1999 WALKING MACHINE DECATHLON™

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1. INTRODUCTION/PHILOSOPHY/GOALS

This package contains the rules for the Walking Machine Decathlon , an annual international competition open to all undergraduate students, which brings into focus the inter-disciplinary nature of engineering.

The Decathlon's objectives are:

- To encourage undergraduate interdisciplinary cooperation among engineering departments and computer science in the design, building, and testing of walking machines. To promote familiarity with, and the technological advancement of, the components and systems necessary for the construction and development of robots (including telerobots) and other complex intelligent machines.

- To challenge students to think creatively about an evolving technology.

- To give students exposure to project planning and budgeting, as well as scheduling that is constrained by a deadline.

- To publicize and promote engineering in general, robotics in particular, and the participating individuals, their accomplishments, and their universities.

There are many potential applications for some type of walking machine for the future. Walking robots will be important in the medical field, where the mobility of disabled patients is important; in space for planetary exploration, where the terrain is rugged, or for mobility on a space station; in undersea missions for dredging or salvage; in radioactive environments, such as for nuclear power plant maintenance; in military logistic support where there are no highways; and in underground mining.

The Walking Machine Decathlon involves ten events of varying difficulty for the Walking Machines to attempt. The reasons for defining the competition as a series of events in the format of a decathlon are:

- To encourage participation by as many universities as possible. We do not want to limit the contest exclusively to those schools that have ample resources and/or experience. Schools should be able to compete to an extent consistent with their experience, resources, and goals. Actually, limitations might even provide for very creative solutions to problems.

- To encourage interdisciplinary cooperation among students working in teams on specialized projects toward a common goal, where communication and sharing of information become essential.

- To engage the interest of the students at different levels of technological development or problem difficulty.

- To provide the students with a sense of what the future holds for this type of technology.

The disciplines that will be addressed by the Decathlon are: kinematics, kinetics, dynamics, controls, materials science, structures, computer science, sensing technology, artificial intelligence, and computer assisted engineering. Some issues that will have to be addressed are: safety,

environmental changes such as those caused by obstacles and terrain, the sensing of and interaction with static and moving objects, real-time control, human factors for supervisory control by an operator, artificial intelligence for autonomous control, and the response of the Walking Machine to natural language.

The benefits to the students from the Walking Machine Decathlon include:

- Awareness of the many areas of technology and of the interdisciplinary approach required for a project such as for the design, construction, and testing of a walking machine.
- Awareness that not all problems in robotics are solved.
- The challenge to think creatively about technology which is still undeveloped.
- Teamwork with the purpose of deciding on and then attaining common goals through individuals specializing in different areas.
- Involvement in a long-term project where organization, goals, schedules and interdisciplinary activities are necessary.
- Preparation for industry, where hands-on, practical experience is very beneficial.
- The challenge to pursue graduate studies with a research orientation resulting from a newly found appreciation for robotics discovered in this competition.

The Decathlon will feature a keynote speaker, student presentations, the competition itself, social events, and, when possible, tours of the host university, local industry or government facilities. Proceedings will be distributed to participating universities after the Decathlon in order to document the results achieved by the students through the technical poster papers and to encourage future participation. Past Decathlon results are listed in the Appendix as A-1. Guidelines for the host university and for the judges are provided in the Appendix as A-2.

The intent in establishing the rules included in this package is to make them as clear and simple as needed for competition. The events themselves are defined in terms of goals. Hopefully, this will have the effect of giving participants the opportunity to explore and evaluate several options for an efficient design to achieve the goals of each event. It will also allow participants with less experience and/or resources the opportunity to participate and to apply creative solutions. Creating the potential for participants to bring many feasible ideas to the competition provides a better opportunity for contestants in subsequent years to learn and improve.

Some general guidelines which apply in this (and most other) design situations are:

- Start with objectives and goals.
- Follow the KISS principle (Keep It Simple, Stupid!).
- Create a lightweight design in order to reduce power.
- Allow plenty of time for testing. Take care of the details in the design.

- Consider the aesthetics of the design.
- Beware of Murphy's Laws --

  If anything can go wrong, it will!
  Nothing is as easy as it looks!
  Everything takes longer than you think!

In order to emphasize safety and to define the spirit of the Walking Machine Decathlon , we would like to quote the classical "Three Laws of Robotics" of Isaac Asimov from the Foreword of the Handbook of Industrial Robotics (S.Y. Nof, editor):

- A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

We would like to emphasize that we welcome both positive and negative comments, questions, and suggestions in order to continually improve each year's competition to build a "better walking machine". Good Luck!

2. SCORING AND GENERAL RULES

Clarification of the competition procedures and rules will be provided in writing within one month if written requests are received by the Rules Committee prior to two months before the start of the Decathlon. **All such clarifications and any corrections will be provided to all registered contestants via E-mail.** Other rules decisions will be made during the competition by the judges meeting privately. The judges will assure that the rules are applied in a fair manner and that above all the competitors respect the spirit of the competition. The judges decisions during the competition are final.

Since this is a student competition, each Walking Machine entered in the contest must be designed, assembled, tested, and operated only by a team of undergraduate students. Only students will make presentations, answer questions from the judges, and prepare and operate machines during the competition. Each team of students will appoint a captain. The captain (or his or her designated alternate) will be the only team representative to discuss rules questions with the judges during the competition.

Each team may have one or more advisors representing the faculty of the university. Before the Decathlon starts, the advisors will represent the team before the Rules Committee members and the organizer on matters of rules and organization of the Decathlon. During the competition, the advisors can only act as coaches, communicating with the students from the sidelines.

