2001 SAE Walking Machine Challenge™

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SAE COLLEGIATE DESIGN SERIES

2001 WALKING MACHINE CHALLENGE™

1. INTRODUCTION/PHILOSOPHY/GOALS

1.1 The Walking Machine Challenge's Objectives

- 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.

1.2 Applications for Walking Machines

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.

1.3 Competition Outline

The Walking Machine Challenge™ for 2001 will involve eight 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 challenge 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 Challenge 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.

1.4 Participation Benefits

- 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 Challenge 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 Challenge in order to document the results achieved by the students through the technical poster papers and to encourage future participation. Past Challenge results are listed in the Appendix as A-1.

The rules for the Walking Machine Challenge™ are written to be clear and simple. 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.

1.5 General Guidelines for Walking Machine Design

- 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 Challenge™, we would like to quote Issac Asimov's classic, "Three Laws of Robotics" from the Foreword of the Handbook of Industrial Robotics (S.Y. Nof, editor):

1.5.1 First Law: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

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

1.5.3 Third 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

2.1 Clarification of 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 Challenge. 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 while 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.

2.2 Participation Requirements

2.2.1 Individual Participant Requirements

Individual members of teams participating in this competition **must** satisfy the following requirements:

(a) Student Status: Team members must be enrolled as degree seeking undergraduate or graduate student in the college or university that the team represents. Team members who have graduated during the seven (7) month period prior to the competition remain eligible to participate.

(b) SAE Membership: Team members must be members of SAE. Proof of SAE membership is required at the event. Applications for membership will not suffice. **This process must be complete and all team member's membership numbers must be provided to the organizer prior to the**

competition! Students must have their membership card, documentation of membership, or membership number present at the competition.

COMMENT: Information on SAE student membership can be found at SAE's website: www.sae.org

(c) Liability Waiver and Insurance: All on-site participants and faculty are required to sign a liability waiver upon registration. Individual medical and accident insurance coverage is the sole responsibility of the participant.

2.2.2 Machine Requirements

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 primarialy 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.

NOTICE: In the event that the number of teams registering for the competition exceeds the number of which the facilities can handle, then registration priority will be given to colleges and universities with SAE collegiate chapters.

2.3 Faculty Advisors

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

2.4 Team Responsibilities

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.

2.5 "Walking Machine" Defined

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.

2.6 Parallels in Nature

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.

2.7 Competition Outline

The Walking Machine Challenge™ consists of a preliminary judging event and - as its name implies eight performance events. A maximum of 5000 points can be awarded for the preliminary judging.

2.8 Scoring

The team with the highest number of total points, will be declared the overall Challenge 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 Challenge. Each team is responsible for maintaining documentation in support of the safety aspects of their Walking Machine. For example:

3.1 Hydraulics and Pneumatics

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. Teams which are unable to comply with the judges' request for relevant safety information will be excluded from the competition.

3.2 Lasers

Lasers must conform to the CDR (United States Center 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 Emergency Stop - Required

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

3.4 Pinch Points

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

4. PRELIMINARY JUDGING

4.1 Objective

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.

4.2 Judging Location

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.

4.3 Scoring

The preliminary judging will consist of a general inspection required for qualification to continue in the Challenge, a technical poster paper worth 1000 points, and a technical presentation worth 1000 points. Also a design evaluation, worth 1000 points.

4.4 Awards of Excellence

At the discretion of the judges Awards of Excellence may be presented in the following categories (The Awards of Excellence have no point value):

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

(2) BEST ANALYTICAL APPROACH TO DESIGN

(3) EXCELLENCE IN AUTONOMY
(including sensors, computers and controls)

(4) MOST INNOVATIVE DESIGN

(5) VALUE ENGINEERING

(6) OPTIONAL AWARD OF EXCELLENCE

4.5 General Inspection

4.5.1 Objective

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 4.6.6), and the

Technical Poster Paper (see 4.8) have been submitted.

4.5.1.1 Competition Goal

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.

4.5.1.2 Versatile Machines Preferred

This modification to the rules is intended to favor 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 2.5 during all events.

4.5.2 Ancillary Components

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 4, it must be carried with the robot during events 1 through 5 and may not be used for events 7 through 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 on board 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 8, they must do so automatically during the normal running of the event.

