The 2008 Space Elevator Conference

Welcome to the proceedings of the 2008 Space Elevator (SE) Conference, held July 18 through 20, 2008 at the Microsoft Conference Center in Redmond, Washington. This was the fourth such international gathering of engineers, scientists, entrepreneurs and enthusiasts devoted to exploring the means of developing and utilizing a Space Elevator. The Space Elevator would provide scalable access to space for mankind as a key to construct infrastructure there, improving stewardship for Earth and explore the resources available in the Solar System. The Redmond location brought the conference home in a sense, as the first conference had been held in nearby Seattle, in 2002. That first one was succeeded the following year by a second event in Santa Fe, NM. The 3rd Space Elevator Conference took place in 2004 in Washington, D.C., organized by the Institute for Scientific Research (ISR). As a result the 2004 conference combined prime location supporting attendance by political officials and exciting news such as the introduction of the NASA Centennial Challenge program, including Spaceward's Elevator Challenge. From 2005 through 2007 the Space Engineering and Science Institute picked up the baton and held conferences with SE sessions, but there was no dedicated Space Elevator conference.

In 2008 it was time to take stock: What progress was there in CNT development, power beaming, and other Space Elevator technologies in the four years since the last conference? How was the progress on defining the challenges in a consistent, quantitative fashion? As the first Space Elevator is a very long term project, tracking the updated landscape for its evolution is a challenging task.

For the 2008 conference we anticipated a lot of new material, defining progress toward the realization of our ultimate goal, the Space Elevator. We chose the theme: "Building Bridges to Our Future", because the Space Elevator will be the ultimate bridge to space for humanity and because conferences play an essential part in fostering the community that will help build it. Microsoft Corporation, as generous sponsor, provided access to the fantastic Conference Center facility at their Redmond campus in Washington and your conference team set out to pull the 2008 conference together.

The conference program was structured as a rough storyline moving through sections such as: Why and how close we were to the Space Elevator, what world would be created if one is built, technical and legal considerations, economics, risks, and pondering additional things to think about.

The conference had a workshop component and an ad-hoc "Shotgun Science Session" for unprepared material, both of which invited participation from the audience. The workshop sessions were specifically geared to challenge people to consider how they could contribute in the future to SE development. What did they think would be appropriate short and medium term goals to set to rally resources in the most effective way for progress. It made for a very interactive, lively conference that ultimately lead to the creation of ISEC, the International Space Elevator Consortium, providing a go-to authority for Space Elevator matters.

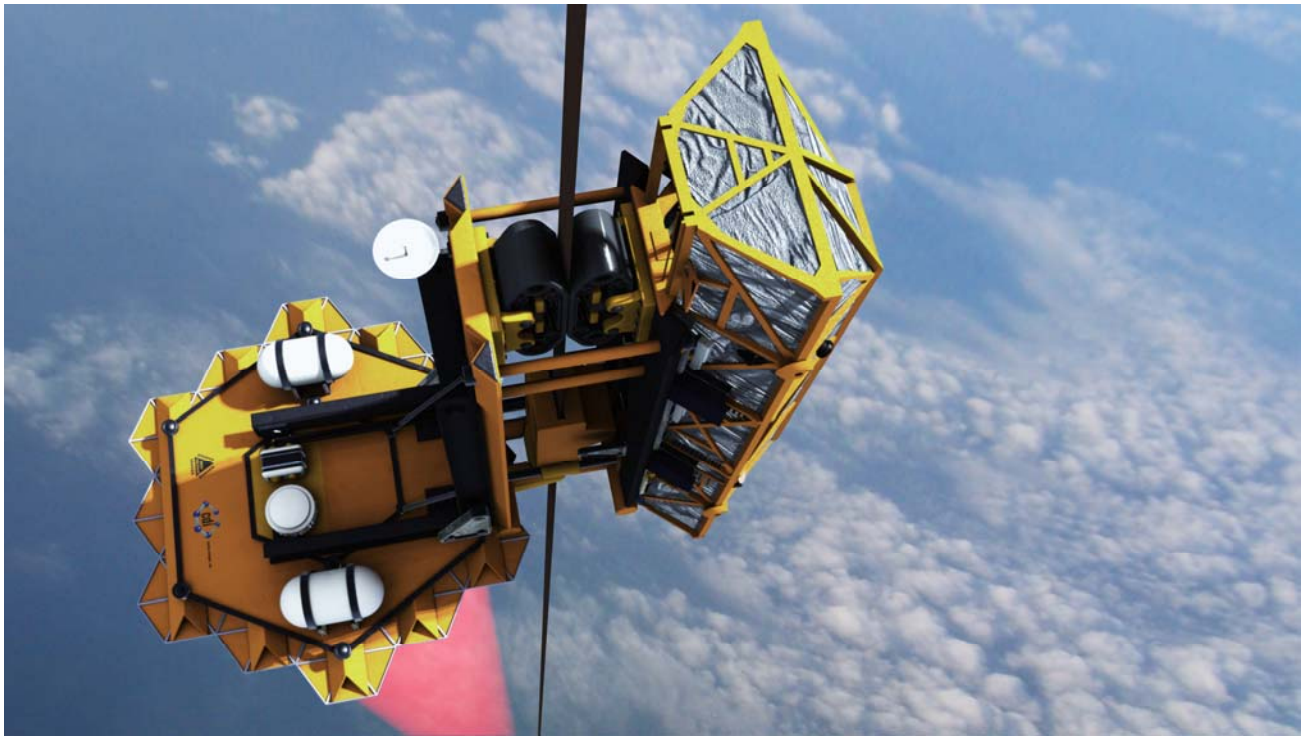
We also have to thank people such as Ivan Bekey for clear challenges to the established Space Elevator paradigms, by pointing out the risk of debris, which is even graver for an SE than it is already for other space enterprises. This would seed the theme to the first ISEC report in 2010 which quantified the debris risk for an SE under use of up-to-date NASA debris data.

Another highlight of the conference was the presentation on the fabrication of high strength CNTs. In 2008 they had entered industrial production for defense related applications in high strength fabrics.

We thank everyone, sponsors, authors, audience, and volunteers for making the 2008 SE conference a success. Their contributions planted roots for the developments of the following years, including the 2009 and 2010 conferences at the same location. Please enjoy the proceedings material included on this CD.

