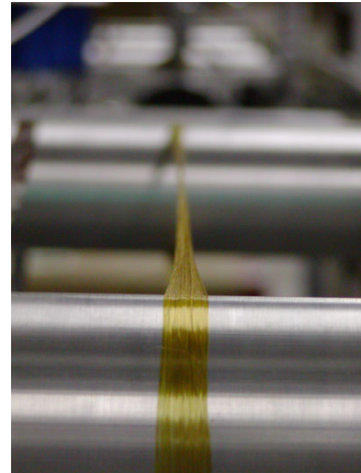


## Tether Competition 2008



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### Web Links:

Tether Competition Page: <http://www.spaceward.org/elevator2010-ts.html>

Elevator:2010 Web Site: <http://www.spaceward.org/elevator2010.html>

Spaceward Foundation: <http://www.spaceward.org>

## 1 Introduction

The tether competition challenges development teams to create tethers with the highest strength-to-weight ratio. Super-strong tethers will enable many great advances in aerospace capability, including reduction in rocket weight, habitable space structures, solar sails, and various tether-based propulsion systems, culminating in the ability to construct a Space Elevator.

In addition to the strength-to-weight metric, space tethers have to satisfy many other requirements, such as space-environment survivability, specific electrical resistance ranges, damping factors, etc. In the initial stage, the competition will concentrate on the strength-to-weight metric, and we will add the other factors in the years to come.

Elevator:2010 is managed by the Spaceward Foundation – <http://www.spaceward.org>.

### 1.1 Technical scope

The competition is looking to encourage the development of high strength-to-weight ratio tethers. An entry to the competition consists of ready-to-test tether samples.

Our intent is to encourage the development of break-through materials. We're looking for significant advances over the state of the art, and the competition rules are designed to not award the prize money for incremental advances that represent optimization in the use of current materials.

### 1.2 Safety

The competition is designed to bring tethers to their breaking points, and a breaking tether can release a lot of mechanical energy. Safety is our first priority, but we cannot control your safety in your own labs and machine shops. Safe procedures for the in-house production and testing of tethers are the responsibility of the teams.

Please be careful. Safety rules are important, and the competition will be there again next year, so always take the time to stop and think before you act. Spaceward will tolerate no unsafe behavior the event.

The competition will have a specific engineer, well involved in its design, designated as safety engineer. All safety related matter ultimately fall within the responsibility of the safety engineer.

### 1.3 Code of conduct

We hold these requirements to be self evident... Regrettably, we have to make them explicit.

- a. Upon arrival, each team will leave a cleanup/damage cash deposit of \$1000 with Spaceward, to be conditionally refunded within 7 days of the end date of the competition, upon compliance with the guidelines below.
- b. Arguing with Spaceward personnel in any but a private forum or disobeying instructions by spaceward personnel can result in immediate disqualification of the team, irrespective of the root cause of the disagreement.
- c. Unsportsmanlike conduct such as hindering the performance of other teams, violence, or harassment can be ground for disqualification.
- d. Teams must clean up after themselves, pick up all of their hardware, and not damage property. Clean up costs will be deducted from the deposit, plus a 100% penalty.

## 2 Rules and Requirements

### 2.1 Units of Measurement

- e. The ratio of UTS to mass density is equivalent to the ratio of breaking strength to linear mass density.
- f. In honor of Yuri Artsutanov, we define a new unit called a Yuri as the SI-Natural Pa-m<sup>3</sup>/kg, or N-m/kg, and thus a MYuri (Mega-Yuri) is equivalent to the commonly used units of GPa-cc/g and N/Tex.

### 2.2 Requirements

- a. A team entry consists of several interchangeable tether samples, referred to as team tethers.
- b. Team tethers must be in the geometrical shape of one or more loops.
- c. Team tethers must weigh a maximum of 2 grams. (See 3.1.a and 3.1.b below)
- d. Team tethers must be a minimum of 2 meters in circumference. (See 3.1.f below)
- e. Team tethers can be no wider than 200 mm.
- f. Teams must be able to place team tethers in the test apparatus in under 5 minutes.
- g. Tethers must be fabricated prior to competition time.
- h. All tethers must be accompanied by an appropriate MSDS. (See 2.3 below)

### 2.3 Material Safety Data Sheets

Prior to the competition and at the event entrants will be required to provide safety and other information related to the tether being entered but no proprietary information will need to be provided unless it is deemed to be safety related.

In the coming years, we expect the tethers to be comprised of materials that are not necessarily “consumer grade” and that may require special handling procedures, either before or after they break. Each team should therefore accompany its entry with an appropriate MSDS.

The purpose of the MSDS is to inform Spaceward of any special steps it needs to take when handling the tethers in their whole and in their broken states.

Instructions on creating an MSDS can be found at

<http://ehso.com/msdscreate.php>

and a sample PDF form can be found at

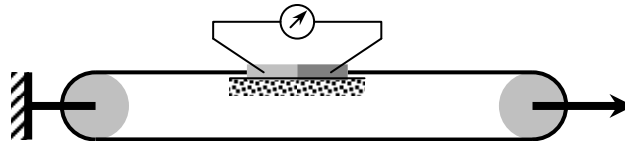
<http://ehso.com/images0407/msds%20form%2016-section.pdf>

Costs to be incurred while complying with the MSDSs for tethers belonging to a team or teams will be the responsibility of the same team or teams, as determined by Spaceward. An estimate of such costs will be negotiated with teams at the time of registration, or once the nature of the tether and the special accommodations required by the MSDS are communicated to Spaceward.