4.5.3 Configuration Document - Not Required

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.

4.6 Walking Machine Inspection - Requirements & Limitations

The inspection will cover the following requirements and limitations:

4.6.1 Configuration

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

4.6.2 Size

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

4.6.3 Safety

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

4.6.4 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. Internal combustion engines are prohibited. The power source must be safe and non-toxic and safe for indoor use.

4.6.5 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 and cannot be changed.

4.6.6 Prohibition on Modification

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.

4.7 Design Evaluation 1000 points

Maximum of 1000 points per machine in regular areas: Sections 4.6.1 - 4.6.4. Design evaluation consists of four areas:

4.7.1 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.

4.7.2 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 Challenge events.

4.7.3 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.

4.7.4 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 not exceed 5 minutes. The judges reserve the right to re-evaluate the machine during its performance in the Challenge events.

4.8 Technical Documentation 1000 points

4.8.1 Objective

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 paper and a poster paper are required from all teams. The poster paper 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.

4.8.2 Format

The technical papers should follow the guidance given by the Society of Automotive Engineers (SAE) standards contained in their Author Instructions Kit, which can be obtained directly from SAE International on-line at: ftp://authors:authors@www.sae.org/authors/ (or call SAE Educational Relations, Steven Daum @ (724) 772-8535 or e-mail daum@sae.org

The poster papers must be presented on three 60.96 cm wide by 121.92 cm high (24 ins. x 48 ins.) sheets and do not have a specific format.

4.8.3 Technical Paper Submission Deadline

Ten reduced copies of the technical paper must be submitted to the organizing committee of the Challenge five working days prior to the start of the competition.

In order to avoid confusion, the exact deadline (date and time) and mailing address for the technical 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 papers arrive on time

irrespect of the city, state or country of origin. The original poster paper may be sent by mail or courier in roll form.

4.8.4 Technical Paper Contents

The technical 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 technical 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.

4.8.5 Poster Paper Contents

The poster paper should include the most relevant information: improvements, key advantages and disadvantages of the design, photos of the prototype, innovative aspects, cost, a chart that lists the name, academic department and class, aqnd areas of specialty for each person who worked on the project, total person-hours, etc.

This poster should foster a FAST interchange of information between the teams and the attending public.

4.8.6 Scoring

The judges will score the technical paper and poster paper for quality and completeness, with a maximum score of 500 points each. Each team must submit technical documentation deemed satisfactory by the judges in order to be allowed to compete in the Challenge.

4.8.7 Penalty for Late Submission of Papers

Papers which arrive late will be penalized 100 points per working day after the deadline. Papers submitted during the competition will be evaluated based on a maximum score of 500 points.

4.9 Technical 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.

4.9.1 Format

The technical presentation 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 on-line at: ftp://authors:authors@www.sae.org/authors/ (or call SAE Educational Relations, Steven Daum @ (724) 772-8535 or e-mail daum@sae.org for information).

4.9.2 Presentation Contents

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. After the presentation, the judges may ask questions for up to 5 minutes.

4.9.3 Excess Time Penalty

A penalty of 50 points will be assessed for each minute, or fraction thereof, over or under the allowed time range.

4.9.4 Scoring

Scoring will be based on the following factors:

(a) Statement of the objectives.

(b) Description of the design approach, including areas of change, improvement, innovation, problem areas, and results.

(c) Approach to autonomy, application of sensors.

(d) Possible application for the Walking Machine beyond the competition.

(e) Conclusions and Summary.

(f) Response to questions.

4.9.5 Audio-Visual Equipment

Participants are responsible for providing their own visual aids and related equipment. An overhead projector and VHS VCR player will be made available by the host university. Teams with specific audio-visual requirements should contact the the host university directly. *NOTE: Teams planning to make presentations requiring a computer and data projector, e.g. Powerpoint, should bring their own equipment unless prior arrangements have been made with the host.*

5. CHALLENGE EVENT PROCEDURES

5.1 General

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.

5.2 Time Limit

Each trial will be limited to a maximum of 10 minutes.