We hope to see you at future Space Elevator events,

Your 2008 Space Elevator Conference Team



2008 Space Elevator Conference

Microsoft Conference Center
Redmond, Washington

www.spaceelevatorconference.org

'08 SEC
Building Bridges to Our Future

Presented by Space Engineering and Science Institute

Conference Program

Conference Program

Time	Scheduled Activity
Day 1:	**Friday, July 18**
7.30 am	Conference Space Open: Registration
9.00 am	Opening Remarks
9:10 am	**Keynote: Space Elevator Overview, Dr. Bradley Edwards, President, Black Line Ascension**
9:55 am	Break
	1st Session – Why the Space Elevator?
10.05 am	Innovation and the Elevator and Introduction for Ivan Bekey, Randy Liebermann
10:15 am	**Kenote: Potentially Fatal Elevator Flaws That Must Be Addressed, Dr. Ivan Bekey, Bekey Designs, Inc.**
11:00 am	Space Elevator History: A Tribute to Sir Arthur Clarke, Jerome Pearson, President, STAR, Inc.
11:20 am	Why We Need an Elevator to Space!, Dr. Bradley Edwards/Markus Klettner, Eurospaceward
11:40 am	Lunch, Sponsored by Randy Liebermann
12:10 pm	**Lunch Keynote: Space Elevator Games - History and Status, Ben Shelef, Director, Spaceward Foundation**
	2nd Session – How Close are We?
12:40 pm	Status Quo on Space Elevator Tether Development as Highlighted by NASA's Tether Challenge at the Spaceward Games, Dr. Bradley Edwards/Markus Klettner, Eurospaceward and others.
1:05 pm	Thin Disc Lasers - a Robust, Scalable Source for Power Beaming Applications, Pat Grace/Dr. Holger Schlueter, TRUMPF
1:30 pm	Space Elevator Development Status in Asia, Akira Tsuchida, Board Director, Japan Space Elevator Association (JSEA)
1:55 pm	Tether Applications Relevant for a Space Elevator, Jeffrey Slostad/Dr. Robert Hoyt, Tethers Unlimited
2:20 pm	Break
	3rd Session – What World will be Created? I
2:35 pm	Space Solar Power Scenario Comparison, Dr. Bryan Laubscher, Founder, Industrial Nano
3:00 pm	The Space Elevator: Solution to Global Climate Control? Jerome Pearson, President, STAR, Inc.
3:25 pm	Impact analysis of the space elevator on space activities, Andreas Hein, Wissenschaftl. AG f. Raketentechnik and Raumfahrt (WARR) TU Munich
3:50 pm	Break
	4th Session – What World will be Created? II
4:00 pm	Solar Augmented Climbers and Implication on Required Tether Strength, Ben Shelef, Director, Spaceward Foundation
4:25 pm	Asteroid Sling-Shot Express - a Useful Space Elevator We Can Construct Today, Ben Shelef, Director, Spaceward Foundation
4:50 pm	Thermoelectric Technology and the Space Elevator, Dr. David Nemir, TXL Group, Inc.
5:15 pm	Disposal of Radioactive Waste by Space Elevator, Shigeo Saito
5:40 pm	Space Elevator - The Future as Foreseen by Scientists, Part 1, Hiroshi Koike, Walk Co., Ltd
5:50 pm	Sessions End
6:20 pm	**Social Mixer,** Hiroshi Koike, Part 2: Japanese DVD
7:30 pm	End of Social Mixer

Time	Scheduled Activity
Day 2:	**Saturday, July 19**
8:00 am	Conference Space Open
	5th Session – Legal Considerations I
8:30 am	The Legal Landscape Relevant for the Space Elevator, Alisa Brodkowitz, J.D./David Schoeggl, J.D., Brodkowitz Law and MMS-Seattle
8:55 am	Workshop Introduction: What will it take to build the Space Elevator? Dr. Martin Lades
9:05 am	Break
9:15 am	**Roadmap Workshop I – Get Involved!** Pillar Discussions

Development Pillar Leads:

Science and Technology:	Dr. Bradley Edwards
Public Relations:	Dr. Peter Swan and Ted Semon
Legal:	Alisa Brodkowitz, J.D. and David Schoeggl, J.D.
Business:	Ed Gray

11:15 am	Break
11:30 am	Results of Workshop I
	5th Session – Legal Considerations II
11:40 pm	Legal Fields and Examples Related to the Space Elevator, J. Gregory Rebholz, J.D.
12:05 am	Lunch
1:05 pm	**Roadmap Workshop II – Ready, set, go!** Pillar Discussions
2:35 pm	Break
	6th Session – Technical Considerations I
2:45 pm	The Role of Requirements Analyses and Carbon Nanotubes in Space Elevator Development, Dr. Bryan Laubscher, Founder, Industrial Nano
3:10 pm	Space Elevator Dynamics through Simple Approximations, Dr. Blaise Gassend
3:35 pm	Production of High-Strength-to-Weight Ratio Tethers from Carbon Nanotube Yarns and Textiles, Stephen Steiner III et al., MIT/Nanocomp
4:00 pm	Technology of Japan that can be utilized for construction of a Space Elevator, Shuichi Ohno, President, Japan Space Elevator Association (JSEA)
4:25 pm	Break
	7th Session – Economics
4:40 pm	Space Elevator – Improving the Human Condition: Why? How? When? Peter Swan, Teaching Science and Technology, Inc.
5:05 pm	One Million Rockets or 10 Space Elevators, Bryan Laubscher, Founder, Industrial Nano
5:30 pm	Laser Power Beaming on a Shoestring, Dr. Tom Nugent, LaserMotive
5:55 pm	Break
6:30 pm	**Banquet** – Workshop Results, Multimedia
8:30 pm	End of Banquet

