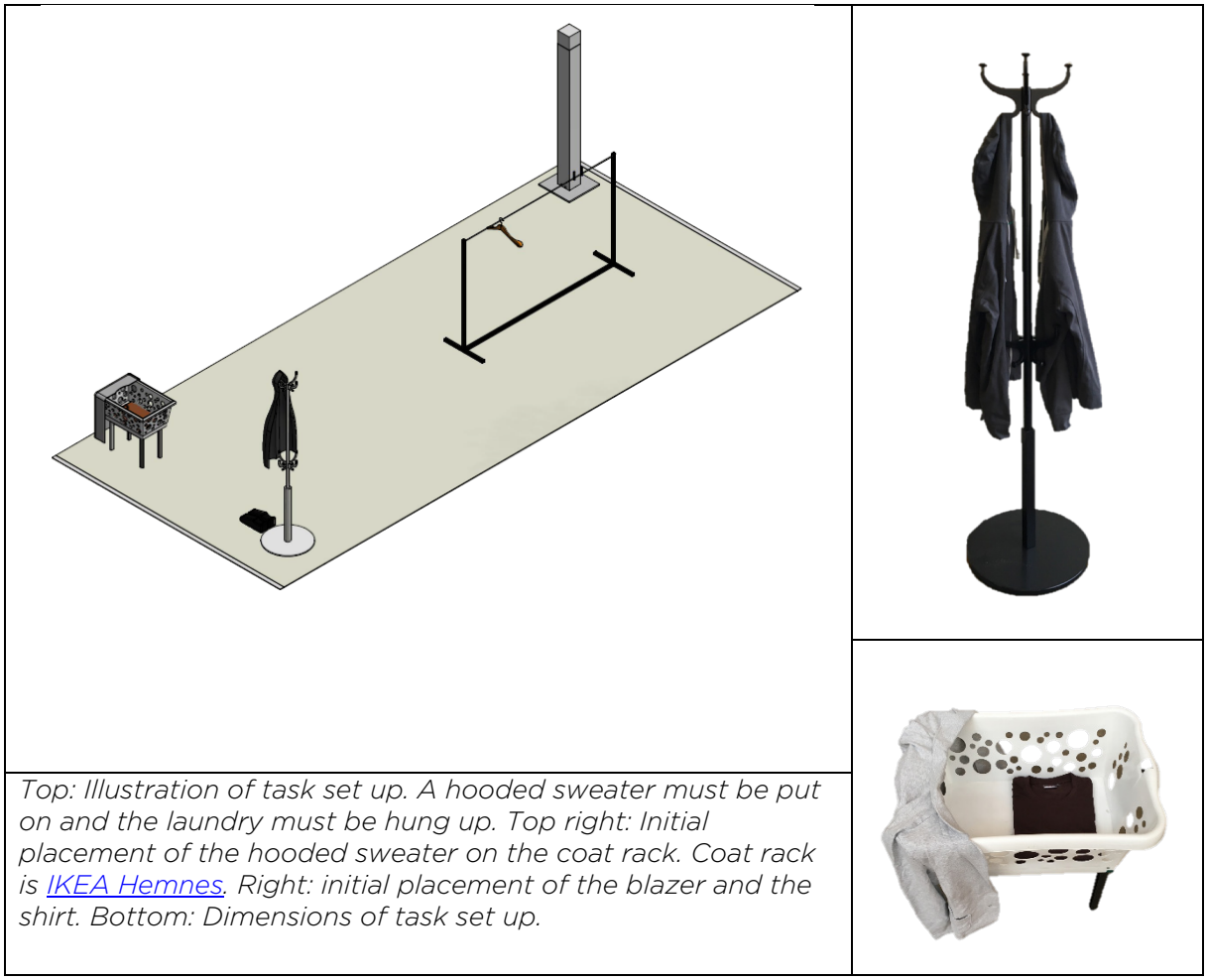
4.4.2 Laundry

4.4.2.1 Introduction

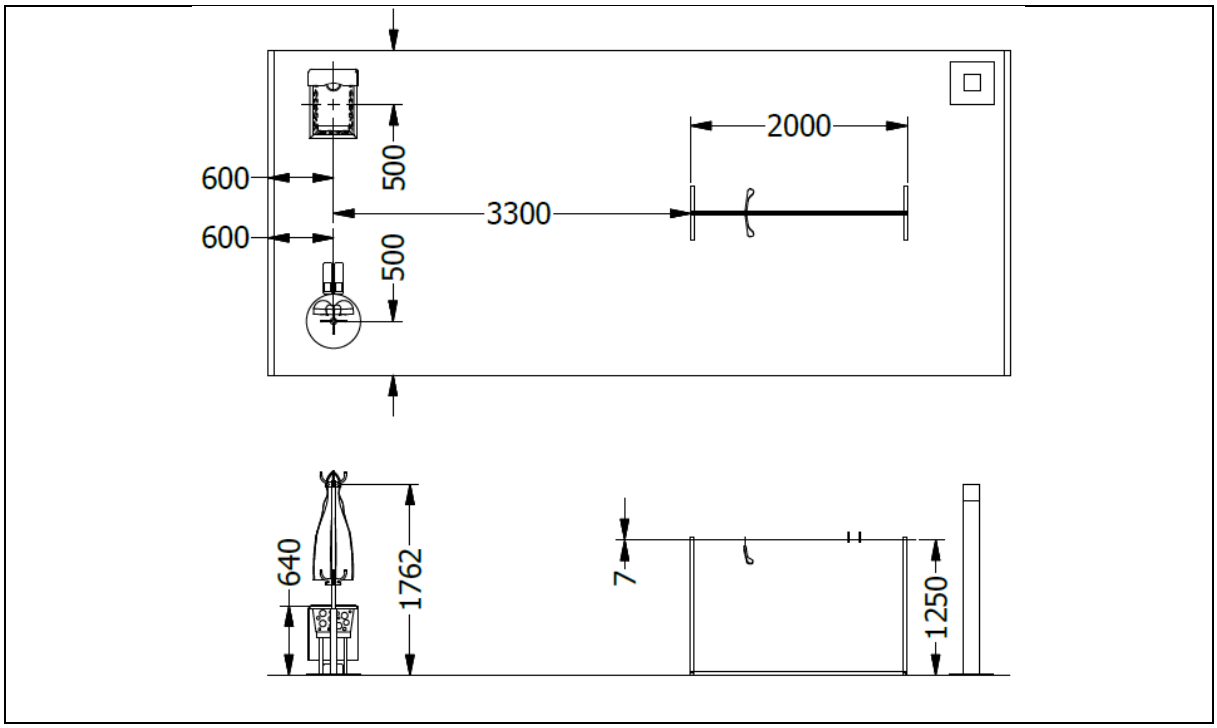
Hanging laundry requires a distinct set of fine motor skills, in particular of the fingers. For an arm prosthesis to be practical for daily use it must be possible to wear standard clothes with it.

In this task, a hooded sweater must be taken from a coat rack, put on and the zipper must be closed. Clothes that are placed in a clothes hamper need to be hung up on a clothes line by using hangers and blue clothes pegs. Moreover, two buttons of a blazer need to be closed and shoes must be tied. The use of a hamper to transport the clothes closer to the clothes line is optional. The hooded sweater can be taken off again at the end of the task.

4.4.2.2 Elements



Top: Illustration of task set up. A hooded sweater must be put on and the laundry must be hung up. Top right: Initial placement of the hooded sweater on the coat rack. Coat rack is IKEA Hemnes. Right: initial placement of the blazer and the shirt. Bottom: Dimensions of task set up.



Object	*Photo*	*Colour* *Material* *Dimensions*	*Brank/Link/Model*
Clothes hamper		white-black plastic h: 600 mm	Migros
Blazer with two large buttons	 	fair grey cloth buttons Ø:23 mm buttonholes: 21 mm (stretch)	tbd
Clothes hanger		Light brown wood w: 430 mm	IKEA Bumerang
T-shirt		brown cloth	tbd
Hooded sweater with zipper	 	anthracite cloth zipper slider graspable part: ~20 mm target zone for zipper slider above lines indicated in green: ~40 mm	tbd
Clothespins		blue plastic l: 78 mm	- -
Pair of shoes		tbd	tbd
Objects that must be manipulated in this task. The depicted objects are not proportional in size.			

4.4.2.3 Task Rules

ARM-LAUNDRY-1	The hooded sweater (size provided according to body size of the pilot) must be taken from the coat rack and put on correctly (i.e. arms inserted into the sleeves). The zipper must be closed at least to the mark. At the end of the task the hooded sweater must be hung on the clothes line or on the coat rack.
ARM-LAUNDRY-2	The two buttons of the blazer need to be closed and the blazer hung on the clothes line using the hanger. The order of buttoning the blazer and hanging the blazer with the hanger on the rail is free.
ARM-LAUNDRY-3	The shirt must be hung on the clothes line and attached with both blue clothespins. It is permitted to put the shirt over the line and then attach it with the blue clothespins.
ARM-LAUNDRY-4	The shoe laces of both shoes must be tied together and the shoes must be hung over the clothes line (to proof that the knot holds). The type of knot is free.
ARM-LAUNDRY-5	If any object (blazer, hooded sweater, shirt, hanger, shoes or blue clothespins) has fallen off the clothes line or the coat rack when passing the start line of the next task, the task is failed.

4.4.2.4 Comment

- The team official who is allowed to access the field must confirm to the referee that the correct size of the hooded sweater for their pilot is available on their allocated race track prior to the race.

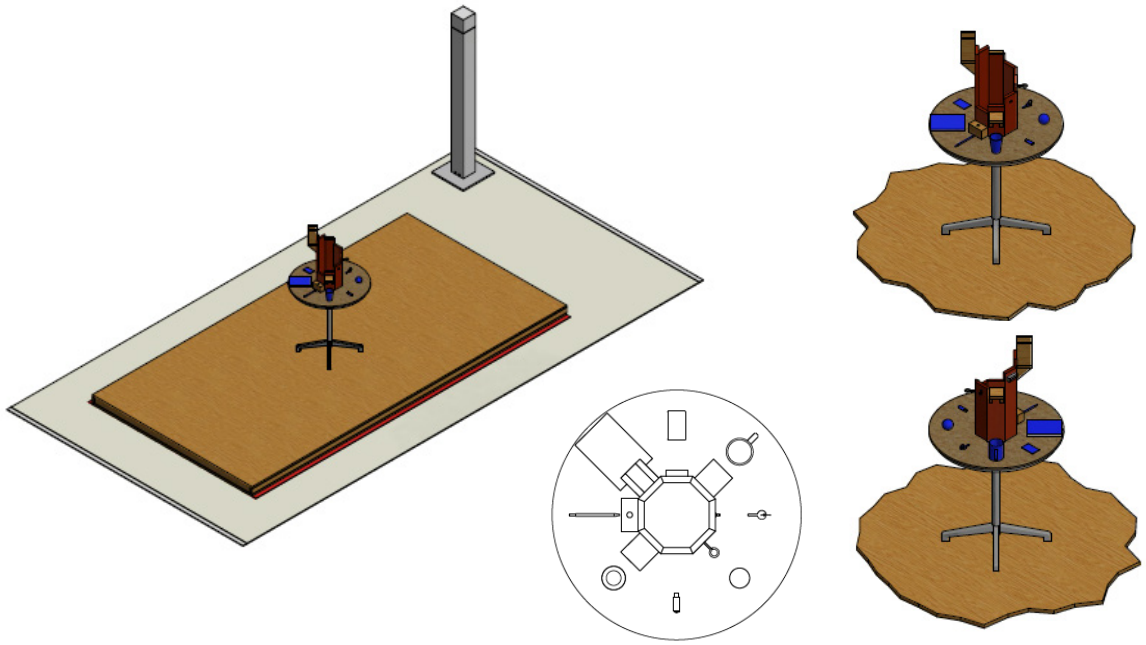
4.4.3 Clean Sweep

4.4.3.1 Introduction

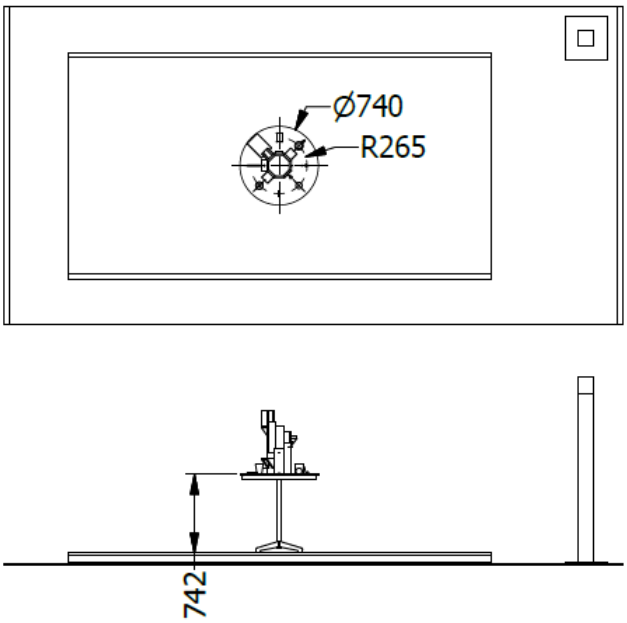
A vast variety of objects of different shape, size, compliance, texture and weight must be grasped and manipulated in everyday life. The ability to cope with this diversity of requirements is challenged in this task. The objects and related grip types were chosen based on literature and their relevance in daily life. Besides the ability to use different grip types, the ability to maintain grips during postural changes of the wrist/arm and the control of grip force are tested in this task.

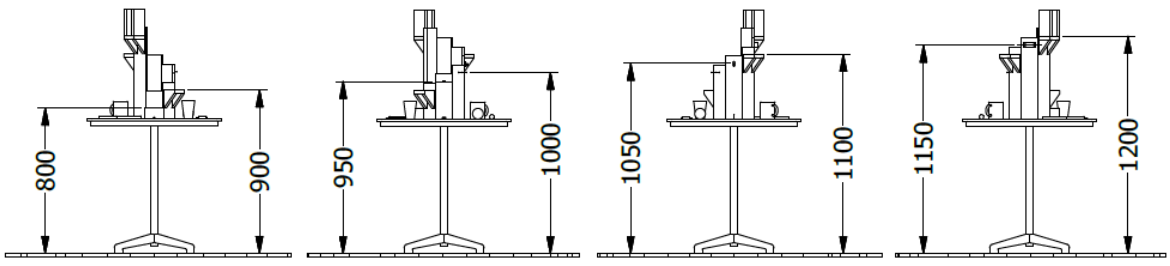
Pilots are asked to grasp and move objects individually from their predefined initial position on the table surface to a predefined target position. The blue objects differ in weight, size, shape, compliance and texture to challenge different grip postures, manipulation types and the control of grip force.

4.4.3.2 Elements



Top: Illustration of task set up. The blue objects must be grasped and moved from their initial position on the table to their target position. Top right: Detail of initial and target positions of blue objects. Bottom left: Detail of initial position of blue objects. Bottom right: Dimension of task set up.





Object	*Colour* *Material* *Surface* *Weight* *Dimensions*	*Object*	*Colour* *Material* *Surface* *Weight* *Dimensions*	*Object*	*Colour* *Material* *Surface* *Weight* *Dimensions*	*Object*	*Colour* *Material* *Surface* *Weight* *Dimensions*
DVD  	blue plastic slick 90 g 190x135x14.6 mm	Pen 	blue plastic slick 12 g 137x10 mm	Plastic cup  (the cup will be filled with red wooden marbles of 15 mm diameter)	blue plastic slick 3 g (empty) 80 g (filled) Height: 81 mm Diameter (at half height): 54 mm	Credit card  	blue plastic slick 5 g 85x54x0.8 mm
USB  	blue rubber sticky 7 g 55x17x8 mm	Rubber ball  	blue foam sticky 23 g Ø: 60 mm	Key and key ring 	blue 17 g Key: steel slick length: 55 mm Ø bow: 23 mm thickness: 2.5 mm Ring: Steel $Ø_{outer}$: 22 mm $Ø_{inner}$: 25 mm	Coffee mug  (the mug will be filled with red wooden marbles of 15 mm diameter)	blue handle ceramic slick 310 g (empty) 443 g (filled) Height: 80 mm IKEA Vardagen
Objects that must be manipulated in this task. The depicted objects are not proportional in size.							

4.4.3.3 Task Rules

ARM-CLEAN-1 The task is solved once all blue objects are moved from their initial position on the table to their respective target position on the tower mounted on the table.

ARM-CLEAN-2 It is not allowed to carry multiple objects at the same time (e.g. by stacking).

ARM-CLEAN-3 The objects must be manipulated in the following order:

1. The pen must be inserted into the holder.
2. The plastic cup must be placed on the shelf above. If any of the red marbles drops out of the plastic cup, the task is failed.
3. The USB-Stick must be fully inserted into the socket
4. The rubber ball must be placed on the eye of the eyebolt.
5. The key must be hung on the hook using the key ring.
6. The coffee mug must be placed on the shelf. If any of the red marbles drops out of the coffee mug, the task is failed.
7. The credit card must be fully inserted into the card slot.
8. The DVD must be placed on the shelf above.

