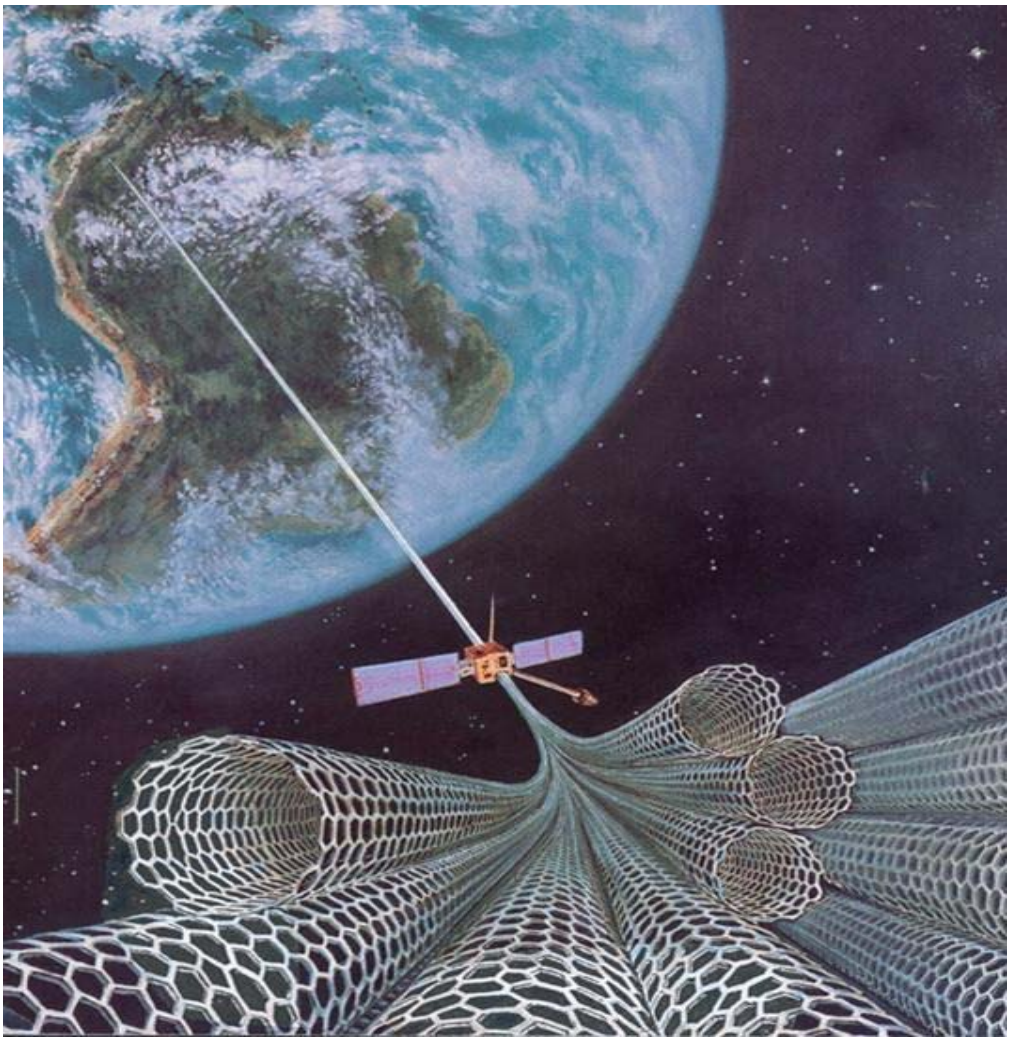
4th International Conference on Carbon Nanotechnology & Space Elevator Systems

BOOK OF ABSTRACTS – PART II

Sunday Dec 5, 2010



Space Elevator Systems

In cooperation with: Fonds National de la Recherche Luxembourg

Day 2: December 5, 2010

Opening of conference stream on space elevator systems

Time	Topic	Speaker
09:15	Introduction	**John Winter**, ESW, Luxembourg
09.30	Keynote: Statistical models for the design of super-strong CNT space elevator cables: investigating the role of hierarchy and self-healing	**Prof. Dr. Nicola Pugno,** Laboratory of Bio-inspired Nanomechanics, Politecnico di Torino, Italy
10:00	Space Elevator: Dilemma and Remedies	**Sourabh Kaushal, Nishant Arora,** ISTK, Haryana, India
10:30	Coffee break	
11:00	From the view point of law: Who can establish the Space Elevator	**Prof. Sunao Kai**, Faculty of Law, Nihon University, Japan