Time	Scheduled Activity
Day 3:	**Sunday, July 20**
8:30 am	Conference Space Open
	8th Session - Technical Considerations II
9:00 am	Space Elevator (Space Train) Alternate Method and Road-Map, Akira Tsuchida, President, Earth-Track-Corporation
9:25 am	E-T-C Climber 2007 Review and 2008/2009 Prep Status, Akira Tsuchida, Team Lead, E-T-C, US/Japanese team Spaceward Power Beaming Competition
9:50 am	The space elevator past, the present, and the future in Japan, Toshiki Hasegawa
10:15 am	Break
	9th Session - Technical Considerations III
10:30 am	Climber Mechanism of the Space Elevator, Hideyuki Natsume, JSEA
10:55 am	Space Elevator Initial Deployment - Problems and Solutions, James Dempsey
11:20 am	Stability of Superconducting Cable Used for Transportation of Electrical Current from Space, Dr. Karen Ghazaryan
11:45 am	Lunch
	10th Session - Space Elevator Risks
12:45 pm	Using a System Safety Analysis to Derive Architectural and Operational Requirements for a Second-generation Space Elevator, Steven Beland
1:10 pm	Why the SE will not be built on Earth, Tom Nugent, Laser Motive
1:35 pm	Break
	Shotgun Science Session
1:55 pm	Superconducting Electromagnetic Applications for a Space Elevator, Abraham Becker
2:00 pm	Resources for the Space Elevator Community, Dr. Martin Lades/Mark Boucher, Spaceelevatorconference.org/Spaceelevator.com
2:05 pm	What it Takes to Do Another Conference, Dr. Bryan Laubscher, Founder, Industrial Nano
2:10 pm	Business Plan Creation and Maintenance, Ed Gray
2:05 pm	Repairable Ribbon Macrostructure, Ben Shelef, Director, Spaceward Foundation
2:35 pm	Shinkansen in Space, Jerome Pearson, President, STAR, Inc.
2:40 pm	Several Time Slots Allotted for Talks Conceived at the Conference
3:15 pm	Break
	11th Session - To Think About
3:25 pm	Raising Public Awareness of The Space Elevator Project Through the Arts, Victor Cummings/Dr. Bryan Laubscher
3:50 pm	Who will build the first, earth-based Space Elevator?, Ted Semon, The SpaceElevatorBlog
4:15 pm	Rejecting the Future: The Societal Impact of Abandoning Technologies and Exploration, Carla Sabotta
4:40 pm	**Conference Wrap-up**
5:00 pm	Conference End

Presentation Abstracts

1. Space Elevator Overview

Dr. Bradley Edwards, President, Black Line Ascension

1st Session – Why the Space Elevator?

2. Innovation and the Elevator and Introduction for Ivan Bekey

Randy Liebermann

3. Potentially Fatal Elevator Flaws That Must Be Addressed

Dr. Ivan Bekey, Bekey Designs, Inc.

4. Space Elevator History: A Tribute to Sir Arthur Clarke

Jerome Pearson, President, STAR, Inc.

This paper recounts the origin and development of the concept of the space elevator from the perspective of one of the two inventors of the concept. The true history of the space elevator is not well known by the larger aerospace engineering community, and with the passing of Sir Arthur Clarke and his era, this is the ideal time for review and reflection. Space elevator concept history is reviewed, from ancient dreams through Konstantin Tsiolkovski's thought experiments, the inventions by Yuri Artsutanov and Jerome Pearson, as well as alternative concepts and near-inventions by Russian, British, French, and American scientists and engineers. The immense boost given by Sir Arthur Clarke to the concept is recounted, building on the personal experiences of the author. Sir Arthur is probably the only person in the world who met with both of the independent inventors of the space elevator, Yuri Artsutanov and Jerome Pearson. Potential applications of the space elevator are described beyond the classic vertical elevator, to include cis-lunar space development, space habitats, and unusual configurations by several authors. Also addressed are some formidable challenges, including construction techniques, materials and logistics, radiation shielding, safe operations, and cost. Arthur Clarke famously said the space elevator would be built "about 50 years after everyone stops laughing." Well, everyone has stopped laughing, and now the space elevator can be built about a decade after carbon nanotube ribbons are available.

5. Why We Need an Elevator to Space!

Dr. Bradley Edwards, Markus Klettner, Eurospaceward

NASA'S beam power and tether challenge as facilitators for the development of a potential "green", low cost and safer transport to space.

In terms of cumulated payload to launcher mass the efficiency of conventional launcher systems does not exceed 3.5% on the average. On the other hand a space elevator, a system of mechanical climbers using a ribbon strung between an anchor on Earth and a satellite beyond geosynchronous orbit, would approach an efficiency of 50% already after one year of operations.

The paper concentrates on the properties of the space elevator for a "green", low-cost and safer transport to space. Being researched and developed in light of constant safety and environmental impact carbon nanotube fibres are presented as ecologically engineered building blocks for the space elevator ribbon. In addition it shows how the space elevator enables a sustainable economy based on solar power satellites. The paper concludes with an outlook on the most likely political pressures that may drive the development of a space elevator.

6. Space Elevator Games - History and Status

Ben Shelef, Director, Spaceward Foundation

2nd Session – How Close are We?

7. Status Quo on Space Elevator Tether Development as Highlighted by NASA's Tether Challenge at the Spaceward Games

Dr. Bradley Edwards/Markus Klettner, Eurospaceward and others.

The single most difficult task in building the Space Elevator is achieving the required tether strength-to-weight ratio, in other words, developing a material that is both strong enough and light enough to support a 100,000 km long tether on which elevator cars or climbers can move up and down.

In order to fuel the development of such super strong materials for the potential future use in a Space Elevator cable (or for other structural aerospace applications) the so-called Tether Challenge has been introduced by NASA. It is the second category of the space elevator games that are managed by the Spaceward Foundation. The competition requires a 50% improvement in breaking force from year to year, and started in year 2005 with the strongest commercially available tether.

While theoretically carbon nanotubes can have tensile strengths beyond 200 GPa (some proposals predict strengths up to 1TPa), in practice the highest tensile strengths ever observed in single/multi-walled tubes range between 50 GPa and 150 GPa. However, even the strongest fibre made of carbon nanotubes is likely to have notably less strength than its components. Improving tensile strength depends on further research on purity and different types of nanotubes.

The paper discusses the status of the art in advanced materials as highlighted by the results of the Tether Challenge at the Spaceward Games since 2005. In addition recent advancements in CNT fibre engineering in Europe and the US are presented where strength improvements of roughly 100 over the last couple of years have been achieved, demonstrating the basic truth that super strong CNT threads can be made.