ARM-CLEAN-4 All objects have to be located at their target position when passing the start line of the next task

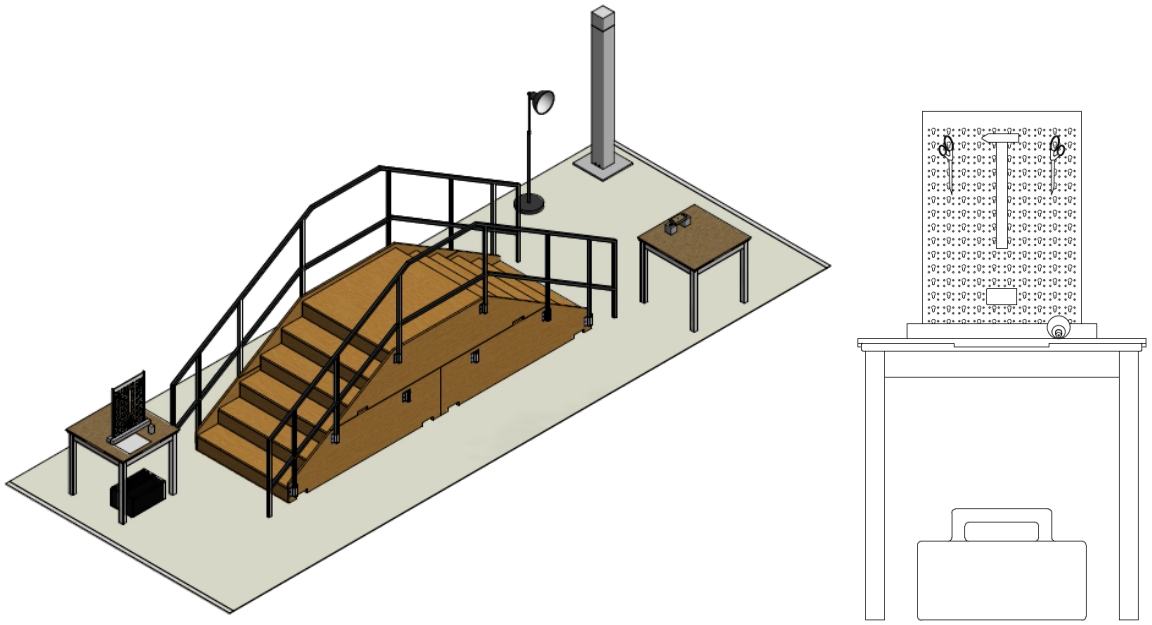
4.4.4 Home Improvement

4.4.4.1 Introduction

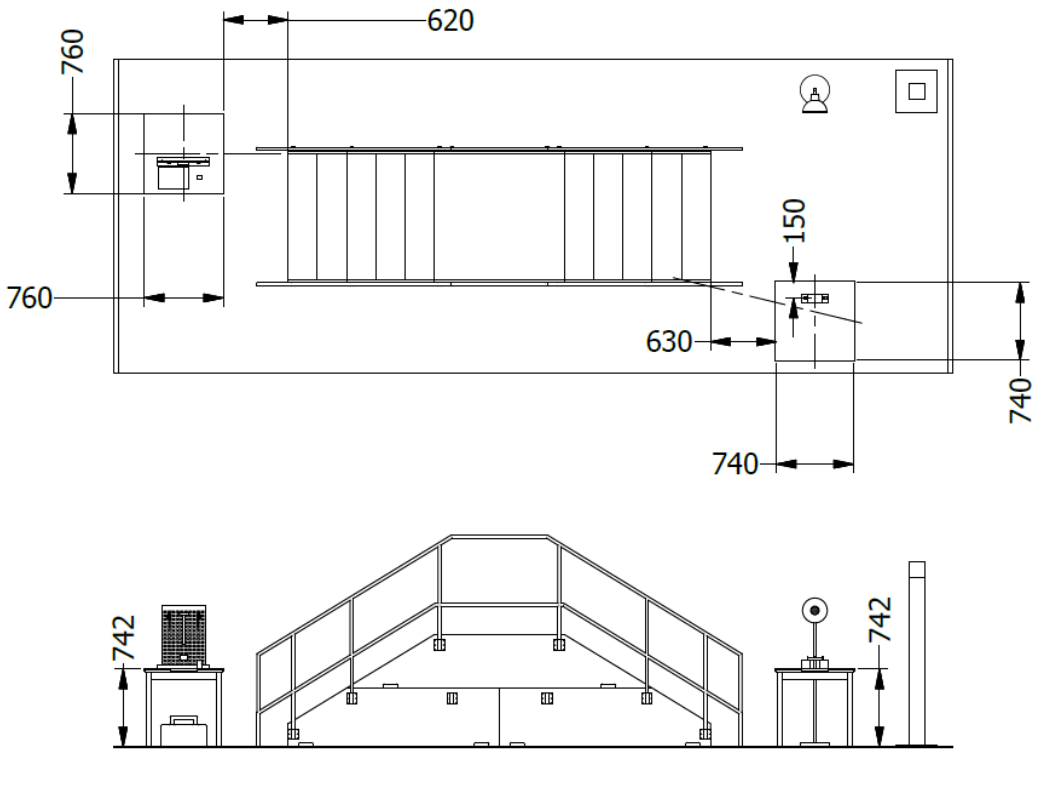
The ability to use tools is critical to complete maintenance work at home such as driving in a nail or exchanging a light bulb.

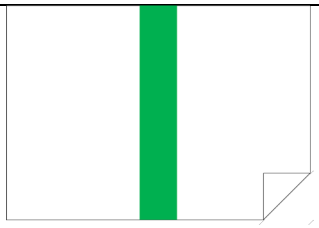
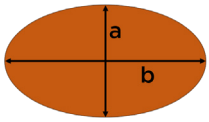
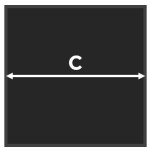
In the home improvement task, various tools and objects (mostly blue objects) are taken off a pegboard, put into a toolbox (optional) and carried over the stairs to a table, where the tools must be used.

4.4.4.2 Elements



Top: Illustration of task set up. Tools and other objects must be transported from the pegboard to the table on the other side of the stairs where the tools have to be used. Bottom: Dimension of task set up.



Object	*Photo*	*Colour Material*	*Weight*	*Dimensions*
Scissors (models for left handed and right handed use will be provided)		blue handle plastic/steel	tbd	tbd
Sheet of paper		white paper	300 g/m²	A4 (297x210 mm)
Bulb		blue plastic/metal	55 g	Ø: 60 mm h: 110 mm
Hammer	 Cross sections  Handle  Head	blue handle wood (handle)/ steel (head)	450 g	Total length: 300 mm a: ~21 mm b: ~29 mm c: 23 mm
Nail		silver steel	7 g	Length: 90 mm Ø: 3.5 mm
Toolbox		plastic	~400 g	

Object	*Photo*	*Colour Material*	*Weight*	*Dimensions*
Floor lamp		Metal, black	-	IKEA Skurup The thread of the bulbholder is 1250 mm off the ground The angle/position of the lampshade cannot be changed
Objects that must be manipulated in this task. The depicted objects are not proportional in size.				

4.4.4.3 Task Rules

ARM-HOME-1 The task is solved once the following sub-tasks are completed

a) Bulb lights up after it is screwed into the bulb holder. If the blue lightbulb breaks into pieces, the task is failed.
b) The nail is driven into the wood using the hammer
c) The paper is cut into two pieces within the marks using the scissors. It is only allowed to actuate (i.e. open and close) the scissors using the prosthetic hand. Thus, it is not allowed to assist actuation using other objects of the task (e.g. the nail, table etc.).

ARM-HOME-2 The order and the number of tools and objects put into the toolbox are not restricted, i.e. it is permitted to carry multiple or single objects (in any order) to the table and walk only once or several times between the pegboard and the table, using the toolbox or not.

ARM-HOME-3 It is allowed to grasp the plastic box with both hands to transport objects, including the blue objects.

ARM-HOME-4 It is not allowed to pass the stairs to the left or to the right when going forth and back between the tables.

4.4.4.4 Comments

- In the initial position, the plastic box is located on the floor underneath the pegboard.
- The blue hammer and blue scissors are initially hung up on the pegboard.
- The nail is initially placed in a small box on the pegboard
- The sheet of paper is initially placed on the table with the pegboard.

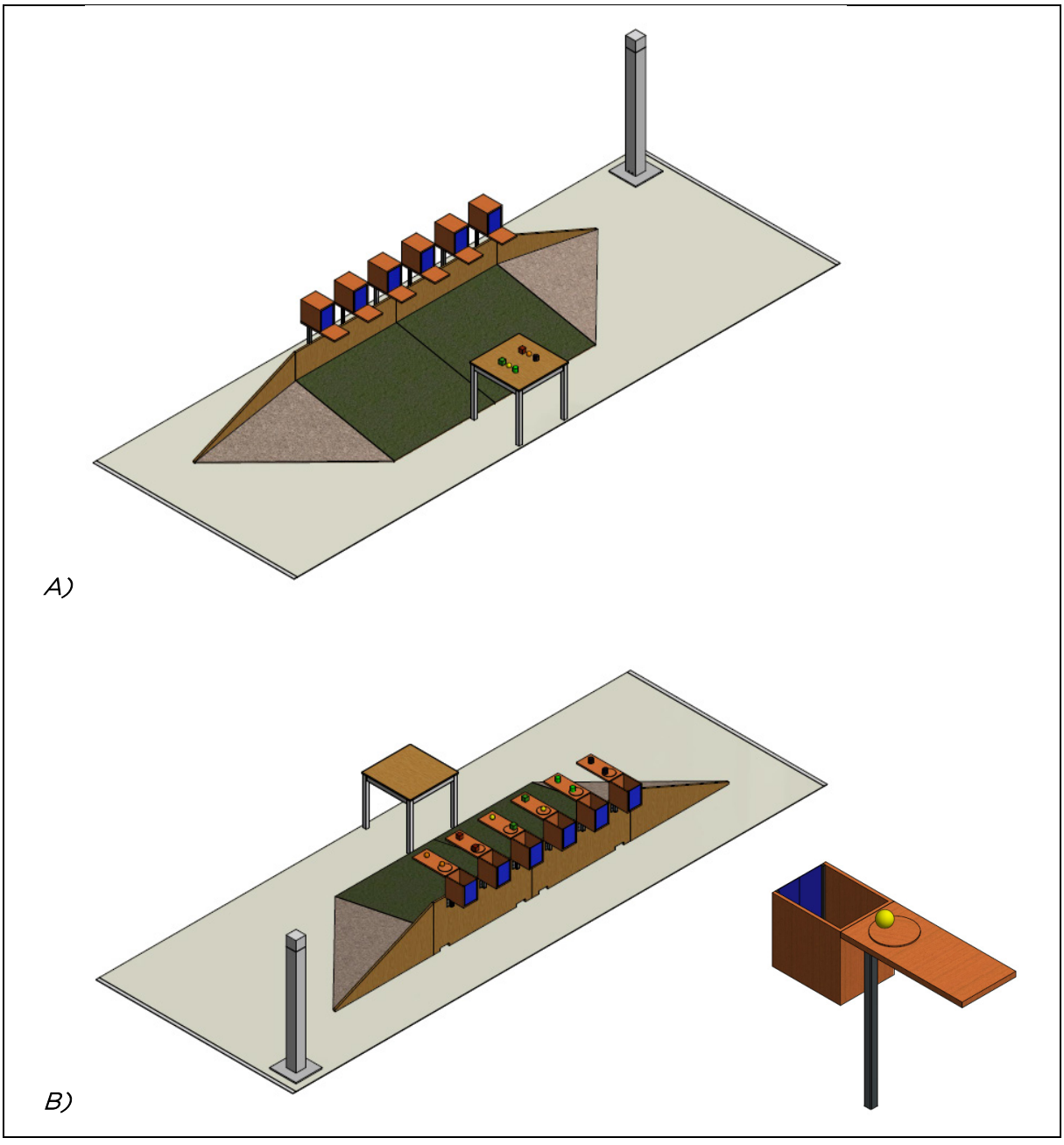
4.4.5 Haptic Box

4.4.5.1 Introduction

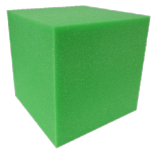
The availability of sensory feedback from the arm prosthesis may help to improve motor control of the prosthetic hand, as well as to improve acceptance and embodiment of the device.

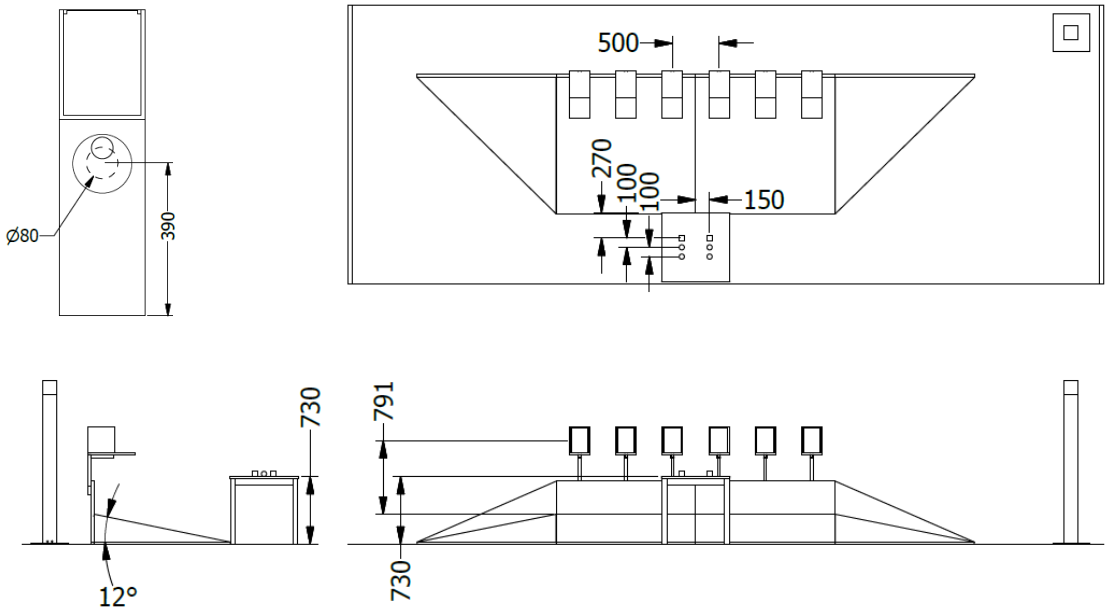
In this task, objects of specific shape, texture and compliance must be identified inside a box without the availability of visual feedback. The pilots can reach into the box with the prosthetic hand, but have no sight of their workspace during task execution (i.e. during object identification). Objects are tightly attached to the bottom of the box such that they cannot be lifted or removed. Objects are presented in a random order. The pilots can only rely on sensory feedback from the prosthesis (e.g. sounds, vibrations at the socket, haptic feedback from the terminal device) to solve the task.

4.4.5.2 Elements



Top: Illustration of task set up. Objects must be identified by haptic exploration inside each haptic box without visual feedback. Matching objects must be placed in front of the box. A) Initial position: all hatches are closed and matching objects are located on the table opposite the haptic boxes, B) final position: (potentially) matching objects are placed in front of the haptic boxes by the pilot and all hatches are opened (view is opposite to A). Detail shows a single haptic box with opened hatch. Inside the box, the individual objects are eccentrically mounted on a disc. The actual position of the object inside the box may vary.
Bottom: Symbolic pictures of the objects that must be identified. Edge length/diameter is 50 – 60 mm. Far below: Dimensions of task set up.

					
Foam cube	Foam ball	Foam cylinder	Wooden cube	Wooden ball	Wooden cylinder



4.4.5.3 Task Rules

ARM-BOX-1 Only the prosthetic hand must be inserted into the box through the blue opening. The other hand must not touch the box.

ARM-BOX-2 Once the pilot has identified an object inside the box, the pilot places the matching object in front of that box.

ARM-BOX-3 Pilots open the hatch of each box to verify if the match is correct. If any object does not match, the task is failed.

ARM-BOX-4 The task is finished if the six objects have been correctly matched.

ARM-BOX-5 Pilots are not allowed to obtain visual information from within the box (e.g. by attaching a camera to the prosthesis).

4.4.5.3.1 Comment

- Each hatch can be opened individually once a (potentially) matching object has been placed in front of the respective box.

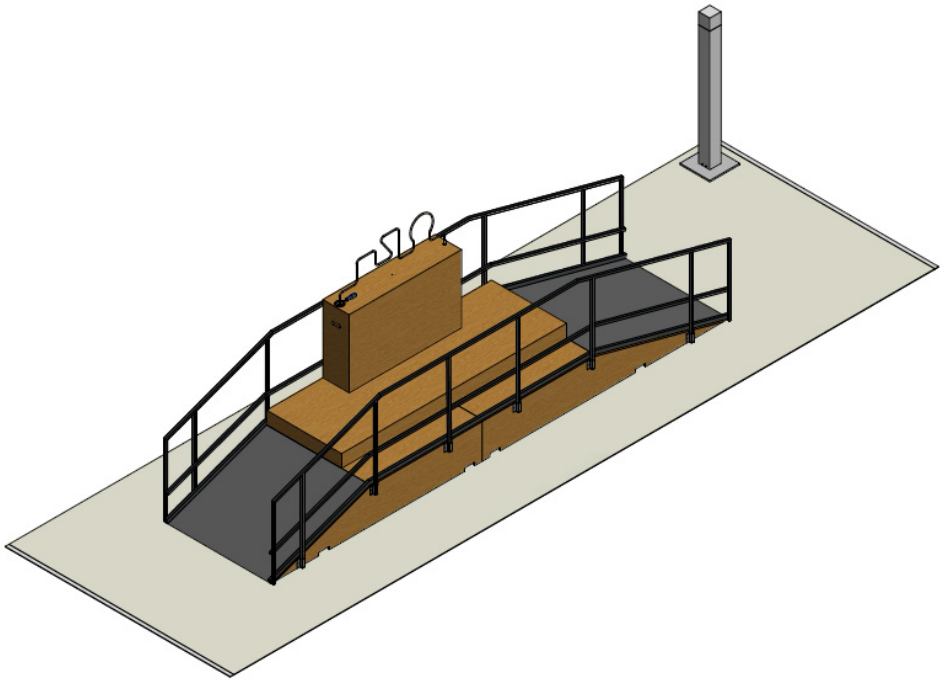
4.4.6 Wire Loop

4.4.6.1 Introduction

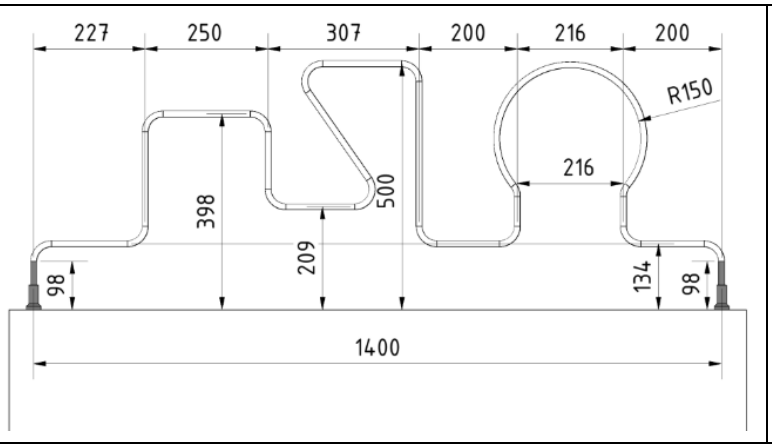
Maintenance of a tight grip during postural changes of the arm (e.g. pronation and supination of the forearm, elbow flexion and extension) can be challenging for prosthetic hand users, but is relevant in many situations in daily life (e.g. when picking up the phone). This aspect of prosthetic hand function is emphasized in this task.

