

Drive & Control profile

Space Elevator Becoming Reality with Bosch Rexroth Aluminum Structural Framing



The "tug-of-war" tether pull machine allows two samples to be tested simultaneously in order to determine a winner.

Space elevator. It sounds like the stuff of science fiction novels, but in fact it is a very real structure proposed by very real scientists, engineers, and space enthusiasts. Each year since 2005, the Spaceward Foundation (www.spaceward.org), a non-profit organization dedicated to furthering space science and technology, hosts the Space Elevator Games. The goal of the games is to unite academic, commercial and educational minds

for a series of challenges designed to reignite the nation's interest in space—specifically interest in the design and construction of a functioning space elevator.

During the inception of the Space Elevator Games, NASA's Centennial Challenges program announced its partnership with the Spaceward Foundation in support of the event. Centennial Challenges is NASA's program of prize contests to stimulate innovation

Challenge

Provide quick turnaround of structural framing products to aid Spaceward Foundation's Space Elevator Games

Bosch Rexroth Solution

Aluminum Structural Framing

Benefits

- Tether pull machine tests and measures tensile strength of proposed space elevator tethers from multiple design teams
- 24-hour response enables Spaceward Foundation to build test rig quickly and economically
- Easy-to-assemble, rugged aluminum structural framing provides perfect test bed support
- Bolt-together connectors can be quickly assembled by the team without special tools or skills
- Flexible structural framing design enables future changes/expansion of test rig when needed

and competition in solar system exploration and ongoing NASA mission areas.

Elevator Replaces Rockets

Essentially, a space elevator is a structure designed to transport material from the Earth's surface into space. The goal is to replace the existing method of rocket propulsion with the traversal of a fixed structure via a climbing mechanism (much like an elevator) in order to move material into or beyond orbit. One method to achieve this is in the form of a tether, which reaches from a ship-based anchor on the surface of the Earth to a counterweight beyond geosynchronous orbit. The climbing mechanism can then travel along the tether beyond the Earth's gravitational pull without the use of rocket propulsion. Theoretically, the space elevator could then deliver cargo and people into orbit at a fraction of the cost of traditional launching methods.

Construction of such a structure may seem like a daunting task, but



Every aluminum structural framing component is reusable, making it simple for the team to adapt the machine as design needs develop and change.

organizations like the Spaceward Foundation are hoping to advance the technology with contests like the Space Elevator Games.

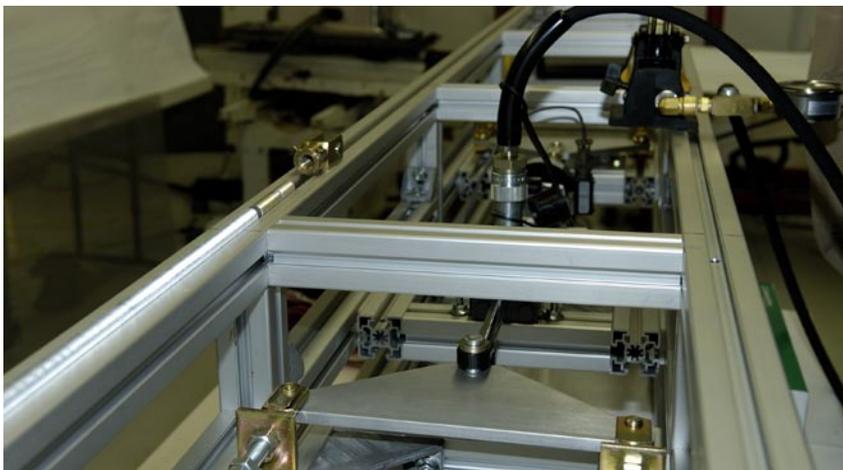
“Right now the technology to complete a space elevator does not exist,” said Ben Shelef, aerospace engineer and co-founder and

leader of the executive crew of the Spaceward Foundation. “The purpose of the Space Elevator Games is to get the right people in industry and academics thinking about how we can make this work and to stimulate the development of new technologies to make the structure a reality.”

The Linear Motion and Assembly Technologies group from the Bosch Rexroth Corporation shares Shelef's vision of encouraging and supporting new technological developments and immediately recognized the merit of the Spaceward Foundation and its efforts to achieve these goals with its Space Elevator Games. When Shelef called upon Bosch Rexroth to supply aluminum structural framing and components for the tether pull machines used in the inaugural 2005 Games, the company agreed this was a project they wanted to ride all the way to the top.

Tether Pull Machine

The extruded aluminum structural framing supplied by Bosch Rexroth is used to construct the tether pull machine—a device for testing and measuring the tensile strength of each of the team's proposed elevator tethers. Each tether is connected to the pull machine end-to-end and then stretched using a hydraulic piston until the tether breaks. The tether pull machine was designed specifically for the Spaceward Foundation's Strong Tether Competition—a \$2,000,000 technology challenge backed by NASA for developing a new class of super-strong tethers.



The tether pull machine tests and measures tensile strength of the proposed elevator tethers.

“The tether pull machine is designed to run a comparative test between two tether samples,” explained Shelef. “One of the decisions made early on in the program was that we wanted to make tether testing an exciting business to watch, so we created a head-to-head strength competition.”