Space Elevator related engineering contests

Time	Topic	Speaker
11:30	Results from the 2nd Japan Space Elevator Technical & Engineering Competition	**Dir. Shuichi Ohno**, President Japan Space Elevator Association, Japan
12:00	Europe's First Space Elevator Competition: A Rationale	**Franciska Völgyi, Andreas Hein, Rüdiger Hink,** WARR, Technical University Munich, Germany
12:30	Liège Space Center: space qualification tests for space tethers	**Dr. Pierre Rochus**, University of Liège & CSL
13:00	Lunch	

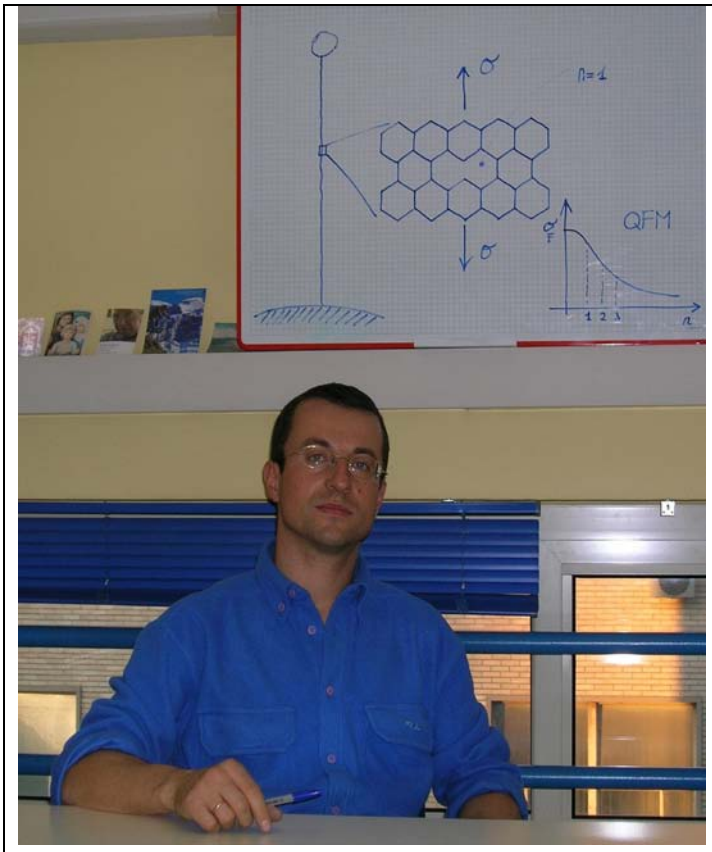
Space Elevator System – New research results

Time	Topic	Speaker
14:00	Survey of current space elevator research: implications and future concepts	**Andreas Hein**, Institute of Astronautics, Technical University Munich, Germany
14:30	Weight, upthrust and other vertical forces on atmospherically buoyant structures such as a SpaceShaft for a space elevator system	**Nelson Semino**, Spaceshaft, USA - Belgium
15:00	Space environment for space elevators: new insights on space elevator and debris collision probabilities	**Dr. Pete Swan,** SouthWest Analytical Network Inc**.,** USA
15:30	Coffee break	

Space Elevator endeavor – Outlook

Time	Topic	Speaker
16:00	Space Elevator Road Map 2010	**Dir. Akira Tsuchida**, JAXA Flight Director, JAMSS & ETC, Japan
16:30	Space Elevator: International policy and outlook	**Ted Semon**, President International Space Elevator Consortium, USA
17:00	Closing address	**Markus Klettner**, ESW, Luxembourg

9.30 – 10.00, Prof. Dr. Nicola Pugno (Laboratory of Bio-inspired Nanomechanics, Polytechnic Institute Torino, Italy): ***Statistical models for the design of super-strong CNT space elevator cables: investigating the role of hierarchy and self-healing***



Prof. Dr. Nicola Pugno is Associate Professor of Structural Mechanics at the Department of Structural Engineering of the Politecnico di Torino, Italy. There he heads the Laboratory of Bio-inspired Nanomechanics. Prof. Pugno is recognised internationally as a leading expert in the important field of Structural Mechanics and Strength of Materials. In addition Prof. Pugno is "Leading Scientists of the World" laureate and has been collaborator of Nobel Laureate Prof. Kroto. Prof. Pugno has already lectured about the role of defects in the design of a space elevator cable at EuroSpaceward's conference in 2008 and 2009.