Each participating team must assume sole and complete responsibilities for:

- reading, understanding, and following all of the rules, including changes from the previous year, and

- all of its equipment, material, and participants. This includes all arrangements, procedures and costs for transportation, shipping, operability, operation, safety, and any damage caused by the machine or team members.

For the purposes of this competition, a Walking Machine is defined as a mobile machine supported discontinuously and propelled by articulated mechanisms ("legs"). Each leg must have one or more joints or hinges by which it moves relative to ALL other legs or the frame. This excludes wheeled vehicles since wheels provide continuous support while rolling. This also excludes rimless, spoked wheels because the spokes do not move one relative to the other. The definition also excludes tracks because the elements of a track do not move relative to one another and the track as a whole provides continuous support. A leg may pivot, slip, or slide on the supporting surface during walking motion, but it cannot roll.

In general, if a team can demonstrate that the configuration of their walking machine parallels a multi-legged creature found in nature, then the configuration is in all likelihood acceptable.

The Walking Machine Decathlon consists of a preliminary judging event and - as its name implies ten performance events. A maximum of 5000 points can be awarded for the preliminary judging and a maximum of **1250 to 5000 points for the various performance events can be obtained.**

The team with the highest number of total points, combining the preliminary judging and performance events, will be declared the overall Decathlon winner. Each participating team will receive a plaque, with special plaques awarded to the top three overall finishers. Awards will also be given for the best technical poster paper and presentation combination, and, where decided by the judges, for the best new design, the best analytical approach to design, excellence in autonomy, and the most innovative design (see 4.3). An optional award of excellence may be granted at the discretion of the judges in recognition of an aspect of design not explicitly covered by the other awards.

3. SAFETY CONSIDERATIONS

All Walking Machines must be judged to be sufficiently safe prior to participating in the Decathlon. Each team is responsible for maintaining documentation in support of the safety aspects of their Walking Machine. For example:

3.1 Teams incorporating hydraulics or pneumatics in their design must be in a position to provide the pressure ratings of all the critical components should the judges request them.

relevant safety information will be excluded from the competition.

3.2 Lasers must conform to the CDR (United States Centre for Devices and Radiological Health) Class II safety requirements. Teams must be in a position to furnish documentation in support of this upon the request of the judges.

3.3 Each Walking Machine must be equipped with a full, non-recoverable emergency stop (E-Stop). Teams must be prepared to demonstrate and provide technical details on the E-Stop to the judges.

3.4 Dangerous "pinch points" should be clearly identified on the Walking Machine itself.

4. PRELIMINARY JUDGING

The purpose of the preliminary judging is to assess the compliance of the Walking Machine with the rules, to evaluate the machine's safety, to note its allowable configurations for the competition, and to give credit for subjective design factors.

The preliminary judging will be held in a large auditorium or, weather permitting, outside in an open area. This will allow participants the opportunity to exhibit their machines and interact with each other, the judges, and spectators.

The preliminary judging will consist of a general inspection required for qualification to continue in the Decathlon, a technical poster paper worth 1000 points, and a technical presentation worth 1000 points. Also a design evaluation, worth 1000 points, with a potential for an additional 1000 points in each of up to five Overall "BEST" Design categories, consisting of: Best New Design, Best Analytical Approach to Design, Excellence in Autonomy, Most Innovative Design and the Optional Award of Excellence; all of which are described below in section 4.3.

4.1 General Inspection

The general inspection covers six areas. No points are awarded; however, at the discretion of the judges, points may be deducted and outright failure in any area will result in disqualification. Also, note that the Walking Machine will not be permitted to participate in any of the performance events until the Photographs (see 4.1.6), and the Technical Paper (see 4.4) have been submitted.

All ancillary components including scoops for the Object Retrieval event, sensor assemblies, ramps, etc. must be integral to and carried with the Walking Machine at the start of the competition. Components may be jettisoned during the course of an event, however, they must be carried with the robot during all preceding events and can not be used during subsequent events. For example, if a ramp is used to traverse the trip wires in event 5.1.6, it must be carried with the robot during events 5.1.1 through 5.1.5 and may not be used for events 5.1.7 through 5.1.10. In other words, only those portions of the robot which are normally intended to complete an event are permitted to compete in subsequent events. In addition, components may only be jettisoned "automatically" during the normal running of an event by means of a signal from the remote control in the case of a manually controlled machine or by means of a signal from the onboard controller in the case of autonomous operation. Components may not be manually removed from the Walking Machine between events.

For example, if a team wishes to remove all the unnecessary ancillary components to facilitate the Hill Climb (Event 5.1.10), they must do so automatically during the normal running of the event.

The students should view the competition as a simulation of an unmanned interplanetary mission to Mars in which the robot has ten tasks (i.e. events) to accomplish. Initially, the robot is configured for all the tasks, however, once a task is completed unnecessary equipment may be jettisoned. Since the mission is unmanned, there is no operator available to manually modify the configuration of the robot. The order in which the events are run may prove critical to certain designs, therefore, all robots will run the ten events in the order presented in this document.

This modification to the rules is intended to favour the development of small, versatile machines or ultimately a "team" of small machines which collaborate together to successfully complete an event and whose individual members are gradually "sacrificed" during the course of the competition. Please note that the machines must always respect the definition of a Walking Machine as presented in Section 2 during all events.