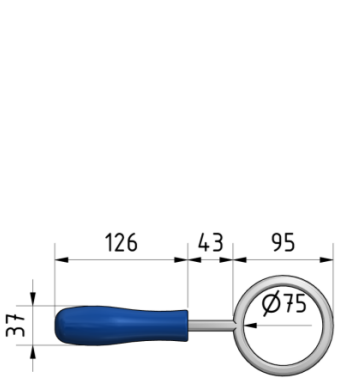
Pilots hold a conductive wire loop with a blue handle. A curved metal wire needs to be tracked without touching the wire with the loop by using the prosthetic hand only.

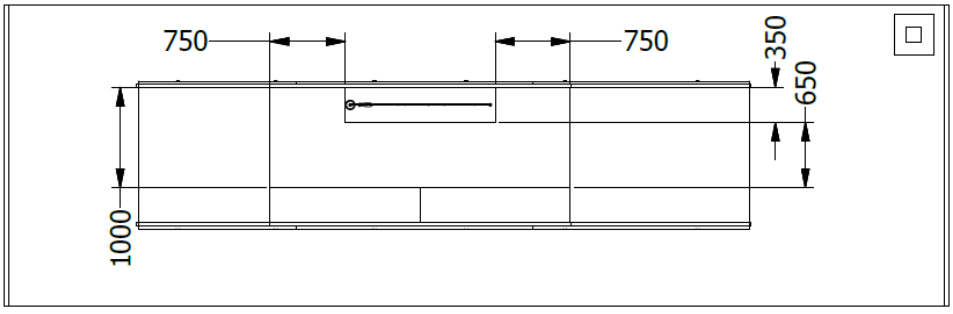
4.4.6.2 Elements

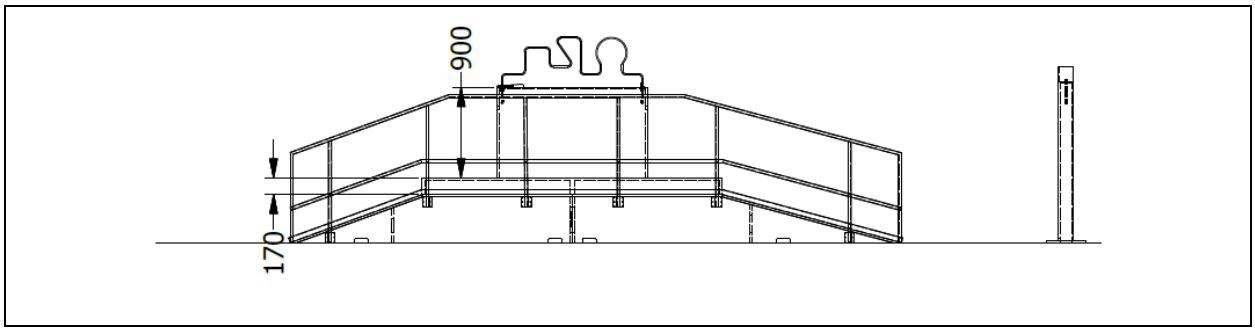


*Top: Illustration of task set up. The metal loop must be moved around the wire loop to reach the target location. The wire loop is located on top of the ramp. The **blue** handle is shown in the start position. Below left: Stainless steel tube Ø 12 mm. Radii of small corners: inner radius 30 mm, outer radius 42 mm. The non-conductive sections at both ends are indicated in grey. Below right. The **blue** handle is a standard file/screwdriver handle. A lamp integrated in the handle lights up when the loop touches the wire. Handle type is Swiss Tools PB 1200.125 BL 10. Far below: Dimensions of task set up.*









4.4.6.3 Task Rules

ARM-WIRE-1 The task must be started and finished in a non-conductive region (start point and finish point), where pilots grasp and drop the loop respectively.

ARM-WIRE-2 The blue handle of the wire loop is shaped to grip it with a power grip (medium wrap), but any other grip is also allowed.

ARM-WIRE-3 If there is contact between the loop and the wire, the task is failed (and cannot be repeated).

ARM-WIRE-4 The wire loop task can be accessed from either the right hand or left hand side, depending on the preference of the pilot.

ARM-WIRE-5 While the loop of the handle is in the non-conductive area at the start of the wire, it is allowed to grasp the handle or loop with the non-prosthetic hand in order to support positioning the blue handle in the prosthetic hand.

4.4.6.4 Comments

- The team official who is allowed to access the field must confirm to the referee that the wire loop is placed on the correct side of the track for their pilot.
- It is not allowed to touch the silver part of the handle with the prosthesis. See examples below:

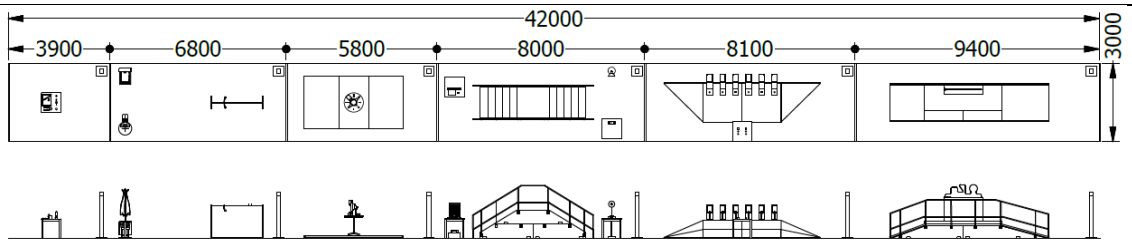
Not allowed, since prosthetic hand is *touching* the silver part of the handle. However, the same grip type touching only the blue part of the handle is allowed.

Allowed, since the prosthetic hand is *not touching* the silver part of the handle. However, the same grip type touching the silver part of the handle would not be allowed.

4.5 Competition Mode and Scoring System

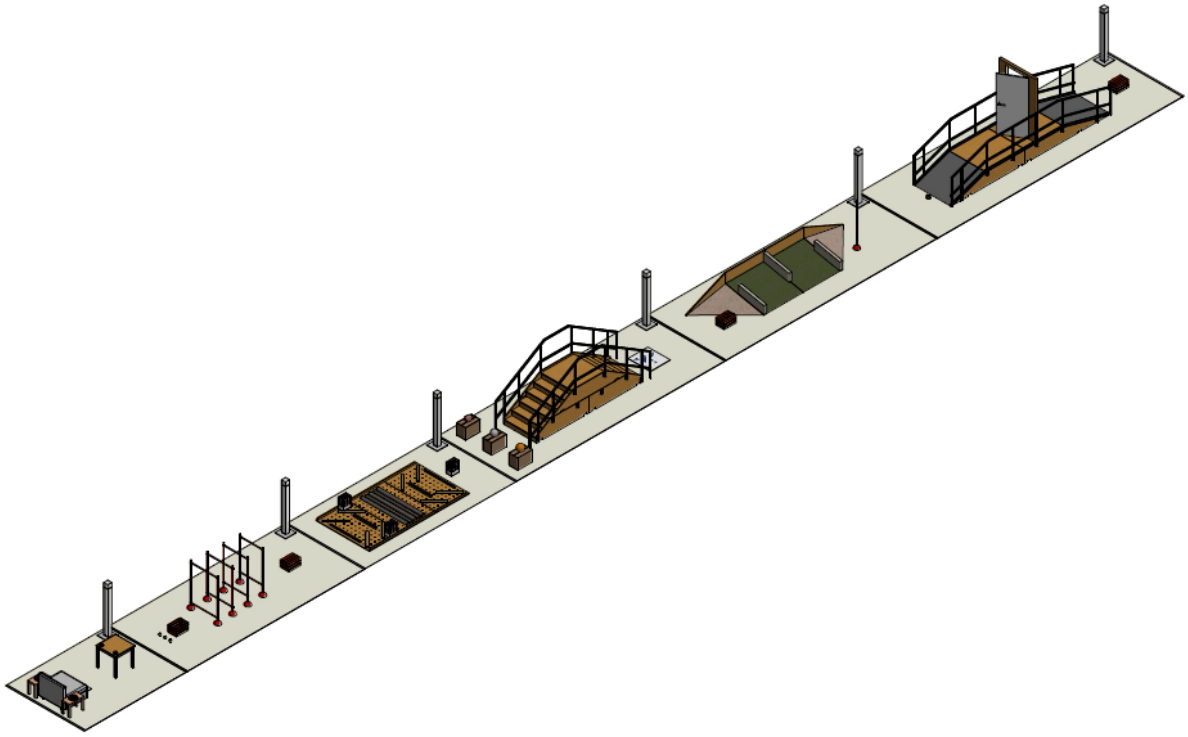
See also sections *1.3* and *0*.

Time limit: 8 min



Task	Breakfast	Laundry	Clean Sweep	Home Improvement	Haptic Box	Wire Loop	Total
Points	101	102	104	108	130	115	660

5. Powered Leg Prosthesis Race



Overview of Powered Leg Prosthesis Race track. Race direction is bottom left to top right.

5.1 Introduction

Pilots with transfemoral or knee exarticulation amputations equipped with exoprosthetic devices (leg prostheses) are challenged by tasks related to daily life activities. Bipedal gait is a highly automated movement and during the majority of time spent walking secondary tasks using the upper limbs are carried out. Therefore, pilots must carry or balance objects with their hands while performing the leg prosthesis tasks. Pilots are asked to solve as many tasks as possible in a given time.

5.2 Inclusion Criteria

5.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Pilots have a knee exarticulation or more proximal amputation of at least one leg.

5.2.2 Technology

In addition to the general rules described in section 1.2, the following criteria apply for the powered leg prosthesis technology:

- Any kind of passive (unpowered or controlled dissipative) or active prostheses are allowed.
- The prosthetic device can have any number of actively driven, i.e. powered, joints. The residual body parts can also be instrumented and electronically and/or mechanically connected to the prosthesis.
- Load transfer to the ground via wheels is not allowed.
- There is no weight limitation.
- The use of crutches or canes is not permitted.

5.3 Specific Rules

LEG-1	Wearing a helmet is mandatory. The teams are required to bring their own helmet.
LEG-2	It is allowed to use the handrails.
LEG-3	Touching the ground on (or beyond) the lines marked in the following illustrations in red with any part of the prosthetic device or other body part is not allowed. Pilots are not allowed to enter, exit or step on the obstacles in a location marked in red in the following illustrations.
LEG-4	Any object on the race track that is red is not allowed to be touched with any part of the body.
LEG-5	It is allowed to touch the prosthesis with the hands or any other part of the body to support movements.
LEG-6	Pilots are not allowed to use trailers, backpacks, bags, pockets, ropes or similar items or to use their clothes to carry objects on the race track (e.g. tools, plates, and bags of the tasks), but it is allowed to use such aids to carry components of the device (e.g. batteries, control units, tools, replacement equipment, etc.).

5.4 Task Description

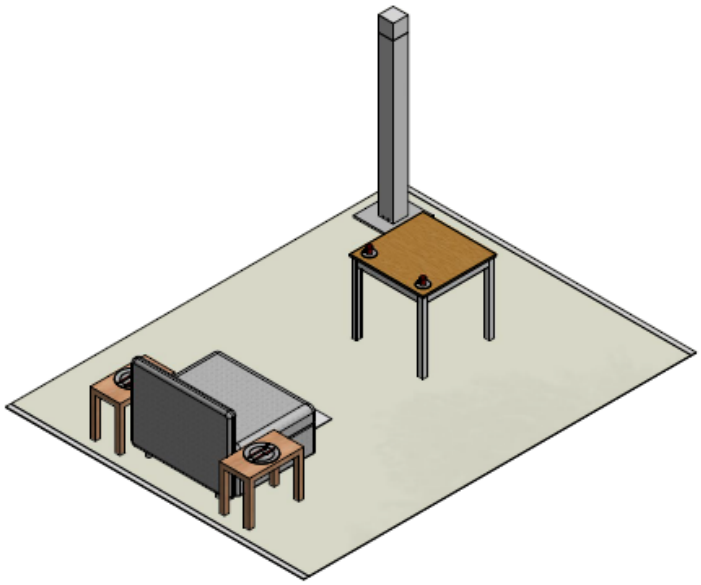
Each task is described in the following sections. In all of the following figures, the direction of the race is (bottom) left to (top) right.

5.4.1 Sofa

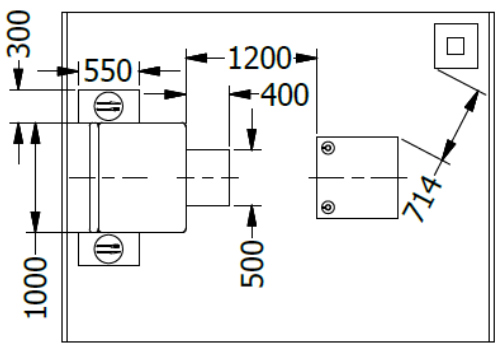
5.4.1.1 Introduction

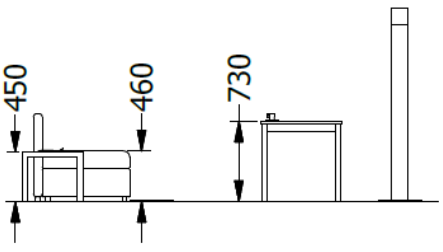
Sitting down and standing up are challenging tasks when wearing a lower-limb prosthesis with an artificial knee joint as joint moments need to be generated or compensated for to enable getting up and control sitting down. In this task pilots must sit down and stand up from a sofa while balancing objects in their hands. When sitting down and standing up, both feet must be placed in a confined space, such as when sitting in a narrow train compartment.

5.4.1.2 Elements



Top left: Illustration of task set up. Tableware must be carried from the dining table to the side tables and vice versa. While exchanging tableware on the side table, pilots must be sitting on the sofa. Sofa is IKEA Vallentuna, table is IKEA Lerhamn, and side tables are (adapted) IKEA Lack. Top right: Details of table ware. Right: Dimensions of task set up.





5.4.1.3 Task Rules

LEG-SOFA-1 Pilots must carry the tableware initially located on the dining table and place it on the side tables located to the left and the right of the sofa.

LEG-SOFA-2 Pilots must carry the tableware initially located on the side tables and place it on the dining table.

LEG-SOFA-3 Pilots must carry tableware while sitting down and standing up. Pilots are only allowed to exchange the tableware on the side tables while sitting on the sofa.

LEG-SOFA-4 Pilots must sit down completely, i.e. with the full body weight. Pilots are not asked to touch the backrest with their backs.

LEG-SOFA-5 While sitting down on and standing up from the sofa, both feet must be placed (in their entirety) on the white carpet in front of the sofa.

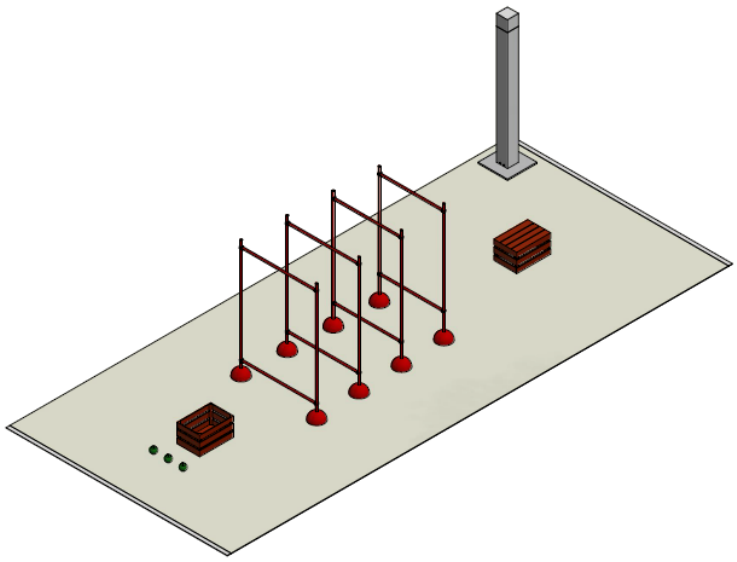
LEG-SOFA-6 Any red part of the tableware is not allowed to be touched by the pilots. Stacking of tableware is not allowed.

5.4.2 HURDLES

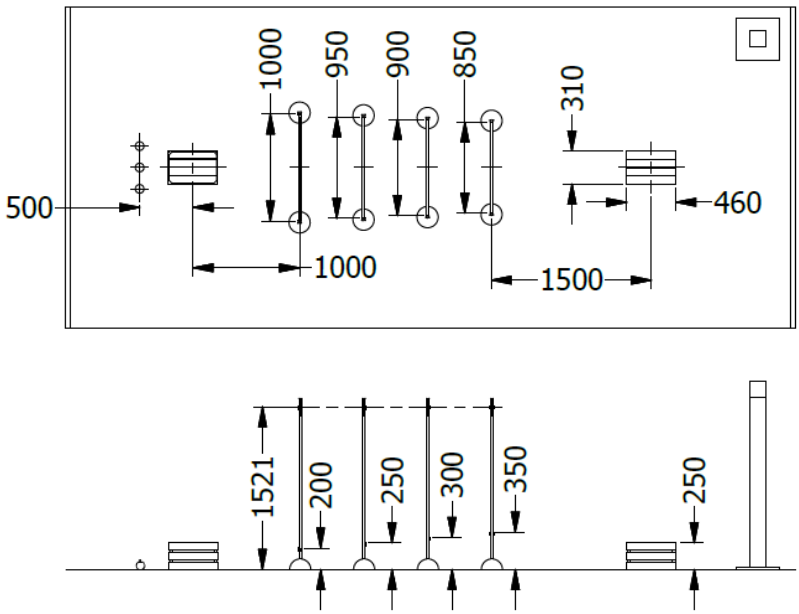
5.4.2.1 Introduction

Sometimes, it is necessary to step over objects that are even higher than standard steps or to crouch to pass beneath objects, e.g. when walking in a forest or on a construction site. In this task, the pilots have to step over or beneath hurdles while carrying a wooden crate and some apples.

5.4.2.2 Elements



Top: Illustration of task set up. Pilots must pass each hurdle while carrying the wooden crate and the apples. Crate is IKEA Knagglig. Bottom: Dimensions of task set up.



5.4.2.3 Task Rules

LEG-HURDLES-1	The pilot must pass between each pair of poles.
LEG-HURDLES-2	If the pilot knocks down a hurdle (horizontal bar), either by hitting a pole or a horizontal bar, the task is failed.
LEG-HURDLES-3	Pilots are not allowed to grasp any hurdle or pole with the hand or steady it with any other part of the body.
LEG-HURDLES-4	Pilots must carry three apples and a wooden crate while passing the hurdles. One or both hands can be used to carry the crate.
LEG-HURDLES-5	After passing the hurdles, pilots must place the wooden crate and the apples at the target position. If the wooden crate and the apples are not located at the target position at the moment the pilot crosses the finish line of the task, the task is failed.

