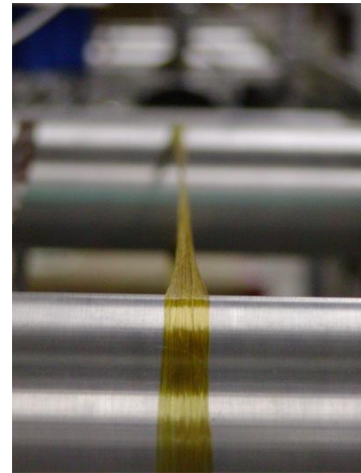




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## Strong Tether Challenge 2010



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### Web links:

Strong Tether Challenge Page: <http://www.spaceward.org/tetherChallenge.html>

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

NASA Centennial Challenges: <http://www.nasa.gov/challenges>



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## 1 Introduction

The Strong Tether challenge requires 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 intend to add the other factors in the years to come.

The Strong Tether Challenge 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 requires ready-to-test tether samples.

Our intent is to encourage the development of break-through materials. Any award of prize money will require significant advances over the state of the art, rather than incremental advances that only represent optimization in the use of current materials.

### 1.2 Safety

Breaking strong tethers releases 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 not tolerate unsafe behavior at the competition event.

Prior to the competition and at the event, entrants will be required to provide any safety information related to tether handling. If special procedures are required to handle the tether, it will be the team's responsibility to carry them out.

Spaceward will designate a safety engineer for the challenge. All safety related matters ultimately fall within the responsibility of the safety engineer.

### 1.3 Code of conduct

- a. Decisions made by the judging panel are final.
- b. A team may file a protest regarding its own score. A team may file a protest about the score of another team only if it has a non-zero score. Filing a protest consist of emailing the protest to Spaceward's representative, and an initial response will be issued in real time.





## 2 Rules and requirements

### 2.1 Units of measurement

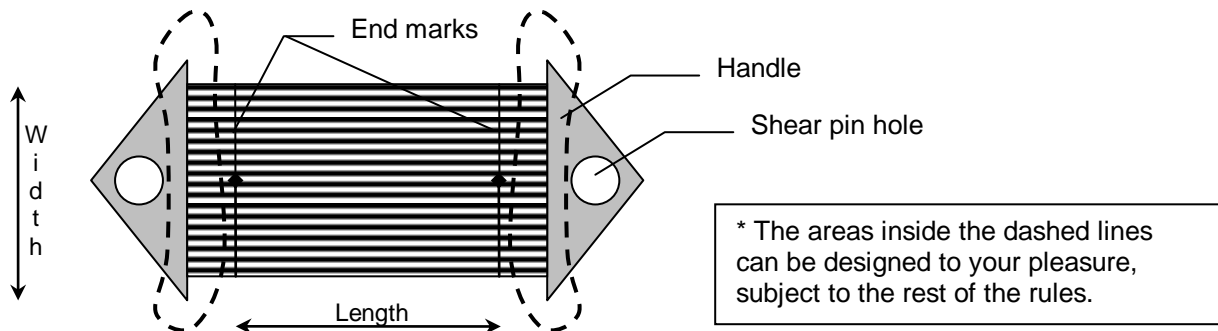
- The tether's specific strength will be measured in the SI derived unit of Yuri, where  $1 \text{ Yuri} = 1 \text{ Pa}/(\text{kg}/\text{m}^3) = 1 \text{ N}/(\text{kg}/\text{m})$ . The commonly used non-SI units N/Tex and GPa/(g/cc) are both equivalent to 1 MYuri.

### 2.2 Requirements

- A team entry consists of one or more interchangeable tether samples.
- All sample must conform to the mechanical specification listen below.
- Teams must be able to place team tethers in the test apparatus in under 5 minutes.
- Tethers must not be altered after being placed in the machine.

### 2.3 Tether sample specification

- Each sample consists of two handles and a tether body
- Each handle must have a shear pin hole as illustrated in the figure below, and be compatible with clevis part to be specified by the time of team registration. Each handle must be detachable from the tether (for the purpose of weighing the tether by itself) or weigh less than 100 times the weight of the tether. .
- The tether body must have two end marks clearly marked on it. The marks must be parallel to each other and perpendicular to the line between the shear pin holes to within  $1^\circ$ . The end marks can coincide or be within the inner edges of the handles, as long as condition d below is satisfied.
- The tether must break between the two end marks in such a way that the length measurement that was performed prior to the pull encompasses the break.
- The cross section of the tether body can be of any shape, but its width cannot exceed 10 cm.
- Tether weights and lengths are specified in section 3.2.