Since the contestants may not manually change the configuration of the machine in any way, the Configuration Document is no longer required. The description of the designated front end of the machine and all other pertinent information must be contained in the Technical Poster Paper.

Participants may choose to run certain events with the robot on its side or upside down. While this is permitted (i.e. it is not viewed as a configuration change), variations in the initial orientation of the machine for certain events must be clearly described in the technical poster paper.

The inspection will cover the following areas:

4.1.1 Walking Machine

All configurations of the machine must comply with the definition of a walking machine given above.

4.1.2 Size

The Walking Machine must be capable of fitting through (not necessarily walking through) an opening one metre square in cross-section (i.e. one metre by one metre, not one square metre) with a flat floor.

4.1.3 Safety

The Walking Machine must be judged to be sufficiently safe for the events of the competition (refer to section 3, "Safety Considerations").

4.1.4 Power Source

The power source for the Walking Machine must be onboard. The Walking Machine cannot be tethered to a power source separate from the machine. No internal combustion engines are permitted because indoor use of the power source must be safe and non-toxic.

4.1.5 Identification

The Walking Machine must have the university's name and the machine's "name" (if any) appear prominently on the machine. In addition, the machine must have a clearly designated front end. An SAE decal must identify the front end and the front end cannot be changed.

4.1.6 Photographs

Two quality 20.32 cm x 25.4 cm (8 in x 10 in) black and white or color photographs of the Walking Machine suitable for publicity must be submitted. It is suggested that the photographs include the university name and the machine "name" (if any).

After completion of the General Inspection, no substantive changes may be made to the Walking Machine other than the replacement of parts with substantially identical parts, replacement or recharging of batteries, repairing broken or loose parts, and changes to software.

4.2 Design Evaluation 1000 points

Maximum of 1000 points per machine in regular areas (sections 4.2.1 - 4.2.4). Design evaluation consists of four areas:

4.2.1 Aesthetics 300 points

The overall appearance and craftsmanship will be judged. It is expected that participants will be concerned with the professional appearance of their Walking Machine.

4.2.2 Structural Integrity 300 points

The structural components of the machine are expected to be rugged. The judges may re-evaluate the structural integrity of the machine during its performance in the decathlon events.

4.2.3 Safety 300 points

The safety of the machine will be judged from the viewpoint of larger and more powerful machines. Sharp protruding surfaces, lack of controllability, and lack of guards over moving parts are all relatively unsafe.

4.2.4 Start-up and Testing Procedure 100 points

The Walking Machine is required to perform a short start-up and test routine. Starting from its Baseline Configuration, it should go through a sequence of motions that will demonstrate as many of the capabilities of the machine as possible. The start-up and test procedure should last no more than 5 minutes.

The judges reserve the right to re-evaluate the machine during its performance in the decathlon events.

4.3 Awards of Excellence 5000 points

In addition to the regular design judging (section 4.2), up to 1000 points may be awarded to a team, at the discretion of the judges, in each of the following categories:

BEST NEW DESIGN 1000 points
(from a university that has not entered before or
a new design from a university that has entered before)

BEST ANALYTICAL APPROACH TO DESIGN 1000 points

EXCELLENCE IN AUTONOMY 1000 points
(including sensors, computers and controls)

MOST INNOVATIVE DESIGN 1000 points

OPTIONAL AWARD OF EXCELLENCE 1000 points

At the discretion of the judges, the 1000 points in each of the categories listed above may be given to an individual team, divided between several teams or not awarded at all.

4.4 Technical Poster Paper 1000 points

In order to foster an information exchange between the participants and judges as well as between the participants and the public at large, a technical poster paper is required from all teams. This document will be used by the judges for the design evaluation and will be on permanent public display during the competition. It is also hoped that the poster papers will better serve the participating universities in terms of recruiting and public relations. The poster papers must be presented on three 60.96 cm wide by 121.92 cm high (24 in by 48 in) sheets.

The original poster paper along with ten reduced copies on U.S. standard letter-size 21.59 cm by 27.94 cm (8.5 in by 11 in) paper must be submitted to the organizing committee of the Decathlon five working days prior to the start of the competition. The reduced copies, which will be made available to the judges prior to the competition, may be either photographic reproductions of the original or, if the appropriate software is available, simply reprints of the original in reduced format. The poster paper must include information on the new and improved aspects of the design with respect to previous entries. It must also provide information on the innovative aspects of the design and the problem areas encountered in the design process. The poster paper must include a complete and detailed cost breakdown of the Walking Machine parts, including the names and addresses of all suppliers. The cost breakdown must include the estimated costs, if they had been purchased new, of all donated or used parts. A chart must be included which lists the name, academic department and class, and areas of speciality for each person who worked on the Walking Machine project, and the project's total number of person-hours expended. The judges will score the technical poster papers for quality and completeness, with a maximum score of 1000 points. **Each team must submit a report deemed satisfactory by the judges in order to be allowed to compete in the Decathlon.**

In order to allow the judges sufficient time to properly evaluate the technical poster papers and to prepare for the Decathlon, the papers must arrive at the competition site five working days prior to the start of the competition. Papers which arrive late will be penalized 100 points per working day. Papers submitted during the competition will be evaluated based on a maximum score of 500 points. In order to avoid confusion, the exact deadline (date and time) and mailing address for the technical poster papers will be announced to all competitors by the organizing committee at least two months prior to the start of the competition. It is the responsibility of all the competitors to ensure that the technical poster

papers arrive on time irrespective of the city, state or country of origin**. The original poster paper may be sent by mail or courier in roll form.**

4.5 Presentation 1000 points

A technical presentation, based on the technical poster paper described above, is also meant to promote the exchange of information among participants. It should follow the oral presentation guidance given by the Society of Automotive Engineers' (SAE) standards contained in their "Author Instructions Kit", which can be obtained directly from SAE International (or call SAE Educational Relations, Anthony Androsky @ (724) 772-8535 or androsky@sae.org for information). The presentation must include discussion of the new, improved, and innovative aspects of the design, as well as problem areas encountered. The presentation must be made by one or more student members of the team to the judges and audience and should last between 14 and 16 minutes. A penalty of 50 points will be assessed for each minute, or fraction thereof, over or under the allowed time range. After the presentation, the judges may ask questions for up to 5 minutes.