5.3 Scoring Formula

The total score, S(n), will be calculated by the following formula:

$$S(n) = [\,(200 * tT(1) / tT(n)) + 300 / NT\,] + [\,(200 * tA(1) / tA(n)) + 300 / NA\,] * [\text{Performance Factor}]$$

where:

tT(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)

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

NA = total number of autonomous finishers for that event

Performance Factor

= 0 -if controlled by tether and event completed successfully

= 1.25 to 5.25 -a performance factor between 1.25 and 5.25 will be applied depending on the event providing the event is successfully completed autonomously

= 1.25 -an additional performance factor of 1.25 (over and above the previous performance factor) will be applied providing the event is successfully completed autonomously without relying on odometry or dead reckoning. This additional performance factor **does not apply** to Walking Machines that navigate autonomously by simply counting the number of steps and turns required to complete an event. This additional performance **does apply** to Walking Machines that navigate by actively sensing the environment through the use of sensors and to Walking Machines that navigate with the aid of navigational beacons. In general, this additional performance factor is to encourage the development of robust Walking Machines that are able to compensate for unforeseen circumstances such as a slipping foot pad or misalignment in the initial placement of the machine within the starting box.

In the case of the Object Seeking Event, the Object Retrieval Event and the Object Seeking through an Obstacle Course Event, the additional performance factor is reserved for Walking Machines that employ sensors to find the cone or object without relying on the X-Y coordinate information provided at the start of the 5 minute preparation time. Walking

Machines that employ a random search pattern to find the object to not qualify for the additional points. In order to qualify, the Walking Machine must sense the environment and act accordingly.

5.4 Second Trials

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.

5.5 Events to be Attempted

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.

5.6 Competition Surface

All performance events will take place indoors on a flat, smooth surface whose exact nature will be announced prior to the competition. Likely material will be unfinished sheet rock 1/2 inch white side up. Boundary lines will be 2 inch wide black duct tape. Numbers will be 24” x 12” wide, centered in the squares, numbers will be made out of 2” wide black duct tape.

5.6.1 Verification of the Course

Prior to the start of the performance events the judges will verify the dimensions and surface of the course and rule any adjustments which need to be made to the course or the affected rules.

5.7 Event Procedure

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

5.8 Team Notification

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 (5) 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 ten (10) minutes of that machine having attempted (at least to the point of crossing the Starting Line) a prior trial for an event.

5.9 Machine Starting Time and Position

Within five (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 center-line of the competition course (i.e. it can not be positioned off to one side of the Starting Box to provide a competitive 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.

5.10 Judges Review

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.

5.11 Operating Orientation

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.

5.12 Starting Configuration

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.

5.13 Start of Run

The machine leaves the Starting Box.

5.14 Event Requirements

The machine performs the prescribed event. It must stay within the 9 m x 9 m 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.

5.15 Boundary Rules

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.

5.16 End of Run

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.

5.17 Real Time Control

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 maneuvered in any way using the tether to apply force. Control by tether or radio control of the Walking Machine is **not** permitted for autonomous events. Tethers will be allowed only for safety.

5.18 Team Limitations

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. Otherwise, no one will be permitted in the immediate operations area for these events after the machine leaves the Starting Box.

5.19 Ancillary Components

Competitors are reminded that the requirements of rule 4.4.2 “Ancillary Components” must be respected.

5.20 Navigational Beacons

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.

6. CHALLENGE PERFORMANCE EVENTS

6.1 Starting Location and Configuration

All events start with the Walking Machine completely within the 3 m (9.843 ft.) square Starting Box, in its initial configuration and facing forward. Events 1, 3, 6, 8, 9 and 10 end when the machine is completely withing the Finishing Box and stationary. Events 2, 4, 5 and 7 end when the machine is completely within the Starting Box and stationary. In the case of a tether, the operator will indicate that he has completed the event by raising both hands in the air.

6.2 Course Layout

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 m x 3 m (9.843 ft. x 9.843 ft.) square. Each pylon is less than 1 m (3.281 ft.) 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 center-line coincides with the perimeter of the various boxes.

6.3 Boundary Lines

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 be 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.