Abstract: Biological materials display hierarchical structures and self-healing properties, from nano to macro, effectively linking nanoscale constituents to larger-scale functional material properties.

In this keynote we will present a model that is capable of determining the strength and toughness of elastic-plastic composites from the properties, percentages, and arrangement of its constituents, and of estimating the corresponding dissipated energy during damage progression, in crack-opening control. Specifically, we adopt a fiber bundle model approach with a hierarchical multi-scale self-similar procedure which enables to span various orders of magnitude in size and to explicitly take into account the hierarchical topology and the self-healing of natural materials. By considering one of the toughest

	known materials today as an example application, a synthetic fiber composed of single-walled carbon nanotubes and polyvinyl alcohol gel, we compute strength and specific energy absorption values that are consistent with those experimentally observed. These results suggest that the model is capable of helping in the design of new hierarchical topologies and self-healing mechanisms for nanotube cables that could be of interest in the space elevator context.

Notes /questions:

10.00 – 10.30, Mr. Sourabh Kaushal, Mr. Nishant Arora (Institute of Science & Technology, Klawad, India): ***Space Elevator – Dilemma and Remedies***

Nishant Arora and **Sourabh Kaushal** are undergraduate students at the Institute of Science & Technology in Klawad, India. They are pursuing a B.Tech. in electronics & communication sciences. Their research work on space debris and its mitigation has been runner-up in the research paper competition for the 'Jerome Pearson Prize 2010' which is awarded by the International Space Elevator Consortium (ISEC).

Abstract: The Space Elevator is the most promising Space Transportation system on the drawing boards today, combining scalability, low cost, quality of ride, and safety to deliver truly commercial-grade space access, practically comparable to a train ride to space. A space elevator is a proposed structure designed to transport material from a celestial body's surface into space.

All studies indicate that the idea, outrageous though it appears at first sight, is theoretically feasible and that its practical realization could follow from the mass-production of high-strength materials now known as laboratory curiosities.

The paper is a semi-technical survey of the expanding literature of the subject. It describes the current methods proposed for the space elevator and its merits and demerits. It depicts new approaches in order to overcome the limitations of previous proposals to build a Space Elevator.

The highlights of our paper are as follows:

- We firstly describe the history from where the idea of the "Space Elevator" came up.
- After that, we describe the current technology considered to be best for the "Space Elevator".
- We describe "Carbon nanotubes" and its use in building the 'Space Elevator'.
- Then we explain the working and components of the "Space Elevator".
- Further we explain the tribulations encountered with the "Space Elevator".
- Then we propose some remedies to the tribulations and we lay stress on the use of 'Graphene' instead of 'Carbon nanotubes'.

The construction of the Space Elevator will be considered to mark the true beginning of the Space Age. The idea of

	space elevator is brilliant. The space elevator could substitute the space shuttle as the main space vehicle, and be used for satellite deployment, defense, tourism and further exploration. To the latter point, a spacecraft would climb the ribbon of the elevator and then would launch toward its main target once in space. We conclude by saying that **"SPACE ELEVATOR IS THE PATH TO HEAVEN."**

Notes /questions:

11.00 - 11.30, Prof. Dr. Sunao Kai (Faculty of Law, Nihon University, Japan): ***From the view point of law: Who can establish the Space Elevator?***

Prof. Dr. Sunao Kai is professor of law at the Faculty of Law of Nihon University, Tokyo. He is author of numerous publications and has been member of the Japan Board of Audit.

Abstract:
I would like to discuss about the institution of establishing and management of the Space Elevator (SE). There are three possibilities, i.e. a State, private enterprises and the International Organization.

1) Possibility of establishing SE by a national institution of a particular state: We must consider the military balance between strong states. When the SE will become real, the state that will control the SE will have the absolute military power. There will be no effective defense methods. So, when the technology for the SE will become true, there may be a serious confrontation between strong states, which may interfere with each other for establishing the SE.

2) Possibility of establishing SE by private enterprises:
The location where you can expect long-term stability for SE is very limited on the planet. Therefore, we must define the location as a common heritage of mankind. Because of such a scarcity value, we cannot expect free competition between private enterprises.

3) Possibility of establishing SE by the International Organization: Hence, I believe, the only one possibility to establish the SE is by the International Organization, if possible, as a UN special agency. If we take the form like IBRD for the ISEO, we need only background contributions from each member state instead of real money. ISEO will be able to finance the construction money from

	the market, and therefore there is no need to rely on taxes from the people of each country.

