

Strong Tether Challenge 2010

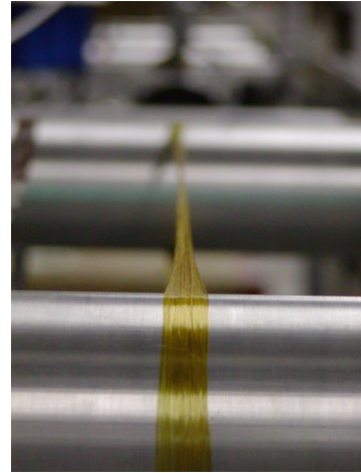


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Web links:

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

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

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

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

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 and the Power Beaming Challenges are 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

We hold these requirements to be self-evident... Unfortunately, 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 grounds for disqualification.
- d. Teams must clean up after themselves, pick up all of their hardware, and not damage property. If required, clean up costs will be deducted from the deposit, plus a 100% penalty.

2 Rules and requirements

2.1 Units of measurement

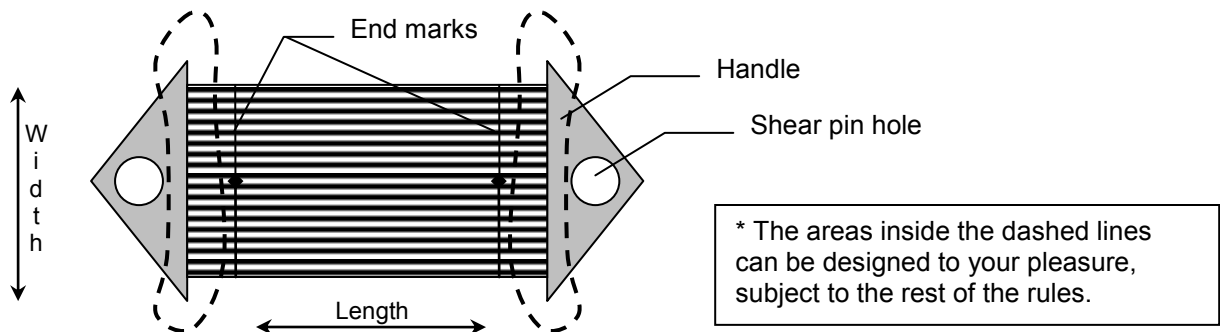
- The tether's specific strength will be measured in the SI derived unit of Yuri, where $1 \text{ Yuri} = 1 \text{ Pa}/(\text{kg}/\text{m}^3) = 1 \text{ N}/(\text{kg}/\text{m})$. For common non-SI units, note that $1 \text{ MYuri} = 1 \text{ N}/\text{Tex} = 1 \text{ GPa}/(\text{g}/\text{cc})$.

2.2 Requirements

- A team entry consists of one or more interchangeable tether samples.
- All samples must conform to the mechanical specification listed 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° . 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.
- The tether must break between the two end marks, and no damage can be sustained outside of the end marks. Damage that affects the measurement (as observed and evaluated by the judges) will disqualify a sample.
- The end marks can coincide with the inner edges of the handles, but they must be visible to confirm that no material is pulled from within the handle.



- 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. If pulling a closed loop, the loop must be removable from the handles after the break, or the end marks must appear on both sides of the loop (four in all).
- A handle design that deviates from that described above may be allowed if 1) it allows for testing in a manner consistent with the objectives of the challenge, 2) it does not create an unfair advantage for the team using it, 3) it can interface properly with the existing test apparatus and 4) it is approved in advance by Spaceward.

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 four 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	$0.09 < m \leq 0.01$	$1.1 \geq L \geq 0.01$	1.0	300,000	≥ 5000
B	5.0	$0.09 < m \leq 0.1$	$1.1 \geq L \geq 0.1$	1.0	300,000	≥ 5000
C	5.0	$0.9 < m \leq 1$	$1.1 \geq L \geq 1$	1.0	400,000	≥ 5000
D	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 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 are eligible to a class A prize, they are awarded $(1/3, 2/3) * \$300k = (\$100k, \$200k)$
- In case of a tie, the teams split in an equal manner the sum of the prizes they would have been awarded had there not been a tie.

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 selecting a winner(s), if any qualify, according to the rules and providing the name(s) of the winning Team Lead to Spaceward Foundation for final verification.
- 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 other complaints about the conduct or results of the competition, the Team Leader must submit the complaint in writing to the Spaceward Foundation consistent with the "Dispute Resolution" clause in the Team Agreement.

3.5 Access to equipment

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

4 Document and revision

Document title: handbook-ts2010

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

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Change History

v0.10 April 9, 2010 Ben Shelef	First 2010 revision
V0.90 June 15, 2010 Ben Shelf	Incorporate comments from Ted Semon, Andrew Petro
V1.0	Final