5.4.2.4 Comment

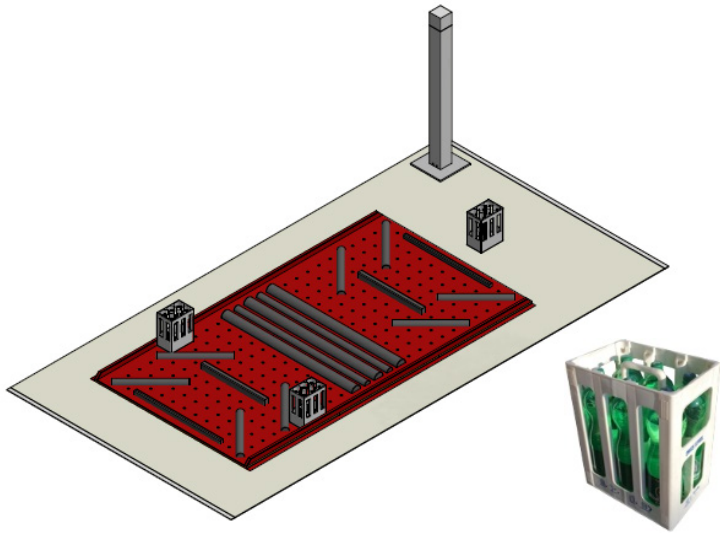
- The apples and the wooden crate can be carried individually or at the same time.

5.4.3 Rough Terrain

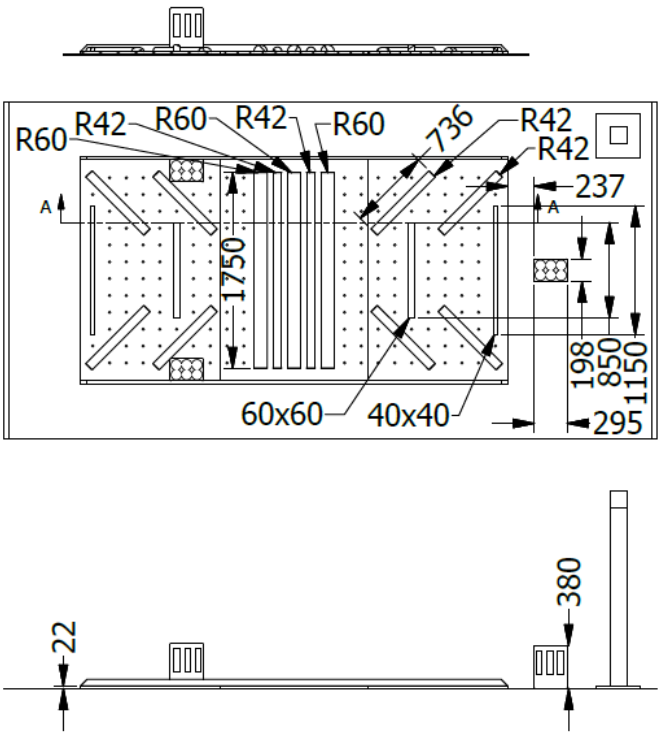
5.4.3.1 Introduction

In certain situations in daily life it is required to accurately control the positioning of the feet, e.g. when entering an escalator, to avoid puddles when it is raining or when walking in a forest (e.g. stepping on stones or roots). In this task, the pilots are challenged to step on wooden bars, to test the abilities of placing the foot on a defined location and maintaining dynamic balance.

5.4.3.2 Elements



Top: Illustration of task set up. The bottle crates must be carried to the other side of the rough terrain and stacked up at the target location (single crate on the floor). The bottle crate is for illustration purposes and not proportional in size. Bottom: Dimensions of task set up.



5.4.3.3 Task Rules

LEG-ROUGH-1 Pilots are free to choose their path when crossing the rough terrain, however, pilots are only allowed to step on the wooden bars. Touching the floor between the wooden bars is not allowed.

LEG-ROUGH-2 The bottle crates must be carried from their initial position and stacked up at the target position. If the bottle crates are not stacked on the target position at the moment the pilot crosses the finish line of the task, the task is failed.

LEG-ROUGH-3 Once the bottle crates are picked up from the initial position, neither the bottle crates, nor the bottles are allowed to touch the floor inside or outside the rough terrain, or any of its parts.

5.4.3.4 Comment

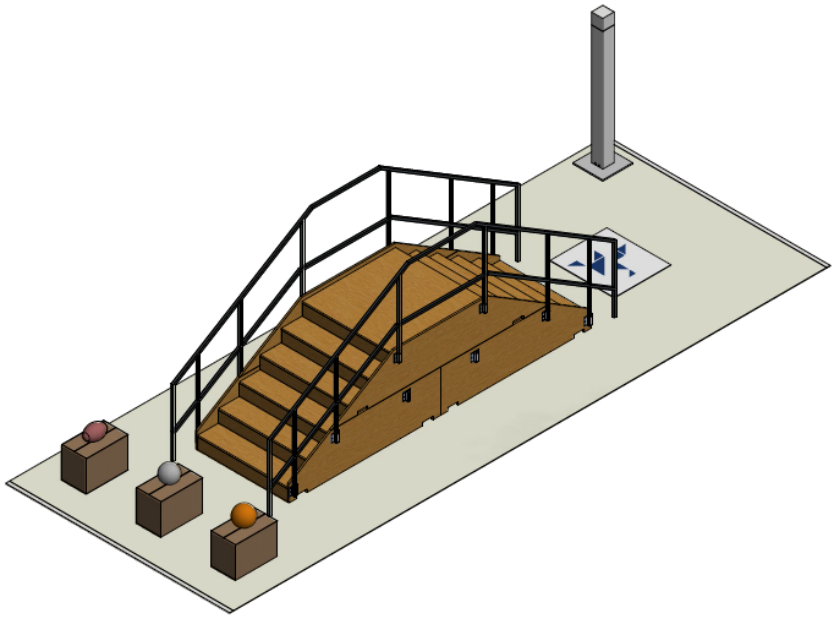
- Pilots may carry one or both bottle crates at the same time.

5.4.4 Stairs

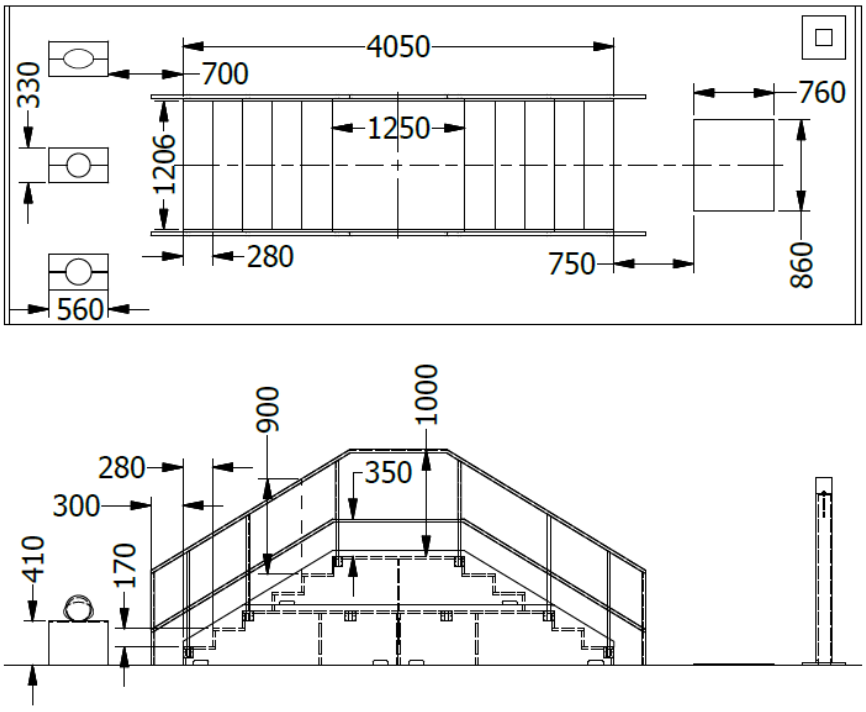
5.4.4.1 Introduction

Stairs are very common in daily life. People using lower-limb prostheses with an artificial knee joint often have to adapt their gait pattern to ascend or descend stairs. The resulting non-physiological and asymmetric movements may lead to secondary discomfort (e.g. back pain). This task tests how well pilots using lower-limb prostheses overcome stairs and if they allow for a natural, alternating gait – especially when it is required to carry bulky and unstable objects at the same time such as when moving.

5.4.4.2 Elements



Top: Illustration of task set up. The boxes and balls must be carried to the other side of the stairs and placed on the white carpet. Bottom: Dimensions of task set up.



Object	*Photo*	*Colour Material*	*Weight [kg]**	*Size [mm]*	*Brand/Link Model*
Basket ball		Orange rubber	~0.6	Ø: ~240	
Soccer ball		leather	~0.45	Ø: 210	
American football		brown rubber	~0.4	Ø: ~170 l: ~280	
Cardboard boxes		brown cardboard	~0.88	l: 560 w: 330 h: 410	IKEA Jättene
Depicted objects are not proportional in size.					

5.4.4.3 Task Rules

LEG-STAIRS-1 All objects must be carried over the stairs and placed on the carpet. If any object is not located on the carpet at the moment the pilot crosses the finish line of the task, the task is failed.

LEG-STAIRS-2 While on the stairs, alternating steps, i.e. left-right-left- or vice-versa are explicitly required. Thus, pilots are not allowed to place two feet on one step at the same time.

LEG-STAIRS-3 Pilots are not allowed to omit single steps or jump over steps. Thus, each step must be stepped on with one foot.

LEG-STAIRS-4 It is allowed to carry more than one object at the same time.

LEG-STAIRS-5 It is allowed to carry the objects with any part of the body. It is not allowed to throw, kick or push any object.

LEG-STAIRS-6 Objects falling on the floor are allowed to be picked up.

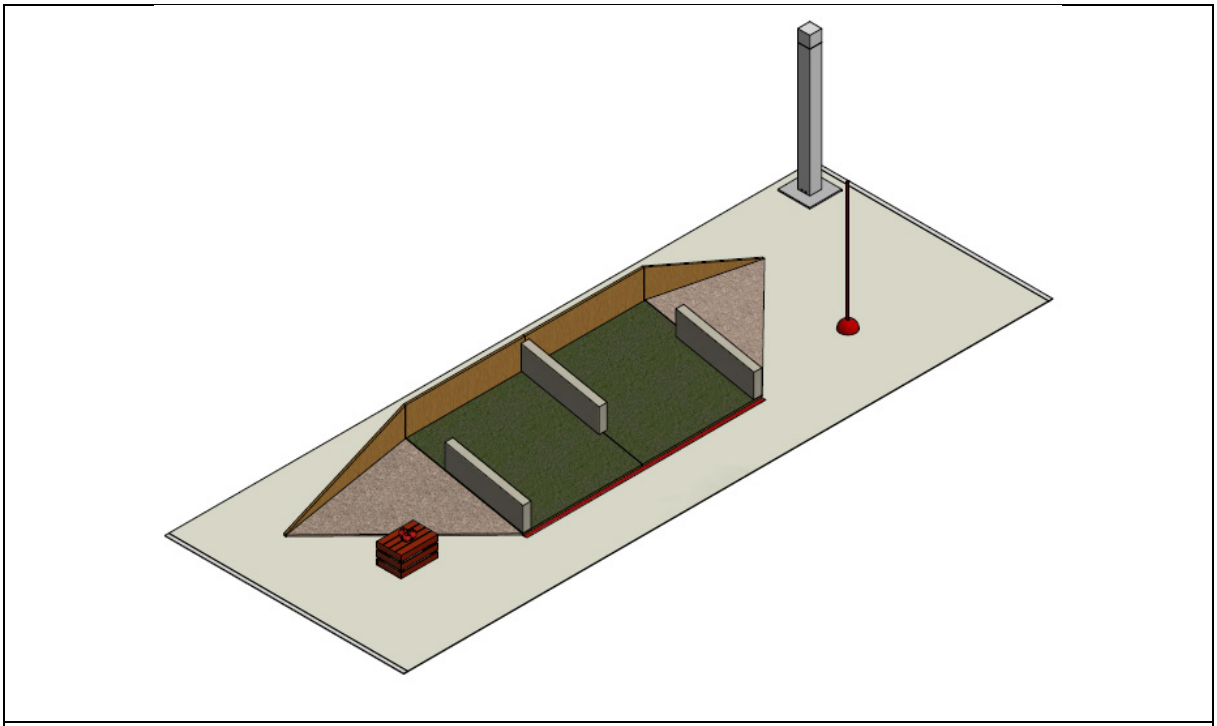
LEG-STAIRS-7 Pilots are not allowed to pass the stairs on the left or on the right.

5.4.5 Tilted Path

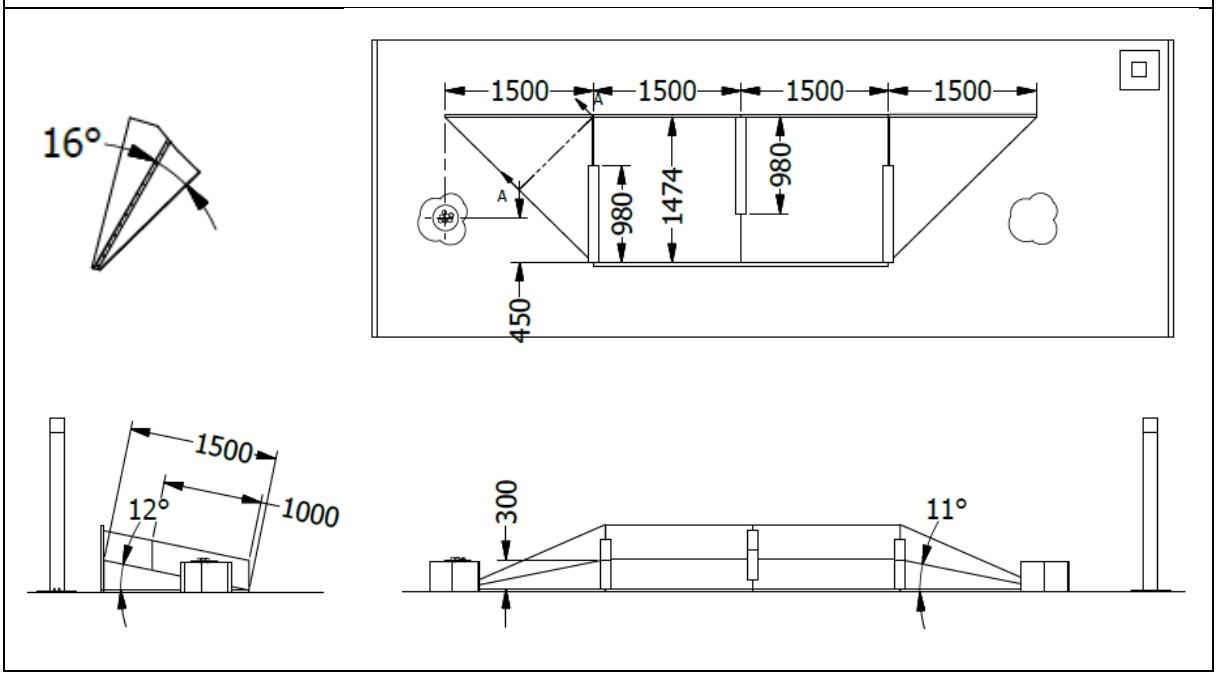
5.4.5.1 Introduction

In daily life, some paths are tilted perpendicular to the walking direction, e.g. when walking on nature trails or across a field. In particular when walking outside, also the surface of the ground might change.
In this task walking with an abducted/adducted hip, and pronated/supinated ankle is challenged. Also the control of foot clearance is emphasized.

5.4.5.2 Elements



*Top: Illustration of task set up. Pilots must cross the tilted path twice while carrying a plate with three **red** apples. When crossing the tilted path, pilots must navigate around the green fences. The centre part of the tilted path is covered with artificial grass.*
Bottom: Dimension of task set up.



5.4.5.3 Task Rules

LEG-TILTED-1 Pilots must cross the tilted path, go around the red pole and then cross the tilted path again.

LEG-TILTED-2 Pilots are only allowed to enter and exit the obstacle on the grey ramps.

LEG-TILTED-3 A plate with three red apples must be carried when crossing the tilted path in both directions. After crossing the tilted path twice, the plate with the red apples must be returned to the first tree stump.

LEG-TILTED-4 If any of the red apples drops before crossing the finish line of the task, the task is failed.

LEG-TILTED-5 It is only allowed to grasp the plate, but not the red apples. It is only allowed to transport the red apples by balancing them in the plate.

LEG-TILTED-6 Pilots are not allowed to step over any of the fences with either leg.

5.4.5.4 Comments

- After completing the task (i.e. crossing the tilted path twice and returning the plate with the red apples to the tree stump), pilots proceed to the start line of next task, passing the task elements on the right-hand side (in race direction).
- Pilots are allowed to touch the fences with either leg, but they are not allowed to step over the fences.

