

TETSUJIN 2005

Powered Exoskeleton Challenge at



**October 6-9 2005
San Jose Convention Center
San Jose, CA.**

Tournament Rules

Version 2.0.04-39

Revised 5/21/2005 5:08 PM



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1 THE CHALLENGES!

Build powered, articulated, strength-augmenting exoskeleton(s) for a human operator capable of meeting one or more of the three challenges. Each challenge focuses on a single area of exo-suit development. Competitors may enter any or all of the challenges; competitors may enter a single suit or multiple suits optimized for each challenge.

- **Challenge 1: Weightlifting.** Ascend stairs in your suit to the lifting platform and lift a load of from **100** to **1000** lbs from a squatting position to a height of at least 24 inches, return the load to the ground in a controlled manner, and descend the stairs. Stair-climbing may be unpowered. The winner is the competitor who lifts the largest weight.
- **Challenge 2: Dexterity.** Stack 9 concrete cylinders weighing ~70 pounds each in a 4-3-2 vertical arrangement. The winner is the competitor who arranges the cylinders in the shortest time.
- **Challenge 3: Walking Race.** Walk the challenge course carrying a load in the shortest time. A time bonus is granted based on the load carried.

1.1 The Spirit and Intent of These Rules

Tetsujin is designed to foster the development of strength amplification implementations. These have many potential applications in real life: powered exo-skeletons can provide mobility, amplify strength, and make tasks that are difficult or impossible for an unassisted human easy.

To further these ends, the Tetsujin organizers are looking for entries that embody the spirit and intent of these rules, namely the development of **powered, articulated** exo-suits that provide **strength amplification** for a human operator. The organizers recognize that this is a very difficult problem space. The **minimum acceptable designs** must exhibit the following characteristics:

- The operator must be **inside** the suit in order to operate it
- The suit must provide sufficient articulation in the powered components to track the movements of the human operator to meet the challenge
- Movement of the suits powered components must be initiated by, and track, the movements of the human operator – e.g. to make the suit squat, the operator squats; to lift a load with the suit arms, the operator's arms make the necessary lifting motions. This can be as simple as micro-switches and limit switches or as complex as closed-loop servo control and bio-electric sensors.

The design review process will identify problem areas and designs that do not meet the minimum requirements. Builders with questions about the acceptability of their designs should contact the organizers as soon as possible.

2 SCHEDULE

The dates of three important milestones preceding the event are listed below:

- **Milestone 1:** Submit a design document describing the system you are entering including the non-refundable entry fee by **June 13, 2005**.
- **Milestone 2:** Submit photographs of the system documenting actual progress by **August 15, 2005**.
- **Milestone 3:** Submit video of the system in operation by **September 26, 2004**.
- **Competition:** Oct 6-9, 2005 in San Jose, CA. at RoboNexus. See www.robonex.com for information on RoboNexus.

3 TOURNAMENT FORMAT AND RULES

3.1 Common Elements of Exoskeleton Design

3.1.1 Self-contained Power

All power for the exoskeleton and any required support systems must be provided by a self-contained system. The system may incorporate remote components connected via a tether, wireless link, etc.

3.1.2 Self-contained Mechanism

The tasks(s) must be accomplished by powered elements that are an integral part of the exoskeleton in response to the operator's movements. External devices such as winches, support frames, jacks, etc. are not allowed.

3.1.3 Auxiliary Supports

The exoskeleton must be able to balance and support itself, the operator, and the load without the use of outriggers, auxiliary braces, etc. other than its own legs and feet. A fixed base is allowed for the Cylinder Stacking challenge.

3.1.4 Stored Mechanical Energy

Stored mechanical energy devices such as springs, torsion bars, gas struts flywheels, etc. are all allowed, **however** all such devices must enter and leave the lifting, walking, and stacking areas in the **unloaded** state. Loading of springs etc. must take place in the challenge area during the time allowed for the challenge. For timed challenges, the time to load a stored mechanical energy device is counted towards the total time.

3.1.5 Emergency Stop

The exoskeleton shall have a removable power link that disables all operation. The link shall be located at the rear top center of the exoskeleton so that it can be pulled by event staff in any situation requiring an emergency shutdown of the competitor's system.

The E-Stop attachment point must accept a snap-hook with a snap opening of no more than 0.5 inches, such as McMaster-Carr part #3716T54 or equivalent.