### 3 Competition Environment Specification

#### 3.1 Test apparatus interface and procedure

- a. Tethers are weighed using a precision microgram lab scale, with a hanging hook.
- b. Tether samples can be weighed while on a support structure. In such a case, we will need to know and approve the approximate weight of the support structure 2 weeks ahead of the competition, and will weigh the support structure immediately after the tether is removed from it.
- c. The tethers are pulled using two free-rolling metal pins, with  $77 \text{ mm} > d \geq 75 \text{ mm}$ .
- d. In their starting position, the pins are brought together so the tether can fit around them.
- e. The pins are removed, and the tether loaded in place. Once the team tether has been placed on the test apparatus, the team lead will be asked by the event operators if their tether is ready to compete. Once the team lead confirms the tether is ready for competition it can not be exchanged for another team tether and must go through the test procedure.
- f. Tension is increased to 100N (~20lb) and a reference tether loop (magnetically-terminated) is placed around the pins. The reference tether, which is shorter than 2 m, must not be able to close. Closure of the loop is detected by measuring electrical conductivity.



- g. A 2.100 m long reference tether loop (magnetically terminated) is then placed next to the test tether, so it can indicate failure when the loop opens.
- h. Load is increased gradually until the tether fails.
- i. Load increase can be suspended if the tether seems to be creeping, until creeping stops.
- j. The test will be conducted at the ambient temperature,  $10\text{C} < T < 40\text{C}$ .
- k. The test apparatus is a controlled-force machine. (as opposed to controlled displacement)
- l. Teams are responsible for weighing their tethers and placing them on the test apparatus.
- m. Spaceward personnel are not required to assist the teams with any of the procedures, but the teams must explicitly state if they want Spaceward personnel to be strictly "hands off".

#### 3.2 House Tether

- a. The house tether is a method to illustrate the improvement we require over existing material art.
- b. The house tether is only allowed to be made out of COTS materials, or out of the previous year's winner's material. In making the house tether, Spaceward is allowed to employ standard COTS processes or "layman skill" shop processes. For example, the 2006 house tether was made from commercial PBO fibers, 3M super 77 adhesive, and a manual winding and bonding procedure.
- c. This year, the house tether will be based on PBO (Zylon) fiber or equivalent, and utilize an obvious scheme for forming the test loops, such as a commercial adhesive, manual knotting/spinning, etc.
- d. In previous years, house tethers constructed using this technology performed at close to 3 MYuri.
- e. The house tether is allowed to weigh 3 grams, so will lose to a tether that performs at 5 MYuri.

## 4 Conduct of the Competition

### 4.1 Competition Format

- a. The competition is conducted in a single-elimination cup format.
- b. Each team may start with either one or two tether samples.
- c. Spaceward will add tethers as necessary to get a power-of-two number of entries.
- d. The initial tournament bracket is populated with randomly drawn match-ups.
- e. After each round, winning teams are allowed to replace their tethers with fresh ones.
- f. Teams may use their tether samples in any order they wish.
- g. Failure is defined as either a physical break or elongation of 5% (relative to the nominal 2 m length), as indicated by the trip loop, or as perceived by the judges.
- h. The result of each pull is a winner tether, and a load rating for the losing tether.
- i. The winner of each match advances to the next round.
- j. The winner of the cup is called the champion tether.
- k. The champion tether is then pitted against the house tether.
- l. If it wins, the champion tether is competed against a steel chain to determine its strength.
- m. A champion tether can opt to go immediately against the steel chain.

### 4.2 Scoring and Winning

- a. Tethers that exceeded 5 MYuri participate in the distribution of the \$900k prize purse.
- b. Tethers that exceeded 7.5 MYuri participate in the distribution of the both \$1.1M prize purse.
- c. Per purse, winnings are distributed as follows:
  - let  $n$  be the number of teams that participate in the distribution of the purse.
  - let  $S = n(n+1)/2 = 1+2+3+\dots+n$
  - let  $i$  be the position of the team in order of increasing score
  - let  $p$  be the total prize purse
  - let  $w$  be the team's winning
  - and so  $w = ip/s$For example: if 2 teams participate, then they are awarded  $(1/3, 2/3) * \$1.1M = (\$366k, \$699k)$

### 4.3 Judging

- a. The Spaceward Foundation is responsible for interpreting and applying the rules.
- b. There will be a panel of 3 judges, selected according to the terms of the Space Act Agreement, and charged with providing oversight and entitled to overturn specific Spaceward decisions if they deem them unreasonable according to the panel's interpretation of the rulebook.
- c. The judges will witness the measurements taken during the competition.

### 4.4 Access to equipment

- a. Upon prior coordination, teams may use the test apparatus at our premises.
- b. A day prior to the competition event, each team will be allowed one hour of time with the test apparatus, to familiarize with it and to practice.

## 5 Document and Revision

Document title: handbook-ts20008

Document URL: <http://www.spaceward.org/elevator2010-ts.html>

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### Change History

v0.10 May 10, 2008 Ben Shelef	First 2008 revision
v0.90	Rewrite
v.0.91	replace best-of-three with multiple starts, also added steel chain.