Notes /questions:

11:30 – 12:00, Dir. Shuichi Ohno, (JSEA, Tokyo, Japan): ***Results from the 2nd Japanese Space Elevator Technical & Engineering Competition (JSETEC)***

Dir. Shuichi Ohno is founder and chairman of the Japan Space Elevator Association (JSEA). Together with his team at JSEA he has already organized various conferences on the Space Elevator in Japan and conducted two successful climber engineering competitions.

Abstract: In this presentation, I will highlight the results of JSETEC 2010 on August 8-10, 2010.

Compared to last year we prepared a tether system that was twice as high: a 300m long belt and rope tether system was hanged on two helium balloons of 4.5m diameter.

13 teams from Japan, German, Canada and USA tried to ascend and descend the 300m high tether safely. We evaluated each team's climber against various factors: Speed is a very important factor but safety and reliability are still more important because our goal is to develop the real space elevator technology and engineering. All entered climbers were battery-driven and had motors that were automated or remote controlled. Various types of mechanism and control methods showed us the ability and expandability of these engineering fields.

I will also explain the result of the LEGO Bricks Climber expedition E-LASER and the Endurance LEGO bricks Activities with Space Elevator Race. We conducted it on the same field. 3 LEGO climbers succeeded to climb up to the height of 100m.

Notes /questions:

12.00 - 12.45, Mr. Andreas Hein, Mr. Rüdiger Hink, Ms. Franciska Völgyi (all WARR, Technical University Munich): ***EuSEC - Europe's First Space Elevator Competition: A Rationale***

Andreas Hein has got an aerospace engineering degree from the Technical University of Munich (TUM), where he currently serves as Research Assistant for Systems Engineering at the Institute of Astronautics. He is founder and scientific head of the Space Elevator Team of the Scientific Workgroup for Rocketry and Spaceflight (WARR) at TUM, which is working on various aspects of the space elevator system.

Rüdiger Hink is studying aerospace engineering at the Technical University of Munich. He is head of the space elevator team at WARR and led the team at the 2010 climber contest in Japan.

Franciska Völgyi is studying mechatronics and computer science at the Technical University of Munich. She is leading the efforts at WARR to conduct the first European Space Elevator Challenge in June 2011.

Abstract: Since 2005, space elevator competitions are organized every year. The two existing competitions are the Spaceward association's "Elevator 2010" competition as part of the NASA Centennial Challenges in the USA and the Japan Space Elevator Technical & Engineering Competition (JSETEC) organized by the Japan Space Elevator Association. However, opportunities for teams to participate in a European competition are still missing. The WARR (Scientific Workgroup for Rocketry and Astronautics) Space Elevator Team has the intention to organize a first European Space Elevator Challenge (EuSEC) in 2011. This paper presents the rationale for EuSEC by first defining broad objectives and then deriving technical and organisational requirements from them. After the foundation of our team in 2005 we gained substantial experience in the construction of space elevator climbers, first by our attempt to participate in the "Elevator 2010" competition in 2007 and then as a participant of JSETEC in 2009 and 2010. By using this experience, we believe that it is now time to foster the space elevator development in Europe by a separate competition. As our observation of the US and Japanese competition tells us, space elevator competitions spur and sustain the development of new climbers by national and international teams. We are convinced that a repeated European competition will encourage the formation of new European teams. Furthermore, our intention is to set the technical requirements in a way that the resulting climber designs increase our understanding of the future space

	elevator system. Particular requirements shall be unique and not yet covered by other competitions. Examples are e.g. climber efficiency and payload capacity. Last but not least, a competition is always a formidable opportunity to catch the eye of the media and to introduce the idea of the space elevator to the public.

Notes /questions:

12.45 – 13.00, Dr. Pierre Rochus (CSL, ULg Liège): **Liège Space Center - *space qualification tests for space tethers.***

Dr. Pierre Rochus is Deputy General Manager (R&D) at Centre Spatial de Liège. He is an expert in optical metrology, new space technologies and space environment testing. Dr. Rochus teaches also design of space instruments and celestial mechanics at the University of Liège and serves as Vice-President of EuroSpaceward.

Abstract: The Space Center Liège (CSL) is a research centre of the University of Liège that has expertise in Space Science instrumentation and in optical metrology for space optics and structures (in particular expandable space structures). CSL is also an ESA coordinated test facility, specialized in optical tests of instrumentation in a space environment.