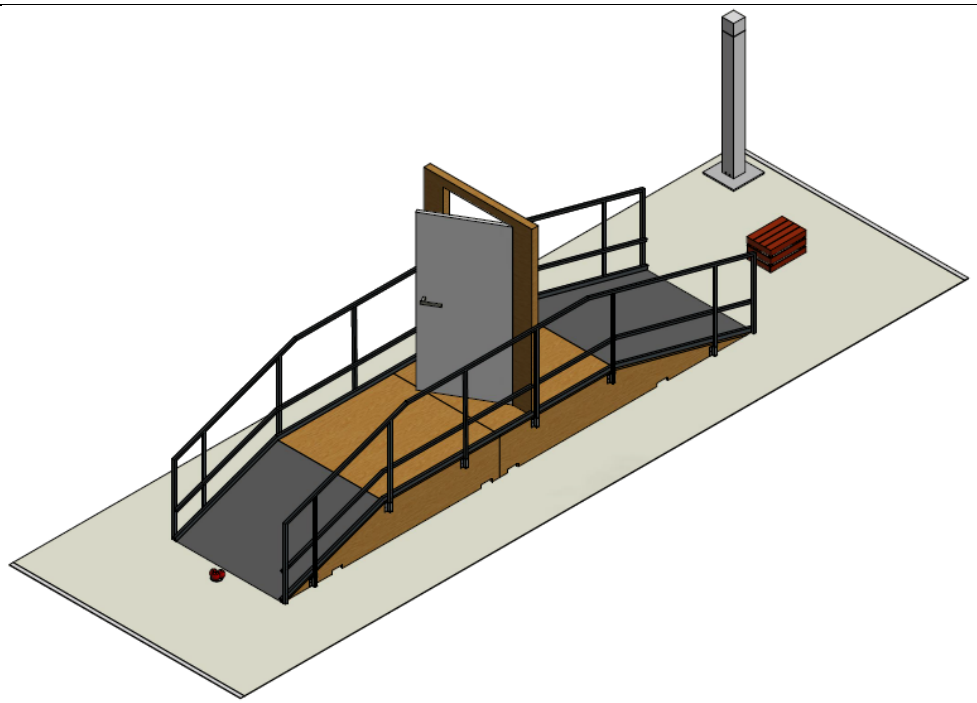
5.4.6 Ramp & Door

5.4.6.1 Introduction

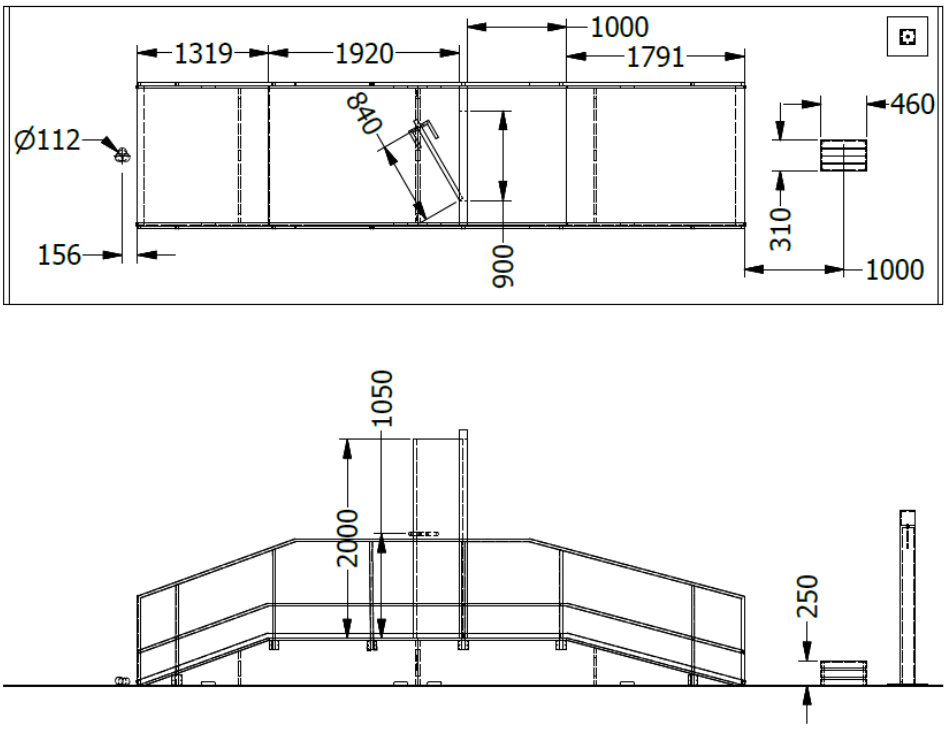
When going for a walk or accessing or leaving public buildings it is often required to climb or descend ramps. Furthermore, opening a closing a door requires precise foot placement in a confined space.

In this task, pilots have to ascend and descend ramps and pass through a doorway. A plate with red apples must be picked up at the bottom of the ascending ramp, carried to the other side of the door and placed on a shelf at the bottom of the descending ramp. Opening and closing the door requires pilots to step backwards and sidewards.

5.4.6.2 Elements



*Top: Illustration of task set up. A plate with three **red** apples must be picked up from the ground at the bottom of the ramp and placed on the box on the other side of the door. Box is IKEA Knagglig. Bottom: Dimension of task set up.*



5.4.6.3 Task Rules

LEG-RAMP-1 The ramp must be ascended on the more inclined slope (20°) and descended on the less inclined slope (15°).

LEG-RAMP-2 The door needs to be opened, passed through and closed. If the door is not closed when passing the finish line, the task is failed.

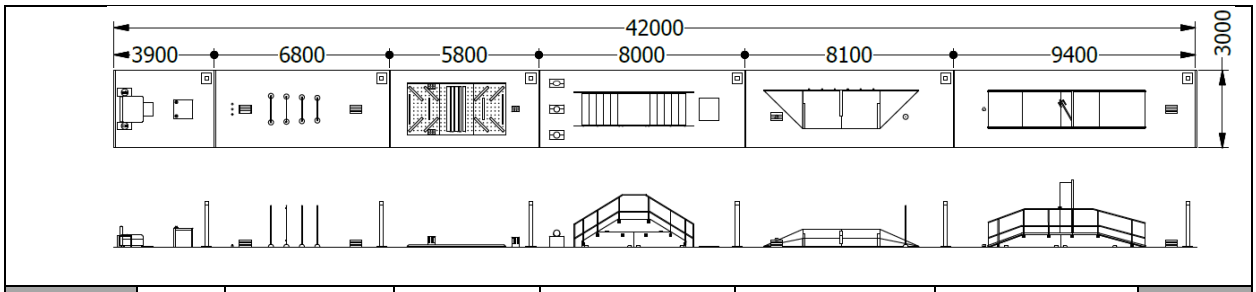
LEG-RAMP-3 A plate with three red apples must be picked up, carried, and placed at a target location at the other side of the ramp. If any of the red apples drops the task is failed.

LEG-RAMP-4 It is only allowed to grasp the plate, but not the red apples. It is only allowed to transport the red apples by balancing them on the plate.

5.5 Competition Mode and Scoring System

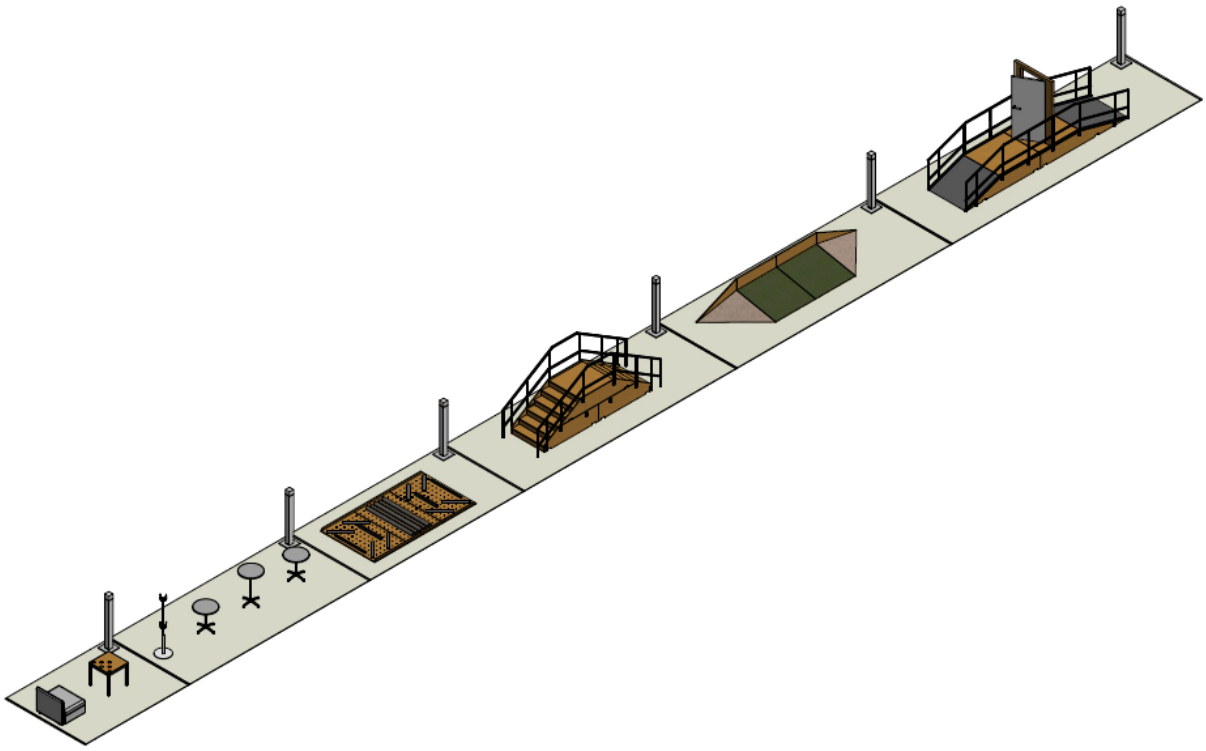
See also sections *1.3* and *0*.

Time limit: 4 min



Task	Sofa	Hurdles	Rough Terrain	Stairs	Tilted Path	Ramp & Door	Total
Points	101	108	115	130	104	102	660

6. Powered Exoskeleton Race



Overview of Powered Exoskeleton Race track. Race direction is bottom left to top right.

6.1 Introduction

Pilots with complete thoracic or lumbar spinal cord injuries (SCI) are equipped with exoskeletal devices (exoskeletons) and are challenged by tasks related to daily life activities.

Besides their use in the gait rehabilitation setting to improve ambulatory functions, exoskeletons are a promising alternative to the wheelchair. Positive health related effects, such as improved cardiorespiratory and bowel function, increased bone density, and a reduction of spasticity and pain have been reported. Users also report positive effects on social interaction and psychological benefits.

Pilots are asked to solve as many tasks as possible in a given time.

6.2 Inclusion Criteria

6.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Spinal cord injured pilots (AIS A or B, with a complete loss of motor function (http://www.sci-info-pages.com/levels.html) with leg paraplegia are eligible.
- Pilots with lesions affecting the control of trunk, arm and/or neck must be evaluated individually, as they must have sufficient voluntary control and strength to hold crutches and/or stabilise the trunk.
- The lesions can be spastic or non-spastic.

6.2.2 Technology

In addition to the general rules described in section 1.2 the following criteria apply for the exoskeleton technology:

- Any kind of input device or automated gait intention detection strategy is allowed.
- Load transfer to the ground via wheels or rolling contact is not allowed.
- Any type of actuation (other than combustion) is allowed; also passive devices are allowed (e.g. based on passive springs or cables), which can be used to wind up the system and store kinetic energy.
- The maximum weight of the exoskeletal device (excluding the pilot) is limited to 75 kg.
- Functional electrical stimulation can be added to hybridise the exoskeleton. Surface and implanted stimulation technologies are allowed.
- Crutches or canes are allowed. If crutches or canes are being used they must be carried by the pilots during the entire race run.

6.3 Specific Rules

EXO-1	Wearing a helmet is mandatory. The teams are required to bring their own helmet.
EXO-2	Use of the handrails is allowed. Crutches, if used, must always be carried by the pilot.
EXO-3	Touching the ground on (or beyond) the areas marked in the following illustrations in red with any part of the body or device, except the crutches, is not allowed.
EXO-4	Pilots must walk such that during any point in time, at least one of their legs is in contact with the ground, i.e. swing-through gait patterns are not allowed.

6.4 Task Description

Each task is described in the following sections. In all of the following figures, the direction of the race is (bottom) left to (top) right.

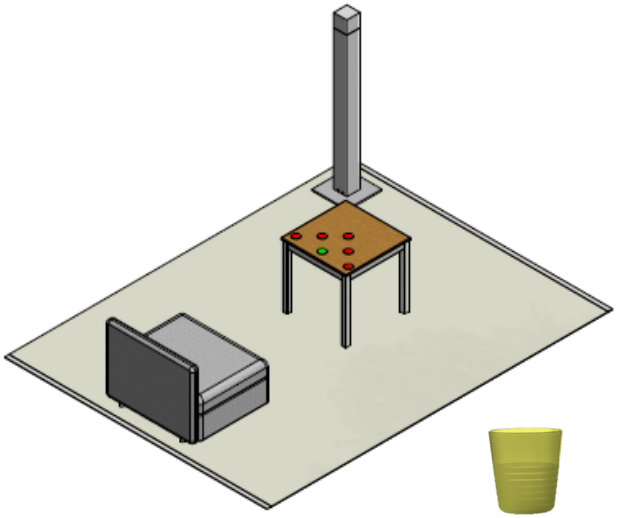
6.4.1 Sit & Stand

6.4.1.1 Introduction

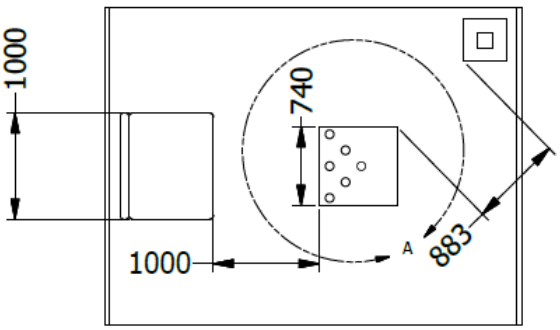
Sitting down and standing up is a general challenge when wearing an exoskeletal device as substantial joint moments about the knee and hip joints are necessary to get up and sit down in a controlled manner. In the first part of this task, pilots are asked to sit down and stand up from a sofa.

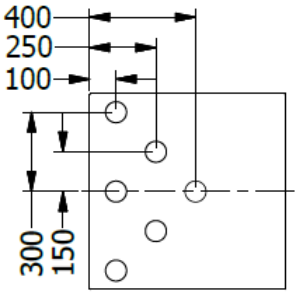
When standing in an exoskeletal device crutches are usually used to maintain balance. However, oftentimes it is required to manipulate objects while standing (e.g. at a kitchen counter). In the second part of this task pilots are asked to stack cups in a target area while standing next to a table.

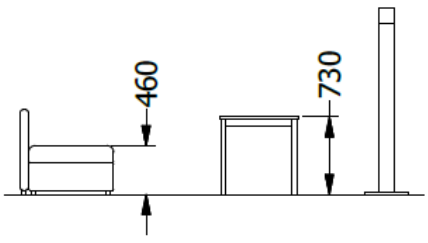
6.4.1.2 Elements



Top: Illustration of task set up and symbolic picture of the type of cup that must be stacked in this task. Pilots must sit down & stand up from the sofa and stack cups while standing next to a table. Sofa is IKEA Vallentuna, table is IKEA Lerhamn, cups are IKEA Kalas. The cup is not proportional in size. Right and bottom: Dimensions of task set up.







6.4.1.3 Task Rules

EXO-SITSTAND-1	Pilots must sit down and stand up once.
EXO-SITSTAND-2	Pilots must sit down completely, i.e. with their full body weight. The knees and the hip are flexed accordingly and the crutches must be lift off the ground once while sitting. Pilots are not asked to touch the backrest with their backs.
EXO-SITSTAND-3	Pilots must stack five cups in the green target area on the table. They are free to conduct the stacking task either with one hand or with both.
EXO-SITSTAND-4	Use of hands, arms and crutches is allowed to stack the cups. If the cups are not stacked at the moment the pilot crosses the finish line of the task, the task is failed.

6.4.1.4 Comments

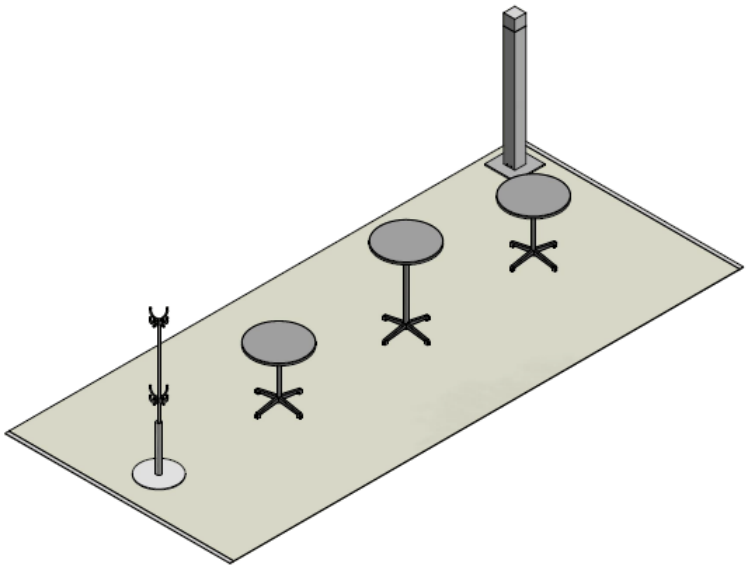
- The referee will verbally confirm correct execution of sitting down and standing up.
- The table is lightweight and not fixed to the ground.
- If any of the cups of the stacking task drop on the ground pilots are allowed to pick them up.

6.4.2 Slalom

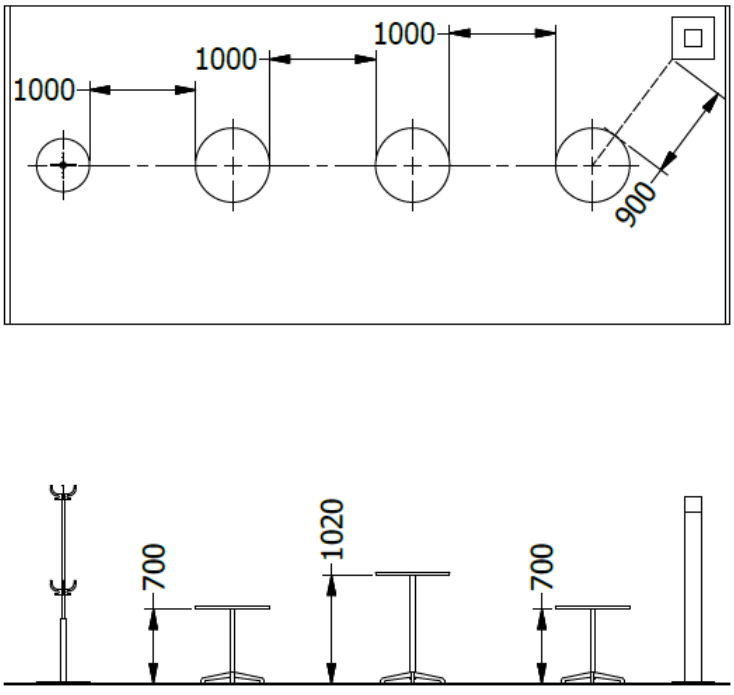
6.4.2.1 Introduction

Often in daily life, it is necessary to navigate around obstacles in order to avoid collisions or to reach a given destination. In this task, pilots negotiate a slalom track composed of single pieces of furniture.

