# A BRIEF HISTORY OF THE SPACE ELEVATOR GAMES

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## Introduction

If you do an Internet Search on the term "space elevator" today, you will find literally millions of hits on web pages which have some connection to the space elevator (I just did this and Google returned 'About 8,270,000 results'). Interest in this concept has increased tremendously in the last couple of decades.

One of the major contributors which greatly increased the visibility of the space elevator to the general public was the Space Elevator Games, a series of four competitions held over a five year period which were dedicated towards advancing technologies needed to build a space elevator. While other competitions have been held since then, I think it is safe to say that these are still the 'gold standard' which all other competitions must be measured against.

As the "*Space Elevator blogger*", I was privileged to be involved with and blog about the last three of these competitions. Without a doubt, this was the most exciting space-elevator related activity I have been associated with. Spending time with people who were involved in the Games was very gratifying – I'm a big fan of the "can do" attitude.

It's been a full 10 years since the first of these Games were held and memories about them are starting to fade. While I blogged extensively about them on The Space Elevator Blog, my blog posts were 'snapshot entries', not a complete record (although a good source of competition details, photos, videos etc.). This article is an attempt to commit to permanent record a summary of these Games.

## Overview of the Games

In 2005, the National Aeronautics & Space Administration (NASA) launched the Centennial Challenges[3]:

*NASA Centennial Challenges were initiated in 2005 to directly engage the public in the process of advanced technology development. The program offers incentive prizes to generate revolutionary solutions to problems of interest to NASA and the nation.*

*The program seeks innovations from diverse and non-traditional sources. Competitors are not supported by government funding and awards are only made to successful teams when the challenges are met.*

There were several of these Challenges; Astronaut Glove, Regolith Excavation, Green Flight, etc. Two of these Challenges, Power Beaming and Strong Tether, involved technologies which have a direct application to the construction and operation of a space elevator.

An Israeli-American engineer, Ben Shelef, had the grand idea to leverage these two challenges into an event he titled **The Space Elevator Games** and formed The Spaceward Foundation[4], in part, to acquire the resources to do so. NASA awarded Spaceward a five-year license to organize these two Challenges. In accordance with how NASA organized these Challenges, Spaceward would devise the rules for each Challenge, procure a competition venue, recruit the competitors and coordinate all of the activities for each event. NASA would review and approve the rules and, if there were any winners, award them prize-money based on the Challenge results. NASA also provided administration and consulting expertise and some advertising as well.

During this five year agreement, four sets of competition events were held:

- 2005 – Both Challenges were held at the NASA facility in Ames, California.
- 2006 – Both Challenges were held in Las Cruces, New Mexico, initially as part of that year's X Prize competition.
- 2007 – Both Challenges were held at the Davis County Event Center in Layton, Utah.
- 2009 – The Power Beaming Competition was held at the NASA Hugh L. Dryden Flight Research Center (renamed the Neil A.

Armstrong Flight Research Center in 2014) located wholly within the Edwards Air Force Base in southern California while the Strong Tether Challenge was held at the Microsoft Conference facility in Redmond, Washington, along with the annual Space Elevator Conference hosted by the International Space Elevator Consortium (ISEC).

For the 2005 event, NASA provided a $100,000 prize purse ($50,000 for each Challenge). In 2006, NASA increased this to $400,000 ($200,000 for each Challenge). In 2007, NASA further increased this to $1,000,000 ($500,000 for each Challenge) and for 2009, NASA provided a total prize purse of $4,000,000 ($2,000,000 for each Challenge).

In the first three events, no winners were declared (though one team from Canada came very close in the Power Beaming Challenge – twice!). In the fourth and final event, the team from Lasermotive LLC[5], an American engineering company based in Seattle, Washington, won the first level of the Power Beaming Challenge and with it, a $900,000 prize.

## The 2005 Challenges

My involvement with space elevators began in early 2006, so I was not involved in the 2005 Challenge. Thus I am indebted to Ben Shelef (and the Internet Archive "WAYBACKMACHINE"[6]) for helping to fill in the details of this event.

This inaugural event was held in October of that year at the NASA Ames Research Center, located in Mountain View, California and was a four-day affair. For this first set of Challenges, NASA put up a total prize purse of $100,000.