Scoring will be based on the following factors:

- Statement of the objectives.
- Description of the design approach, including areas of change, improvement, innovation, problem areas, and results.
- Approach to autonomy, application of sensors.
- Possible application for the Walking Machine beyond the competition.
- Conclusions and Summary.
- Response to questions.

Participants are responsible for providing their own visual aids and related equipment. A view graph projector, 35-mm slide projector, and VHS VCR player will be made available by the host university. Teams with specific audio-visual requirements should contact the organizing committee at the host university directly.

5. DECATHLON EVENT PROCEDURES

There are ten performance events, each of which can be worth a maximum of between 1250 and 5000 points. In an effort to promote autonomy and the use of sensors, the performance of the Walking Machine will earn points based upon the elapsed time required to complete an event relative to the fastest overall time as well as relative to the fastest time considering the autonomous machines only. In this way, if only one machine successfully completes an event autonomously, it will always outscore the fastest teleoperated

machine regardless of the elapsed times. All participating machines will be allowed two trials at every event. Each trial will be limited to a maximum of 10 minutes. ***The total score, S(n), will be calculated by the following formula:***

$$S(n) = [\ (200 * t_T(1) / t_T(n)) + 300 / N_T\ ] + [\ (200 * t_A(1) / t_A(n)) + 300 / N_A\ ] * [\text{Performance Factor}]$$

where:

$t_T(1)$ = ***fastest finisher's time including both the autonomous and teleoperated machines (in either trial)***

$tT(n)$ = ***"n"th place finisher's time including both the autonomous and teleoperated machines (better time if two trials are attempted)***

NT = ***total number of finishers (both autonomous and teleoperated) for that event***

$TA(1)$ = ***fastest finisher's time among the autonomous machines only (in either trial)***

$T_A(n)$ = ***"n"th place finisher's time among the autonomous machines only (better time if two trials are attempted)***

N_A = ***total number of autonomous finishers for that event***

Performance Factor

= 0	-if controlled by tether and event completed successfully
= 1.25 to **5**	-a performance factor between 1.25 and **5** will be applied depending on the event providing the event is successfully completed autonomously

Any score obtained for a second trial at an event will be subsequently reduced by 100 points and the better score between the two trials, after the reduction, will count for the event. If a team successfully completes an event teleoperated (i.e tethered), the second trial must be autonomous.

Following the General Inspection, each team will provide the judges a written list of all of the events that will be attempted. No further event entries will be permitted**. The events will take place in numerical sequence.** The judges will determine and announce the order (based on an initial random draw) that the teams will compete within each event. The judges may run simultaneous trials on separate courses and may overlap the scheduling of events in order to keep the competition moving smoothly and rapidly. All performance events will take place indoors on a flat, smooth surface whose exact nature will be announced prior to the competition.

It is planned to conduct each of the performance events as follows:

- The judges will announce that a machine is to compete in an event. They will notify the team by physically placing a red flag on the machine which is to compete. The red flag signifies that the team has five minutes to ready the machine and place it in the Starting Box. The judges will only make such announcement when the team has already been notified adequately, usually through a schedule, of the approximate time of the event. The judges will not make such an announcement for any machine within 10 minutes of that machine having attempted (at least to the point of crossing the Starting Line) a prior trial for an event.

- ***Within 5 minutes after the announcement, the team must place the machine completely within the Starting Box with the designated front end of the machine directed towards the finishing box and the machine in its initial configuration (with any non-permissible tether removed for autonomous events). The machine may not be angled to provide a competitive edge during an event. No part of the machine will be outside the Starting Box and the machine must be initially placed on the centre-line of the competition course (i.e. it can not be positioned off to one side of the Starting Box to provide a competitve edge)***. When the machine is ready, the team will so indicate to the judges and will not touch the machine until the judges issue the start command.

- The judges will verify the presence of all the ancillary devices, verify the proper starting position, and issue a start command and simultaneously start the timers.

- Prior to the start of an event, all machines must respect their initial configuration. The contestants may not change the configuration of the machine at any time.

- The machine leaves the Starting Box.

- The machine performs the prescribed event. It must stay within the 9-metre by 9-metre course boundaries. The Walking Machine cannot be touched or handled by anyone, other than for its control on a tether. If during an event, the judges concur that the machine has no chance of completing the event within the allotted 10 minutes, the judges may end the trial for that machine prematurely.

- ***The machine may not "touch", step outside or “overhang” the perimeter of the contest area. Additionally, where it is specified below that the machine may not "enter" a box, the machine may not “touch”, step into or “overhang” that box.***

- The judges will stop the timers when the final action specified for that event, such as having stopped in either the Starting or Finishing Box, has occurred. In the case of autonomous control, the machine must come to a complete stop. In the case of a teleoperated machine (i.e.

tethered), the machine must also come to a complete stop, however, the operator must signal the end of the event by releasing the remote control and placing both hands in the air. Times will be recorded in minutes and seconds to the nearest tenth second.