6.4.2.2 Elements



Top: Illustration of task set up. Pilots must pass between each pair of furniture. Coat rack is IKEA Hemnes, tables are IKEA Billsta. Bottom: Dimensions of the task set up.



6.4.2.3 Task Rules

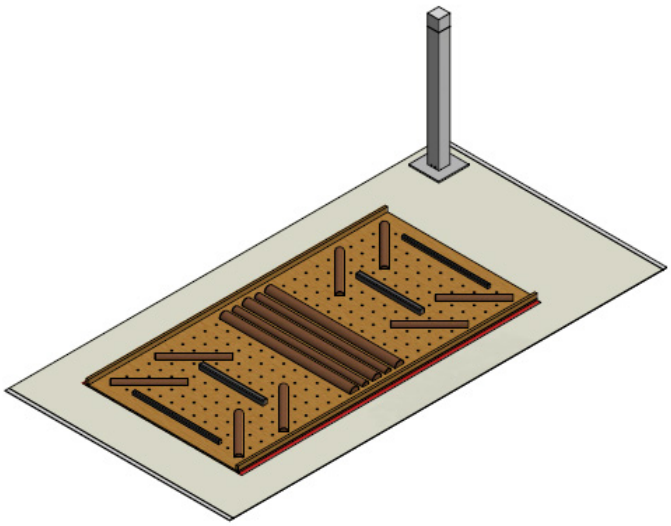
EXO-SLALOM-1 Two consecutive pieces of furniture are considered a pair. To start the task, the first two pieces (i.e. pair) of furniture are entered from the left or from the right-hand side. All three pairs must be passed through once.

6.4.3 Rough Terrain

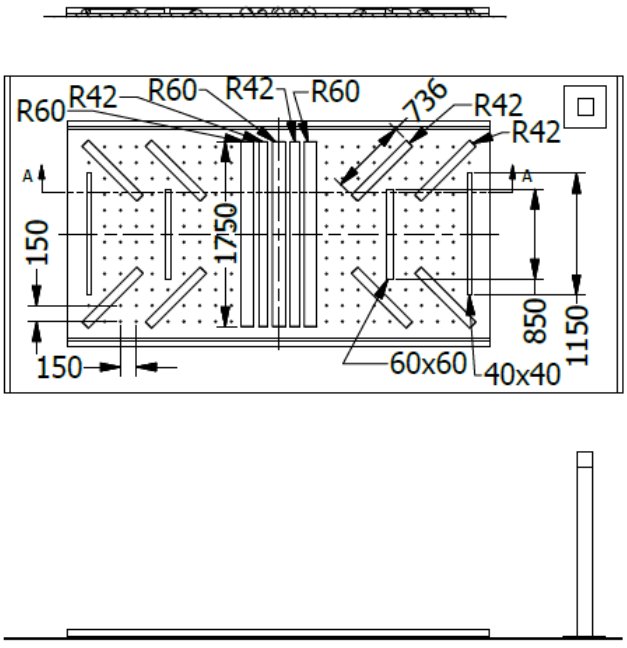
6.4.3.1 Introduction

In certain situations in daily life it is required to step over obstacles on the ground and to accurately control the positioning of the feet (e.g. when entering an escalator or stepping over stones or roots). In this task, the pilot is challenged to negotiate an uneven terrain and the ability to place the foot in a defined location is tested.

6.4.3.2 Elements



Top: Illustration of task set up. Pilots must pass the obstacle once in direction of the race. Bottom: Dimensions of task set up.



6.4.3.3 Task Rules

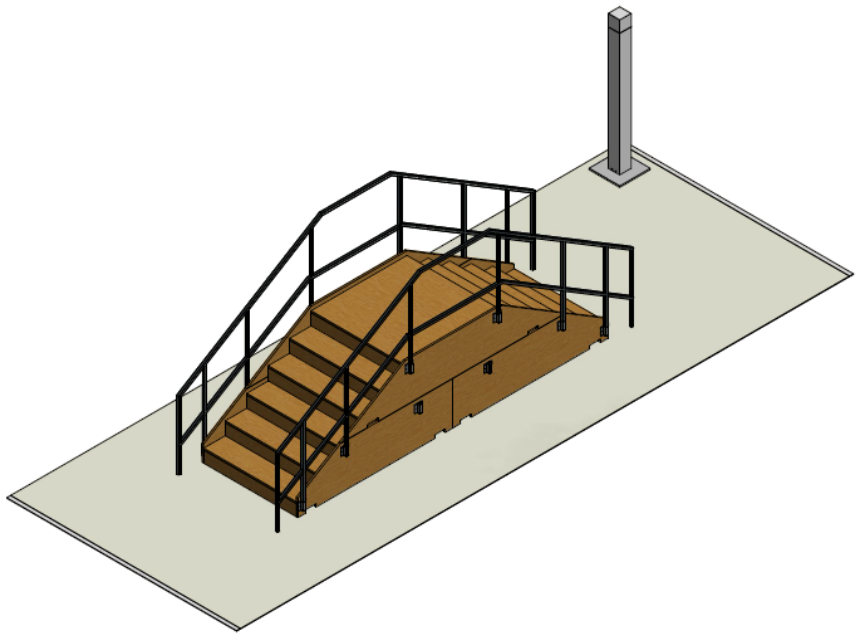
EXO-ROUGH-1	Pilots are free to choose their path across the rough terrain.
EXO-ROUGH-2	Crossing the boundary on the sides is not allowed (i.e. the pilots can only exit at the start and finish). Touching the wooden rails placed on each side or the terrain is allowed, but it is not allowed to step on these rails.
EXO-ROUGH-3	The crutches may be placed anywhere on the obstacle (also outside the red lines).

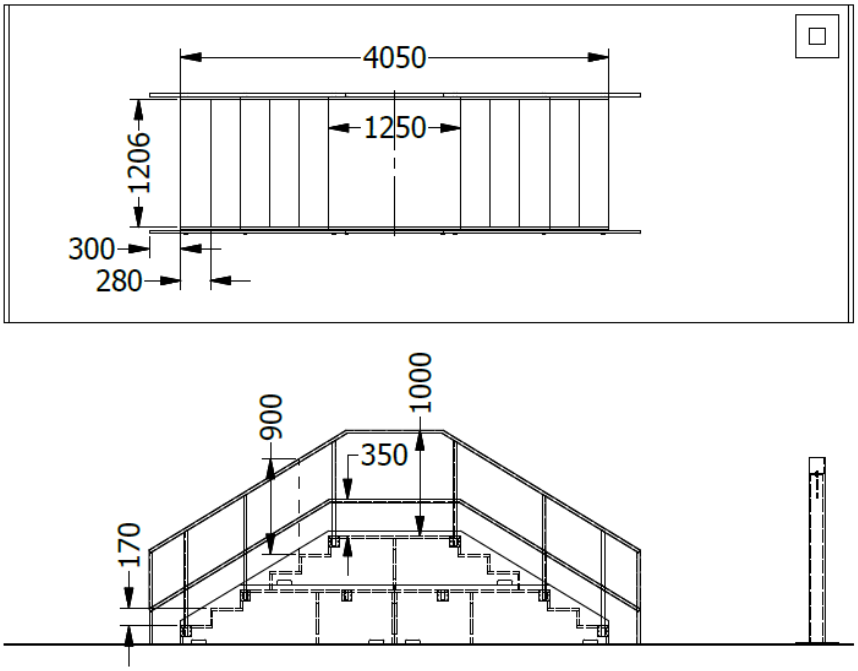
6.4.4 Stairs

6.4.4.1 Introduction

Stairs are very common in daily life. This task tests how well the exoskeleton supports the action of ascending and descending stairs.

6.4.4.2 Elements





Top: Illustration of task set up. Pilots must pass the stairs once in direction of the race. Bottom: Dimension of task set up.

6.4.4.3 Task Rules

EXO-STAIRS-1 Pilots must ascend and descend the stairs once in the direction of the race track (once up, once down).

EXO-STAIRS-2 Pilots are allowed to place two feet on one step.

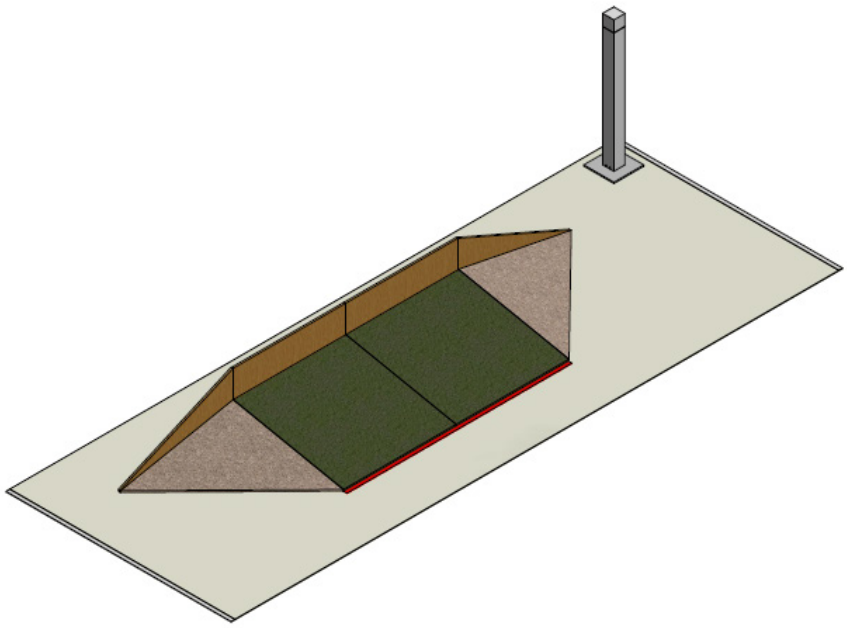
EXO-STAIRS-3 Pilots are not allowed to omit single steps or jump over steps. Thus, each step must be stepped on with at least one foot.

6.4.5 Tilted Path

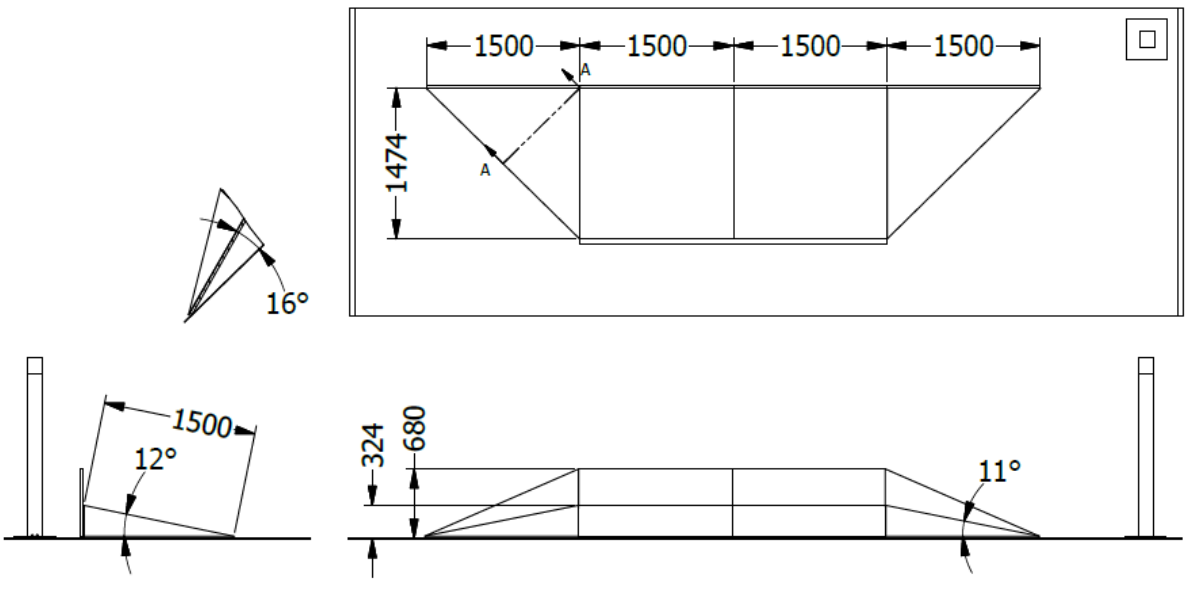
6.4.5.1 Introduction

In daily life, some paths are tilted perpendicular to the direction of travel and walking surfaces may vary (e.g. when walking on nature paths or across a field). Negotiating a tilted path in an exoskeleton is challenging as it requires abduction/adduction in the hip and pronation/supination in the ankle. A tilted path with different surfaces (sanded wood and artificial grass) is used to create the challenge of such a situation.

6.4.5.2 Elements



Top: Illustration of task set up. Pilots must pass the tilted path once in direction of the race. Bottom: Dimensions of task set up.



6.4.5.3 Task Rules

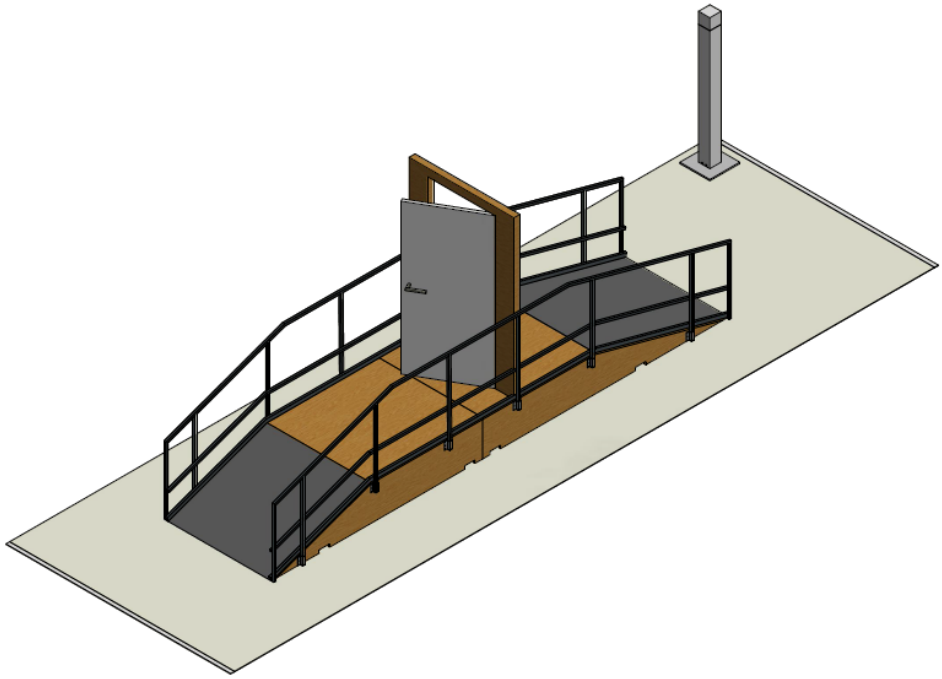
EXO-TILTED-1	Pilots must walk across the tilted path once in the direction of the race. Pilots are only allowed to enter and exit the obstacle on the grey ramps.
EXO-TILTED-2	The crutches may be placed anywhere on the obstacle (also outside the red line).

6.4.6 Ramp & Door

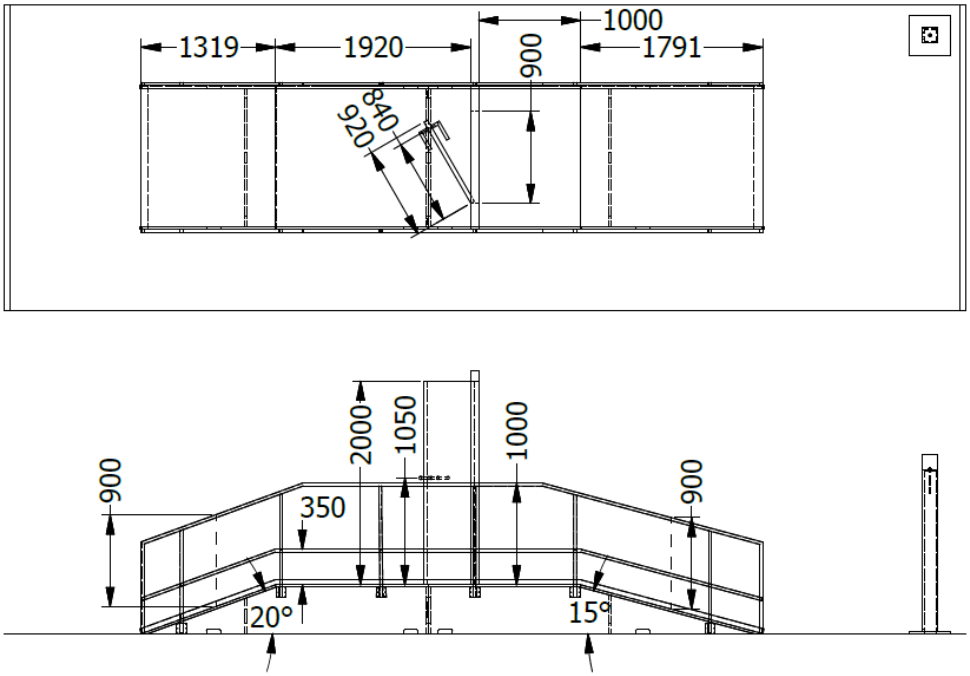
6.4.6.1 Introduction

In this task, the pilots with exoskeletons have to climb a ramp, pass through a doorway and descend a ramp. The ability to negotiate steep inclines and to navigate in confined space (i.e. step backwards and sidewards, respectively) is tested. Moreover, pilots are asked to open and close a door (lever type handle) which challenges them to stand stably.

6.4.6.2 Elements



Top: Illustration of task set up. Pilots must pass the ramp and the door once in direction of the race. Bottom: dimension of task set up.



6.4.6.3 Task Rules

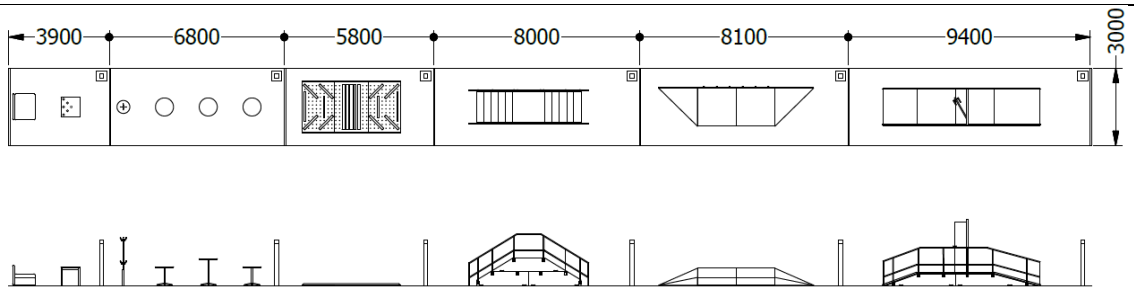
EXO-RAMP-1 The ramp must be ascended on the more inclined slope (20°) and descended on the less inclined slope (15°).