### *The 2005 Power Beaming competition*

NASA offered a prize purse of $50,000 in this first year. Climbers were mounted on a 50 meter long, 4" wide tether suspended from a crane at the height of 5 meters and had to climb to the 50 meter level at an average speed of at least 1 meter per second (m/s) to be eligible for the prize. There were also other requirements; Climbers had to descend within a maximum length of time, they had to do so under control, etc. If only one team succeeded in meeting all of the requirements, it would win the full $50,000. If multiple teams succeeded, the prize purse would be divided according to a set of criteria set out in the rules. The Climbers could not carry any fuel, they had to be beam-powered, i.e. power transmitted to

them wirelessly. For this first competition, all of the beam power was generated by 70 kW portable searchlights provided by Spaceward.

Six teams entered this competition;

| Team Name | Where from | Power Source |
|---|---|---|
| USST (University of Saskatchewan Space Design Team) | University of Saskatchewan, Saskatchewan, Canada | Spaceward provided searchlights. |
| Snow Star | University of British Columbia, British Columbia, Canada | Spaceward provided searchlights. |
| MClimber | University of Michigan, USA | Spaceward provided searchlights. |
| Star Climber | Private group from Maryland, USA | Spaceward provided searchlights. |
| SpaceMiners | Private group from Texas, USA | Spaceward provided searchlights. |
| Centaurus Aerospace | Private group from Utah, USA | Spaceward provided searchlights. |

**Table 1.**

Every team except Star Climber used photovoltaic cells on their Climber to convert the light beam to electricity to power their Climbers. Star Climber used a Stirling Engine which was powered by the heat generated from thermoelectric cells.

Only the two Climbers from the Canadian teams were able to successfully make a beam-powered climb on the ribbon. The Snow Star team was first to actually succeed in climbing, ascending about 20 feet before stalling out. Starting a tradition that was to carry forward to future competitions, USST performed the best, ascending about 40 feet, but not quickly enough to be eligible for any prize money.

### *The 2005 Strong Tether competition*

For the Strong Tether competition, NASA provided a separate $50,000 prize purse. The rules were simple. Tethers had to be in the form of a closed loop, had to weigh a maximum of 2.5 grams, had to be at least 2.5 meters long and could be no wider than 200mm. Each team also had to provide four identical tethers. Once a tether was measured and certified as being within specifications, it was placed on a competition apparatus (nicknamed the "Tether Torture Rack" - TTR). The TTR allowed two tethers

to be placed on separate rollers which, when the competition started, were simultaneously forced apart with hydraulic pressure. Whichever tether broke apart first was the loser. A strain meter was attached to the TTR to provide a numerical value of the force applied to it.

When a tether would break, it was eliminated and the team with the winning tether would move on to the next round. This would continue until only one team was left. This team's tether was then matched against a 'House Tether', a tether made of COTS (Commercial, Off-The-Shelf) materials which was identical in form to the competition Tethers except it weighed 50% more. If the competition tether was able to defeat the House Tether, it would mean that it was at least 50% stronger than the House Tether and would therefore be eligible for prize money.

Four teams entered this competition;

| Team Name | Where from | Tether Type |
|---|---|---|
| Centaurus Aerospace | Private group from Utah, USA | Unknown |
| Fireball | Private group from New Mexico, USA | Unknown |
| Tethers Unlimited | Company from Washington, USA | Unknown |
| Carbon Neanderthals | Private group from Washington, USA | Unknown |

**Table 2.**

The Tether from Centaurus Aerospace won both of its matches and was then was matched against the House Tether. The Centaurus Aerospace tether lost but broke at a very respectable 1200+ pounds. The House Tether was then tested and broke at 1300+ pounds so the Centaurus Aerospace tether came very close to winning.

## The 2006 Challenges

This event was held in Las Cruces, New Mexico in conjunction with that years X Prize Cup. The venue for the X Prize Cup was the Las Cruces International Airport and, for two days, the Power Beaming Challenge was also held there. One of the teams, however, had a microwave powered Climber and the Airport refused to allow it compete on Airport grounds. So on Day 3, the Space Elevator Games moved to the nearby County Fairgrounds and finished up there.

Coverage of the 2005 Challenge drew worldwide interest and resulted in 20 teams registering for the 2006 event, including the first non-North American entries. For this year's Challenges, NASA put up a total prize purse of $400,000, $300,000 in 'new' money plus the $100,000 left over from the 2005 event.