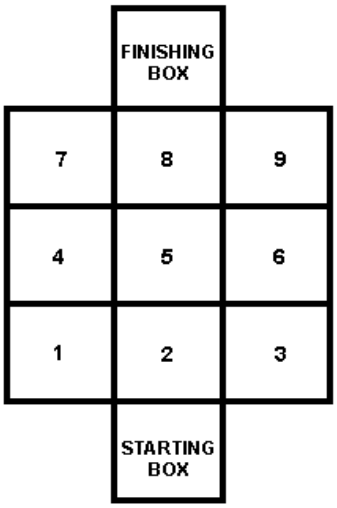

FIGURE 1

6.4 Event 1 - Dash (Autonomous Type 1 - Performance Factor = 1.25) (Autonomous Type 2 - Performance Factor = 1.25 x 1.5)

CHANGE FOR 2001

6.4.1 Goal

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

6.5 Event 2 - Load Retrieval (Autonomous Type 1 - Performance Factor = 1.5) (Autonomous Type 2 - Performance Factor = 2.25)

CHANGE FOR 2001

6.5.1 Goal

This event demonstrates the Walking Machines capacity for carrying a useful load.

6.5.2 Procedure

CHANGE FOR 2001

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 Kg. 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 load. The team has the option of competing in this event without a load.

Mulitple trips - Multiple trips are allowed, although all attempted trips must be successfully completed or the machine will be classified as "Did Not Finish." Prior to the start of the event the team captain must announce how many trips will be attempted.

6.5.3 Bonus Points

A bonus of 250 points for each sack will be added to the team's score.

6.5.4 Load Platform

A suitable platform for the load must be incorporated into the design of each machine.

6.5.5 Autonomous Operation

For autonomous operation, the machine must have a minimum two second pre-programmed delay while in the finishing box to facilitate loading.

6.6 Event 3 - Slalom (Autonomous Type 1 - Performance Factor = 2.5) (Autonomous Type 2 - Performance Factor = 3.75)

6.6.1 Goal

This event is intended to test the maneuverability of the Walking Machines through a series of tight turns and narrow gates.

6.6.2 Procedure

Beginning in the Starting Box, the machines must maneuver 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 m apart. The point midway between the two flags always coincides with the center 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.

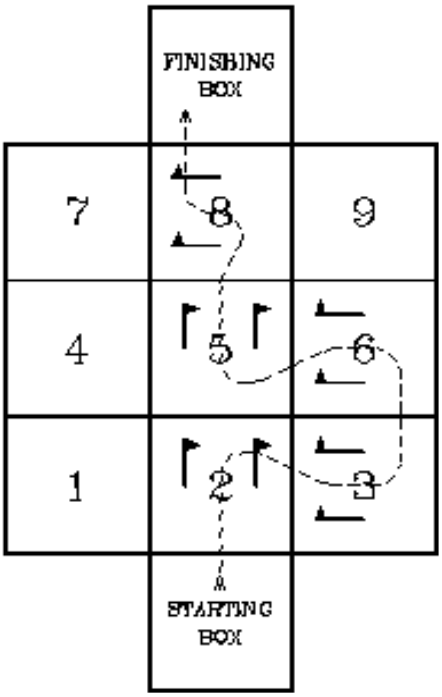

FIGURE 2

6.7 Event 4 - Trip Wire (Autonomous Type 1 - Performance Factor = 1.5) (Autonomous Type 2 - Performance Factor = 2.25)

CHANGE FOR 2001

6.7.1 Goal

Walk from the Starting Box to the Finishing Box while stepping over and not touching two trip wires.

6.7.2 Procedure

The trip wires will be stretched across the center 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.

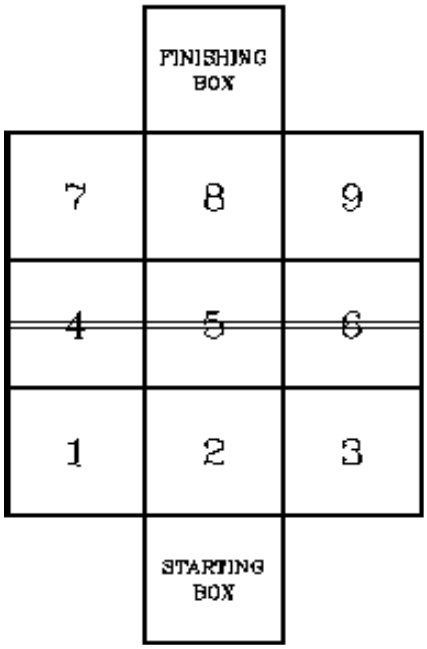

FIGURE 3

6.8 Event 5 - Object Retrieval (Autonomous Type 1 - Performance Factor = 3.0) (Autonomous Type 2 - Perormance Factor = 4.5)