EXO-RAMP-2 The door must be opened, passed through and closed. If the door is not closed when passing the finish line, the task is failed.

6.5 Competition Mode and Scoring System

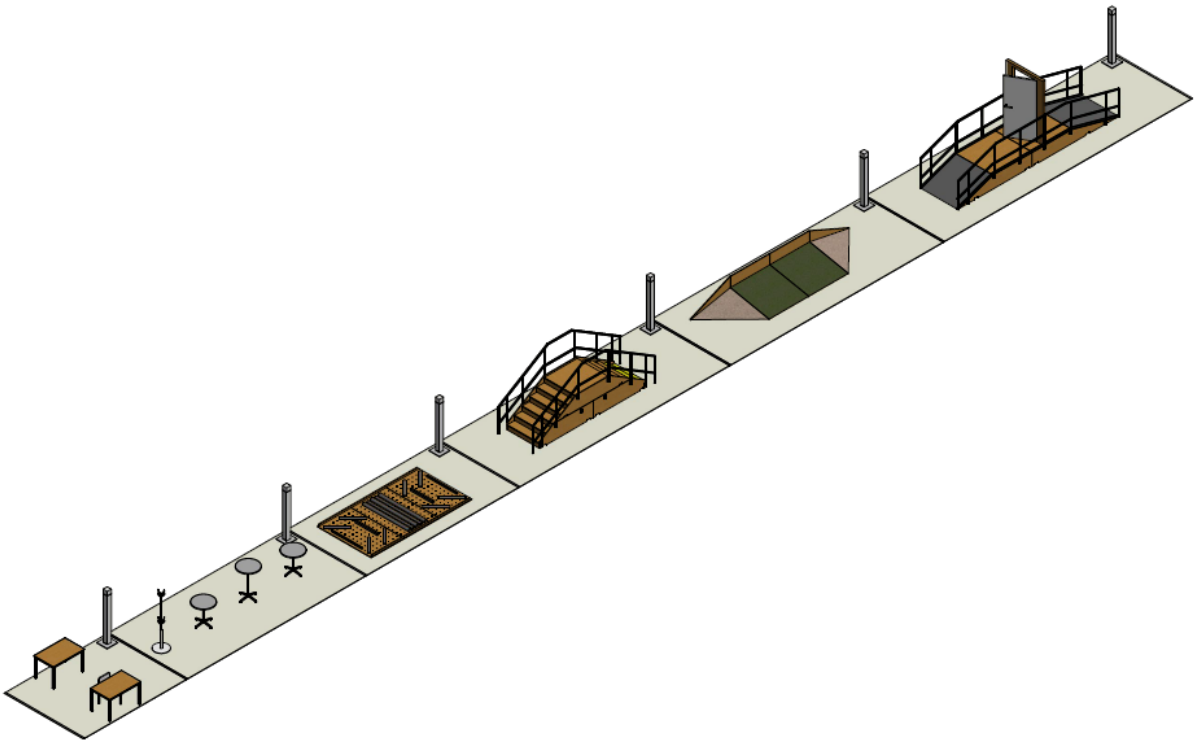
See also sections *1.3* and *0*.

Time limit: 10 min



Task	Sit & Stand	Slalom	Rough Terrain	Stairs	Tilted Path	Ramp & Door	Total
Points	101	102	108	130	115	104	660

7. Powered Wheelchair Race



Overview of Powered Wheelchair Race track. Race direction is bottom left to top right.

7.1 Introduction

Pilots with a severe walking disability (e.g. due to tetraplegia, an amputation or a neurodegenerative disease) equipped with powered wheelchairs are challenged by tasks related to daily life activities. The tasks are designed to test the technology and how skillfully the pilots can navigate their powered wheelchair. Furthermore, the tasks challenge if the design of the devices take in to account size restrictions given in daily life (e.g. the height of a standard table, inner width of a door). Pilots are asked to solve as many tasks as possible in a given time.

7.2 Inclusion Criteria

7.2.1 Pilots

In addition to the general inclusion criteria described in section 1.1, pilots must fulfil the following criteria to be eligible for participation:

- Pilots with severe walking disability due to any kind of central nervous system disease or injury, any systemic neural or muscular disease or bilateral above knee amputation are eligible.
- The pilots must be able to operate and steer their wheelchair. Thus, the pilots must have sufficient voluntary control of head, shoulder, hand, finger, tongue and/or voice in order to operate an input device.

7.2.2 Technology

In addition to the general rules described in section 1.2, the following criteria apply for the powered wheelchair technology:

- Both actuated wheelchairs and manual wheelchairs that are powered by an external device are allowed as long as the power is solely produced by the device and not by the pilot.
- Input (control) devices can include any standard or novel technology such as a hand joystick, head joystick, a sip & puff controller, a tongue drive, headrest switches, a touchpad, a tiller, speech processing methods or any other technology.
- The maximum weight of the wheelchair (excluding the pilot) is limited to 200 kg.
- The width of the wheelchair must be less than 900 mm (otherwise, it cannot pass many of the obstacles).
- Backpacks, bags, etc. are not allowed to be attached to powered wheelchairs during the race (essential equipment is accepted, e.g. oxygen, feeds, ventilators).
- Chest, shoulder, leg, foot and head restraints are allowed.

7.3 Specific Rules

WHL-1 Wearing a helmet is mandatory. The teams are required to bring their own helmet.

WHL-2 If any handrails are used to support movement or action or used to keep balance by grasping, pulling, pushing or similar, with any part of the body, the task is failed. Handrails are provided for safety reasons only.

WHL-3 Touching the ground on (or beyond) the areas marked in the following illustrations in red with any part of the wheelchair or body is not allowed.

WHL-4 Pilots are not allowed to enter or exit the obstacles in any location marked in red in the following illustrations.

WHL-5 Pilots are only allowed to operate the technical support used for opening and closing the door while they are attempting the respective task. During

completion of all other tasks, the technical support must be in a safe state such that it cannot present an impending hazard.

7.4 Task Description

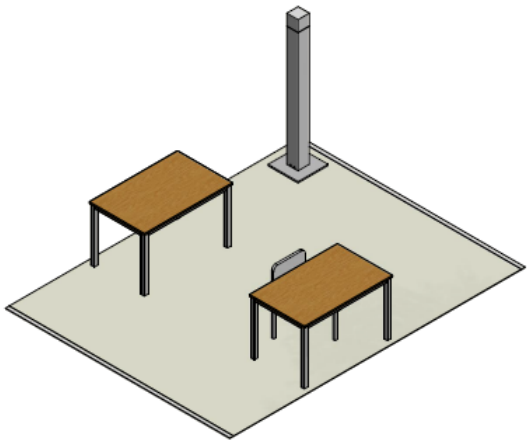
Each task is described in the following sections. In all of the following figures, the direction of the race is (bottom) left to (top) right.

7.4.1 TABLE

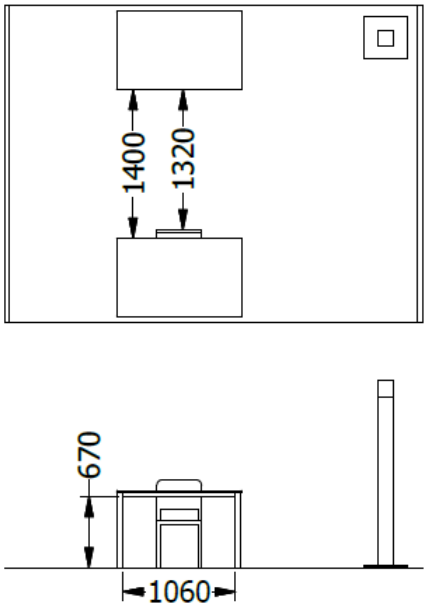
7.4.1.1 Introduction

Powered wheelchairs are often too bulky to fit under a standard table, yet this is critical for social interaction. Pilots should be able to drive close to a table in such a way that the thighs of the pilot fit below the table top.

7.4.1.2 Elements



Top: Illustration of task set up. Pilots must drive underneath the left-hand table and then continue in direction of the race. Tables and chair are IKEA Lerhamn. Right: Dimensions of task set up.



7.4.1.3 Task Rules

WHL-TABLE-1 The knees and half of the thighs must be placed beneath to long side of the left hand table (in the direction of the race track). The pilots are not allowed to remove their feet from the footrest.

7.4.1.4 Comment

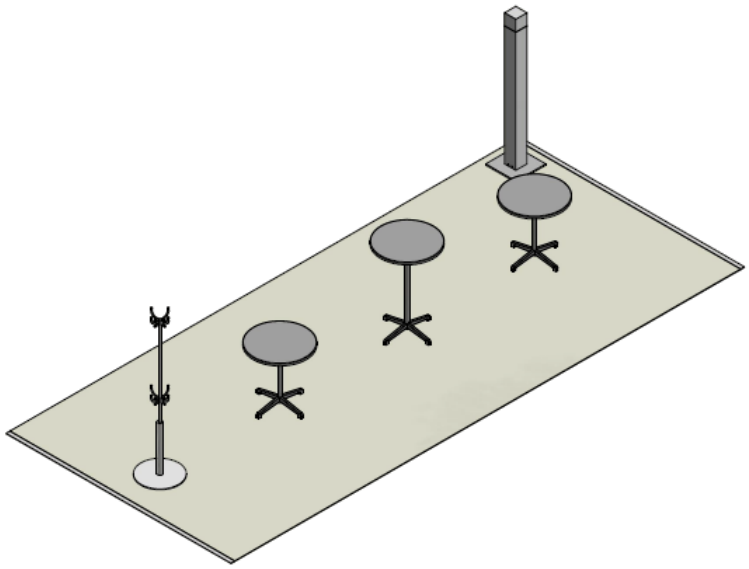
- The referee will verbally confirm correct execution.

7.4.2 Slalom

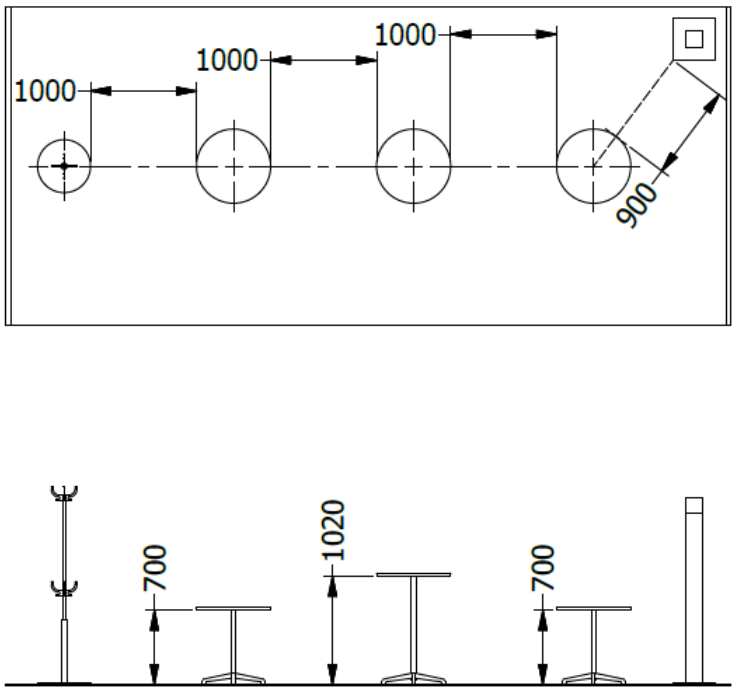
7.4.2.1 Introduction

Often in daily life, it is necessary to navigate around static or moving obstacles in order to avoid collisions or to reach a given destination. In this task, pilots negotiate a slalom track composed of single pieces of furniture.

7.4.2.2 Elements



Top: Illustration of task set up. Pilots must pass between each pair of furniture. Coat rack is IKEA Hemnes, tables are IKEA Billsta. Bottom: Dimensions of the task set up.



7.4.2.3 Task Rules

WHL-SLALOM-1 Two consecutive pieces of furniture are considered a pair. To start the task, the first two pieces (i.e. pair) of furniture are entered from the left or from the right-hand side. The three pairs must be passed through once.

This amendment is **only applicable to the WHL Series in Japan** and replaces the task described under 7.4.2.2.

Elements

Coat rack will be: https://www.nitori-net.jp

The low coffee tables will be: https://www.amazon.co.jp

The high bistro table will be same as defined under 7.4.2.2

Distances between the objects will be the same as defined under 7.4.2.2.

Rules

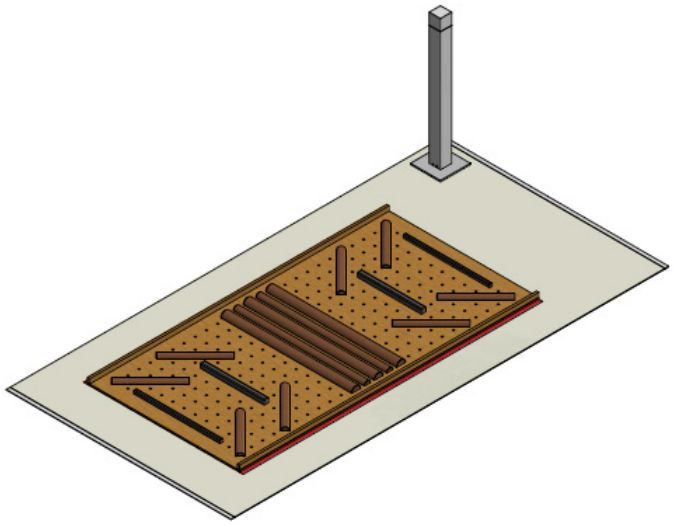
The same rules as defined under 7.4.2.3 will be applied.

7.4.3 Rough Terrain

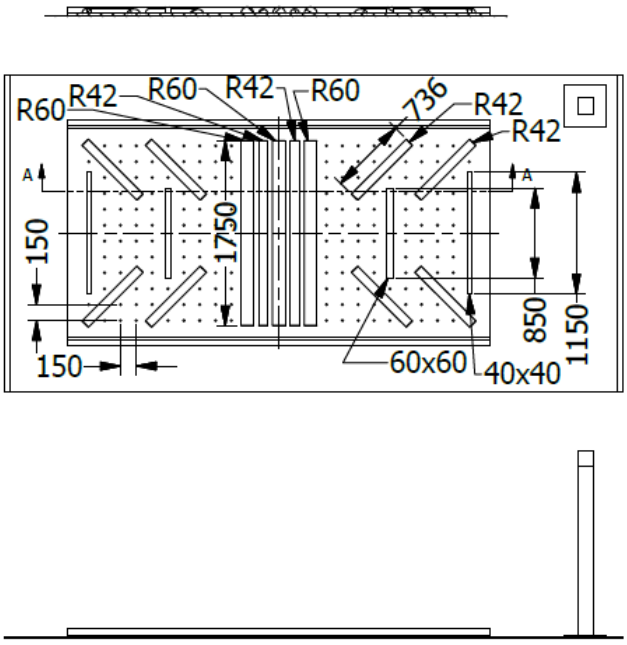
7.4.3.1 Introduction

In daily life, not all surfaces are paved and smooth and powered wheelchairs must be able to cope with such situations. This task tests the ability of a wheelchair pilot to drive over uneven terrain such as cobblestones.

7.4.3.2 Elements



Top: Illustration of task set up. Pilots must pass the obstacle once in direction of the race. Bottom: Dimensions of task set up.



7.4.3.3 Task Rules

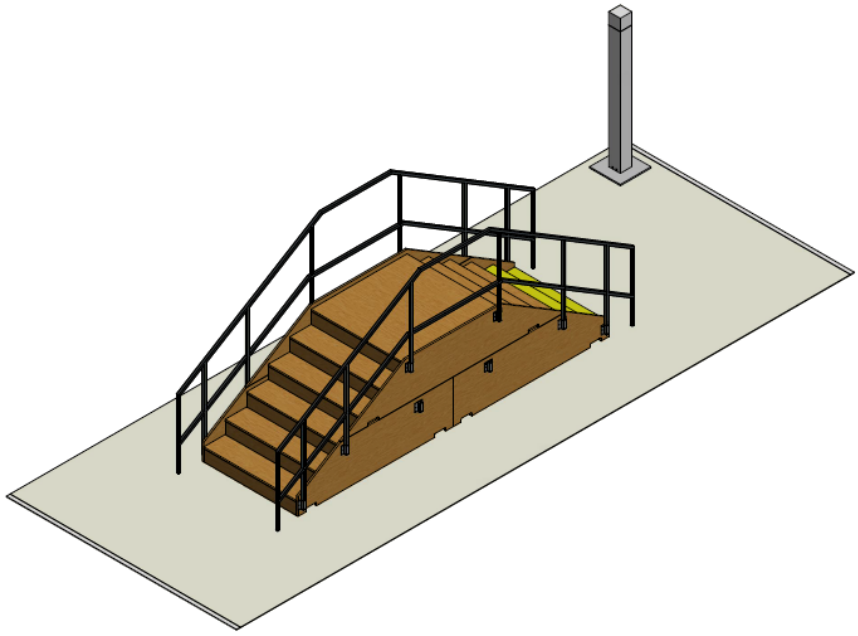
WHL-ROUGH-1 Crossing the boundary on the sides is not allowed (i.e. the pilot can only exit at the start and finish). Touching the wooden rails at the side of the terrain is allowed, however, driving on them is not allowed.