3.1.6 Operator Protection

Due to the nature of the challenges, attachment of the suit to a spotting system at all times is not practical. All suits entered in the Weightlifting and Walking Race challenge must have adequate protection for the operator in the event of a fall – for example a safety cage. Entrants in these events must wear DOT-approved motorcycle crash helmets while operating their suits.

3.2 Weightlifting

Each team has at least **two** opportunities to achieve a winning weight – these are called "Lift Sessions".

Prior to each lift session the team selects a starting weight. When the team is called to the lifting area the selected starting weight will be on the bar. The team has **10 minutes** to leave the starting circle and ascend the stairs to the lifting platform wearing their suit, complete a minimum of one valid lift and a maximum of 3 valid lifts, descend the stairs and return to the starting circle. After each lift the team has the option of adding weight to the bar and lifting again without leaving the platform.

The clock will be stopped while:

- the suit is attached to the spotting system
- additional weight is added to the bar
- the suit is detached from the spotting system following the lift.

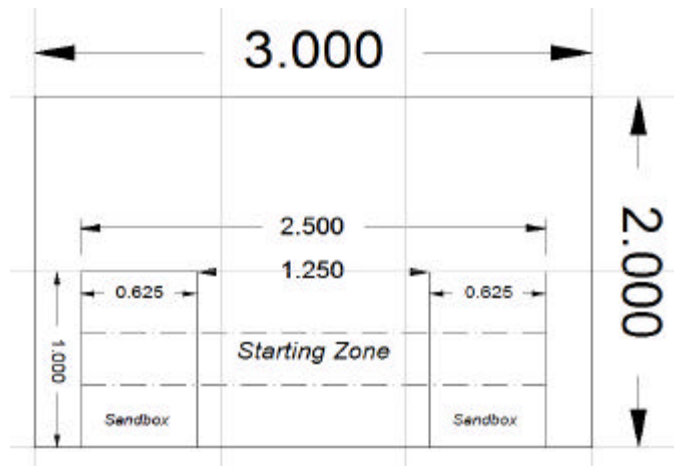
3.2.1 Score

The highest weight from each lift session is recorded. After the last lift session the highest weight lifted is recorded. The tournament winner is the team with the highest weight lifted after the last lift session of the tournament. In the event of a tie the shortest elapsed time for a lift session at the tie weight shall be the winner.

3.2.2 Lifting Area

Each lifting area is 3M x 2M. The bar and attached weights are placed in a **starting zone** centered at the front edge of the lifting area (see diagram). The weights rest in a pair of "sandboxes" located at the outed edges of the starting zone. The surface of the sandbox is as level as possible with the surface of the lifting area. All dimensions in the diagram are in **meters**.

The feet of the competitor's suit must not extend outside the edges of the lifting area nor over the sandboxes when positioned to begin a lift.



3.2.3 Stairs

There are two sets of stairs, one at the rear of the platform and one at the front. Each staircase is **48" wide**. The steps are **24" deep** and **6" high**. There are two steps in each staircase, with the final (third) step being the platform itself. The platform is **17" above floor level** so the third step is **5"** above the top step of the staircase.

3.2.4 Weights

The bar and weights are standard Olympic weightlifting equipment, as supplied by <tbs>.

- **Bar:** <tbs>
- **Plates:** 5, 10, 15, 20, 25, 50 and 100 lb. each. Mounted in pairs. The diameter of the largest (100 and 45 lb.) plate <tbs>

The event organizers and officials shall have sole discretion on the amount of weight allowed for a given suit or suits,

3.2.5 Valid Lift

No part of the exoskeleton may extend into or over the sandboxes. At **no time** can any part of the exoskeleton touch the surface of the sandboxes.

A valid lift begins with the bar placed in the **starting zone**. The starting zone is a 30cm wide strip centered on the long axis of the sandboxes. The bar may **not** be moved while in contact with the surface of the sandbox, e.g. rolling or dragging the load is not permitted – the load **must** be lifted cleanly from the starting zone.

The bar must move 24 vertical inches for a valid lift..

3.2.6 Releasing the Load

After a valid lift is achieved the bar and attached weights must be lowered back to the surface of the lifting area. Dropping the load is not permitted. The bar and weights do **not** have to be returned to the starting zone, **however** the weights must rest in the sandboxes when lowered fully. Failure to return the load in a controlled manner will invalidate the lift.