8. Thin Disc Lasers - a Robust, Scalable Source for Power Beaming Applications

Pat Grace/Dr. Holger Schlueter, TRUMPF

Diode pumped thin disc lasers are currently one of the most successful DPSSL technologies capable of high brightness multi-kW operation. They are providing reliable operation in hundreds of installations for welding and other applications in the demanding automotive production environment. The thin disc laser is based on a laser medium of about 10 mm diameter and 0.2 mm thickness. This thin disc of Yb:YAG is mounted on a highly reflective, spray cooled heat sink and is therefore often called: active mirror. Because of the unique geometry and the back side heat removal that it offers, it is possible to extract 5 kW cw power from a single disc!

While its industrial reliability and very high efficiency - 25% wall plug efficiency for an 8 kW system with 4 discs, for instance - are already prequalifying the thin disc laser for power beaming applications - its power scaling capability makes it truly the first choice for 100 kW and MW class applications like power beaming. We will present these unique power scaling capabilities, which are based on fundamental geometrical properties of the thin disc laser medium.

9. Space Elevator Development Status in Asia

Akira Tsuchida, Board Director, Japan Space Elevator Association (JSEA)

An overview of the current status regarding Space Elevator development in Japan and other countries in Asia will be explained.

The JSEA (Japan Space Elevator Association, http://jsea.jp) was established in July 2007. Dr. Bradley Edwards was invited as a member of JSEA in April 2008. JSEA has an international conference in Japan planned for Nov 2008. JSEA will present some activities for an educational program for children and their SE competition plans for 2009.

JSEA is working with the Spaceward Foundation and the Euro Spaceward association to promote the SE worldwide.

10. Tether Applications Relevant for a Space Elevator

Jeffrey Slostad/Dr. Robert Hoyt, Tethers Unlimited

Space tether technologies are a near-term, commercially viable technology that can serve as a stepping-stone towards the vision of developing a space elevator transportation system. Space tethers can enable propellantless propulsion for a number of different space missions including orbital maneuvering, formation flight, end-of-mission deorbit to meet debris mitigation requirements, and orbit transfer for GEO, lunar, and interplanetary missions. Despite the considerable promise of space tether technologies, its transition to operational applications has been hindered by mixed results in on-flight testing, with several high-profile mistakes overshadowing multiple lower-profile successful missions. In this presentation, we will first summarize the basic concepts and principles of propellantless propulsion using tethers, and then discuss several applications and their potential net payoff in terms of mission capability and cost. We will then review the results of the space tether experiments that have been conducted over the past two decades. Finally, we will describe the current status of key technology components for these systems, and discuss plans for future risk reduction and validation of space tether technologies.

3rd Session – What World will be Created? I

11. Space Solar Power Scenario Comparison

Dr. Bryan Laubscher, Founder, Industrial Nano

This paper compares and contrasts the 2003 Space Solar Power study by Kellum and Laubscher (3rd Annual International Space Elevator Conference) and the 1975 NASA solar power satellite study. The primary difference between these studies is that the 2003 study assumes the existence of space elevator technology whereas the 1975 study uses chemical rockets. Of particular interest are the differing philosophies of each scenario upon which each study was based. These philosophies guide the different scenarios and so determine the resulting systems that each study describes. The projected time for financial "breakeven" for each scenario will be discussed. The current impetus for clean, renewable power created by global warming concerns will be presented.

12. The Space Elevator: Solution to Global Climate Control?

Jerome Pearson, President, STAR, Inc.

The space elevator has potential applications beyond reducing the cost of getting into space and transforming space development and habitats. It also makes possible the realization of a practical method for overcoming global warming and stabilizing the climate of the Earth. This has enormous implications for gaining public interest and government support for the largest engineering accomplishment in history, and space programs in general. Despite the widespread interest and activism concerning manmade global warming, it is not widely realized that the Earth has been much warmer in the past than it is now, and that we are still in an unusual ice age. Even without human activity, the Earth will warm so much that the polar ice caps will disappear, there will be no mountain glaciers, and sea level will rise by tens of meters, flooding all the world's seaports, unless we take control of Earth's climate. Current efforts at greenhouse gas emission control do not address this problem; we need to provide a positive control of the amount of sunlight reaching Earth, or the Earth's reflectivity, to solve global warming. The ideal solution uses the space elevator as the launching system for building an active "sunshade" for the Earth that will reduce the solar insolation by about 3%, maintaining our current pleasant but unstable moderate ice-age climate. The space elevator can be used to launch materials from the ground into GEO, and thence to its final location, either in Earth orbit or at the Sun-Earth L1 Lagrangian point.

13. Impact analysis of the space elevator on space activities

Andreas Hein, Wissenschaftl. AG f. Raketentechnik and Raumfahrt (WARR) TU Munich

This paper analyses the impact of a hypothetical space elevator on different areas of space activities. The space elevator promises to drastically reduce space transportation costs and greatly facilitate the access to space and is often proposed as a mean to vastly increase the scope and amount of space activities. In order to investigate this claim, first, the cost structure of current space missions is analysed and the impact of an idealized space elevator evaluated, in order to explore the whole range of possible benefits. The idealized elevator is capable of delivering any spacecraft mass and volume into space, its usage is for free and it is 100% reliable. The maximum potential for space mission cost reduction is estimated. Second, current and proposed future space missions are analysed with respect to the existence of an "ideal" space elevator. For current activities, probable benefits are assessed and for future activities, the change in potential feasibility estimated.

4th Session – What World will be Created? II

14. Solar Augmented Climbers and Implication on Required Tether Strength

Ben Shelef, Director, Spaceward Foundation

This paper discusses a climber design that derives a large fraction of its power from direct sunlight conversion. This concept is enabled due to recent advances in photovoltaic technology. While presenting some challenges, this design relaxes the requirement on the power beaming system considerably and offers much increased power levels to the climber, enabling faster motion and increased system throughput. This in turn relaxes the requirements on the ribbon material through a general throughput-lifetime-strength relationship we develop. Finally, the paper argues that the solar-optimized PV panels have great utility at GEO, enabling us to calculate them as payload.

15. Asteroid Sling-Shot Express - a Useful Space Elevator We Can Construct Today

Ben Shelef, Director, Spaceward Foundation

This paper examines the possibility of returning payloads from a spinning asteroid using a tether system and evaluates its merit in comparison to a conventional rocket-based return.

16. Thermoelectric Technology and the Space Elevator

Dr. David Nemir, TXL Group, Inc.