Real-time control by an operator using a tether or radio-control is permitted. Also, a tether may connect the Walking Machine to a computer or manual controller. The Walking Machine cannot be pulled or manoeuvred in any way using the tether to apply force. After the machine has left the Starting Box, a maximum of two students from the team will be permitted in the immediate operation area during all ten performance events. Only one student may actively control the Walking Machine by means of a tethered computer or manual controller. The second student may operate a safety switch. Control by tether or radio control of the Walking Machine is not permitted for autonomous events. Tethers will be allowed only for safety. Otherwise, no one will be permitted in the immediate operations area for these events after the machine leaves the Starting Box. Control by tether or radio control of the Walking Machine is not permitted for autonomous events.

All ancillary components including scoops for the Object Retrieval event, sensor assemblies, ramps, etc. must be integral to and carried with the Walking Machine at the start of the competition. Components may be jettisoned during the course of an event, however, they must be carried with the robot during all preceding events and can not be used during subsequent events. For example, if a ramp is used to traverse the trip wires in event 5.1.6, it must be carried with the robot during events 5.1.1 through 5.1.5 and may not be used for events 5.1.7 through 5.1.10. This rule does not apply to beacons which are placed on the course for events 5.1.5, 5.1.7 and 5.1.9 (Object Retrieval, Object Seeking and Object Seeking Through an Obstacle Course).

For the purposes of triangulation, navigation beacons may be placed off the course at up to three predetermined locations. These locations are: the lower left-hand corner of box 1, the lower right-hand corner of box 3 and the upper left-hand corner of box 7. Beacons may not be placed at any other location off the course. The time required to place these beacons is not included in the elapsed time for the event but it is in included in the 5 minute preparation time.

5.1 Decathlon Performance Events

All events start with the Walking Machine completely within the 3 metre (9.843 foot) square Starting Box, in its initial configuration and facing forward. All events finish when the machine is completely within the Finish Box (Except for events 5.1.2, 5.1.4, 5.1.5, 5.1.7 and 5.1.9. In these events, the machine will return to the Starting Box.) and be completely stationary. In the case of a tether, the operator will indicate that he has completed the event by raising both hands in the air.

Refer to Figure 1 for general course layout and box numbers for description of events. The lines are no wider than 5 cm. Each box is 3 metres x 3 metres (9.843 feet x 9.843 feet) square. Each pylon is less than 1 metre (3.281 foot) high. ***In order to facilitate the preparation of the competition site and to avoid misunderstandings during the competition, the lines will be***

placed such that their centre-line coincides with the perimeter of the various boxes. In the event that a robot touches but does not cross or overhang the physical (i.e. 5 cm) line defining the boundaries of the course for a particular event, it will judged to be within the prescribed competition area even though strictly speaking it could be outside the box by as much as 2.5 cm.

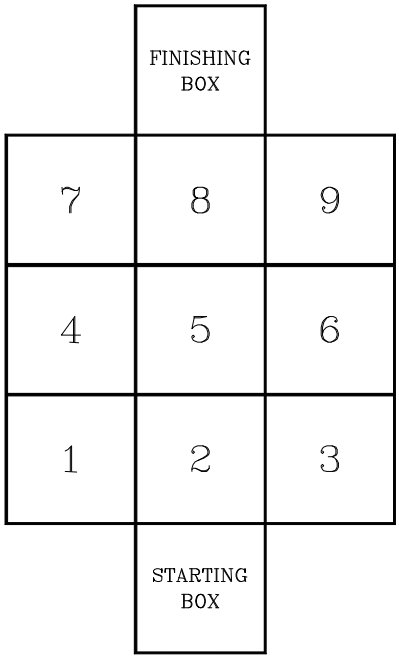

FIGURE 1

5.1.1 Dash **(Performance Factor = 1.25)**

Walk across the floor from the Starting Box to the Finishing Box while remaining completely inside the 3 metre wide centre section of the course; boxes 2, 5 and 8. The dash will normally be run as an introductory event immediately following the preliminary judging.

5.1.2 Load Retrieval (Performance Factor = 1.5)

Walk from the Starting Box to the Finishing Box. Once inside the Finishing Box, the machine must come to complete stop during which time one of the two designated team members will place a load onto the machine. The load will consist of up to ***six*** sacks of lead shot, each sack weighing 10 kilograms. The machine must then carry the load from the Finishing Box back to the Starting Box where the machine must come to a complete stop with its

the option of competing in this event without a load.

A suitable platform for the load must be incorporated into the design of each machine. For autonomous operation, the machine must have a minimum two second preprogrammed delay while in the finishing box to facilitate loading.

5.1.3 Slalom (Performance Factor = 2.0)

This event is intended to test the manoeuvrability of the Walking Machines through a series of tight turns and narrow gates. Beginning in the Starting Box, the machines must manoeuvre through five gates to the Finishing Box along the approximate path shown in figure 2. Each gate is defined by two flags which are positioned 1.5 meters apart. The point midway between the two flags always coincides with the centre of a box. The gates are oriented either north-south or east-west. The Walking Machines must remain within boxes 2,3,5,6,8 and 9 and may not touch the flags.