3.2.7 Team Members

A team may have **at most** two team members in addition to the suit operator present on the lifting platform. Team members on the platform must be present for the **sole purpose** of assisting in spotting the operator during a lift. Team members **may not assist in the lift in any way**.

3.2.8 Exoskeleton Design

3.2.8.1 Grippers

The operator must lift the load by grasping the bar with grippers located at the end of the exoskeleton's arms, as an unassisted weightlifter would. Static attachment of the load to the suit is not permitted. The grippers must be able to engage and release the load in response to operator motion.

3.2.8.2 Mobility

The operator **must** walk, ascend, and descend stairs while wearing the exoskeleton. Walking and traversing stairs may be powered or unpowered.

3.2.8.3 Attachment to the Lifting Area

The exoskeleton must not use any mechanism or method to attach itself to the lifting area surface – for example suction devices, magnets, adhesives, mechanical fasteners, etc.

3.2.8.4 Dimensional Limits

No part of the exoskeleton may extend beyond the 2M x 3M lifting area with the operator standing erect at the position selected to begin a lift. The maximum height of an exoskeleton with the operator standing erect is 3M.

3.2.8.5 Load Attachment Points

The exoskeleton shall have a load attachment point capable of supporting the suit, operator and 150% of the maximum weight the team intends to lift. The load attachment point must be capable of supporting the load with the power removed.

3.2.8.6 Spotting System Attachment Points

The exoskeleton shall have rigid attachment points located at the top rear left and right for connection of the spotting system. The spotting system supports the suit and operator during a lift session in the event of a loss of balance, power failure, etc.

The spotting system attachment points must be capable of withstanding a shock load of at least 2x the combined weight of the exoskeleton and the maximum intended lift weight. The attachment points must accept a snap-hook with a maximum opening of 1.75 inches, such as McMaster-Carr part#3927T43 or equivalent.

3.3 *Dexterity – Cylinder Stacking*

Each team has at least **two** opportunities to achieve a winning time. These are called “Stacking Sessions.”

Prior to each stacking session the team positions their suit in the stacking area. Each team is allowed **10 minutes** to move their suit into position and prepare it for the challenge. This time includes the time required for the operator to enter the suit. If the team takes more than 10 minutes the excess time will be added to their stacking session time.

When the team indicates that they are ready the Tetsujin official will start the challenge clock and signal the operator to begin. The operator must then move the 9 concrete cylinders from the starting area to the destination area, arranging them in the prescribed manner. When the cylinders are arranged **or** the allowed maximum time of **5 minutes** has passed the Tetsujin official will stop the challenge clock and record the time and number of cylinders arranged.

The team is then allowed **10 minutes** to remove their suit from the stacking area. If the team takes more than 10 minutes the excess time will be added to their stacking session time.

3.3.1 Time Bonus

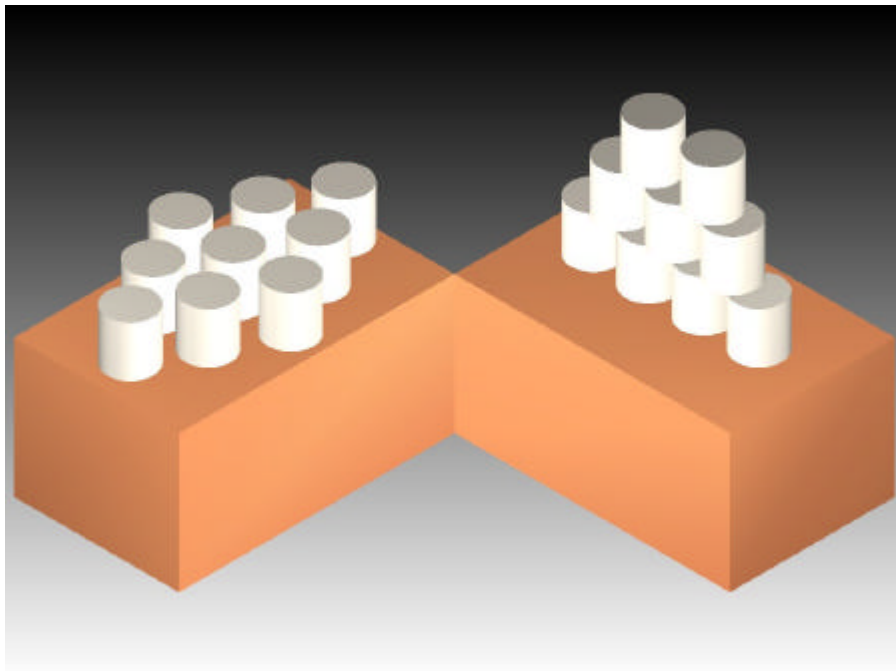
The competitor receives a 5 second time bonus for each correctly-arranged cylinder. The time bonus is subtracted from the challenge time.

3.3.2 Score

The adjusted time (actual – bonus) is recorded for each stacking session. After the last stacking session the team with the lowest time is the winner.

3.3.3 Stacking Area

The stacking area consists of two platforms, 30” high, at least 5’ in length, and at least 3’ deep. The platforms are placed at right angles to each other. The exo-suit will be positioned in the corner created by the two platforms. 9 concrete cylinders are placed in the “starting circle” in a roughly hexagonal arrangement on one of the platforms. The destination platform has a “finish rectangle” marked on it, 4’ long by 1’ deep. The 9 cylinders must be arranged in the finish rectangle in three layers – 4 cylinders in a row on the bottom, completely within the rectangle, three cylinders placed in a second row atop the first and the final two cylinders placed atop the second row, in a pyramidal arrangement (see rendered image below).



3.3.4 Cylinders

The cylinders are 10" in diameter and 11" tall, made from standard gravel mix available at any building supply store. Standard 10" diameter concrete form tube is used to cast the cylinders. Each cylinder weighs ~70 lbs. Home Depot part numbers for the form tube and gravel mix are <bs>.

3.3.5 Valid Arrangement

A competitor completes a valid arrangement when the 9 cylinders are stacked in the prescribed 4-3-2 manner in the destination rectangle.

3.3.6 Exoskeleton Design

3.3.6.1 Grippers

The operator grasp the cylinders with grippers located at the end of the exoskeleton's arms, as an unassisted human would. Static attachment of the load to the suit is not permitted. The grippers must be able to engage and release the load in response to operator motion.

3.3.6.2 Mobility

Mobility is not required for the Dexterity Challenge. The powered, articulated elements of the suit may be mounted to a fixed base.

3.3.6.3 Attachment to the Stacking Area

If the design of your suit requires attachment to the floor of the stacking area please contact the Tetsujin organizers at the earliest possible date so we can discuss your needs with you.

3.3.6.4 Dimensional Limits

The base of the exo-skeleton may not exceed 1.5m x 1.5m. The maximum height in any configuration may not exceed 3m.

3.3.6.5 Spotting System Attachment Points

The exoskeleton shall have rigid attachment points located at the top rear left and right for connection of the spotting system. The spotting system supports the suit and operator during a stacking session in the event of a loss of balance, power failure, etc.

3.4 Walking Race

Each team has at least **two** opportunities to achieve a winning time. These are called "Races".

Prior to each race the team positions their suit in the starting circle. The team is allowed **5 minutes** to position their suit in the starting circle and prepare it for the race. If the team takes more than 5 minutes, the excess time will be added to their race time.

When the team indicates that they are ready the Tetsujin official will start the challenge clock and signal the operator to start. The operator must then complete a circuit of the race course. When the competitor crosses the finish line the Tetsujin official will stop the clock and record the time.

The team is then allowed **5 minutes** to remove their suit from the finish circle. If the team takes more than 5 minutes the excess time will be added to their race time.