Thermoelectric (TE) generation is the conversion of thermal energy into electrical energy without the intermediary of rotating machinery. A reciprocal property is thermoelectric (Peltier) cooling which converts electrical energy into a thermal differential. TE generators and coolers are generally constructed using doped semiconductor materials as the active element, but due to the relatively low efficiencies of status-quo devices, they have attracted little attention for use in harvesting beamed power. The advent of improved thermoelectric devices will open the door to wider applications, including the space elevator.

This paper will describe the ways in which thermoelectrics may find a home in the space elevator as an adjunct to conventional photovoltaic cells in generating electricity from a ground based laser. While a thermoelectric cell may represent a favorable means for electric generation, its most promising application may be as a heat pump, carrying away waste heat from photovoltaic cells in order to keep photovoltaic operation around the operational "sweet spot". Graphical plots contrasting performance as a function of thermoelectric coefficient of performance, ZT, illustrate the state of the present technology and outline the improvements required to make thermoelectrics a viable choice for powering a space elevator from ground based beamed power.

17. Disposal of Radioactive Waste by Space Elevator

Shigeo Saito

This presentation introduces a concept of disposing of toxic waste, particularly high-level radioactive (nuclear) waste to outer space using Space Elevator that is recently getting more attention as a next-generation space transport system.
The Space Elevator will connect the ground and space without dangers such as crash, explosion, and air pollution, and its transportation cost can be to a few tenths to thousandths, compared to that of rockets.
The concept of the Space Elevator has not yet become reality, however, it will be in near future. Many researchers consider that the Space Elevator will be constructed in 10 to 20 years at earliest. Meanwhile, human society has too much toxic waste to dispose of, and its amount continues to increase year by year. As for radioactive waste in particular, the only way of disposal is to bury it underground. It could cause environmental contamination and health damage if radiation leaked. This is a human's negative heritage that we keep facing without any fundamental solutions.

18. Space Elevator - The Future as Foreseen by Scientists

Hiroshi Koike, Walk Co., Ltd

The Japanese Movie company 'Walk Corporation' produced an I-MAX (or big screen) video called 'Space Elevator - The Future as Foreseen by Scientists'. Mr. Hiroshi Koike presents the story how the movie was made and a DVD version will be played.

5th Session – Legal Considerations

19. The Legal Landscape Relevant for the Space Elevator

Alisa Brodkowitz, J.D./David Schoeggl, J.D., Brodkowitz Law and MMS-Seattle

19a. Legal Fields and Examples Related to the Space Elevator

J. Gregory Rebholz, J.D.

The construction of a space elevator will introduce several cases of first impression before the U.S. legal system. It could be the first device to transport citizens en masse to the edges of space, challenging the existing conception of an "astronaut" for the purposes of many laws and treaties. This single unique structure will likely implicate legal issues in maritime law, aviation law, and space law simultaneously. It will be governed by numerous existing laws, and will be the subject of many novel legal devices to address public safety, personal property rights, and international concerns involved in its construction and operation.
This paper looks at the numerous legal fields touched upon by the space elevator concept primarily from a U.S. perspective, focusing on international treaty obligations at sea and in outer space, as well as U.S. federal agency regulation. While surveying the legal landscape, an examination of past legal problems offers potential solutions to the novel issues raised by the space elevator. For example, the bi-lateral agreements establishing U.S. jurisdiction in the waters surrounding the Louisiana Offshore Oil Port may serve as models for the maritime operations of a space elevator base station.
While the legal regime that will provide public safety assurances, equitable resolution of civil disputes, and international cooperation is certainly not the most difficult challenge faced by the space elevator initiative, it is an important factor to keep in mind while the project progresses. By proactively exploring the unique legal situations that will arise under the space elevator, project planners may avoid costly litigation expenses and remove legal barriers before they impede progress.

20. Workshop Introduction

Dr. Martin Lades

Introducing the Four Pillar Discussions: Science and Technology, Public Relations, Legal, and Business.

6th Session – Technical Considerations I

21. The Role of Requirements Analyses and Carbon Nanotubes in Space Elevator Development

Dr. Bryan Laubscher, Founder, Industrial Nano

Most of society dismisses as impossible concepts that have not been realized. Also, an existing but immature technology is seen as a drawback to a concept's development. This paper takes the unconventional view that a rigorous requirements analysis, based upon systems engineering principles, should guide future development rather than past experience. In addition, this paper points out that the materials revolution promised by carbon nanotubes provides, in a natural way, the essential technology and public acceptance required by Space Elevator technology.

22. Space Elevator Dynamics through Simple Approximations

Dr. Blaise Gassend

When it is built, the space elevator will be the largest structure ever built, as well as one of the flimsiest.

Such a structure is certain to have interesting dynamics. Understanding these dynamics is important because guarantees are needed that the elevator will not deviate so far from its equilibrium position that it is unable to remain aloft. Moreover, control for orbital debris avoidance is required.

In the literature, pessimistic claims abound. They say that the elevator is unstable, that the oscillations are too complex to understand, that thrusters will be needed on the cable to get it under control. The truth is that despite its size, the elevator is just a one dimensional system, quite simple compared with gigabit communication or vibration cancellation systems. While it is true an exact prediction of the motion of the elevator will be difficult to achieve, that level of prediction is hardly necessary. All that is needed is to understand the magnitude of the perturbations acting on the elevator, and to devise ways to detect the resulting motion in a way that is sufficient to allow it to be kept under control.

This talk will consider the space elevator dynamics using simplified but insightful models, that compare it with a taut string, or a system of pendulums. With these models, it will be possible to see the effect of taper, the atmosphere, climbers and lunar/solar tidal forces on the elevator, and to understand the basic oscillation modes of the elevator. Moreover, it will be seen that simple techniques such as impedance matching at the anchor point can be used to damp motion of the elevator with almost no knowledge of its global state, nor need for precise prediction of the elevator's motion.

With the simple cases out of the way, the talk will mention more complicated questions such as twisting oscillations causing cyclic thermal expansion and contraction and aeroelastic interaction of the elevator with the atmosphere.