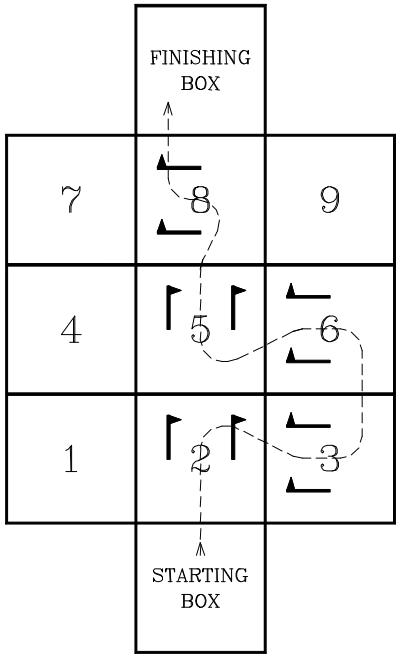

Figure 2

5.1.4 Grand Tour **(Performance Factor = 2.0)**

Walk from the Starting Box and traverse clockwise boxes 2, 1, 4, 7, 8, 9, 6, 3, 2 and return to the Starting Box where the machine will stop. Entering ***or overhanging*** box 5 is NOT permitted.

5.1.5 Object Seeking **(Performance Factor = *3.0*)**

Walk from the Starting Box, locate and touch a traffic cone. The traffic cone must remain upright and within the box where it was initially placed. After touching the traffic cone return back to the Starting Box. The traffic cone will be placed on the course in an arbitrary position in box 4 or 6 before the run. Placing beacons on the course to locate the traffic cone is permitted.

The Walking Machine must be placed in the starting box with the designated front end oriented towards the finishing box. Once the machine is positioned, the judges will then place the traffic cone in an arbitrary position in box 4 or 6. If required, team members will then be permitted to place beacons on the course, however, the time required to place the beacons is included in the elapsed time for the event. This sequence is intended to discourage teams from simply aligning their robots with the traffic cone. Tethered machines must also be initially aligned with the finishing box and actively directed towards the traffic cone by the operator during the event.

The coordinates of the cone to the nearest centimeter will be made available to the team at the start of the 5 minute preparation period. For the purposes of this event, the origin of the coordinate system is defined as the lower left-hand corner of box 1. The positive X axis is defined by the lower right-hand corner of box 3 and positive Y axis by the upper left-hand corner of box 7. Teams may enter the coordinate information into the controller of the walking machine during the 5 minute preparation time.

5.1.6 Trip Wire (Performance Factor = 1.5)

Walk from the Starting Box to the Finishing Box while stepping over and not touching two trip wires stretched across the centre of the course through boxes 4, 5, and 6 as shown in Figure 3. The two wires are 15 cm above the ground and 15 cm apart. The robot may not pass under the wires but may step between the wires. The use of a ramp or other ancillary device is permitted providing the device does not touch the wires and providing the device meets the criteria outlined in section 4.1 above.

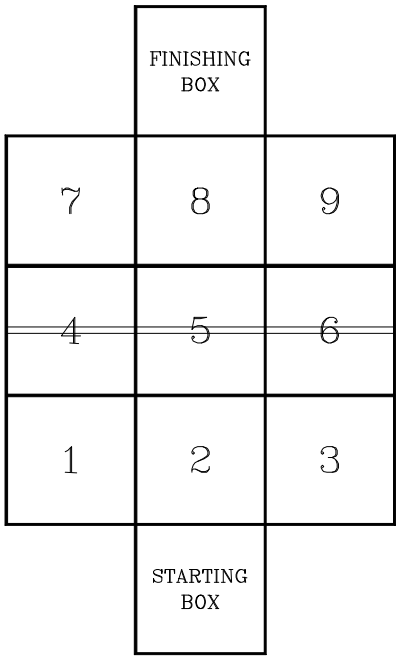

Figure 3

5.1.7 Object Retrieval **(Performance Factor = 3.0)**

From the Starting Box locate and pickup a standard, regulation billiard ball then return to the Starting Box with the object aboard. The ball will be placed in an arbitrary position in box 5 before the run. Placing beacons on the course to locate the ball is permitted.

The Walking Machine must be placed in the starting box with the designated front end oriented towards the finishing box. Once the machine is positioned, the judges will then place the ball in an arbitrary position in box 5. If required, team members will then be permitted to place beacons on the course, however, the time required to place the beacons is included in the elapsed time for the event. This sequence is intended to discourage teams from simply aligning their robots with the ball and "running over" it with a simple scoop. Tethered machines must also have to be initially aligned with the finishing box and actively directed towards the ball by the operator during the event.

The coordinates of the ball to the nearest centimeter will be made available to the team at the start of the 5 minute preparation period. For the purposes of this event, the origin of the coordinate system is defined as the lower left-hand corner of box 1. The positive X axis is defined by the lower right-hand corner of box 3 and positive Y axis by the upper left-hand corner of box 7. Teams may enter the coordinate information into the controller of the walking machine during the 5 minute preparation time.

Teams will be permitted to select the color of the billiard ball from the standard set. This is intended to encourage the development of totally autonomous, vision-based systems for object retrieval. A performance factor of 5.0 will be applied instead of the usual 3.0 if a team successfully completes this event autonomously without the use of beacons on the course.