### *The 2006 Power Beaming competition*

The Power Beaming rules had many similarities to the 2005 competition; the racecourse was still a 50m high, 4" wide ribbon suspended from a crane, competitors would still mount their Climbers on the ribbon and start their timed climb at 5 meters and the goal was still 1m/s. However, the teams now had to provide an end-to-end solution, i.e. they had to bring their own beam source. Also, NASA increased the prize purse to $200,000. Six teams passed the Qualification runs and were able to compete:

| **Team Name** | **Where from** | **Power Source** |
|---|---|---|
| USST (University of Saskatchewan Space Design Team) | University of Saskatchewan, Saskatchewan, Canada | Searchlights |
| Snow Star | University of British Columbia, British Columbia, Canada | Reflected sunlight |
| MClimber | University of Michigan, USA | Searchlights |
| TurboCrawler | Max Born College, Germany | Searchlights |
| Kansas City Space Pirates | Kansas City, Kansas, USA | Reflected sunlight |
| Lite Won | Campbell, CA, USA | Searchlights |

**Table 3.**

In addition, there were several other teams that registered and showed up, but were unable to compete for various reasons. These were:

Recens – A team from Spain. Their equipment got caught up with a Customs issue in Germany and ultimately did not arrive at the competition.

SpaceMiners – They burned out 4 cells on their photocell array on a qualification attempt and ultimately were unable to repair their Climber in time.

Star Climber – They suffered an ultimately fatal mechanical problem with the ribbon gripping mechanism and the gears driving it trying to qualify.

Beamer1 – When their Climber was being weighed in, it somehow got disconnected from the scale and crashed to the ground. The lens fractured and became unusable.

PunkTaurus – This was a combination of the PunkWorks and the Centaurus Aerospace teams. The PunkWorks Climber was powered by microwaves. They could not get their equipment working and it looked like they wouldn't be able to compete. At the last minute, however, the Centaurus Aerospace team showed up and they too, had a microwave powered Climber. The two teams decided to combine forces and thus PunkTaurus was born. As mentioned earlier, the Power Beaming competition was eventually moved to the local County Fairgrounds to give them a chance, but they could not get their equipment working.

All of the competing teams Climbers were able to successfully climb to the top of the tether except the Kansas City Space Pirates (which did successfully negotiate a significant portion of the course) and Snow Star. MClimber had the distinction of being the very first Climber to ascend the entire length of the ribbon while USST completed the course in, by far, the best time – 57 seconds, just two seconds two slow to claim the prize. USST's time was so close that the Spaceward team had to re-measure the ribbon for elastic and plastic elongation to determine if a winning run had been made.

One other note about the entry from USST is worth mentioning. They came very close to winning with their second choice of beam power. They had brought a laser and hoped to power their Climber with it, but were ultimately unable to get it working properly and had to resort to using searchlights.

### *The 2006 Strong Tether competition*

The rules for the 2006 Strong Tether Challenge were similar to those from 2005, but the weight requirement was reduced from 2.5 grams to 2 grams and the length requirement was reduced from 2.5 meters to 2 meters. NASA also increased the prize purse for this Challenge to $200,000. Four teams registered for and competed in the Challenge:

| Team Name | Where From | Tether Composition |
|---|---|---|
| Astroaraneae | Private group from California, USA | Unknown |
| Snow Star | University of British Columbia, Canada | Unknown |
| Centaurus Aerospace | Private group from Utah, USA | Unknown |
| Fireball | Private group from Washington, USA | Unknown |

**Table 4.**

While tethers from all four teams met the 2 gram limit qualification, only the tether from Astroaraneae met the 2 meter limit qualification. This meant that Astroaraneae won the competition among the individual teams by default, something which caused much heartache from the disqualified teams.

In the spirit of competition, however, the Fireball and Snow Star tethers were matched against each other in a "non-title" match. Snow Star won when Fireball's tether parted at 531 pounds. Snow Star then took on Centaurus Aerospace in another friendly competition. Centaurus Aerospace won when the Snow Star tether parted at about 880 pounds.

The Astroaraneae tether was then matched against the "House Tether" to see if it would qualify for prize money. Alas, it did not, breaking at about 1,336 pounds. And as it turned out, this was the strongest measurement of any competitor's tethers in the entire Games.

Once that was completed, the House Tether was then matched against some rope, just to see what level the House Tether would break at. Unfortunately, both tethers proved to be too strong for the TTR and they broke the machine – a fitting end to a disappointing competition.

## The 2007 Challenges

This year's Challenges were held at the Davis County Event Center in Layton, Utah (near Salt Lake City). Originally scheduled to run from October 19th through the 21st, they were extended by several days due to weather-caused delays and also to accommodate additional competition runs.

### *The 2007 Power Beaming competition*

The rules for the 2007 competition again were similar to the 2006 rules, but the height of the racecourse was doubled to ~100 meters and the speed necessary to win a prize was also doubled to 2 m/s. The prize purse was also significantly increased to $500,000.

While many teams (~20) registered, 'only' seven showed up at the competition.

| **Team Name** | **Where from** | **Power Source** |
|---|---|---|
| USST (University of Saskatchewan Space Design Team) | University of Saskatchewan, Saskatchewan, Canada | Laser |
| LaserMotive | Professional group from Washington, USA | Laser |
| Punkworks / McGill | Canada | Microwaves |
| E-T-C | Japan | Searchlights |
| Technology Tycoons | Campbell, CA, USA | Searchlights |
| Kansas City Space Pirates | Kansas City, Kansas, USA | Reflected sunlight |
| Snow Star | British Columbia, Canada | Reflected sunlight |

**Table 5.**

All of these teams were able to mount Climbers on the ribbon and attempt runs, but three of them, LaserMotive, Punkworks and Snow Star, were unable to make it to the top of the ribbon.

The Kansas City Space Pirates (KCSP) had the fastest measured climb rate over a significant portion of the ribbon, well over 3.5 m/s, but unfortunately could not keep this up over the entire climb. Their best time to the top of the ribbon averaged out at 1.25 m/s. USST had the fastest climb to the top of the ribbon (and they were able to make multiple climbs to the top, the only team to do so) but their best time, 1.8 m/s, was just slightly under the required 2 m/s necessary to be eligible for a prize. This was the third Power Beaming competition in a row where the USST Climber had the best performance.

### *The 2007 Strong Tether competition*

The rules for the 2007 Strong Tether Challenge were very similar to the 2006 Challenge; the tethers had to be at least 2 meters in length, they could weigh no more than 2 grams and they had to beat the House Tether (which could weigh 50% more) in order to be eligible for prize money. The prize purse in this Challenge was also increased, to $500,000.

Only two teams entered tethers for this Challenge:

| Team Name | Where From | Tether Composition |
|---|---|---|
| Astroaraneae | Private group from California, USA | Unknown |
| Delta-X | MIT, Massachusetts, USA | Carbon nanotubes |

**Table 6.**

Delta-X brought the first carbon nanotube tether ever entered into the Strong Tether competition but it was so new that they had not had time to form it into a true loop – they wound up tying the ends together in a knot.

The tethers from both teams met the qualification criteria, so they were matched up in a head-to-head competition. It was a foregone conclusion that the Delta-X entry would separate at the knot and this was, in fact, what happened – it was a rather anticlimactic victory for Astroaraneae. They were then to be matched against the House Tether to see if they would be eligible to win a prize, but they inexplicably refused to do so. So, once again, there was no prize winner this year.

## The 2009 Challenges

It had originally been hoped to have the next set of Challenges in 2008, but several factors, most significantly that of trying to find a venue which could handle the new Power Beaming Challenge requirements, conspired against this. After a lot of searching, the venue selected was the NASA Dryden Flight Center located in southern California near Mojave.

The Power Beaming competition was first scheduled in early 2009, and then in August but it was finally held in November of that year. The Strong Tether Challenge was held in conjunction with the annual Space Elevator Conference held by the International Space Elevator Consortium (ISEC) in August.

### *The 2009 Power Beaming competition*

The rules for the 2009 Power Beaming Challenge were similar to prior year's competitions but the requirements to win any money were made significantly more difficult. The prize purse for this Challenge had been increased by NASA to $2,000,000. Teams had to have their Climber ascend the competition tether with a minimum speed of 3 m/s to be eligible for the first-level prize of $900,000. If a team could make the run with an average speed of at least 5 m/s, they would then be eligible to win the entire $2,000,000. The 'racecourse' for this event was a kilometer long steel cable held aloft by a helicopter. The starting point was at 100 meters so the timed run was 900 meters long.