7.4.4 Stairs

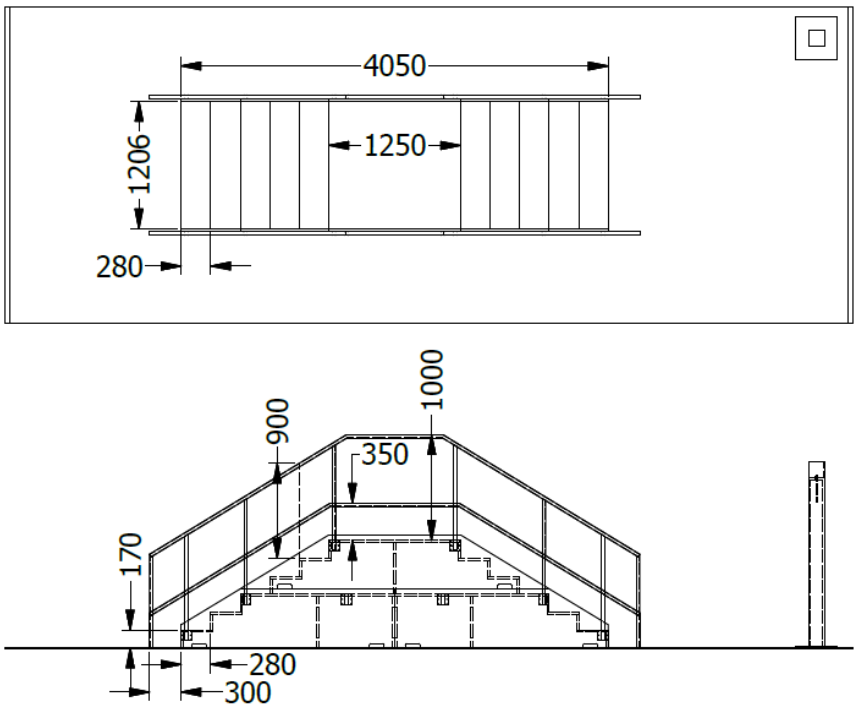
7.4.4.1 Introduction

Stairs are very common in daily life. In this task, pilots with powered wheelchairs have to ascend and descend standard stairs. Pilots have to bring their wheelchair to a standstill while on the descent from the ramp to show that they are able to stop on the stairs at any time.

7.4.4.2 Elements



Top: Illustration of task set up. Pilots must pass the stairs once in direction of the race. While the wheelchair is in contact with the second to last or last step (coloured yellow for visualization purposes) it must be brought to a complete standstill. Bottom: Dimensions of task set up.



7.4.4.3 Task Rules

WHL-STAIRS-1 Pilots must ascend and descend the stairs once in the direction of the race track (once up, once down).

WHL-STAIRS-2 When descending the stairs, pilots must bring their vehicle to a standstill while the foremost part of their wheelchair that can touch the ground is in contact with any part of the second to last or last step and not touching the ground. If the ground is touched before standstill of the vehicle, the task is failed.

7.4.4.4 Comments

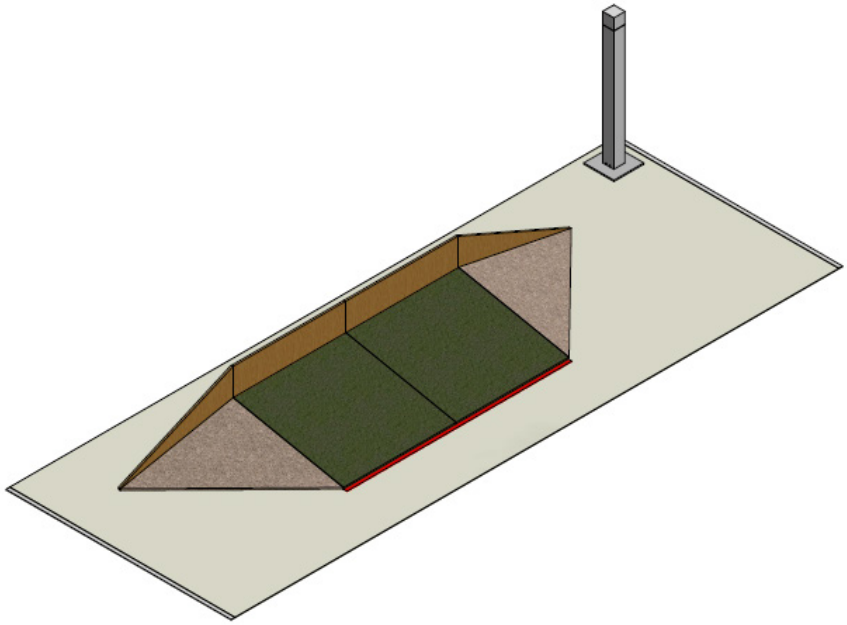
- The second to last and last step will be marked for better visibility.
- The referee will verbally confirm standstill of the wheelchair.

7.4.5 Tilted Path

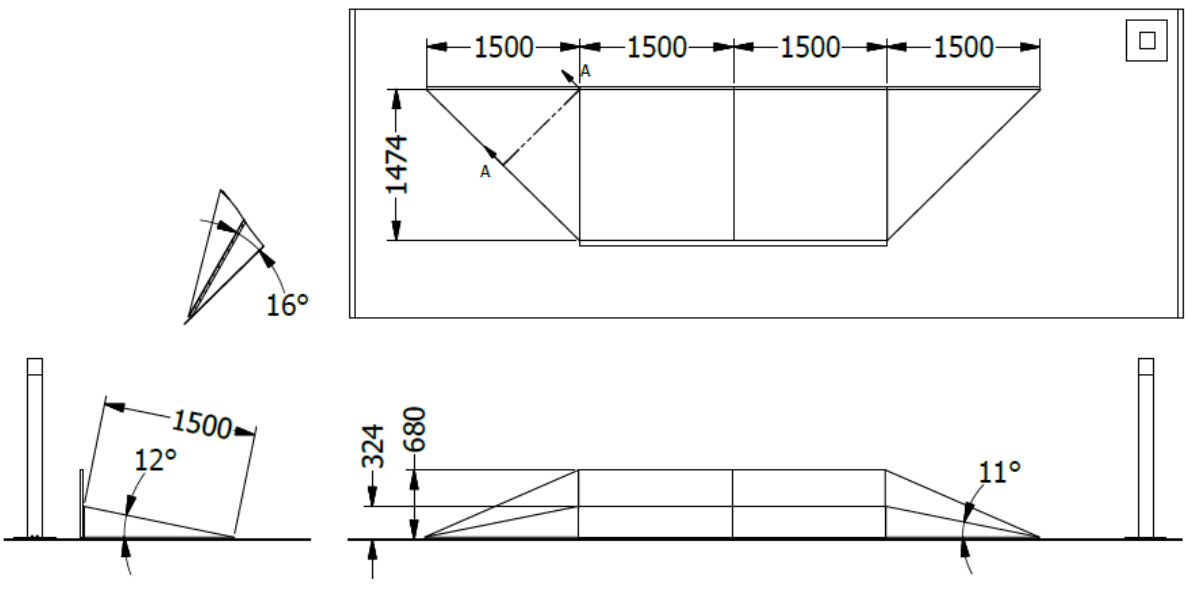
7.4.5.1 Introduction

In daily life, some paths are tilted perpendicular to the direction of travel and surfaces may vary (e.g. when walking on nature paths or across a field). A tilted path with different surfaces (sanded wood and artificial grass) is used to create the challenge of such a situation for the wheelchair pilots and their devices.

7.4.5.2 Elements



Top: Illustration of task set up. Pilots must pass the tilted path once in direction of the race. Bottom: Dimensions of task set up.



7.4.5.3 Task Rules

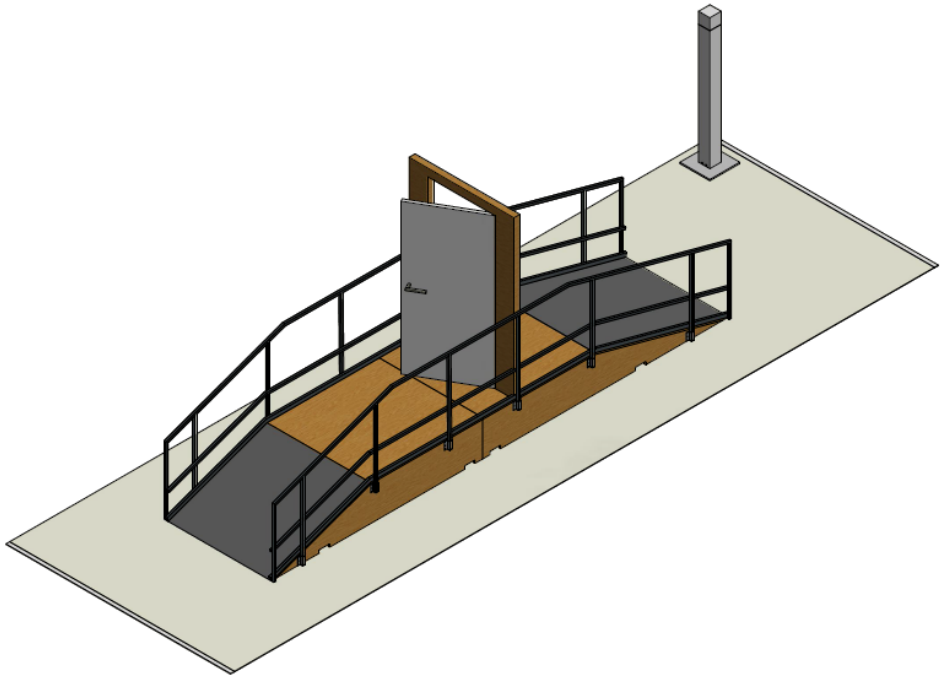
WHL-TILTED-1	Pilots must drive across the tilted path once in the direction of the race track.
WHL-TILTED-2	Pilots are only allowed to enter and exit the obstacle on the grey ramps.

7.4.6 Ramp & Door

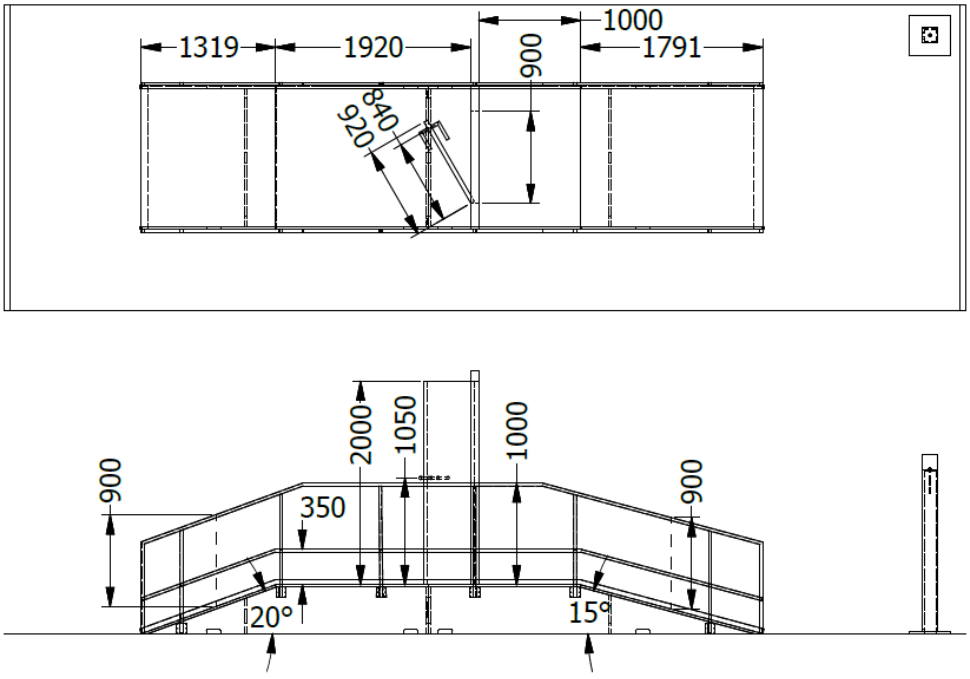
7.4.6.1 Introduction

In this task, the pilots have to climb and descend ramps and pass through a doorway. The ability to negotiate steep inclines and to navigate in confined space (i.e. drive backwards and side wards, respectively) is tested. Moreover, pilots are challenged to open a door and close a door with a technical support. The technical support must be externally powered as is it very challenging for many users of powered wheelchairs to open and close doors.

7.4.6.2 Elements



Top: Illustration of task set up. Pilots must climb the ramp, open and close the door using an externally powered technical support and descend the ramp. Bottom: dimension of task set up.



7.4.6.3 Task Rules

WHL-RAMP-1 The ramp must be ascended on the more inclined slope (20°) and descended on the less inclined slope (15°).

WHL-RAMP-2 The door must be opened and closed using an externally powered technical support (e.g. robotic arm). After opening the door, the pilot must pass through the doorway and then close the door. If the door is not closed when the pilot passes the finish line, the task if failed.

WHL-RAMP-3 The energy required for actuating the externally powered technical support (e.g. positioning, press door handle, open/close door) must be provided by the technical support only and not by the pilot.

WHL-RAMP-4 The technical support is only allowed to be out of its safe state and to be operated while all of the elements of the device transferring load to the ground (e.g. wheels or tracks) are, in their entirety, on the obstacle (i.e. ascending or descending ramps, or horizontal platform).

WHL-RAMP-5 Pilots are not allowed to exchange the end effector of the technical support unless the process is fully externally powered and does not require any manipulation by the pilot other than the operation of the input device.

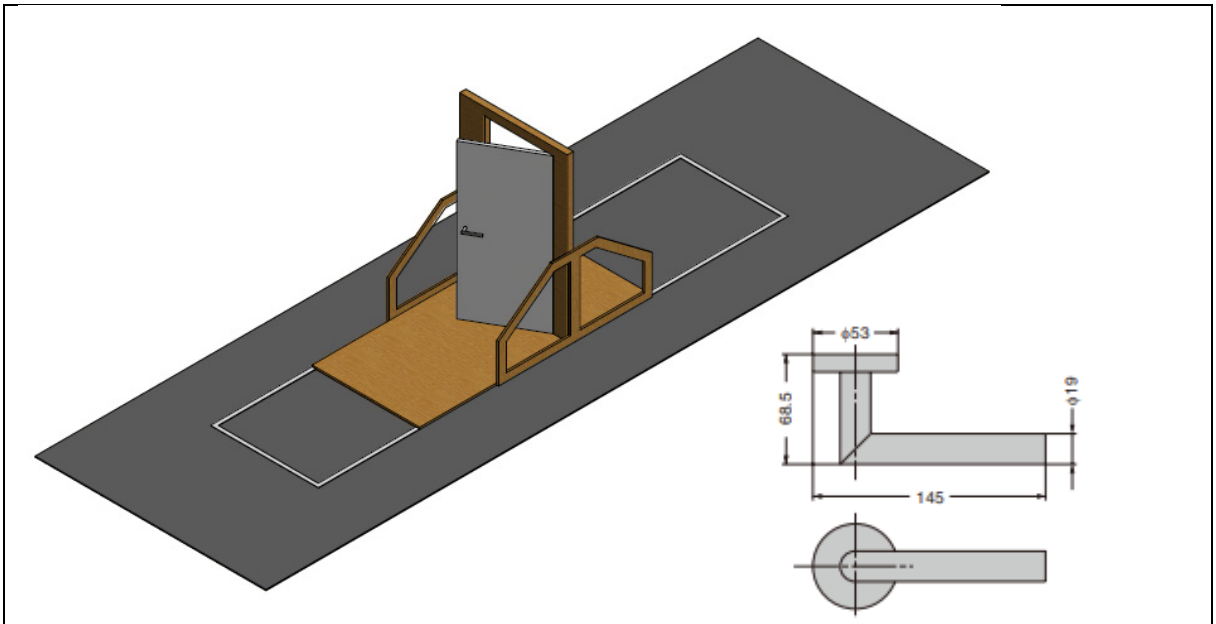
7.4.6.4 Comment

- Re. WHL-RAMP-5: Pilots with good motor function of their upper extremities (e.g. low lesion level) would have an advantage over pilots with more severely impaired motor function of their upper extremities (e.g. high lesion level) if manual exchange of the end effector was allowed.

This amendment is **only applicable to the WHL Series in Japan** and replaces the Ramp & Door task described under 7.4.6:

Introduction

Pilots are challenged to open and close a door with an externally powered technical support. Moreover, the ability to navigate in confined space (i.e. drive backwards and side wards, respectively) is tested.



Top: Illustration of amended Ramp & Door task. Dimensions of the door opening and the width of the platform correspond to those of the Ramp & Door task described under 7.4.6. The detail shows the dimensions of door handle.

Task Rules

WHL-DOOR-1	The door must be opened and closed using an externally powered technical support (e.g. robotic arm). After opening the door, the pilot must pass through the doorway and then close the door. If the door is not closed when the pilot passes the finish line, the task if failed.
WHL-DOOR-2	The energy required for actuating the externally powered technical support (e.g. positioning, press door handle, open/close door) must be provided by the technical support only and not by the pilot.
WHL-DOOR-3	The technical support is only allowed to be out of its safe state and to be operated while all of the elements of the device transferring load to the ground (e.g. wheels or tracks) are, in their entirety, inside the marks on the ground or in contact with the horizontal wooden platform.
WHL-DOOR-4	Pilots are not allowed to exchange the end effector of the technical support unless the process is fully externally powered and does not require any manipulation by the pilot other than the operation of the input device.

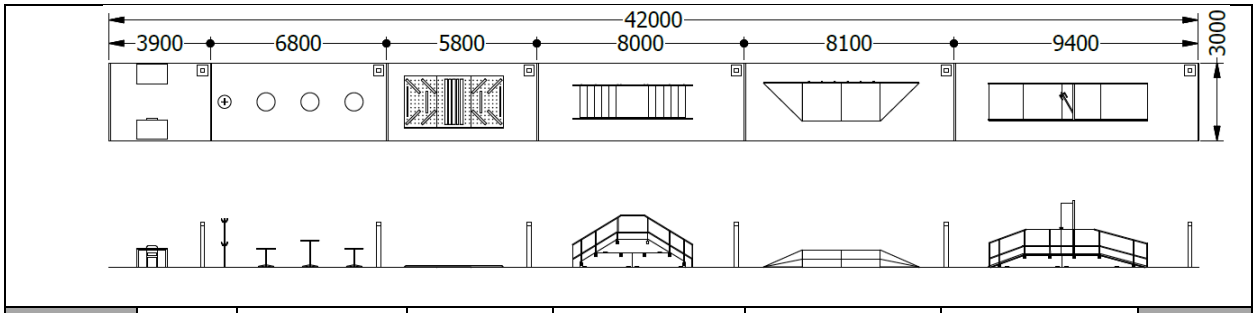
Comment:

- The marks on the ground represent the ground contact area of the Ramp obstacle as outlined under 7.4.6.2.
- Re. WHL-DOOR-3: Pilots with good motor function of their upper extremities (e.g. low lesion level) would have an advantage over pilots with more severely impaired motor function of their upper extremities (e.g. high lesion level) if manual exchange of the end effector was allowed.

7.5 Competition Mode and Scoring System

See also sections *1.3* and 1.4.

Time limit: 8 min



Task	Table	Slalom	Rough Terrain	Stairs	Tilted Path	Ramp & Door	Total
Points	101	102	108	115	104	130	660