5.1.8 Obstacle Course **(Performance Factor = 2.0)**

Walk from the Starting Box to the Finishing Box through an obstacle course constructed across the centre of the competition area. The obstacle course will consist of one layer of used automobile tires laid out randomly in boxes 4, 5 and 6. A minimum of 30 tires will be used to construct the obstacle course. The tires will be bound together by means of nylon rope to prevent the Walking Machines from displacing the tires and clearing a path. Although the participants can expect gaps between the tires in some areas, they should not expect a continuous path through the entire obstacle course. In certain areas, the rope may represent an additional obstacle. The Walking Machines may step on the tires, on the floor between the tires or on the floor through the centres of the tires. As a general guideline, the width of the tires will not exceed 200 mm and the tires will not exceed the dimensions of a P235-75R15.

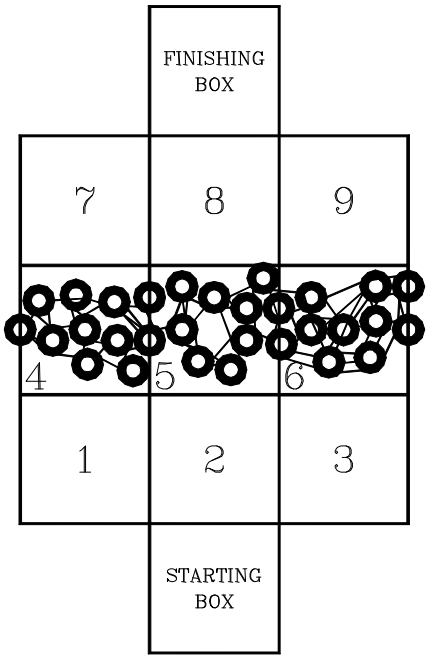

Figure 4

5.1.9 Object Seeking through an Obstacle Course **(Performance Factor = 3.0)**

Walk from the Starting Box, locate and touch a traffic cone located somewhere within the Obstacle Course specified in Figure 4. ***At the discretion of the judges, the cone can be positioned either on the floor between the tires or on the floor through the centres of the tires.*** The traffic cone must remain upright and within the box where it was initially placed. After touching the traffic cone**,** the machine must traverse the rest of the obstacle course and reach the Finishing Box. The traffic cone will be placed on the course in an arbitrary position in box 4 or 6 before the run. Placing beacons on the course to locate the traffic cone is permitted. In order to attempt this event, the team must successfully complete event 5.1.8 (Obstacle Course).

The Walking Machine must be placed in the starting box with the designated front end oriented towards the finishing box. Once the machine is positioned, the judges will then place the traffic cone in an arbitrary position in box 4 or 6. If required, team members will then be permitted to place beacons on the course, however, the time required to place the beacons is included in the elapsed time for the event. This sequence is intended to discourage teams from simply aligning their robots with the traffic cone. Tethered machines must also be initially aligned with the finishing box and actively directed towards the traffic cone by the operator during the event.

The coordinates of the cone to the nearest centimeter will be made available to the team at the start of the 5 minute preparation period. For the purposes of this event, the origin of the coordinate system is defined as the lower left-hand corner of box 1. The positive X axis is defined by the lower right-hand corner of box 3 and positive Y axis by the upper left-hand corner of box 7. Teams may enter the coordinate information into the controller of the walking machine during the 5 minute preparation time.

5.1.10 Hill Climb **(Performance Factor = 3.0)**

Walk from the Starting Box to a "hill" located perpendicular to travel in box 5. The machine must travel over the "hill" to the Finishing Box. The dimensions of the "hill" are shown in Figure 5. The machine must traverse the hill even if the hill only occupies box 5 (i.e. the machine can not manoeuvre around the hill). Please be reminded that the event ends as soon as a team member touches the machine.

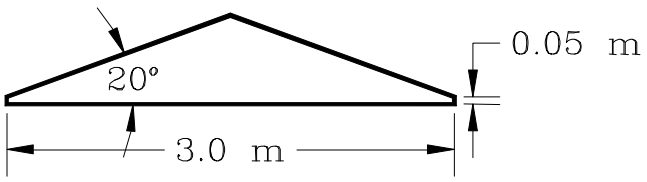

Figure 5

6. SELECTED BIBLIOGRAPHY

I. Alesksander, ed., Computing Techniques for Robots, Chapman and Hall, 1985.

M. Andreasen, et. al., Design for assembly, Springer-Verlag, 1983.

S. Azarm, J. Chen, and L.W. Tsai, Walking Robot: A Multidisciplinary Design Project for Undergraduate Students, Int. J. of Mechanical Engineering Education, Vol. 18, No. 2, 1990.

G. Beni and S. Hackwood, Recent Advances in Robotics, Wiley, 1985.

M. Brady, et. al., Robot Motion: Planning and Control, MIT Press, 1984.

P. Coiffet and M. Chirouze, An Introduction to Robot Technology, McGraw-Hill, 1983.

J. Craig, Introduction to Robotics: Dynamics and Control, Addision-Wesley, 1986.

J. Duffy, Analysis of Mechanisms and Robot Manipulators, Wiley, 1980.

J.F. Engleberger, Robots in Practice, American Management Assn., 1980.

W.B. Gevarter, Intelligent Machines, Prentice-Hall, 1985.

R.S. Hartenberg and J. Denavit, Kinematic Synthesis of Linkages, McGraw-Hill, 1964.

W.B. Heginbotham, ed., Programmable Assembly, Springer-Verlag, 1984.

M. Mason and J.K. Salisbury, Robot Hands and the Mechanics of Manipulation, MIT Press, 1986.

NASA Tech Briefs, NASA=s Planetary Rover Project: Building ASmart@ Robots for Space Exploration, Vol. 14, No. 9, September 1990.

S.Y. Nof, ed., Handbook of Industrial Robotics, John Wiley & Sons, 1985.