After a short presentation of CSL, this lecture will cover three topics: the space qualification tests (under vacuum and at cryogenic temperatures) to be performed on the CNT composite material samples, the potentialities of these materials for space instrumentation applications and a preliminary description of a tether test stand (mechanical / dynamical / material endurance tests for tethers).

Notes /questions:

14.00 - 14.30, Mr. Andreas Hein (Institute of Astronautics, Technical University Munich, Germany): ***Survey of current space elevator research: implications and future concepts***

Andreas Hein has got an aerospace engineering degree from the Technical University of Munich (TUM), where he currently serves as Research Assistant for Systems Engineering at the Institute of Astronautics. He is founder and scientific head of the Space Elevator Team of the Scientific Workgroup for Rocketry and Spaceflight (WARR) at TUM, which is working on various aspects of the space elevator system.

Abstract: During the last years the available literature on the space elevator has constantly grown. Many core issues have been more or less successfully addressed. However, it seems that due to the segmentation of this knowledge in different domains, this knowledge has not been properly established within the space elevator community. This paper tries to fill this gap by giving a view of the "big picture" and highlighting the important issues. On the basis of the results, revised space elevator system concepts are developed, which might serve as a starting point for further research. Seven areas are addressed: mechanics, material science, environmental effects, tether deployment, economy, politics and space elevator system concepts. In mechanics, latest publications have addressed the question of the dynamics of climber transitions and the question of relative stability. In material science, the discovery of the Stone-Walls defect shows that the strength of carbon nanotubes is inherently limited but the discovery of new materials like colossal carbon tubes might pose an alternative to nanotubes. Regarding environmental effects, one important unsolved issue is the question of space debris impacts. Looking at tether deployment, recent numerical simulations showed the huge difficulty of simulating the dynamics of the deployment process. Additionally, results from the climber competitions showed the difficulty of tether deployment via climbers. Regarding the economics, research has shown that the pay-off of the elevator will be rather incremental and evolutionary than revolutionary due to issues like the dual-launch capability. Findings from space transportation policy indicate that a purely commercial space elevator won't be feasible due to the intrinsic political nature of space transportation systems. These findings lead to the conclusion that the original space elevator concept of Brad Edwards has to be partly revised.

Notes /questions:

14.30 – 15.00, Mr. Nelson Semino (SpaceShaft, USA): ***Weight, uptrust and other vertical forces on atmospherically buoyant structures such as a SpaceShaft for a space elevator***

Nelson Semino was born in Montevideo (Uruguay). As an engineer, he has been active for years in the off-shore industry. Currently he is commuting between Brussels and Sacramento where he created the SME Buoyant Force with the objective to realize the simple but ingenious idea of a buoyant tower to gain access to space. Nelson Semino is to be considered the intellectual father of the SpaceShaft project.

Abstract: Based on several premises related to buoyancy; a SpaceShaft is a LTH structure tailored and deployed into a tubular shape.

While acting as a spar-buoy, it could theoretically harness the weight of a gaseous column throughout the dense regions of the planet's atmosphere converting it into ecologically green upthrust.

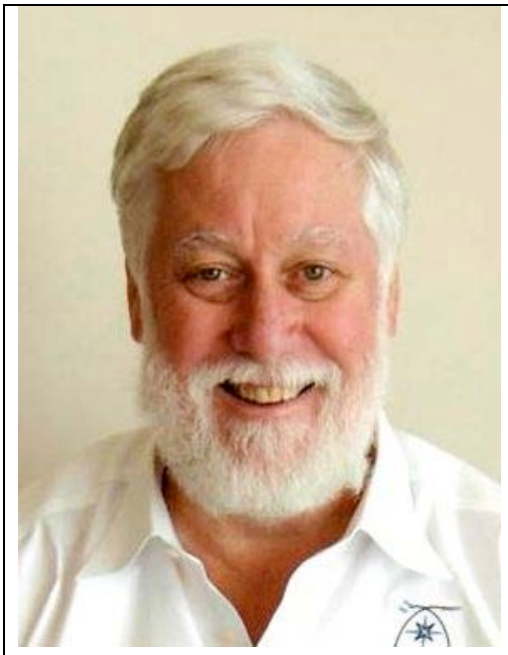
Calculations show that the atmosphere of our planet can be used as an undepleteable source of energy, which in combination with the spar-buoy effect, could power a hydraulic like system to jack-up massive quantities of materials beyond the Karman line.