23. Production of High-Strength-to-Weight Ratio Tethers from Carbon Nanotube Yarns and Textiles

Stephen Steiner III Stephen Steiner III, Daniel Pressl, Lauren DeFlores, MIT
Brian White, Meghann White, Jennifer Mann, Mark Schauer, David Lashmore, Nanocomp Technologies

Although the ultimate tensile strength of individual carbon nanotubes (CNTs) is believed to lie between 40 and 100 GPa, achieving useful macroscopic materials with such strengths is a challenging problem. Nanocom p Technologies of Concord, NH has developed scalable processes for producing continuous yarns and textiles composed of single-walled carbon nanotubes and is rapidly scaling up manufacture of these materials. Team DeltaX is a joint effort between a group of researchers at MIT and Nanocomp working to develop techniques for enhancing the strength of CNT yarns and felts for use in high strength-to-weight ratio tethers. In this talk, we will discuss the manufacture and characterization of high-strength CNT yarns and textiles made at Nanocomp and the efforts undertaken by Team DeltaX in preparing tethers from such CNT-based materials and next-generation graphitic "hyperfilaments" derived from carbon nanotubes.

24. Technology of Japan which can be utilized for construction of a Space Elevator

Shuichi Ohno, President, Japan Space Elevator Association (JSEA)

Overview of current Japanese industrial technologies which may apply to the Space Elevator.

-Elevator for buildings

Japanese elevating company developed the fastest elevator in the world.

-Shinkansen bullet train

382 autonomous controled bullet trains run 342,000km per day.

-Ultra-sonic motor

Ultra sonic motor will change electric energy to mechanical energy directly.

-Solar excitation laser

Study of solar power satellite have produced solar excitation laser.

7th Session – Economics

25. Space Elevator – Improving the Human Condition: Why? How? When?

Dr. Peter Swan, Teaching Science and Technology, Inc.

Many of us believe there will be a series of space elevators by 2020. As the ribbon material has been tested beyond the required tensile strength (the long pole in the engineering design) the commercial world will demand the capability as soon as it is shown to exist. This belief, that the space elevator will exist, leads to the natural question of what will it accomplish. This presentation will address how it will literally improve the Human Condition. The principle thrust will be to address the leverage that a space elevator will provide -- which will then enable the Space Based Solar Power (SBSP) community in their quest to provide pollution free energy anywhere, anytime, for anyone. To achieve this, the SBSP development team must believe that there will be $ 100/kg access to GEO with an easy and smooth transportation infrastructure.

26. One Million Rockets or 10 Space Elevators

Dr. Bryan Laubscher, Founder, Industrial Nano

One argument rocket proponents make is that mass produced chemical rockets will be very inexpensive. This paper discussed one model of estimating the cost of mass produced chemical rockets. Then the final cost per unit of mass produced will be compared to projected Space Elevator launch costs. The constraints on both mass produced rockets and Space Elevator technology will be presented. Finally a brief estimate of the environmental impact of many chemical rocket launches and Space Elevator launches will be discussed. Nuclear rocket possibilities and constraints will be briefly covered.

27. Laser Power Beaming on a Shoestring

Dr. Tom Nugent, LaserMotive

The NASA Centennial Challenge for Power Beaming is a prize offered for a competitive demonstration of wireless power transmission. The minimum viable competition entry for 2007 was required to deliver greater than 200 watts to a moving 10-kilogram vehicle over a vertical distance of 100 meters. We describe the design, construction, and operation of a laser power transmission system which considerably exceeds these minimum requirements, and which was built by a largely non-professional team with minimal financial support in less than one year. The system uses commercially-available 808 nm diode arrays and simple optics to produce a multi-kilowatt beam, approximately 1 x 0.6 m. An automated video tracking system with manual backup and a 1 m^2 steerable mirror direct the beam. The receiver is assembled from two types of GaAs photovoltaic cells in a unique configuration. Overall, the system could deliver in excess of 1 kW of DC power to a vehicle with an end to end efficiency of well over 10%, but due to inadequate testing and on-site failures, it failed to win the 2007 prize.

8th Session - Technical Considerations II

28. Space Elevator (Space Train) Alternate Method and Road-Map

Akira Tsuchida, President, Earth-Track-Corporation

Akira Tsuchida, the president of Earth-Track Corporation, will present alternatives to power beaming technology. Hybrid technology (direct power feeding combined with an on-board PV array) is used so that an SE can be operated more robustly, safely, and be maintained at low cost.

His presentation includes design concepts for their SE system and an operations concept for both, manned vehicles for space tourism and unmanned cargo transfer vehicles.

He will also show their preliminary road map to accomplish an SE in 2030's.

29. E-T-C Climber 2007 Review and 2008/2009 Prep Status

Akira Tsuchida, Team Lead, E-T-C, US/Japanese team Spaceward Power Beaming Competition

E-T-C will review the result of Powerbeaming 2007 games and present the current preparation status of their E-T-C Climber for the 2008/2009 Spaceward games.

Earth-Track-Controllers (E-T-C) is a group of volunteer U.S. and Japanese Engineers and college students that started a small team (not company) to research and develop a Space Elevator design concept. Our Team is idealistic - we believe engineers change the world for the better, and that we can make a difference! We are hard-working and fun-loving and do both hand-in-hand.

E-T-C joined the Power Beaming competition in 2007.

30. The space elevator past, the present, and the future in Japan

Toshiki Hasegawa

The concept of the Space Elevator, which Yuri N.Artsutanov announced in 1960, was immediately introduced in Japanese SF (science fiction) magazine right after it.

Science fiction using the Space Elevator is popular in Japan, and new concepts and ideas are introduced even at present.

It will be explained how the Space Elevator has been recognized by the Japanese public. The progress of the meme of the "Space Elevator" is followed through the subculture of Japan, such as SF, animation, and comics.

9th Session - Technical Considerations III

31. Climber Mechanism of the Space Elevator

Hideyuki Natsume, JSEA

Today, with the aim of constructing the Space Elevator (SE), climber mechanism technologies such as linear motor drives and supersonic motor drives have been widely researched and developed in many countries.
However, the structure of climb ribbon/line tends to be complicated and heavy with these approaches. Considering the need of simpler and lighter-weight climb ribbon/line structure at the early phase of the SE construction:
I introduce one technical possibility to focus on making a simple climb ribbon/line drive system. It is now being developed and planned to be applied for a team's climber from Japan for the SE power beaming competition in 2009.

32. Space Elevator Initial Deployment - Problems and Solutions

James Dempsey

As shown by investigators (principally Lang and Dempsey) there appears to be a stability issue relating to the initial deployment of the Space Elevator. These initial investigations, though neither conclusive nor exhaustive, indicate if the dynamic balance of the structure is not carefully maintained during deployment, that there is a substantial risk that the deploying structure will either crash into the Earth or be flung outwards into an unusual orbit. The presentation will discuss the problems and offer two potential solutions for initial deployment.

33. Stability of Superconducting Cable Used for Transportation of Electrical Current from Space

Dr. Karen Ghazaryan

Along with the well-known advantages of the space elevator concept another advantage is the possibility to transport electric energy from space with its help. Using the properties of the ultra low temperature of space it is possible to transfer electric current with the help of a superconductive construction. Besides the huge tensions occurring in the construction of the space elevator, when designing a superconductive current-carrying system the elastic strengths conditioned by electromagnetic loads have to be considered. Otherwise they can lead to the loss of stability of the SE system.

These problems are the main subject matter of the presentation.

Two coaxial cylindrical shells made of superconducting materials as part of a closed electrical current are considered. The electrical current flows along the generator of the inner shell and returns back along the generator of the outside shell. The coaxial shells are separated by a dielectric layer. The cable is subject to Earth's gravitational inward force, as defined by the Newton gravity law and a centrifugal outward force, conditioned by the Earth daily rotation.

A very long elastic structure anchored on the Earth equatorial point and free out in space is studied. This structure is considered to be a mathematical model of superconducting cable transporting electrical current from space. Based both on London’s equations for superconducting material and the technical theory of thin elastic shells the critical maximal values of superconducting current are defined beyond which the structure is stable.

10th Session - Space Elevator Risks

34. Using a System Safety Analysis to Derive Architectural and Operational Requirements for a Second-generation Space Elevator

Steven Beland

While there can be considerable value gained when creating new complex transportation technologies like a space elevator system, there are also increased possibilities for danger. The main purpose of the paper will be to raise awareness of potential hazards in such a system, and describe how to identify and address them so as to prevent their occurrences when deployed. T he analysis method uses a Functional Hazard Assessment (FHA) and Fault Tree Analysis (FTA) to assess the system hazards presented by a space elevator, specifically a second-generation human-rated one carrying passengers from the Earth's surface to a station at geosynchronous orbit above the anchor. As no space elevator exists yet, the purpose of this fault tree analysis is to derive safety-related requirements for the space elevator architecture and identify any applicable operational constraints. Safety targets are drawn from comparable industries providing specialized infrastructures for human transportation, essentially a somewhat lenient adaptation of that used for commercial jet transportation. Safety targets and a rationale for them are introduced. After a brief system description, the analysis approach is described, the analysis results provided, and the derived architectural requirements and operational constraints are captured.

35. Why the SE will not be built on Earth

Dr. Tom Nugent, Laser Motive

The ribbon safety factor for the SE has always been assumed to be 2, but this value is almost certainly too low. Regular elevators have a safety factor of 5, climbing ropes use a factor of 10, and even if those values are higher than needed, the various stresses placed on the SE will require a wide margin of safety. Using a possibly-low safety factor of 3, it is easy to show that the SE becomes un-economical for the Earth.

Shotgun Science Session

36. Economic and Financial Model

Charles Polk

Identifying if an when a Space Elevator is ready as the basis for business. Parameterized tool as group design nexus. Risk model tied to financial stages. Supply and demand model for first SE.

37. Superconducting Electromagnetic Applications for a Space Elevator

Abraham Becker

It seems that the near vacuum of the exosphere, low earth orbit, and the distance to geostationary orbit would be an ideal application of superconducting technology. The nominal temperature in these areas is below the threshold for superconducting activity and would thus require no cooling. This could provide near power transmission for something akin to an electrically powered building constructed of or with electromagnets. With a redundant nuclear powered base, and solar panels branching off the top, this idea for a space elevator would eventually, if even possible, resemble a tree, powered from the roots and from the leaves. As photovoltaics evolve, the nuclear powered base might even become redundant.

38. Resources for the Space Elevator Community

Dr. Martin Lades/Mark Boucher, Spaceelevatorconference.org/Spaceelevator.com

We will present new resources the SE community can use:
1. New Space Elevator Site, Spaceelevator.com
2. SpaceElevatorConference site, Spaceelevatorconference.org
- SE conferences and content
- 4 Pillar work
- Community contact and task management (CRM system)
- Online Chat client

39. Shinkansen to Space

Dr. Jerome Pearson, President, STAR, Inc.

Linear Motor LEO Space Elevator, Launch Loop Alternative,

40. What it Takes to Do Another Conference

Dr. Bryan Laubscher, Founder, Industrial Nano

41. Business Plan Creation and Maintenance

Ed Gray, MBA

42. Repairable Ribbon Macrostructure

Ben Shelef, Director, Spaceward Foundation

11th Session - To Think About

43. Raising Public Awareness of The Space Elevator Project Through the Arts

Victor Cummings/Dr. Bryan Laubscher

- The motivation in this presentation is to stimulate individuals in the arts of various medias to communicate as individuals in a manner that is supportive of future space exploration, and in particular of the Space Elevator. Space exploration should be viewed as a necessary vehicle to the further evolution of our planet. A key pillar is in making the Space Elevator a reality is the political-social pillar - capable of making the Space Elevator concept ubiquitous.
- The problem is that in order to allow legal and economic discussions of the Space Elevator, it is first essential that the general public be made aware of the Space Elevator concept and what it may mean to our future as a planet. The scope of our presentation is to outline the various artistic and social medias that may be used in order to accomplish this task, and to offer the presentation as a stimulus to artists of various medias to spread the word of the importance of the Space Elevator and its possible uses.
- The approach will be to give as an example the recent screenplay “High Lift”. There will be a brief discussion on how the screenplay was conceived, and the steps that are being taken to find representation in the film industry to make the production possible. An outline of some of the other artistic vehicles possible will be enumerated. The approach is two fold:
    - Target and stimulate interest in the various medias that may be of assistance in spreading the word about the Space Elevator.
    - Educate in layman’s terms those artists in such a manner that they may portray the concept to their contemporaries in those terms that they may understand.
- Creating awareness may mean stimulating knowledge by exciting passion in the general populous for the Space Elevator concept.