CHANGE FOR 2001

6.8.1 Goal

CHANGE FOR 2001

From the Starting Box locate and pickup (i.e. removed from contact with the floor) ball/wood block then return to the Starting Box with the object aboard (**the robot MUST carry the ball/block not push/pull/ roll it into the Starting Box. Block surface may not be pierced as part of hte pick up process.)**. The ball/block will be placed in an arbitrary position in box 5 before the run. Placing beacons on the course to locate the ball is permitted. Ball/Block will be 10 cm x 10 cm x 10 cm.

6.8.2 Procedure

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.

6.8.3 Object Coordinates

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.

6.8.4 Object Color Option

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.

6.8.5 Autonomous Performance Bonus

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.

6.9 Event 6 - Obstacle Course (Auto. Type 1 - Performance Factor = 2.0) (Auto. Type 2 - Performance Factor = 2.75 X 1.5)

6.9.1 Goal

Walk from the Starting Box to the Finishing Box through an obstacle course constructed across the center of the competition area.

6.9.2 Course Layout

The obstacle course will consist of one layer of used automobile tires laid out randomly in boxes 4, 5 and 6. A minimum of 35 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.

6.9.3 Procedure

The Walking Machines may step on the tires, on the floor between the tires or on the floor through the centers of the tires. Opening a clear path by sliding/moving the tires is NOT allowedas a primary strategy. 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.

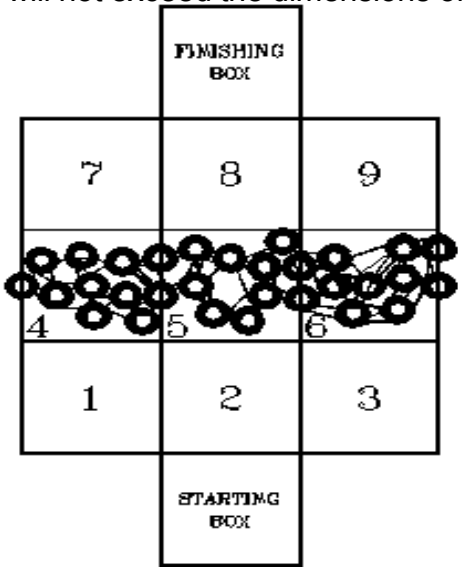

FIGURE 4

6.10 Event 7 - Object Seeking Through an Obstacle Course (Autonomous Type 1 - Performance Factor = 3.5) (Autonomous Type 2 - Perofrmance Factor = 5.25)

6.10.1 Goal

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 centers 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 8.

6.10.2 Procedure

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.

6.10.3 Cone Coordinates

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.

6.11 Event 8 - Hill Climb (Autonomous Type 1 - Performance Factor = 3.0) (Autonomous Type 2 - Performance Factor = 4.5)

6.11.1 Goal

To demonstrate the machines ability to traverse a “hill” oriented perpendicular to its direction of travel.

6.11.2 Procedure

The “hill” will be located in Box 5. The dimensions of the “hill” are shown in Figure 5. The machine will begin in the Starting Box to the “hill,” scale the “hill” and continue on to the Finishing Box. The

machine must scale the hill. Maneuvering around the hill will result in a "did not finish."

Please be reminded that a trial ends as soon as a team member touches the machine.

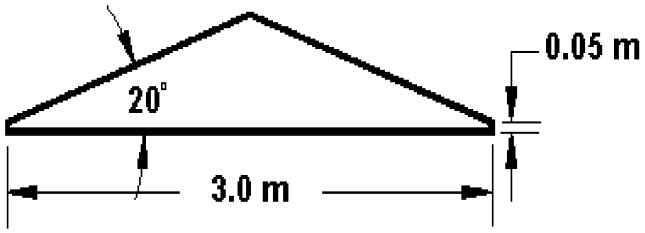

FIGURE 5

7. ORGANIZERS AUTHORITY

The organizer(s) of the competition reserve the exclusive right to revise the schedule of the competition and/or to interpret the competition rules at any time and in any manner which is in their sole judgement, required for efficient operation or safety of the competition.