Because of the difficulty in satisfying these requirements, only teams with laser-powered Climbers joined this competition. There were three of them, all veterans of previous years' events.

| **Team Name** | **Where from** | **Power Source** |
|---|---|---|
| USST (University of Saskatchewan Space Design Team) | University of Saskatchewan, Saskatchewan, Canada | Laser |
| LaserMotive | Professional group from Washington, USA | Laser |
| Kansas City Space Pirates | Kansas City, Kansas, USA | Laser |

**Table 7.**

Each team used a different tracking mechanism to keep their laser pointed at the photovoltaic cells on the Climber. USST used a GPS-based system. The Kansas City Space Pirates (KCSP) team used an automatic beam tracking system while LaserMotive tracked their Climber manually with a camera and a joystick.

LaserMotive was the only team to be able to climb the entire length of the cable and they did so multiple times. In addition, they were able to climb the cable in a best time of 3 minutes, 48 seconds, which worked out to a speed of about 3.95 m/s, more than enough to win the $900,000 prize. Once they had qualified for that prize, they then stripped off every gram they could from their Climber in an attempt to win the $2,000,000 prize, but their Climber failed during the attempt. KCSP was able to climb several hundred meters multiple times, but different failures kept causing them to

be unable to ascend the full distance. And, in something which remains inexplicable, the USST Climber was barely able to climb any distance at all. It was most puzzling. They were the most experienced team (all-around and with lasers) and they had performed the best in the previous three competitions, but this time around it was just not to be.

Still, these Challenges were finally able to award some prize money, $900,000, to the LaserMotive team – congratulations!

### *The 2009 Strong Tether competition*

For this year's Challenge, NASA had increased the prize purse to $2,000,000 and, concomitantly, rules to win prize money were even more difficult than in previous years. A competition tether still had to meet the 'no less than two meters long and weigh no more than 2 grams requirement' and then would have to beat the house tether in a head-to-head match. If successful, it would then have an absolute measurement made of its breaking strength. If this exceeded 5 Mega-Yuris (5 GPa-cc/g or 5 N/Tex), then it would eligible to win prize money.

There was only one entrant into this year's competition;

| **Team Name** | **Where From** | **Tether Composition** |
|---|---|---|
| Shizuoka University | Japan | Carbon nanotubes |

**Table 8.**

This was only the second carbon nanotube tether we had seen in a Strong Tether competition and, alas, it didn't perform any better than the one from Delta X in 2007. While it was formed as a true loop without a knot holding it together (it looked like a thin ribbon, very similar to the old VHS or Betamax video tapes) it parted at a very low load, barely registering on the strain meter.

## Some Final Notes…

There was some interest in holding one more set of competitions in 2010, but ultimately it did not happen.

Unfortunately, NASA decided not to renew these two Challenges (despite persistent efforts from ISEC to get them to renew the Strong Tether Challenge). In 2010 and 2011, ISEC sponsored its own Strong Tether competition, using the same basic rules and equipment which had been

used in the NASA-Spaceward Challenge, but these events produced no winners either. There were multiple carbon nanotube entries for both of these competitions, but none of them even approached the strength of commercial materials, let alone exceed them, as would be necessary to win some prize money (or build an earth-based space elevator).

Two other organizations have held 'serious' Climber competitions, EuroSpaceward[7] and the Japan Space Elevator Association (JSEA)[8]. EuroSpaceward has held two competitions and there is talk of organizing a third. JSEA has been holding Climber competitions for several years, each with an increasing level of difficulty (much the same as the Space Elevator Games), but the climbers in these two competitions (as well all of the other academic / school kid / robotics / science fair competitions I'm aware of) are battery powered.

No one yet knows, of course, how we're actually going to build a space elevator, but when that day comes, I think it's fair to say that The Space Elevator Games will be seen as an important early step in the process. Most, if not all of the technologies used in the Power Beaming competition will probably be relevant, even if lasers are ultimately replaced with another power source. And the need for a material to create a strong tether, is, of course, absolutely crucial to building an earth-based space elevator.

It's been estimated that the minimum tether strength to build an earth-based space elevator is in the range of 25-30 MYuris[9] (stronger is better, of course), about an order of magnitude above the material we have today. It's fortunate we now have several possibilities for ultra-strong materials in the lab (boron-nitride nanotubes, carbyne, diamond nanothreads and graphene as well as carbon nanotubes) and hopefully a breakthrough will happen in at least one of them in the relatively near future.

We're all waiting as fast as we can…

## Additional Reading

- The Space Elevator Blog[1]
- The Spaceward Foundation[4]
- The International Space Elevator Consortium[2]
- The Space Elevator Reference[10]
- The NASA Centennial Challenges website[3]

## References

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