R.P. Paul, Robot Manipulators, MIT Press, 1981.

A. Pugh, ed., Robot Sensors: Vol. 1 - Vision, Springer-Verlag, 1986.

A. Pugh, ed., Robot Sensors: Vol. 2 - Tactile & Nonvision, Springer-Verlag, 1986.

M.H. Raibert, Legged Robots That Balance, MIT Press, 1986.

K. Rathmill, Robotic Assembly, Springer-Verlag, 1985.

S. Song and K.J. Waldron, Machines That Walk, MIT Press, 1989.

Special issue on Legged Locomotion, Int. J. of Robotics Research, Vol. 3, No. 2, MIT Press, Summer 1984.

Special Issue on Legged Locomotion, Int. J. of Robotics Research, Vol. 9, No. 2, MIT Press, April 1990.

D.J. Todd, Walking Machines - An introduction to Legged Robots, Chapman and Hall, 1985.

W. Triplett, Getting Around on Mars, Air & Space/Smithsonian, June/July 1991.

Walking Machine Decathlon Winners

COMP. DATE	HOST INSTITUTION	WINNERS
1987 April 16-18	Colorado State University Ft. Collins, CO	1. University of Central Florida 2. University of Maryland 3. Colorado State University
1988 April 14-16	University of Maryland College Park, MD	1. Colorado State University 2. University of Maryland 3. Ohio State University
1989 April 20-22	Texas Tech University Lubbock, TX	1. Colorado State University 2. University of Maryland 3. Texas Tech University
1990 April 5-7	University of Central Florida Orlando, FL	1. University of Delaware 2. Grove City College 3. Colorado State University <u>Best Paper</u> -North Carolina State University
1991 April 18-20	University of Maryland College Park, MD	1. Colorado State University 2. Grove City College 3. University of Delaware
1992 April 9-11	North Carolina State University Raleigh, NC	1. Colorado State University 2. Concordia University 3. North Carolina State University
1993 April 1-3	Texas Tech University Lubbock, TX	1. Colorado State University 2. Carnegie Mellon University 3. North Carolina State University <u>Best Electrical & Mechanical Design</u> -Ecole Polytechnique de Montreal <u>Most Innovative Design</u> -Ecole Polytechnique de Montreal <u>Best New Machine Design</u> -Texas Tech University - Team 2

1994 April 29-May 1	Carnegie Mellon University Pittsburgh, PA	1. University of Toronto 2. Colorado State University 3. Grove City College <u>Best Electrical Design</u> -University of Toronto <u>Best Paper-Presentation</u> -Colorado State University
1995 April 20-22	Colorado State University Ft. Collins, CO	1. Colorado State University 2. Washington State University 3. Carnegie Mellon University
1996 April 25-27	Ecole de Technologie Superieure Montreal, Quebec	1. Colorado State University 2. Universidad Panamericana 3. Carnegie Mellon University <u>Best Design</u> -Northern Illinois University <u>Most Innovative Design</u> -Universidad Panamericana <u>Best Mechanical Design (Tie)</u> -Ecole Technologie Superieure (hydraulic) & -Colorado State University <u>Best Electrical Design</u> -Colorado State University <u>Best Paper & Presentation</u> -Universidad Panamericana
1997 April 24-26	Universidad Panamericana Mexico City, Mexico	1. Colorado State University 2. Universidad Bonaterra 3. Universidad Panamericana <u>Best Paper & Presentation</u> -Colorado State University <u>Award of Excellence</u> -Colorado State University <u>Best Design</u> -Colorado State University

1998 April 30 May 2	Northern Illinois University DeKalb, Illinois	1. Ecole de Technologie Superieure 2. Washington State University, Caliban 3. University Bonaterra Excellence in Autonomy -University of Alabama Best New Design -University of Bonaterra Excellence in Professionalism -Ecole de Technologie Superieure

1999 WALKING MACHINE DECATHLON™

April 29 - May 1, 1999

REGISTRATION FORM

TEAM INFORMATION

School Name	
Team Name	

NOTE: PLEASE SELECT MAIL RECIPIENT! INCLUDE A COMPLETE PREFERRED MAILING ADDRESS!

FACULTY ADVISOR ❑ TEAM CAPTAIN ❑

FACULTY ADVISOR INFORMATION

Professor/Advisor Name	
Department	
Street Address	
City, State, Zip	
Telephone Number	
FAX Number & E-Mail	

TEAM CAPTAIN INFORMATION

Team Captain Name & SAE Member Number	
Department	
Street Address	
City, State, Zip	
Telephone Number	
FAX Number & E-Mail	

ENTRY INFORMATION:

The registration fee is $250.00 (U.S. dollars) per machine. ***This includes the Faculty Advisor and four student competitors. Additional faculty/student attendees will require a $25.00 per person fee, which can be paid at the event.***

Check or Money Order in the amount of $ _____ made payable "ETS Walking Machine

Please return this registration form
By **December 31, 1998** to:

Dr. Nicholas Krouglicof
Ecole de Technologie Superieure
1100 Notre-Dame West
Montreal, Quebec H3C 1K3
CANADA

<u>If you are entering more than (1) machine, complete a registration for each entry</u>.

TEAM MEMBERS	*SAE MEMBER NUMBERS*

NOTE: SAE MEMBER NUMBERS ARE REQUIRED. FAILURE TO PROVIDE THE NUMBERS MAY JEOPARDIZE THE TEAMS PARTICIPATION IN THE COMPETITION.