3.4.1 Score

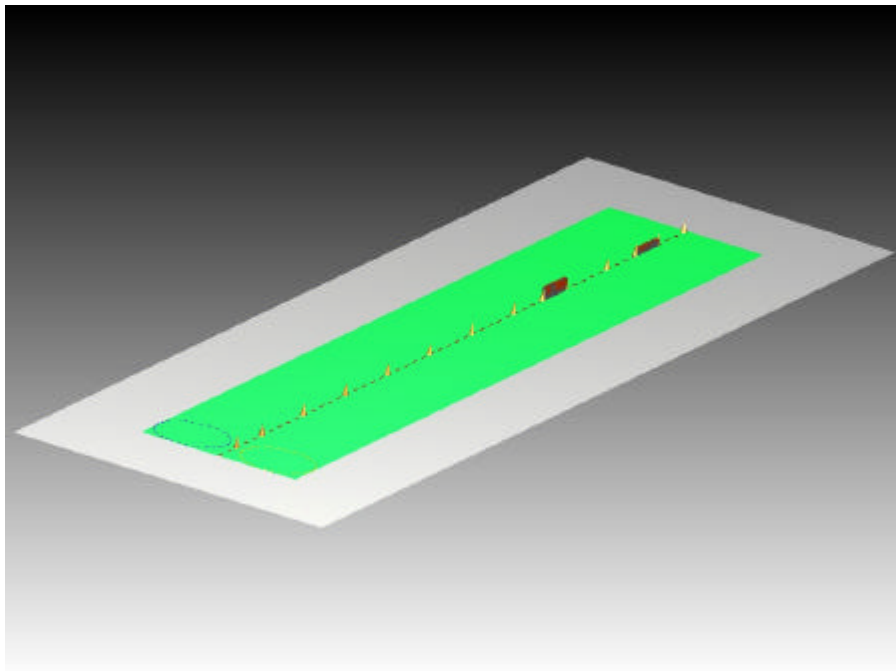
The time is recorded after each race and adjusted for any weight bonus (see below). After the last race the team with the lowest adjusted time is the winner.

3.4.2 Race Course

The race course consists of two 100' lanes on a section of flat, finished concrete floor. Orange traffic cones separate the lanes. Competitors must walk down one lane of and return along the other lane. At the far end of the course the lanes are separated by a low wall for a distance of 5'. The wall is at least 6" but no more than 9" tall. A competitor must step over the wall at the far end of the course to enter the "return" lane.

3.4.3 Short Cut Wall

A second 5' wall, 18" high, is located 75' from the start/finish line. A competitor may choose to shorten the course by stepping over this "short cut wall" to enter the return lane.



3.4.4 Time Penalty

A competitor who elects to shorten the course by stepping over the wall must do so without knocking down or displacing any part of the wall. A competitor knocking down or displacing any part of the wall will incur a **60 second** penalty.

3.4.5 Time Bonus

Walking race competitors are encouraged to carry a load. For each 25 lbs of load carried the competitor will receive a 1 second time bonus. Thus a competitor who completes the course carrying an additional 100 lbs will receive a 4 second bonus (reduction) in their race time.

The maximum load a competitor can carry during a race without prior review and approval is 400 lbs. A competitor may apply to the event organizers for a waiver increasing the limit to 1200 lbs. To obtain the waiver the competitor **must**:

- Request the waiver as in writing as part of the **Milestone 1** design document
- Meet all of the event milestones listed in Section 2
- Provide a video of the suit walking with the weight requested as part of the **Milestone 3** video.

3.4.6 Weights

The weights are the 25 lb weights used in the Weightlifting challenge, as described in 3.2.3 above. Specific dimensions of the 25 lb weights are:

- Slightly greater than 11" in diameter
- 1.5" thick at their thickest point
- 2" bore

3.4.7 Valid Course Completion

The competitor achieves a valid course completion by traversing the entire course under power and crossing the finish line.

3.4.8 Exoskeleton Design

3.4.8.1 Mobility

Powered Walking is required.

3.4.8.2 Weight Mounting Points

The suit must provide secure mounting points adequate to support the load the team elects to carry.

3.4.8.3 Dimensional Limits

The exo-skeleton must fit inside the 1,5m diameter starting circle. . The maximum height in any configuration may not exceed 3m.

4 GENERAL

4.1 Event Organizers and Officials

The Event Organizers and officials shall have sole discretion regarding the suitability of a given entry for competition, compliance with the rules as described herein, and any other matter relating to this event whether explicitly defined or not. Decisions of the Event Organizers and Officials are final.

4.2 Advertising - Sponsor Logos

The exoskeleton shall provide 2 reserved spaces of at least 4" x 6" on the front for display of Tetsujin event sponsor logos. Team sponsor logos may be placed anywhere on the competitor's system provided that the logos:

- Are tasteful, e.g. do not involve offensive language or graphics
- Do not conflict with the event sponsors.

Additional details will be provided as the event develops, but SERVO Magazine does not want to discourage the acquisition of sponsors. Decisions of the event organizers regarding team sponsor logos are final.