44. Who will build the first, earth-based Space Elevator?

Ted Semon, The SpaceElevatorBlog

Speculating as to who will build the first, earth-based Space Elevator is both a useful and fun exercise. It focuses attention on the difference between real and imagined benefits of such a structure and can also spark discussion and interest from both within and outside the "Space Elevator community." In this paper, I have briefly discussed the 7 “technical capabilities” that will be needed to build an earth-based Space Elevator (based on Dr. Bradley C. Edwards’ carbon nanotube ribbon model) and matched them against entities which could be capable of developing them. This gave interesting, but inconclusive results; many entities could develop these capabilities. A brief discussion of real vs. imagined benefits of such a structure was then used to try and bring clarity as to who would benefit the most, and thus would have the most incentive to do it. This paper concludes that either a consortium of American businesses or a joint effort between the governments of Dubai and India are the most likely candidates to actually build and operate this structure. It is hoped that this conclusion will further move along this effort.

45. Rejecting the Future: The Societal Impact of Abandoning Technologies and Exploration

Carla Sabotta

There exist historical examples of human societies abandoning technologies and exploration. The Viking discovery of North America and China’s abandonment of the Treasure fleets are two examples. A few examples will be discussed including the long term impacts of these choices.
The above discussion sets the stage for an analysis of what our society has done in the wake of the Apollo program. Did the United States abandon technologies and turn its back on exploration at the end of the Apollo program? The complex answer to the question includes the fate of nuclear rocket technology, a perspective on our space program that remains in low Earth orbit and the motivation for exploration and technology development.
Space Elevator technology enables another opportunity to explore the solar system. In sharp contrast to chemical rocket technology, the Space Elevator paradigm implies an “economic equation” so compelling that solar system exploration becomes an imperative. Moreover, within the context of the earth as we now understand it, solving problems here on Earth will be possible with a Space Elevator infrastructure.

Shotgun Science Session

Introduction

The "shotgun science session" describes a conference part geared for the rapid exchange of raw material. The session offers short timeslots to conference participants in which they can present an "elevator speech" to stimulate further discussion and ask for feedback. The material provided in these proceedings is at best an incomplete reflection of the energetic session at the 2008 conference. In the presentations folder material from the shotgun science session can be identified by an 'SSS' prefix. The talk numbers are from the full program sequence.

Presentations

36. Space Elevator Development Tool, Economic and Financing Model, Polk
Identifying if and when a space elevator design is ready as the basis for business. Proposed is to construct a Supply, Demand, and Risk model so that the impact of technical progress on business viability becomes tractable. The risk model becomes a bottom-up input to Financing.

37. Superconducting Applications for Space Elevator, Becker
The discussion touched on several options using high temperature superconductiors in the Space Elevator Framework.

38. New Online Resources for the SE Community, Lades
Presenting a collection of new tools that could be used by many. M. Boucher promised a new mash-up platform at spaceelevator.com, including new wiki infrastructure. For this conference already implemented was a reusable site including a store component to sell the tickets as a SESI store. Also exists a Customer Relationship Management System (CRM) that can be used to grow contact lists and work with people consistently, track projects, tasks, campaigns, a file repository, etc. The site also offers a flash chat component to meet online.

39. Shinkansen in Space, Pearson
Birch orbital ring as a linear motor LEO space elevator at 300km altitude. Multiple short elevators lift to the ring that moves with super-orbital speed. A Lofstrom launch loop alternative that also includes a short elevator. These constructs avoid debris, do not require CNTs, have no radiation problems, and could be constructed near big cities offering a 45min ride to space. Dynamics of the tubes and stability of the ring and orbit selection are still open challenges.

40. What it Takes to Develop the Next Conference, Laubscher
The 2008 conference was organized by very few dedicated individuals. While Microsoft has graciously contributed serious funding, it is tough to organize well with less than the necessary crew of volunteers. Please contact Bryan Laubscher if you want to help with future Space Elevator conferences.

41. Business Plan Creation and Maintenance, Gray
Various topics relevant for the structure and maintenance of a Space Elevator business plan.

42. Repairable Ribbon Macrostructure, Ben Shelef

SEC 08
Development Pillar Workshops
Summary

The conference included interactive workshops for goal finding in areas identified as crucial for the long term Space Elevator enterprise. Discussions for each one of these areas called Development Pillars proceeded under the auspices of subject matter experts. Development Pillars and respective leads recognized fore the breakout discussions were:

Science and Technology:	Dr. Bradley Edwards
Public Relations:	Dr. Peter Swan and Ted Semon
Legal:	Alisa Brodkowitz, J.D. and David Schoeggl, J.D.
Business:	Ed Gray

While the purpose of the first round of workshops was to jump start communication within the groups, the second round intended to fine specific reachable goals. This is a difficult task in such a long term project as a Space Elevator. Many fundamental questions such as the tether material have to remain open. However at least the thrust directions need to be well defined to make most effective use of the resources in the SE community.

Goals

The following preliminary goals were defined by the participating groups:

TIME	FOUR PILLARS			
	Public Outreach	Science and Technology	Legal	Business
2008	• Create common message for SE community	• Start Wiki Site	• Create a Yahoo group for Legal Pillar to stay in touch; or integrate with conference-wide collaboration platform	• Create guidelines for the analysis of antecedent markets • Publish business plan best practices, oriented towards funding of projects on path to SE • Agree on format of ISEC CRM database
2009	• Functioning ISEC, having as members all major international SE groups, along with public membership • Create distribution method for SE common message	• Achieve an active Space Elevator Technology Wiki site at http://spaceelevatorwiki.com • Construct a comprehensive model for ribbon decay	• Determine process for agency creation	• 10 or more new business contacts per quarter captured in CRM database previously unaffiliated with SE conference • Give at least two presentations to sophisticated business audiences on business issues related to the SE • Perform at least two benchmark analyses related to SE (e.g., highway financing, advanced textile production)
2010	• Finding at least one government or one corporate entity that will significantly fund the development of an SE	• CNT fibers strong enough for Space Elevator	• Participate/Brief UN working groups	• Deliver operating plan that incorporates state of technology, legal theory and market as they stand at the end of 2010

ISEC, The International Space Elevator Consortium

The 2008 SE conference workshops voiced the high priority need for an international Space Elevator organization, as an authoritative resource for SE related information. As a direct consequence of the conference, ISEC, the International Space Elevator Consortium, was founded and incorporated in 2008. By July 2011 ISEC is recognized by National Geographic as the go-to organization in SE matters.