8. NOTICE OF RULE CHANGES FOR 2002

This is to notify you that the Walking Machine Challenge Rules Committee is considering the following changes to the rules effective with the 2002 competition:

(A) Events - The Challenge will consist of the following six events:
1 Dash
2 Slalom
3 Load Retrieval
4 Trip Wire
5 Object Retrieval
6 Obstacle

(B) The Obstace Event will carry higher points than any other part of the competition and may be run outdoors on a natural surface.

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WALKING MACHINE CHALLENGE™ WINNERS

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

COMP. DATE	HOST INSTITUTION	WINNERS
1994 April 29-May 1 Pittsburgh, Pennsylvania	Carnegie Mellon University	1. University of Toronto 2. Colorado State University 3. Grove City College
	Best Electrical Design	University of Toronto
	Best Paper Presentation	Colorado State University
1995 April 20-22 Ft. Collins, Colorado	Colorado State University	1. Colorado State University 2. Washington State University 3. Carnegie Mellon University
1996 April 25-27 Montreal, Quebec	Ecole de technologie superieure	1. Colorado State University 2. Universidad Panamericana 3. Carnegie Mellon University
	Best New Design	Northern Illinois University
	Most Innovative Design	Universidad Panamericana
	Best Mechanical Design (Tie)	Ecole technologie superieure (hydraulic) & Colorado State University
	Best Electrical Design	Colorado State University
	Best Paper & Presentation	Universidad Panamericana
1997 April 24-26 Mexico City, Mexico	Universidad Panamericana	1. Colorado State University 2. Universidad Bonaterra 3. Universidad Panamericana
	Best Paper & Presentation, Award of Excellence and Best Design	Colorado State University

COMP. DATE	HOST INSTITUTION	WINNERS
1998 April 30 - May 2 DeKalb, Illinois	Northern Illinois University	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 April 29 - May 1 Montreal, Quebec	Ecole de technologie superieure	1. Ecole de technologie superieure 2. Universidad Bonaterra 3. Washington State University
	Best New Design	Northern Illinois University
	Most Innovative Design	Colorado State University, Team Triad
	Excellence in Professionalism	Ecole de technologie superieure
2000 April 27 - 29 Ft. Collins, Colorado	Colorado State University	1. Carnegie Mellon University 2. Universidad Bonaterra 3. Universite Quebec a Rimouski
	Excellence in Autonomy & Excellence in Professionalism	Carnegie Mellon University
	Best New Design	Universite Quebec a Rimouski
	Most Innovative Design	Colorado State University
	Best Analytical Approach	Colorado State University

2001 WALKING MACHINE DECATHLON™

May 3 - 5

REGISTRATION FORM

TEAM INFORMATION (Team member registration and Team Captain information on reverse side)

School Name	Team Captain Name & SAE #:
Machine Name	Total Number of Team Members:

Complete preferred mailing address: ***check one!***

Faculty Advisor _____ Team Captain _____

FACULTY ADVISOR INFORMATION

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

TEAM CAPTAIN INFORMATION

Team Captain Name	
Street Address	
City, State, Zip	
Telephone & Fax Number	
E-Mail address	

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.

Check or Money Order in the amount of $ _____ made payable to " BONA TERRA AC, Banamex Bank, Acct. Number: 0849110659"

_____Number of additional faculty and student attendees purchased at $25.00 per person

Please return this registration form by **January 31, 2001**.

Francisco Patino
Bonaterra University
Av. Josemaría Escrivá de Balaguer 101
Rusticos Calpulli
Aguascalientes Ags.
CP 20290 México

Phone: 011 52 49 106217
Fax: 011 52 49 106200

If you are entering more than one (1) machine, complete a registration form for each entry.

Team members	***E-mail Address(not required)***	***SAE Member Number***

Please note: *SAE Membership numbers are required at the event during registration!* If you would like a complete roster of all SAE members at your school, please send an e-mail to: ccyphert@sae.org If you are inquiring about your membership number (not the entire team), you may call: 1-800-TEAMSAE

All students must be SAE members, to join log on to: www.sae.org/students/