- A rolling-pin closed-loop system such as Spaceward's setup in previous years is allowed, by incorporating the rolling-pin into the handle design, and so can comply with the requirements. Length will be measured using a string placed around the pull pins.





### 3 Conduct of the competition

#### 3.1 Tether measurement

- The length of a tether is defined as the distance between the centers of the end marks (black dots in the figure above), measured under a load  $L$ ,  $200\text{ N} > L > 100\text{ N}$  as applied to the handles.
- The mass of the tether is defined as the mass of the material between the end marks, and is measured by subtracting the post-pull tether sample mass after the tether body is cut along the end marks from the pre-pull tether sample mass. Weighing will be done while hanging the sample from one of the handles.
- The breaking force is the maximum force recorded before the distance between the handles increased by at least 30%, or the force dropped to below 75% of peak.
- The test will be conducted at the ambient temperature,  $10\text{C} < T < 30\text{C}$ .
- Load will be increased using a manual hydraulic pump, no faster (on average per second) than 500 N/sec.
- Teams are responsible for handling their tether samples through all pre-pull procedures.

#### 3.2 Scoring and winning

- There are three prize levels, as indicated in the following table:

Prize level	Required specific strength	Allowed tether mass	Allowed tether length	Max linear mass density	Prize purse	Max expected breaking force
		m	L			F
	MYuri	gram	meter	g/m	\$	Newton
A	5.0	$0.09 < m \leq 0.1$	$1.1 \geq L \geq 0.1$	1.0	400,000	$\geq 5000$
B	5.0	$0.9 < m \leq 1$	$1.1 \geq L \geq 1$	1.0	600,000	$\geq 5000$
C	7.5	$0.9 < m \leq 1$	$1.1 \geq L \geq 1$	1.0	1,000,000	$F \geq 7500$

- A winning tether is eligible for funds from all prize purses equal or lower to the purse it won. For example, if a class B tether was measured at more than 5 MYuri, it is eligible for funds from purses B and A.
- Per purse, winnings are distributed as follows:  
let  $s_i$  denote the specific strength achieved by team  $i$ , and let  $s = \sum s_i$   
let  $p$  be the total prize purse, and let  $w_i$  denote the winning of team  $i$   
 $w_i = p \cdot s_i / s$

#### 3.3 Judging

- The Spaceward Foundation is responsible for interpreting and applying the rules.
- 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.
- The judges will witness the measurements taken during the competition.

#### 3.4 Complaints

- If a competitor is dissatisfied with the ruling of a judge or has any other complaints about the conduct or results of the competition, the Team Leader must submit the complaint in writing with a full explanation of the circumstances, to the Spaceward Foundation.

#### 3.5 Access to equipment

- Upon prior coordination, teams may use Spaceward's test apparatus at our premises.





### 3.6 Registration

- a. All teams must register with Spaceward in order to compete.
- b. At the time of registration, the team will provide Spaceward with the identity of the team leader and team members, and general technical plan including a preliminary sketch of the tether sample and material spec. A team agreement will be signed within 2 weeks of the registration date. Registration fees will be refunded if the team agreement cannot be signed. We encourage teams to register as soon as possible.
- c. Three weeks before the challenge, the teams must submit a final sketch of the tether sample, and material specification.
- d. Regular registration will close two weeks before the challenge. Late registration might be possible at Spaceward's discretion, and will cost twice the regular fee.
- e. Registration fee for class A is \$1000, for class B is \$1200, and for class C is \$2000.
- f. Up to three samples are allowed per registration. The score will be calculated based on the best sample.

### 4 Eligibility

The prize is open to teams lead by a US person (citizen or permanent resident) or US entity such as a corporation. The team leader must be a bone-fide participant in the team's activities, and a short description of their role with the team is required at the time of team registration. The team leader does not have to be the technical lead of the team.

The prize will be paid directly to the team leader.

### 5 Document and revision

Document title: handbook-ts2011

Document URL: <http://www.spaceward.org/elevator2011-ts.html>

Contact: ben@spaceward.org 408-334-2682

#### Change History

Rev 1 April 28, 2011 Ben Shelef	First 2011 revision, based on 2010 rules
Rev 2 May 17, 2011 Ben Shelef	General cleanup, removed Class A challenge.
Rev 2.1 June 1, 2011 Ben Shelef	Modified end-lines requirements
Rev 2.2 June 28, 2011 Ben Shelef	Added per-class registration, multiple tether samples per class