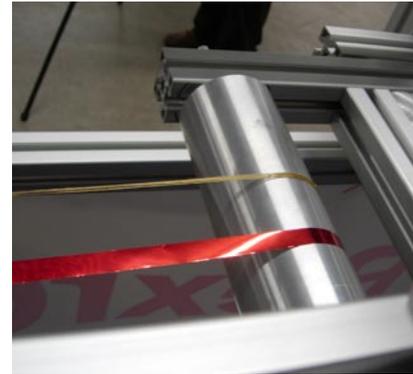
For this purpose Shelef and his team designed what is essentially a tug-of-war machine. The tether pull machine grabs two tether samples at their respective ends, and then pulls their free ends towards each other. Since the pulling mechanism floats, the resultant force on the tethers is equal, and as the force increases, one will break first “and with a very loud bang!” noted Shelef. The remaining tether, along with the pull mechanism, will lunge the other way and clearly indicate a winner.

The tether machine itself comprises a rectangular box structure about 12-feet long and 18-inches high on each side. “It has sliding parts, it needed to look sleek, and from our experience as designers, Rexroth’s aluminum structural framing system was the natural way to go as the material to build the machine,” said Shelef.

Using Rexroth bolt-together connectors, the tether pull structure can be quickly assembled by the team without special tools or skills and the extruded aluminum framing looks clean and attractive without painting or other finishing.

The team could also choose from a broad selection of Rexroth accessories to extend the machine beyond a simple frame and base to a complete multi-functional structure. And, every aluminum structural framing component is reusable, which made it simple for the team to change the tether pull machine as their design needs developed and changed.

NASA sponsors the Strong Tether challenge to encourage development of an appropriate tether material for use in various structural applications. The competition requires a 50 percent



Tether and reference band on tether pull machine.

improvement in breaking force from year to year, starting with a commercially available tether in 2005 when the contest began.

Space Elevator Fast Facts

- The Space Elevator is a thin ribbon, with a cross-section area roughly half that of a pencil, extending from a ship-borne anchor to a counterweight well beyond geo-synchronous orbit.
- The ribbon is kept taut due to the rotation of the earth (and that of the counterweight around the earth). At its bottom, it pulls up on the anchor with a force of about 20 tons.
- Electric vehicles, called climbers, ascend the ribbon using electricity generated by solar panels and a ground-based booster light beam.
- In addition to lifting payloads from earth to orbit, the elevator can also release them directly into lunar-injection or earth-escape trajectories.
- The baseline system weighs about 1,500 tons (including counterweight) and can carry up to 15-ton payloads at a rate of easily one per day.
- The ribbon is 62,000 miles long, about three feet wide, and is thinner than a sheet of paper. It is made out of a carbon nanotube composite material.
- The climbers travel at a steady 200 kilometers per hour (120 mph), do not undergo accelerations and vibrations, can carry large and fragile payloads, and have no propellant stored onboard.
- Orbital debris is avoided by moving the anchor ship, and the ribbon itself is made resilient to local space debris damage.
- The elevator can be made larger by using itself to carry more ribbon pieces into place. There is no limit on how large a Space Elevator can be!



The Strong Tether challenge is conducted in two rounds. The first round pits tethers from two teams directly against each other to determine the team with the strongest tether. The second round then determines if the first-round winner is at least 50 percent stronger than a “house” tether that represents off-the-shelf materials. If it is, that team will win the competition.

“The aluminum structural framing was able to meet our performance criteria while also allowing us to assemble the tether machine quickly and easily,” explained Shelef, who attributed his knowledge of aluminum extrusions to his frequent use of the product in constructing lab equipment for his day job.

Rexroth Distributors Deliver On-The-Fly

Jay Blum is the Southwest branch manager for Pacific Integrated Handling (www.pacificintegrated.com), a Rexroth distributor located in Tempe, AZ. Blum was on the receiving end of a call for a last minute order from Shelef when the Spaceward Foundation team was on its way to a competition in Albuquerque, NM. The team had not yet finalized the project parts list.

“When they called for assistance, they told us they would be passing through Phoenix on their way to the competition and would appreciate any help we could give them,” said Blum. “The Rexroth parts list was finalized, and we were able to have the aluminum extrusions machined and kitted for them in less than 24 hours to accommodate their trip through Phoenix. All in all it was a great team effort between Bosch Rexroth and Pacific Integrated Handling to come through for the customer.”

Recently, the Space Elevator Games were held at NASA’s Ames Research Center in Mountain View, CA, so Bosch Rexroth distribution manager Steve Kirnig called upon local Rexroth distributor Automation Controls (www.automationcontrols.com) to supply the requested structural framing. Shelef used Rexroth’s Aluminum Structural Framing Online Shop to view catalog items and generate an online bill of materials for the distributor, which also streamlined this portion of the project. Michelle Fischer, Automation Controls director of marketing, recalled the months of order changes and additions and multiple short-lead deliveries that were part of their commitment to the project, but she also recalled the rewarding experience of



Bosch Rexroth uses quick-load connectors that fit anywhere along the T-slot, making it easy to add accessories or fixtures anywhere to make a multi-functional structure.

attending the exhibition and seeing their efforts pay off.

“When I went to the exhibition, it was amazing to see these ideas come to life,” recalled Fischer. “It made all of our work well worth it.”

In the 2005 and 2006 Space Elevator Games, teams participated in the challenges before spectator crowds of more than 20,000 people, but each event was unable to produce a winner. At the 2007 Space Elevator Games a total prize of \$1 million was up for grabs. (Visit <http://www.spaceward.org/games07Wrapup> for more information on the Strong Tether competition.)

Rexroth
Bosch Group