While never in contact with the surface of the planet, its height can be constantly increased by adding new buoyant sections at its base. By its application, this elevator mechanism could slowly and in a constant FIFO flow attain orbital altitudes. Although delivery of possible cargo contained within the structure's wall would happen unidirectionally, the system could extend a CNT tether housed within its flue, therefore serving as a traditionally looking elevator system that would reach up to the critical LEO regions.

Several spin-off applications beyond the delivery of cargo at its summit are possible these may include serving as an assisting launching platform for vehicles capable of taking-off tangentially, platform for new atmospheric industries: such as gas sequestration and harvesting, e.g. helium, etc.

Notes /questions:

15:00 – 15:30, Dr. Pete Swan (SouthWest Analytic Network Inc., USA): **Space environment for space elevators: new insights on space elevator and debris collision probabilities**



Dr. Peter Swan is a Fellow of the American Institute of Aeronautics and Astronautics and member of the International Academy of Astronautics. He has over 40 years of experience in both government and commercial space systems. He is co-author of Global Mobile Satellite Systems and Impact of Space Activities upon Society. Currently he is with SouthWest Analytic Network Inc. In addition Dr. Swan serves as Vice-President of the International Space Elevator Consortium ISEC.

Abstract: This paper will address, at a high level, the risk of debris (focusing on the LEO environment) to a space elevator, and make recommendations with respect to the space elevator and the space debris environment. Space debris will pose a hazard to a 104,000 km long, one meter wide space elevator. Some questions to be asked and answered are: How precisely does one need to know the location of the space elevator ribbon? How precisely does one have to know the location, and propagated location of large space debris?

Co-authors of the paper:
Cathy Swan, Ph.D., SouthWest Analytic Network, Inc.
Robert “Skip” Penny, Cholla Space Systems

Notes /questions:

16.00 – 16: 30, Dir. Akira Tsuchida (JAXA Flight Director, JMSS Japan Manned Space Systems Corporation & ETC, Tokyo & Tsukuba, Japan): ***Space Elevator Roadmap 2010***

Dir. Akira Tsuchida is with Japan Manned Space Systems Corporation. He is also JAXA Flight Director at Tsukuba Space Center of the Japanese experiment module 'Kibo' (Hope) of the International Space Station ISS. He led the first Japanese climber team ETC during the NASA beam power challenge in Salt Lake City in 2007.

Abstract: In 2010, members of the Japan Space Elevator Association (JSEA) started developing a draft version of the Space Elevator Road Map. We reviewed and discussed (1) Key Milestones in Japanese National Policy, (2) Scope of Study needed by JSEA members. After that, we started a monthly study meeting to discuss on (a) Feasibility Study and (b) System Requirements so that we can make 'Road Map'.

In this manuscript, the study teams activities are summarized such as: (A) Draft version of Mission Definition as part of Feasibility Study, (B) Draft version of Conceptual Design of Space Elevator as part of Feasibility Study, (C) Draft Cost Feasibility Study as a part of Feasibility Study, (D) Gathering Study/Research of Core Technology to accomplish Space Elevator as a part of System Requirements development.

Notes /questions:

16.30 - 17.00, Mr. Ted Semon (ISEC International Space Elevator Consortium, USA): ***Space Elevator: International policy and outlook***

Ted Semon is a retired software engineer and the author of the Space Elevator Blog (www.spaceelevatorblog.com). He is also the President of the International Space Elevator Consortium (ISEC - www.isec.info), an organization that was founded in 2008 with the aim to "promote the development, construction and operation of a space elevator as a revolutionary and efficient way to space for all humanity".

Abstract: The Space Elevator is an idea that is still 'under the radar' as regards to worldwide acceptance or even knowledge. This is likely to remain the case unless and until carbon nanotube creation and spinning technology can produce fibers that test out at 20 Mega-Yuris or better. While worldwide research continues to focus the majority of its efforts towards developing other properties of carbon nanotubes, it is clear that there is also increasing interest and research into tapping into the tremendous high-strength potential of CNT fibers. At the 2010 Strong Tether competition, there was, for the first time, multiple CNT tether entries, even though the results of the competition show that there is a long ways to go before we can develop a fiber that could serve as the basis for building an elevator to space.

In the meantime, organizations such as EuroSpaceward, the Japan Space Elevator Association and the International Space Elevator Consortium (ISEC) continue to address the other issues; legal, business, public-outreach and other, non-CNT engineering items, that must be answered before a Space Elevator can become a reality. ISEC will focus the majority of efforts in 2011 towards furthering efforts in CNT high-strength research.

Notes /questions: