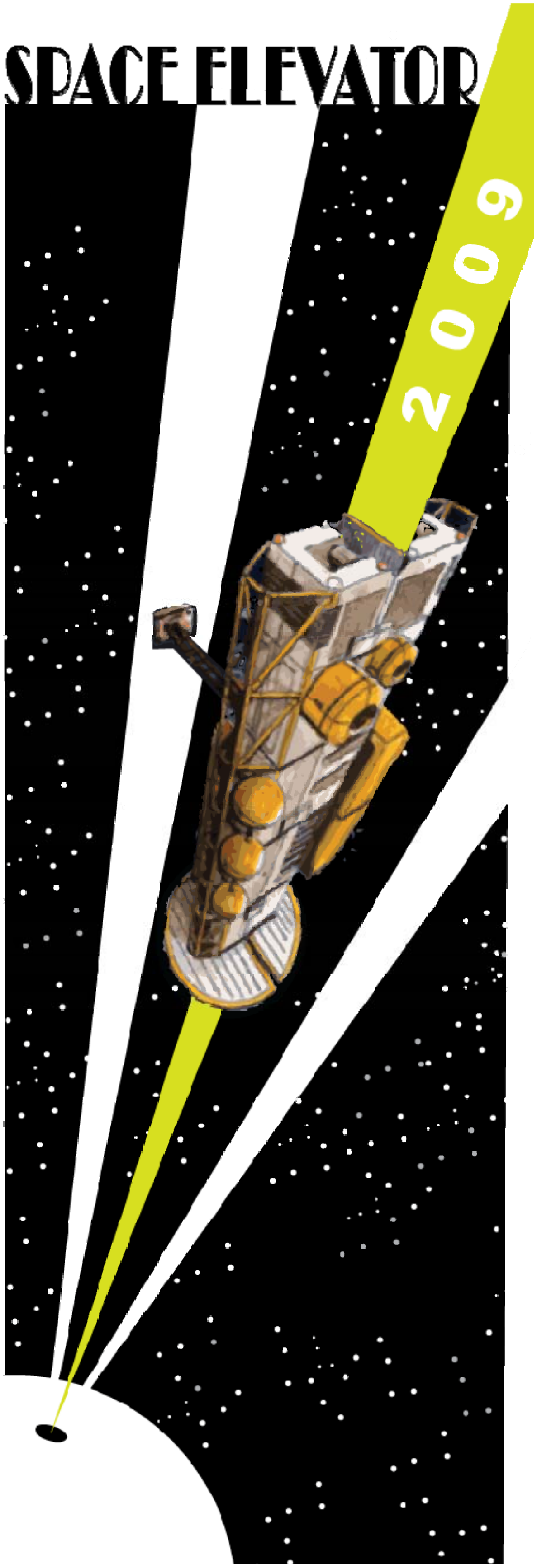
Conference Program



2009 Space Elevator Conference

August 13 – 16, 2009
Microsoft Conference Center
Redmond, Washington

Presented by

The Space Engineering and Science Institute

Sponsored by

Microsoft

and

JPL Space Foundation

2009 Space Elevator Conference

Thursday, August 13, 2009 - Day 1

7:00am - 8:00am **Check in** and **Breakfast** (provided)

8:00am - 8:45am **Conference Introduction and Overview of SE Science and Technology** by Dr. Bryan Laubscher

8:45am - 12:00pm **Science and Technology Session I** (20-25 min. presentations and 5 min. questions per talk)

1. **The Construction and Operation of a Practical Space Elevator Using Moving Cables** by Gaylen Hinton
2. **Gravity-Pumped Space Elevator Catapult** by Frederick Cowan
3. **Reusable Rocket Analysis** by Dr. Bryan Laubscher
4. 15 minute break at about 10:15am
5. **Moving Cable Elevators - An Economic Argument Against Climbers** by Keith Henson
6. **Dynamics of a Compound Elastic Cable for the Space Elevator** by Karen Ghazaryan
7. **The Space Elevator Feasibility Condition** by Ben Shelef

12:00pm - 1:00pm **Lunch** at Conference Center (provided)

1:00pm - 1:30pm **Microsoft Robotics Developer Studio** (RDS) by Tandy Trower

1:30pm - 4:15pm **Science and Technology Session II** (20-25 min. presentations and 5 min. questions per talk)

1. **Space Elevator Red Team 1** by Bryan Laubscher
2. **Mars Reentry Using an Orbital Space Elevator Anchored to Phobos** by Ben Shelef
3. **The Effect of Climber Transit on the Space Elevator Dynamics** by Stephen Cohen
4. 15 minute break at about 3:00pm
5. **How Safe is "Safe Enough?"** by Ted Semon
6. **The Launch Loop - An Earth to High Orbit Launch System** by Keith Lofstrum

4:15pm - 5:15pm **WorldWide Telescope** (WWT) by Jonathan Fay

5:15pm - 5:30pm Break

5:30pm - 6:30pm **Mixer** at Conference Center

7:00pm - 9:00pm **ISEC Board, Officers, and Pillar Leads Meeting and Dinner at local restaurant**

2009 Space Elevator Conference

Friday, August 14, 2009 - Day 2

7:00am - 8:00am **Check in** and breakfast (provided)

8:00am - 8:30am **The Business Basics of Space Elevator Development** by Michael Laine

8:30am - 9:00am **Carbon Nanotube Tether from Spinnable Ultra-Long Nanotube Array** by Yoku Inoue

9:00am - 9:30am **NASA Centennial Challenges** by Andrew Petro and Andrew Jones

9:30am - 9:45am Break

9:45am - 11:00am **NASA Centennial Challenge Strong Tethers Competition**

11:00am - 12:00pm **The Space Elevator Power Beaming Challenge – Status Report** by Ben Shelef

12:00pm - 1:00pm **Lunch** at Conference Center (provided)

1:00pm - 4:00pm **Planning and Intermediate Steps Session** (20-25 min. presentations and 5 min. questions per talk)

1. **Noumenia Process - Holistic Operations Plan A New Paradigm for the Space Elevator** by Michael Laine
2. **Space Elevator - A Global Venture** by Stephen Cohen
3. **Challenges to the Space Elevator** by Michael Laine
4. 15 minute break at about 2:30pm
5. **A Collaborative Model for Space Elevator Business Plan Development** by Ed Gray
6. **Action Matrix: Example Tasks Required for the Space Elevator** by Michael Laine

4:00pm - 5:00pm **The International Space Elevator Consortium (**ISEC**)** by Ted Semon

5:00pm - 6:30pm Break

6:30pm - 7:00pm Doors open and admission to movie presentation

7:00pm - 8:30pm **Orphans of Apollo Movie Presentation** ($10 admission at the door for the public and all conference attendees)

2009 Space Elevator Conference

Saturday, August 15, 2009 - Day 3

7:00am - 8:00am **Check in** and breakfast (provided)

8:00am - 11:00am **The World Created by the Space Elevator Session** (20-25 min. presentations and 5 min. questions per talk)

1. **Military Access to Space in the Era of the Space Elevator** by Jason Kent
2. **Feasability Analysis of Solar Power Satellites Based on Comparable Terrestrial Systems and the Possible Effects Due to the Usage of the Space Elevator for Transportation** by Joachim Sturm
3. **Human Expansion into the Solar System and Military Roles in Space** by Jason Kent
4. 15 minute break at about 9:30am
5. **Space Elevator, Debris Mitigation Enabler** by Robert Penny and Peter Swan
6. **Server-Sky: Solar Powered Server and Communication Arrays in Earth Orbit** by Keith Lofstrom

11:00am - 12:00pm TBD

12:00pm - 1:00pm **Lunch** at Conference Center (provided)

1:00pm - 3:45pm **Public Relations and Outreach Session** (20-25 min. presentations, 5 min. questions per talk)

1. **LiftPort Past, Present, and Future: Lessons Learned Building an Elevator to Space** by Michael Laine
2. **The Inevitability of the Space Elevator** by Dr. Bryan Laubscher
3. **Tips, Techniques, and Uses of Social Media in Developing an Elevator to Space** by Chelsea Barackman
4. 15 minute break at about 2:30pm
5. **If We All Looked Up** by Robert McLin
6. **"To Infinity and Beyond!" - Role of Public Relations in the Development of the Elevator to Space** by Belinda Young

3:45pm - 5:30pm **Panel Discussions of the Future with the Space Elevator**

5:30pm - 6:00pm Break

6:00pm - 8:00pm **Dinner Banquet** (on-site at the conference center, provided with multi-day registration)

2009 Space Elevator Conference

Sunday, August 16, 2009 - Day 4

7:00am - 8:00am **Check in** and breakfast (provided)

8:00am - 9:00am **Academic Research Session** (20-25 min. presentations, 5 min. questions per talk)

1. **An Academic Center for Space Elevator Research** by Tom Marotta
2. **The Creation of a Space Elevator Institute** by Stephen Cohen and Arun Misra

9:00am - 9:30am **Workshop Introduction**

9:30am - 12:00pm **4 Pillars Workshops** (break-out sessions)

1. **Science and Technology**
2. **Economics**
3. **Legal**
4. **Public Relations and Outreach**

12:00pm - 1:00pm **Lunch** at Conference Center (provided)

1:00pm - 2:00pm **Pillar Leaders Reports**

2:00pm - 2:30pm **The Next Space Elevator Conference**

2:30pm - 2:45pm Break

2:45pm - 4:00pm **Shotgun Science Session** (science ideas not ready for prime time: rapid sequence, 5 min per topic)

4:00pm - 4:20pm **Three Feet From Gold - Lessons in Perseverance** by Greg S. Reid

4:20pm - 5:00pm **Conference Review and Wrap-Up**

6:00pm Meeting of conference organizers (old and new) at a nearby restaurant

Presentation Abstracts and Summaries

Alphabetical by author/presenter last name

Tips, Techniques, and Uses of Social Media in Developing an Elevator to Space

Chelsea Barackman and Michael Laine, LiftPort

Social Media is literally a tool to connect the dots. These dots can be something like a blogger to readers, news to subscribing individuals, or as simple as people to their friends. Social Media covers a lot of territory, and thus it takes many different forms including blogs, and internet forums. It's Social Media's versatility and accessibility that makes it so important for continuing the Space Elevator movement. Because of its relevance to the Space Elevator, I will go into the importance of Social Media, simple steps on using Social Media, as well as sharing some tips.

As one of the first of its kind, Social Media enables a personal, political, or business relationship between two people. It also is extremely accessible; most Social Media tools are available at little to no cost. Because of this, it is important to harness this power, particularly in the case of advancing Space Elevator technologies.

Having a presence in influential Social Media is very important to the success of any idea, project, etc. The future of the development of the Space Elevator lies in this new phenomenon. The Space Elevator is a huge undertaking, so it's going to need a vast array of people of all divisions from political to technical. Social Media can be utilized to find them.

The Creation of a Space Elevator Institute

Stephen Cohen and Professor Arun Misra, McGill University

A Space Elevator Institute (SEI) is a necessity to monitor and possibly coordinate activities related to the space elevator taking place in parallel around the world. The SEI will begin as a virtual institute with nodes at several locations. These nodes will consist mainly of academic institutions and companies. McGill University will be one such node, with at least two researchers and a group of students. The SEI will facilitate research and also be providers of information. The SEI will focus on the final realization of the space elevator as well as all intermediate steps. It will facilitate the process of writing collaborative research proposals. Initially, all participation in the SEI will be on a voluntary basis. There will be an administrative body, an advisory committee (approximately ten members), and researchers. The advisory committee will propose research activities, and attempt to align them with the best-suited researchers. The public will be invited to become members for a small fee. All members will receive information in the form of technical papers as well as a bulletin, which will be accessible to the layman.

Members will also pay reduced rates for space elevator conferences. Eventually, membership fees will fund full-time managers, and later, a physical home.

The Effect of Climber Transit on the Space Elevator Dynamics

Stephen Cohen and Professor Arun Misra, McGill University

The space elevator offers an alternate and efficient method for space travel. It will have two main components. The first component is the tether (or the ribbon), which extends from the Earth to an equatorial satellite at an altitude beyond the geostationary orbit, and is fixed to a base on the surface of the Earth at its lower end. The second component is the climber, which scales the ribbon, transporting payloads to space. An important issue for effective operation of the space elevator will be to understand its dynamics. This paper attempts to develop a realistic and yet simple planar model for this purpose. The basic response of the ribbon to climber transit is determined. Both analytical and numerical results are presented. Specific climbing procedures are devised based on these results so as to minimize the adverse effects of climber transit on the ribbon.

Space Elevator - A Global Venture

Stephen Cohen, McGill University

Although the construction of a space elevator represents a major engineering challenge, it is one that will eventually be taken on by mankind. It is a project on a global scale that would impact the world in a multitude of ways. Its construction is inevitable because its potential economic benefits are already becoming too great to ignore. An operational space elevator would reduce the cost to place satellites into orbit or send probes to other planets by two or three orders of magnitude. It may take some decades for material technology to advance to the point where construction may begin. However, it may take even longer until humanity is ready for the responsibility of such a powerful tool. It is clear that the space elevator project will be a global one. While catalysts for the project (investors) will be localized, access to space via this new and elegant medium must be universal. The engineering details of how it will be built will be ironed out over time. In parallel, a master plan must be carefully devised to ensure that the effect of a space elevator on the world is a positive one.

Space Elevator Catapult

Frederick Cowan

A space catapult, riding on a Space Elevator, is analyzed as a means for space transportation without rockets. A space catapult is a tumbling tether with a mass on each end. A catapult, would permanently rotate on the elevator at geosynchronous altitude, and would be spun up by Lorenz Force propulsion. The catapult would release a spacecraft at a point that gives the desired velocity vector. A Space Elevator catapult could thus deliver a spacecraft to the Moon, Mars, etc. without rockets. In the proposed design, a 10 mT elevator truck would carry a 10 mT spacecraft to the launch point. At a specific time, the truck would release the spacecraft, launching it to a desired arrival point near the Moon, and with the desired arrival velocity. A lunar catapult would tumble while in orbit around the Moon. At the designated arrival time, the lunar catapult's tethered docking probe would be near the same position, and would fly out and capture the spacecraft. The lunar catapult's probe would come close to the lunar surface, and its tip velocity would be equal and opposite its orbital velocity, giving zero velocity with respect to the surface. The probe would thus gently lower the spacecraft onto the lunar surface, and pick it up again later. For the return trip, the lunar catapult would launch the spacecraft back to Earth. The spacecraft would be captured by the elevator truck's tethered docking probe, and brought down to the Earth's surface. The orbital mechanics and timelines are analyzed for the lunar trip scenario.

WorldWide Telescope

Jonathan Fay, Microsoft Corporation

The WorldWide Telescope (WWT) is a Web 2.0 visualization software environment that enables your computer to function as a virtual telescope—bringing together imagery from the best ground and space-based telescopes in the world for a seamless exploration of the universe.

Choose from a growing number of guided tours of the sky by astronomers and educators from some of the most famous observatories and planetariums in the country. Feel free at any time to pause the tour, explore on your own (with multiple information sources for objects at your fingertips), and rejoin the tour where you left off. Join Harvard Astronomer Alyssa Goodman on a journey showing how dust in the Milky Way Galaxy condenses into stars and planets. Take a tour with University of Chicago Cosmologist Mike Gladders two billion years into the past to see a gravitational lens bending the light from galaxies allowing you to see billions more years into the past.

WorldWide Telescope is created with the Microsoft® high performance Visual Experience Engine™ and allows seamless panning and zooming around the night sky, planets, and image environments. View the sky from multiple wavelengths: See the x-ray view of the sky and zoom into bright radiation clouds, and then crossfade into the visible light view and discover the cloud remnants of a supernova explosion from a thousand years ago. Switch to the Hydrogen Alpha view to see the distribution and illumination of massive primordial hydrogen cloud structures lit up by the high energy radiation coming from nearby stars in the Milky Way. These are just two of many different ways to reveal the hidden structures in the universe with the WorldWide Telescope. Seamlessly pan and zoom from aerial views of the Moon and selected planets, as well as see their precise positions in the sky from any location on Earth and any time in the past or future with the Microsoft Visual Experience Engine.

WWT is a single rich application portal that blends terabytes of images, information, and stories from multiple sources over the Internet into a seamless, immersive, rich media experience. Kids of all ages will feel empowered to explore and understand the universe with its simple and powerful user interface.

Dynamics of a Compound Elastic Cable of Space Elevator

Dr. Karen Ghazaryan, Institute of Mechanics, National Academy of Sciences - Yerevan, Armenia

The possibility of the realization and exploitation of the space elevator project come across a number of complicated problems. One of them is the dynamic behavior of an extraordinarily long elastic cable under action of an extreme non- uniform tension.

We shall consider the compound cable made from two uniform materials with different bulk densities. The density of the lower part of cable is less than the density of higher part. The cable material is separated at the point of geostationary orbit. This model of the compound cable provides an opportunity to reduce the cable length.

First of all we would like to formulate the problems of transversal (lateral) bending vibrations for a compound non-uniformly tensioned cable, considering the cable as an elastic Timoshenko' beam. For beam boundary conditions we assume that one edge of the beam is fixed, the other outward edge is free from force with an attached mass "counterweight." The more general case of external loading is considered together with initial conditions for the cable normal displacement and velocity. The internal dumping properties of the cable material are taken into account also.

In the same mathematical statement the longitudinal vibrations are considered when elastic wave is traveling along length of cable. For both cases forced and free vibrations are studied.

Based on the numerical results of the solution of the problems under consideration the estimates of cable vibration frequencies, resonance conditions and practical recommendations will be provided.

A Collaborative Model for Space Elevator Business Plan Development

Ed Gray

Whatever its ultimate design and financing approach, the space elevator is a vast project whose "moving parts" will continually evolve. By creating a secure, flexible, digestible business model that renders the program in a way in that can be reviewed, enhanced and edited by contributors from multiple disciplines, a world-class knowledge repository will emerge that will result in more efficient planning and design work and thus, improved quality in both the financial program and the physical project. This paper and its accompanying presentation will show key features of such a model and propose a strategy for collaboration.

Moving Cable Elevators - An Economic Argument Against Climbers

Keith Henson, Founder, L5 Society

Space based solar power is the dominant potential market for earth to GOE transportation. The size of the energy market is so large that it would require delivery of ~1 M tonnes per year (~100 tonnes per hour). The gain in potential energy per kg is ~15 kWh/kg, or 15 MWh/t. A simple loop of cable raising 100 t per hour would require a 1.5 GW motor driving it at near 100 percent efficiency. The chain from electric power through lasers, optics, PV cells, and motors plus the mass fraction devoted to PV cells, support structures, power conditioning and motors is unlikely to exceed 10%. Thus, the laser input (at 50%) would be at least 15 GW. At $10 per output watt, the lasers would cost $75 billion in addition to the cost of the elevator.

If space elevators can be constructed at all, they should use moving cables to provide the lift energy. Step taper using pulleys allows a constant sized cable to be used if the cable strength is not high enough for a simple loop.

The Construction and Operation of a Practical Space Elevator Using Moving Cables

Gaylen Hinton, ZQ Tech

A practical space elevator (SE) can be built using moving cables to greatly decrease the operating costs of sending people and cargo into space. Two separate scenarios are presented: The first scenario is where the specific strength of the tether material is greater than 50 x 10^6 N-m/kg, and the second is where the specific strength is less than 20 x 10^6 N-m/kg. Very different designs are required for the two scenarios.

An SE with moving cables could carry cars up and down, just like an elevator in a hotel. Elevator cables provide an almost 100% efficient means of energy transfer. The SE cars could be attached to the cable going up, or coming down, as needed. Such an arrangement would be vastly superior to an SE where climbers received energy through inefficient means like laser beams. Not only would an SE cable car be much more efficient and simpler than a climber, but 100 MW motors on the ground could raise the car much faster than a self-contained climber ever could. In addition, those big motors would double as generators as the cars came down, recouping the energy put in. Therefore, passenger travel to space would require almost zero net energy, as the energy input to send them up would be retrieved when they came down.

The recouped energy would be stored in a flywheel energy storage system. A material strong enough to make an SE could also easily make a flywheel that would store 100 MWh of energy.

With the SE cables moving up and down in a big loop, the Coriolis force from the rotation of the earth would keep the cables apart. If the cables stopped for seconds, or even minutes, to attach or detach cars, the cables would still remain apart because the oscillation period of the SE cables would be hours, due to their extremely long length.

An SE with moving cables could be built with a single rocket launch, even if the specific strength of the tether material was less than 20 x 10^6 N-m/kg. The details of how this can be accomplished will be shown.

Carbon Nanotube Tether from Spinnable Ultra-Long Nanotube Array

Yoku Inoue, Shizuoka University

Carbon nanotubes (CNTs) have been regarded as a key nanomaterial for a wide range of applications. Their small tubular structure is responsible for diverse features, such as high mechanical strength, strong electric properties, good heat conductance, and high electron emission, which are of interest for academic researchers and industries. We invented a simple one-step growth method of ultra-long (millimeter-scale) vertically aligned multi-walled CNT (MWNT) arrays. Our method requires no pre-process for catalyst thin film (pre-deposition), and only requires iron chloride powder and acetylene gas. The MWNT array can easily be spun into ribbons (or yarns) by hand with naked eyes, and the ribbons are fabricated into the anisotropic nanotube fiber, sheet, and the tether for the Space Elevator Game.

MWNT array was synthesized using a conventional thermal chemical vapor deposition (CVD) system. A smooth quartz substrate was placed in a horizontal quartz tube furnace with $FeCl_2$ powder. We refer to this method as “chloride mediated CVD (CM-CVD)”. To grow MWNT, single acetylene gas was flown. Densely grown MWNTs are vertically aligned on a quartz substrate. The height of MWNT array reached 2.1 mm in 20 min with the growth rate of 100 μm/min. This growth rate is remarkably high. The established one-step growth method, CM-CVD, offers a potentially viable MWNT mass production method. In the present system, 1 g of MWNT array is grown in 2 hours including 20 minutes of growth time, and material cost performance is as low as US$0.5/g.

Our MWNT array sample has a high spinnable feature. The CNT ribbon (or yarn) is easily drawn using tweezers by pulling out the edge of the array. The CNT bundle ribbon (yarn) can be spun over 40 m just by drawing MWNTs with no twisting. During drawing, nanotubes are drawn with taking neighbors one after another with the aid of van der Waals force. Tiny nanotubes are connected at the both ends with some overlap, and are highly aligned in the drawing direction. Therefore the nanotube products, such as fiber, tether, sheet etc, have anisotropic properties. Our carbon nanotube fiber and tether are made of only MWNTs, and no binder material is used. The achieved fiber strength is ~750 MPa and electrical resistivity is 8.0×10^{-4} Ω·cm. Array samples are consistently spinnable for each trial. Low cost, easy to scale up and high spinnability CM-CVD method promises advanced CNT products.

Human Expansion into the Solar System and Military Roles in Space

Major Jason Kent, USAF

What role will the U.S. military have in as humans move off planet and spread out into the solar system? History is full of examples of the military forces moving out with colonists. Military forces have also been used to secure key routes, access to resources, and protect national assets. The SE will open up the unbounded frontier of space – will the U.S. military be along for the ride?

Why? What adversary could the U.S possibly face? As the SE lives up to its potential, there will likely (and sadly) remain the same adversaries the U.S. faces today around the globe: nation-states, non-state actors (i.e. terrorists), acts of god (asteroids heading for Iowa), and, of course space pirates. A brief examination of the conditions which would spawn such adversaries in space will be presented.

The U.S. Marines have a long history of fighting on distant shores – including the Barbary pirates ("From the shores of Tripoli" ring a bell?) and adversaries around the globe. Marines, working in tandem with the Navy, have provided protection for key strategic points around the globe. Even now, the sea lines of communication (SLOCs) are under siege by pirates. The Straits of Malacca and the shores off Somalia pop into mind. Will Lagrange points and key orbital planes be any different in the future?

Protection of national and commercial assets in orbit and beyond as well as assuring access to resources will be a key role for the US military. An examination of the current missions of the U.S. military services is in order. Who is best suited to carry out the military space mission? Is it time for a new Space Corps? When the unimaginable wealth of the solar system is at stake, who will fend off the pirates?

Military Access to Space in the Era of the Space Elevator

Major Jason Kent, USAF

Will the U.S. need to maintain a back-up capability to access space after the construction of a space elevator? The importance of space assets in everyday and contingency operations requires the U.S. to be able to maintain the critical constellations supporting the military. Even if the U.S. military should make use of the space elevator, would the U.S. need to maintain legacy launch capability?

In the era of the space elevator, the U.S. can be assumed to use it to access to space on a regular basis. The lower cost-to-orbit and design options allowed by the SE will prove too good a deal for the military to pass up. But, due to the importance of space assets in national security, alternate means to access space may be required; ensuring the ability to replenish satellites as needed should the SE route to orbit be closed.

This paper will include a summary of U.S. national security missions. Legacy missions include communications, GPS, intel, surveillance & reconnaissance (ISR), and missile warning. New missions may include remote power generation and transmission and spotlights from space. Other future mission may include asset protection and force projection.

The current family of Evolved Expendable Launch Vehicles (EELVs) can continue to be produced and used as a back-up for the military. How long would production lines stay open? A short examination of the Titan/Atlas/Delta transition to EELV will be completed will provide some insight. (EELV as a dual path program is particularly interesting.) I will also look at national security launch requirements and compare these against spacelift needs in the SE era.

The U.S. is a space-faring nation with vital national interests protected and enabled by assets in orbit requiring assured access to space.

Noumenia Process – Holistics Operations Plan: A New Paradigm for the Space Elevator

Michael Laine, LiftPort

The "Noumenia Process" is a tool that was specifically designed for use in the Space Elevator community, yet it can also be used in any 'large project' environment. It is a "To-Do" list, a calendar, and a project management tool rolled into one. It picks up where Gantt charts and dependencies leave off. The Noumenia Process is a tool to help the manager put a sub-project into context of the greater, much larger, program. To be blunt - I don't know how we are going to build an Elevator to Space without this tool. The project is simply too big to succeed without an organizational structure behind it.

That said, there are no blueprints for building our Elevator. I have drawn on knowledge gained from: Naval warship construction, US Marine Corp operational planning doctrine, specialized education and communications training, portfolio management, skyscraper construction, "failed" projects in the space community, and public works infrastructure. Also, there are a lot of lessons to be drawn from projects where 'capital' is plentiful - energy projects (pipelines, opening oil fields, and wind farms).

Let's face it - building the Elevator to Space is not merely the task of sending a strong-string into space, and climbing back and forth. *It requires a complete global infrastructure - and it needs to be built from scratch.* Its construction is on a scale that surpasses the Great Wall, and particularly on a scale that dwarfs any "modern" construction like the Brooklyn Bridge or Three Gorges Dam. Which means, before we start to build the "biggest thing, ever," we need an operational management tool that is up to the task. Noumenia Process is that tool.

Action Matrix: Example Tasks Required for the Space Elevator

Michael Laine, LiftPort

The Action Matrix is a system that allows the managing, processing, and correct labeling of enormous amounts of information garnered from the Challenges and Stakeholder parts of the Noumenia Process. By creating a spreadsheet of combined Stakeholders and Challenges one can have categorical sub-projects defined and developed. It provides an organized method of establishing expectations, providing deliverable dates, and assigning a champion. In using the Action Matrix, the consequences of failure, inaction, or success become clearer.

Creation of the Action Matrix is a sub-component of the Noumenia Process. The second step is the proper identification of Stakeholders, who are aware and actively interested in the company, project etc. This is also the part where one figures out if the project Stakeholder is a hindrance or a help. Challenges have already been classified and organized and Stakeholders have been identified prior to the Matrix's creation. Then taking the Challenges and the Stakeholders, one builds a spread sheet with Stakeholders on top, Challenges and their sub-components on the side. Where Stakeholder and Challenges intersect, insert specific tasks to accomplish in that zone. Stakeholders and Challenges/component remain the same through the length of operation, tasks and dates change.

This Action Matrix is an essential part of the Noumenia Process. Any project needs a sound plan. Without it, the ability to make day-by-day and long term decisions would be severely limited.

Challenges to the Space Elevator

Michael Laine, LiftPort

Thousands of pages have been written regarding the Hardware aspect of building an Elevator to Space. But that is only one of five essential parts. Despite the deep interconnection between the "fashionable" Hardware element and the other four, these additional elements have been virtually ignored. These essential parts are: Hardware, Outreach, Business, Framework and Temporal. By identifying the key issues in the Challenges of Space Elevator development, the solutions can begin to grow in a coordinated fashion.

The set of Challenges for a project with the enormity of the Space Elevator is usually under-appreciated. In Hardware, the first level is known as Science/Discovery, this is where most of the public and research attention is focused and where the Space Elevator "conversation" tends to stick. In Outreach, the main issues lie in making the connections *and* gaining active involvement. For the Business part, a valid pricing model is very important; as is an in-depth analysis of Space Elevator cost-effectiveness (complete with a cost/benefit analysis and a credible and executable financing plan) - none of which exist. In the topic of Framework, things like insuring a space elevator is one of many, many valid concerns. Finally in Temporal, is the need for a constant, real-time, and objective, assessment of all Challenges and the ability to make forecasts. This 'Challenges' tool is a sub-level of the more encompassing Noumenia Process. It is a simple tool, but the task is ongoing: Make a list of the Challenges and their components and then add, remove and adapt problems/issues as things change.

The Challenges and their sub-components are paradigm constructs of the Noumenia Process; valuable in their ability to provide a tool to identify problems. These problems are many, and can be fluid, but this process is the best tool available for identifying the issues. By using these Challenges, the total sum of all the issues that span this project are covered and the relationship between them taken into account. A short example list has been developed for this paper, however an exhaustive list must be developed. It is hoped that this conference will provide a venue to expand this list. This is a very important tool for the future development and implementation of an Elevator to Space. It is a "problems identification tool", not a "problems solving tool".

LiftPort Past, Present, and Future: Lessons Learned Building an Elevator to Space

Michael Laine, LiftPort

In 2002 HighLift Systems was incorporated. This was the precursor to LiftPort Group, and a huge jump forward in the Space Elevator project. In this paper I will be going through the history of my involvement with the Space Elevator, using examples from HighLift Systems and LiftPort, giving a detailed account of the times, and providing a correct and coherent time-line.

I will be doing this as a way of clearing the air, telling what happened, and share where we plan to go from here. It is about the lessons learned on the LiftPort journey, and what experiences will be taken into the future. Many things contributed to what happened, and I plan to account for them.

Many people have contributed their valuable time and experiences to seeing this thing through. In the end, the lessons learned from our successes and failures at LiftPort are essential to the future of the Space Elevator.

The Business Basics of Space Elevator Development

Michael Laine, LiftPort

This paper is about a few basic concepts behind the business side of the Space Elevator. If humanity is ever going to see the benefits of space activity, it must do so in the era of decreasing space budgets and increasing cynicism towards the huge government space programs of the 1960s. The area of launch services and access to orbit must be commercialized in order to fully open up the space frontier for industrialization, colonization, and entertainment. The Space Elevator is a concept that will radically change the aerospace industry and indeed the entire world. Large government space programs and large aerospace/defense companies are too entrenched in their current programs to take on anything as risky as the Space Elevator. That is way a new, smaller, entity must be created whose main purpose is the construction of an Elevator to Space. Still, there are many, many things that need careful consideration in order to successfully build the Space Elevator. Three concepts to keep in mind are the creation of a “first lift” date, the use of “dual-tack technology development”, and the idea of “the four pillars of infrastructure development.” These three basic principles will allow the Space Elevator to be built in a fast, inexpensive, and ultimately safe manner.

The Inevitability of the Space Elevator

Dr. Bryan Laubscher, Odysseus Technologies

The Space Elevator is inevitable. Before the first Space Elevator is deployed, a carbon nanotube-based revolution will have occurred on Earth. This revolution will be two-pronged, one enabled by the remarkable electrical properties of carbon nanotubes (CNTs) and the other enabled by the high strength properties of CNTs. CNT electrical properties will revolutionize energy storage and electronics of all kinds, including computer technology. The high strength materials revolution will transform the way we design, manufacture and use homes and buildings, transportation systems of all kinds and commodities.

This paper will predict these two revolutions and speculate on their impact for our future. Finally the author will show how the Space Elevator is a natural outcome of these revolutions.

Misfire – Rocket Launch Misunderstood

Dr. Bryan Laubscher, Odysseus Technologies

On the May 4, 2009 Space Show, the author “encountered” an individual that claimed to have studied rockets for over 10 years. This individual asserted that: The energy required to place an object in orbit is the same no matter what launch system is used to orbit the object. This “sacred” energy was believed, by that person, to be the energy required to lift a test mass from the surface of the earth and place it into low earth orbit, i.e., the potential and kinetic energy of the orbiting body. This fundamental misunderstanding of the physics of launching objects into orbit pervades the “new space community” as has been discussed time and again on the Space Show.

This paper will discuss the misperception, gauge its impact and illustrate its relevance for distinguishing the Space Elevator launch economics from other systems.

Reusable Rocket Analysis

Dr. Bryan Laubscher, Odysseus Technologies

Reusable rockets are believed by many to be the future of low cost access to space. This paper presents a fundamental analysis of renewable rocket technology requirements and suggests the enabling technologies needed to realize reusability. The paper also assumes fabrication costs and then derives a very rough estimate of cost per flight of orbital vehicles. The expendable Saturn V and the partially reusable Space Shuttle performances are compared to illustrate the important constraints on reusable systems. Finally, the projected flight costs of reusable rockets are compared to projected Space Elevator costs.

Space Elevator Red Team 1

Dr. Bryan Laubscher, Odysseus Technologies

At the 2008 Space Elevator Conference, Ivan Bekey raised concerns about the Space Elevator's ability to survive the space debris and satellite environmental threat. The author agreed to lead a "red team" to look at these issues. Primarily, Mr. Bekey was concerned that one satellite collision, at any altitude, would breach the ribbon. Additionally, surviving the worsening space debris situation was another issue. The one new facet that Ivan raised was that the constant movement of the ground-based end could cause the elevator ribbon to go into chaotic motion. The position of the ribbon would be very difficult to predict, and the ribbon would be difficult to control (damp oscillations) once the ribbon is in chaotic motion.

Progress has not been made over the last year and this paper presents the proposed outline of the work and a call for individuals to contribute to the effort.

The Launch Loop - An Earth to High Orbit Launch System

Keith Lofstrum, KLIC

The Launch Loop is an Earth-surface-based electromechanical launch system that stores energy and momentum in a centimeter cross-section iron loop moving at 14 kilometers per second. The loop is contained in a stationary vacuum sheath. The loop, the sheath, and stabilization cables to the ground comprise a "dynamic structure", which can support itself at 80km altitudes against gravity by the deflection forces conforming it to the earth's curvature. The launch track of the launch loop is 2000km long, producing launch velocities of up to 11000 meters per second at 3 gee accelerations. Energy is restored with high efficiency linear electric motors, from electric generators on the ground, or rectenna farms supplied with space solar power.

This paper presents a proposed system that can launch five metric ton payloads to geosynchronous or trans-lunar orbits at rates of up to 80 per hour. The system can be built with ordinary materials and existing technologies, and deployed from the earth's surface.

More information at http://www.launchloop.com or http://en.wikipedia.org/wiki/Launch_loop

Server-Sky: Solar Powered Server and Communication Arrays in Earth Orbit

Keith Lofstrum, KLIC

Large data centers may soon consume 50MW or more of electrical energy. The EPA estimated US data center power consumption in 2006 at 60 billion kilowatt hours, or 1.5% of total US power consumption, and predicts a doubling by 2011. This will have huge environmental, social, and economic consequences unless we find alternative ways to power our digital economy.

Server sky is a proposal to build large arrays of ultralight solar powered server satellites and launch them into 6400km equatorial earth orbits, between the inner and outer Van Allen belts. There will be coordination issues with other equatorial resources such as space elevators.

A 7 gram server-sat consists of an ultrathin 6 inch solar cell, with power efficient processors, solid state memory, and microwave transceivers bonded to the edges. Thousands of server-sats position themselves into dozens of dispersed three dimensional arrays (hundreds of meters on a side) using light pressure for thrust and liquid-crystal shutters for trimtab steering. A server-sat array acts as a large phased array antenna, permitting it to steer thousands of communication beams at receiving stations and communities under its position in orbit, handing off communication and control to the server-sat arrays that follow it in orbit.

Since server-sat arrays operate outside the biosphere, the environmental impact of power generation and heat disposal is close to zero. Server-sat arrays can grow to practically unlimited size – space is big, and filled with unused solar energy. In time, new launch techniques, and solar cells made from lunar rock, can greatly reduce the environmental and economic costs of manufacturing and launch. There is room for billions of server-sats within a 100 millisecond ping time distance from earth.

Earth can return to what it is good at – green and growing things – while space can be filled with gray and computing things. More information at http://www.server-sky.com

An Academic Center for Space Elevator Research

Tom Marotta

The Space Elevator has incredible potential to open space for humankind, but its spin-off potential could be equally, if not more, rewarding. However, in order to have any hope of constructing a Space Elevator and realizing the benefits of its spin-off technologies, the research effort must be coordinated. A Center for Space Elevator Research is needed to act as a clearinghouse of Space Elevator knowledge in all fields: technical, legal, social, economic and otherwise. Ideally this Center would be physically located on a large university campus in order to tap into the natural synergy of academia. A private corporation such as the LiftPort Group would assist in the formation of the Center and have a symbiotic relationship with it i.e. LiftPort Group would act as the commercialization conduit giving guidance to the Center on what could work in the marketplace while the Center would supply basic research capabilities supplying LiftPort with intellectual property. No matter what the final form the Center takes, its establishment would organize and expand the scope of Space Elevator research and increase the chances that it is eventually constructed.

If We All Looked Up

Robert McLin

What is the result if the Space Elevator never existed? How would that impact society, our economy and the health of the planet? What about the spiritual nature of the project? How would it inspire people to see space as a viable option for generations to come through the Space Elevator? How would it affect our relationship nations have with each other? How has the pioneering spirit affected the development of society? We have a new frontier, why are we ignoring it? And what affect has our ignorance of this frontier had on our socioeconomic climate?

Space Elevator, Debris Mitigation Enabler

Robert Penny, Cholla Space Systems
Peter Swan, SouthWest Analytic Network Inc.

As we described in our paper last year in Glasgow, space debris will pose a hazard to a 104,000 km long, one meter wide space elevator. Many questions arise as to how to mitigate and, clearly, debris mitigation must be addressed through the establishment of requirements for the knowledge of the debris location and the propagation of that knowledge into the future. Derivative requirements such as response time and anchor platform maneuverability must also be addressed. This paper will review the risk of debris (focusing on the LEO environment) to a space elevator then describe mitigation strategies are enabled by the space elevator for the elevator itself and for all objects in earth orbit including operational spacecraft. For example, the same “tug” that must be developed for orbit raising can be used for capture and return of objects to the elevator at their end of life. Several other enablers that derive from the space elevator will also be discussed.

How Safe is "Safe Enough?"

Ted Semon, ISEC and The Space Elevator Blog

Building, maintaining and operating the first, earth-based Space Elevator will be one of the largest and most technologically advanced projects ever undertaken. One of the key questions which will have to be answered before it is built is “Will it be Safe?” Well, what is “Safe?” How “Safe” is “Safe enough?” This paper will explore the concept of “Safety” as it relates to large projects and technologically advanced projects, in general, and the Space Elevator, in particular. It will identify the riskiest portions of this project and assign a “safety factor” to each of them. This “safety factor” can then be used as one of the constraints in this system.

The International Space Elevator Consortium (ISEC)

Ted Semon, ISEC and The Space Elevator Blog

While efforts promoting a Space Elevator have been largely centered in the United States, Europe and Japan now have independent organizations and efforts promoting this concept. It was recognized at the 2008 Space Elevator conference that an international organization devoted to centralizing and coordinating efforts to build a Space Elevator would be very useful in promoting this cause.

Consequently, most of the organizations and individuals who have been involved in promoting the concept of a Space Elevator have come together to form the International Space Elevator Consortium (ISEC). ISEC is built on the “Four Pillar” model, with efforts in the Technological, Legal, Business and Public Outreach arenas. ISEC solicits memberships from both industry and the public and uses the proceeds to promote research and development and public outreach.

Mars Reentry Using an Orbital Space Elevator Anchored to Phobos

Ben Shelef, Spaceward Foundation

This paper examines the possibility of using an orbital Martian Space Elevator (not anchored to the Martian surface) that is based on the Martian Moon Phobos, utilizing the fact that it is tidally locked to the planet. A tether is extended from Phobos down to the edge of the Martian atmosphere, and a second tether upwards away from Mars. Incoming spacecraft dock with the outer tether, climb down to Phobos (where they are orbital), then descend down the second tether until they are released at the edge of the atmosphere at a velocity low enough to either parachute down or use a small rocket to complete the descent. The paper examines the parameters of such a system including size, required materials, required power systems, and estimated traffic that would justify such an infrastructure.

The Space Elevator Feasibility Condition

Ben Shelef, Spaceward Foundation

This paper ties together parameters pertaining to tether specific strength and to power system mass density to arrive at an inequality that determines whether a Space Elevator system is viable. The principle for the feasibility condition (FC) is that a Space Elevator must be able to lift its own weight fast enough – fast enough to grow by bootstrapping, fast enough to replace aging material, and fast enough to have a significant margin for commercial cargo beyond these housekeeping tasks. The FC therefore sets a 3 dimensional design space comprised of {specific strength, power density, survival time span}. After developing the condition, real life limitations on power density and specific strength are plugged in, and the resultant viable design subspace is examined. Finally, a design architecture that satisfies the Feasibility Condition is briefly introduced.

The Space Elevator Power Beaming Challenge – Status Report

Ben Shelef, Spaceward Foundation

The Space Elevator Power Beaming Challenge is a $2M technology competition organized by the Spaceward Foundation, in partnership with NASA's Centennial Challenges office which provides the prize purse. The challenge requires competing teams to design, build, and race vertical tether climbing machines that are powered by a power source that must remain on the ground. The games started in 2005 with a 50 m crane-suspended vertical racetrack and rudimentary power beaming based on commercial searchlights, and have progressed to the 2009 challenge of a 1 km helicopter suspended race track, and laser powered vehicles capable of moving at more than 5 meters per second. The challenge will be held at NASA's Dryden Research Center in the coming weeks.

Feasibility Analysis of Solar Power Satellites Based on Comparable Terrestrial Systems and the Possible Effects Due to the Usage of the Space Elevator for Transportation

Joachim Sturm, WARR

Most current publications that deal with the topic of Solar Power Satellites (SPS) analyze the feasibility of this system separately from alternative terrestrial systems, which are also capable of providing large quantities of renewable energy. This paper analyses the possibility of implementing the SPS system in a competitive position to a terrestrial system with the same characteristics. First, the assumptions and boundary conditions under which this analysis is performed are defined and a brief overview of the two systems and their relevant characteristics are given. Next, the interdependence of the specific transportation costs and the system size is analysed under the assumption that the SPS system is competitive to the terrestrial alternative. In a third step the specific transportation costs in reference to the power beaming efficiency and the specific mass per surface area are analysed. The implementation of an SPS system is discussed based on current space transportation options and the estimated specific

mass of promoted future SPS systems. Finally the possible impact of the space elevator, due to the estimated reduction of the transportation costs is analysed.

Microsoft Robotics Development Studio

Tandy Trower, Microsoft Corporation

The Microsoft(r) Robotics Developer Studio 2008 R2 (Microsoft RDS) is a Windows(r)-based environment for academic, hobbyist, and commercial developers to easily create robotics applications across a wide variety of hardware.

Microsoft RDS provides a wide range of support to make it easy to develop robot applications. Microsoft RDS includes a programming model that makes it easy to develop asynchronous, state-driven applications. Microsoft RDS provides a common programming framework that can be applied to support a wide variety of robots, enabling code and skill transfer.

Microsoft RDS includes a lightweight asynchronous services-oriented runtime, a set of visual authoring and simulation tools, as well as templates, tutorials, and sample code to help you get started.

Conference Program

2010 Space Elevator Conference

August 13 – 15, 2010
Microsoft Conference Center
Redmond, Washington

Presented by
The Space Engineering and Science Institute

Sponsored by

Microsoft

ISEC

LEEWARD SPACE FOUNDATION

Technical Program Agenda

Day 1 - Friday, August 13, 2010

8:00am-8:30am Check in and registration
8:00am-8:30am ***Breakfast*** (provided)

Conference Opening
8:30am-8:40am **Welcome and Conference Opening** - David Horn
8:40am-9:45am **Space Elevator Overview** - Bryan Laubscher

9:45am-10:00am Break

Space Debris Mitigation Session
10:00am-11:00am **Space Debris Mitigation Keynote: Enhancing Space Elevator Safety by Active Debris Removal** - Jerome Pearson
11:00am-11:30pm **Space Debris Mitigation** - Shane Chaddha
11:30am-12:00pm **Space Debris Mitigation** - B. Kartheka

12:00pm-1:00pm ***Lunch*** (provided)

Space Debris Mitigation Session ***(continued)***
1:00pm-2:30pm **Panel Discussion on Space Debris Mitigation**

Space Elevator Tethers Session
2:30pm-3:00pm **Optimal Design of the Space Elevator Tether** - Karen Ghazaryan

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3:00pm-3:15pm Break (snacks provided)

Space Elevator Tethers Session ***(continued)***
3:15pm-3:45pm **An Updated Review of Nanotechnologies for the Space Elevator Tether** - Gilberto Brambilla
3:45pm-4:15pm **NASA Centennial Challenges -** Andrew Petro
4:15pm-5:30pm **NASA Centennial Challenge - Strong Tether Competition -** Ben Shelef & competitors

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5:30pm-7:00pm ***Evening Mixer*** (at the conference center)

Technical Program Agenda

Day 2 - Saturday, August 14, 2010

8:00am-8:30am Check in and registration
8:00am-8:30am ***Breakfast*** (provided)

8:30am - 10:00am **Q&A Session with Yuri Artsutanov and Jerome Pearson**

10:00am-10:15am Break

Construction and Operation Session
10:15am-10:45am **Design and Feasibility of a 20 km Free-Standing Pneumatically-Supported Space Tower** - Raj Seth
10:45am-11:15am **Steps to the Space Elevator** - Bryan Laubscher
11:15am-12:00pm **Seven Deadly Assumptions about Space Elevators** - Gaylen Hinton

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12:00pm-1:00pm ***Lunch*** (provided)

Construction and Operation Session (continued)
1:00pm-1:30pm **Space Elevator: Dilemma and Remedies** - Sourabh Kaushal & Nishant Arora
1:30pm-2:00pm **Zero Relative Velocity Transfer Orbits for Space Elevators** - Thomas Marshall Eubanks
2:00pm-2:30pm **Space Elevator Construction Issues** - Gaylen Hinton

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2:30pm-3:00pm **Space Elevator Games Update** - Ben Shelef

3:00pm-3:15pm Break (snacks provided)

Enabling Exploration Session
3:15pm-4:00pm **Lunar Space Elevators : A Strategy for the Human Exploration of the Moon** - Thomas Marshall Eubanks
4:00pm-4:45pm **The Colonization of Mars via a Martian Space Elevator** - Gaylen Hinton
4:45pm-5:15pm **Space Elevator technologies for Mars Exploration** - Ben Shelef

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5:15pm-5:30pm **The International Space Elevator Consortium (ISEC)** - Ted Semon

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6:00pm-8:00pm ***Evening Banquet*** (at the conference center)

Technical Program Agenda

Day 3 - Sunday, August 15, 2010

8:00am-8:30am Check in and registration
8:00am-8:30am ***Breakfast*** (provided)

Political/Social Session
8:30am-9:30am **Space Elevator in 7** - Keith Curtis
9:30am-10:15am **The SkyLift Project: Paradigm Shifts and Sustainable Development** - Bryan Laubscher

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10:15am-10:30am Break

Legal Session
10:30am-11:15am **Who can establish the Space Elevator?** - Sunao Kai
11:15am - 12:00pm **Ensuring the Safety of Commercial Human Spaceflights** - Shane Chaddha

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12:00pm-1:00pm ***Lunch*** (provided)

1:00pm-2:00pm **Shotgun Science Session**

- 5-minute presentations on any ideas you have thought of during the conference
- Show everyone that back-of-the-napkin idea you came up with over lunch
- open to all attendees

2:00pm-4:00pm **SE Roadmap Workshops** (break-out sessions by pillar to brainstorm the next steps for the space elevator)

- Science/Technical
- Political/Social
- Legal
- Economic

3:00pm-3:15pm Snacks available during workshop break outs

4:00pm-5:00pm **SE Roadmap Summaries** - Pillar Leads (15 minutes each)
4:30pm-5:00pm **Conference Wrap-Up, Next Steps, Get Involved**

The 2010 Space Elevator Conference

Welcomes Space Elevator Pioneers
Yuri Artsutanov and Jerome Pearson

We are very pleased and privileged to welcome Russian engineer Yuri Artsutanov and American engineer Jerome Pearson, pioneers of the modern Space Elevator concept, to the 2010 Space Elevator Conference.

Known as the "Fathers of the Modern Space Elevator Program," Artsutanov and Pearson are credited with independently creating the first modern blueprints for building an Elevator to Space. Artsutanov's proposal, created in the early 1960s, used the newly discovered graphite whiskers to propose an Elevator to Space using cables attached to a satellite, and running in both directions. Independently of Artsutanov, Pearson conducted his own research on an Elevator to Space while at NASA. In 1975, Pearson published a proposal "The Orbital Tower: A Spacecraft Launcher Using the Earth's Rotational Energy."

The International Space Elevator Consortium (ISEC), an independent coalition designed to promote outreach and foster research relating to the construction of an Elevator to Space, is sponsoring Messrs. Artsutanov and Pearson's conference attendance and travel arrangements, for which we are very grateful.

As Ted Semon, president of ISEC, said upon the announcement in July of their attendance, "We are thrilled beyond words that both Mr. Artsutanov and Mr. Pearson have agreed to come to the Space Elevator Conference. Those who are familiar with the idea of the Space Elevator know that Yuri and Jerome were originators of the modern-day concept of a 'tensile' structure as the foundation for a realistic Space Elevator. Their ability to take the idea of a Space Elevator, first proposed as a tower by Russian Konstantin Tsiolkovsky, and come up with an Engineering solution which can actually make something like this happen, is the basis for all work done on this concept since then."

Presentation Abstracts and Summaries

In program order

FRIDAY:

Enhancing Space Elevator Safety by Active Debris Removal

Jerome Pearson (STAR, Inc.) jp@star-tech-inc.com
Eugene Levin (STAR, Inc.) e.m.levin@comcast.net
Joseph Carroll (TAI) tether@cox.net

We propose a low-cost solution for LEO space debris removal. The ElectroDynamic Debris Eliminator (EDDE) can affordably remove nearly all the 2500 objects of more than 2 kg that are now in low Earth orbit. They have more than 99% of the total mass, collision area, and debris-generation potential in LEO. These are the debris objects that most threaten the safety of a space elevator. EDDE is a propellantless vehicle that reacts against the Earth's magnetic field. EDDE can climb about 200 km/day, decay at 1200 km/day (times the mass ratio of EDDE to EDDE-plus-payload), and change orbit plane at 1.5 degrees/day, even in polar orbit. No other electric vehicle can match these rates, much less sustain them for years.

Most LEO debris is in a few narrow inclination clusters. After releasing one object, EDDE can climb and torque its orbit to reach another object in a cluster within a few days, while actively avoiding other catalog objects. Binocular imaging allows accurate relative orbit determination from a distance. Capture uses lightweight expendable nets and real-time man-in-the-loop control. After capture, EDDE drags its payload down and releases it and the net into a short-lived orbit safely below ISS. EDDE can sling debris into controlled reentry, or can attach an adjustable drag device to the net before release, to allow later adjustment of payload reentry location. It could even capture upper stages and re-cycle them for aluminum space construction.

Up to 12 EDDEs can be launched on any EELV with enough unused launch capacity, because two 100-kg EDDEs can share a single ESPA slot. A dozen EDDEs could remove nearly all 2200 tons of large LEO orbital debris in 7 years, clearing the way for space elevator construction. Smaller objects could be removed later. The estimated overall removal cost is $100 per kilogram. A dynamic simulation shows the removal operation.

Presentation Abstracts and Summaries

FRIDAY (cont.):

Space Debris Mitigation

Shane Chaddha (PhD Candidate) shane.chaddha@postgrad.manchester.ac.uk

Space debris has been and still remains a growing threat for the international space community. As a source of pollution, orbiting debris adversely damages the space environment. There is an increased risk of additional debris being generated by colliding with space objects, and such fragments remaining in space permanently. Every space actors, whether State-sponsored, civilians or commercial, are affected by the space debris population. Human lives are endangered: astronauts undertaking extra-vehicular activities or even the paying public enjoying commercial human spaceflights run the risk of colliding with pieces of debris. The continuing growth of debris in heavily used orbital regions, like Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO), not causes minor or complete abruptions to space operations, but potentially could prevent launches of planned space vehicles; thus, denying future access to, and use of, outer space. Further to stifling space development, the quality of the space environment is degrading, therefore. Preserving and sustaining that environment as a valuable resource for future space users has motivated interested space bodies to consider mechanisms to control the increase of debris. Such international meetings like the 5th European Conference on Space Debris and the US House of Representatives Committee on Science and Technology's Subcommittee on Space and Aeronautics on 'Keeping the Space Environment Safe for Civil and Commercial Space Users' have arrived to the same conclusion: better internationally agreed space debris mitigation methods to reduce the probability of additional debris must be created as well as remediation mechanisms being imposed. This Paper shall explore the different meanings and sources of 'space debris'. The population of orbital debris, also, is quantified, and three galvanizing events are identified and commented as exacerbating its growth since 2007. This Paper then shall examine the effectiveness of space debris mitigation practices, which were adopted by the international space community, to tackle the rising population of orbiting debris. These measures are not binding under international space law: compliance is voluntary. The Space Debris Mitigation Guidelines are preventative practices designed to control the increase of space congestion in popular orbital regions like LEO and GEO to preserve their commercial and scientific value as well as use of, and access to, by future space users. It shall be demonstrated that in the absence of legal liability and sanctioning being imposed on space operators the mitigation practices can be ignored.

Presentation Abstracts and Summaries

FRIDAY (cont.):

Space Debris Mitigation

B. Kartheka (Anna University, India) karthekabojan@gmail.com

Space debris is the collection of objects around the earth that were created by man but no longer serve any useful purpose. Most of the debris is the spent rocket stages and defunct satellites. This debris attacks the spacecraft and the satellites that are sent into the space. [2] Thus space debris mitigation is necessary for the space development. A better method of limiting space debris is by designing self-igniting boosters that are present in the rocket. In the booster once the fuel is burned, the space and the structure which contained it and the motor themselves are useless and only adds weight to the vehicle which slows down its future acceleration. So, these stages are detached which are perhaps called as debris. The stages that are removed should be designed with a crushing system which self-ignites exactly after few minutes from the time of detachment. The booster which gets ignited also ignites the debris that is close to them. Like a chain reaction, the small debris that is close to each other has a chance of getting ignited. The ignited debris cannot harm the earth since before they reach the earth the fall into ashes and by the time they reach the atmospheric zone they get cooled down. By this method the debris mitigation process can be started.

Also, debris can be cleared from the space whenever the spacecrafts or spaceships are sent into the space. The shielding of the spacecraft should be done with a thin foil of metallic sheet with a small distance from the spacecraft. The metallic sheet should be with magnetic properties that should be capable of producing stronger electromagnetic current around it. The electromagnetic current has the capacity to destroy the smaller debris and can greatly affect the larger debris by melting them into smaller ones that can be destroyed later or on an other attack. A magnetic launcher which attracts all the waste metals in the space can be sent into space to clear the metallic wastes in space.

Presentation Abstracts and Summaries

FRIDAY (cont.):

Optimal Design of the Space Elevator Tether

Karen Ghazaryan (Institute of Mechanics, Armenia) ghkarren@gmail.com
Sergey Ambartsumian (Institute of Mechanics, Armenia) samb@sci.am
Mels Belubekyan (Institute of Mechanics, Armenia) mbelubekyan@yahoo.com

In this paper we examine the optimal design problems of a thin vertical tether stretched from the Earth surface to the geostationary orbit and a counter-mass far out in space. Aiming to reduce the tether's strength and length (weight) three different optimal problems are proposed. The strength problem was first solved by Jerome Pearson, who suggested to overcome the strength requirements by tapering tether cross-section (with very large non reasonable taper ratio) as an exponential function from a maximum at the geostationary point to a minimum at the ends. We propose a new optimal problem based on Pearson's conception of a cross-section tapering. Considering the weight of the ribbon as a variable of the optimal design and the strength as a function of the objective, it is shown that taking the tether strength to be uniform at the neighborhood of the geostationary point, it is possible to minimize the strength and length of the tether for reasonable taper ratios. The optimal size of equal strength zone is determined. In the second optimal project a step-piece homogeneous tether model is proposed. The tether under consideration has three different uniform step-piece cross-sections, thickening at the neighborhood of the geostationary point. It is shown that by means of the appropriate choice of tether geometry one can minimize both the length and the maximum stress of the tether under restriction of the taper ratios. The comparison of two optimization problems is carried out. Another optimal problem is solved for an inhomogeneous tether, when the density of the tether material is a function of its length. It is shown that optimal project will be the compound tether made of two homogeneous materials of different densities separated at the geostationary point, whereas the density of the tether upper part must be bigger than the density of the lower part. The combination of different optimal conceptions is discussed. Based on the analysis of suggested optimization problems new qualitative and quantitative results are obtained for reducing the tether's maximal strength.

Presentation Abstracts and Summaries
FRIDAY (cont.):

An Updated Review of Nanotechnologies for the Space Elevator Tether

Gilberto Brambilla (O.R.C. - Univ. of Southampton) gb2@orc.soton.ac.uk

The space elevator tether requires an extraordinary specific ultimate strength SUS (ratio between ultimate strength and density) and carbon nanotubes (CNTs) have been identified as the ideal candidate because of their astonishing strength (SUS>60MYuri for CNT manufactured by CVD with radii in the region of r~50nm). Yet, the highest values of SUS were measured on samples only few microns long, and long tethers are as strong as the weakest link. Indeed, the fabrication of flawless wires has been proved very challenging. Since 2007 reports of CNTs longer than 15mm have become common (a single CNT as long as 300 mm was allegedly made at the MIT Institute for Soldier Nanotechnologies in 2009) and CNT bundles longer than 18mm have also been achieved; unfortunately their SUS has not been reported, yet.

An alternative path to manufacture km-long tethers with SUS>20MYuri could rely on the possibility to join different CNTs with joints as strong as the CNT themselves, if parallel processing can be employed.

Finally, combinations with other high-SUS nanowires can be envisaged: in the last few years, four types of nanowires with SUS>5MYuri have been reported in the literature: silicon carbide (SiC), silicon nitride (Si_3N_4), and silica (SiO_2). SiC and Si_3N_4 at their best can provide SUS>16 MYuri, while the greatest value reported for silica glass is smaller, SUS~12MYuri. The great benefit of these nanowires relies in their possibility to be manufactured in extremely long lengths with minor changes to the current fabrication technology: silica glass allows for the prompt manufacture of km-long wires.

Presentation Abstracts and Summaries

SATURDAY:

Design and Feasibility Of A 20 Km Freestanding Pneumatically Supported Space Tower

Raj Seth (York University, Toronto) rajseth@yorku.ca
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The research presents the theory and analysis for the construction of a thin walled pneumatically supported space tower of 20 km vertical extent in an equatorial location on Earth using gas pressure. The suborbital tower of 20 km height would provide an ideal surface mounting point where the geosynchronous orbital space tether could be attached without experiencing the atmospheric turbulence and weathering in the lower atmosphere. The tower can be utilized for harvesting high altitude renewable energies such as wind energy and atmospheric electricity in addition to its potential utilization in various space missions. Kevlar is chosen as an example material in most of the computations due to its compatibility in space environment. The Euler beam theory is employed to the inflatable cylindrical beam structure. The critical wrinkling moment of the inflated beam and the lateral wind load moments are taken into account as the key factors for design guidelines. A comparison between single inflatable cylindrical beam and inflatable multiple-beam structures is also presented in order to consider the problems involving control, repair and stability of the inflated space tower. The attitude control of the pneumatically supported space tower utilizing active control mechanism is also presented. For enhancing load bearing capacity of the tower and for availability of more surface area at the top, the non-tapered inflatable structure design is chosen for the basic analysis, however further analysis can be performed with tapered structures.

Steps to the Space Elevator

Bryan Laubscher (Odysseus Technologies, LLC) skyhookbel@hotmail.com

The Space Elevator is at least 15 years in the future. There are many technologies that could be developed for access to low Earth orbit (LEO) in the meantime. Any of these that lower the cost to LEO will facilitate the development of the Space Elevator by lowering the cost and risk to launch the elevator components to orbit. Indeed, most of the technologies I envision will require new, high strength materials just as the Space Elevator. This reinforces my strategy that by pursuing high strength material development, we ensure the eventual creation of the Space Elevator. I will briefly discuss these possible technologies and call for our community to engage other groups interested in developing these launch techniques.

Presentation Abstracts and Summaries
SATURDAY (cont.):

Seven Deadly Assumptions About Space Elevators
Gaylen Hinton (ZQ Tech) gaylenhinton@yahoo.com

There are many space elevator (SE) concepts that have been widely accepted as "gospel truth" that are not necessarily so. This paper addresses seven of these assumptions that have slowed the progress and development of SEs. These assumptions are as follows:

1. An SE needs to be built from carbon nanotubes.
   Although carbon nanotubes have an impressive theoretical maximum strength, their real-world strength will probably never be good enough to make a practical SE. When the unavoidable nanotube defects are factored into the equation, there are many other substances whose real-world strength could far exceed that of carbon nanotubes. Some of these substances will be discussed.
2. There will be problems with oscillations and vibrations on an SE.
   In space there is no air resistance to dampen oscillations. Therefore, there have been fears that oscillations could be amplified by a resonance until the SE was destroyed or damaged. This incorrect assumption has been propagated by a common mathematical simplification that masks the real physics behind the SE oscillation modes.
3. An SE needs to be tapered.
   Theoretically, a tapered SE looks good, as the stresses on all parts would be equal. However, in the real world, a tapered construction would be unnecessary, very expensive, and very impractical to make.
4. SEs will have climbers that go up and down the cable.
   An SE could be made with moving cables that would have ten times more cargo throughput than climbers ever could. In addition, the energy cost for lifting cargo on a moving cable SE vs. climbers would be at least 4X lower.
5. In order to avoid storms and lightning, it has been assumed that an SE base station needs to be on a boat in a largely storm-free location. Recent research has shown that lightning can be discharged using high powered laser pulses. Therefore, an SE could be located on land at any location near the equator, with no fear of lightning damage.
6. An SE needs to be on a mobile base in order to avoid space junk.
   However, a fixed SE could use the Coriolis force on moving cables to avoid collisions.
7. An SE will be very expensive to construct.
   A properly designed SE could be fully constructed, deployed, and put in operation for a cost of less than one billion US dollars.

Presentation Abstracts and Summaries
SATURDAY (cont.):

Space Elevator: Dilemma And Remedies
Sourabh Kaushal (Student) sourabh.engineer@rediff.com

The Space Elevator is the most promising Space Transportation system on the drawing boards, combining scalability, low cost, quality of ride, and safety to deliver commercial-grade space access-practically comparable to a train ride. Having the potential to place massive payload into LEO and beyond at a fraction of today's cost, on paper, the space elevator seemingly may have what it make to open up the inner solar system for business.

This paper describe the current methods used for space elevator and merits and demerits of current method and give some proposed method's to overcome the limitation of recent methods to build a Space elevator. Recent conceptualizations for a space elevator are notable in their plans to use carbon nanotube or boron nitride nanotube based materials as the tensile element in the tether design, since the measured strength of microscopic carbon nanotubes appears great enough to make this theoretically possible.

Limitation of making space elevator:

- The main technical problem is long cable's own length. For a cable of sensible dimensions, need a material with mammoth tensile strength.
- Major problem related to making a space elevator is gravitational problem as the gravity of earth attracts the climbing object.
- Technical and Space Elevator annual budget is very costly or expensive. The cost of making nanotubes is set to fall.
- Space debris problem related to space debris as debris damage the elevator.
- Environmental facts like lightening, cloud, wind affect the space elevator.

In this paper we proposed some methods to overcome the problems:

- Graphene is stronger, stiffer, and less prone to failure than composites infused with carbon nanotubes or other nanoparticles. This means graphene, an atom-thick sheet of carbon atoms arranged like a nanoscale chain-link fence, could be a key enabler in the development of next-generation nanocomposite materials.
- Capture an asteroid and bring it into earth's orbit, mine the asteroid for carbon, extrude cable and asteroid become counter weight.
- Induced current from earth's magnetic field use it as a power source in space elevator.
- The problem of space debris is sort out by using the special radars, sensors. By using the special magnet as the magnetic field around the earth and the magnet which we use has the opposite force as a result of which force of repulsion is create and we repel the debris from the

LEO and collect the debris in the junkyard.

Presentation Abstracts and Summaries

SATURDAY (cont.):

Zero Relative Velocity Transfer Orbits for Space Elevators

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A working system of space elevators will require transfer of passengers and material, both between separate elevators for the same primary body, and between elevators for different primary bodies. An energy-efficient means of doing this is through the use of Zero Relative Velocity Transfer Orbits (ZRVTOs). A ZRVTO between any two elevators is defined as an orbit that requires (in principle) no thrust or acceleration at either end of the transfer. A ZRTO for two space elevators on the Earth's equator is conceptually very simple. Any material dropped from a space elevator below the geostationary altitude is, at the moment of release, at the apogee of an elliptical orbit about the Earth. If the release point is sufficiently high (> 4.67 Earth radii), this orbit will not intersect the Earth's surface and the dropped material will return to the same orbital altitude after one orbital period. While the dropped material will rise to the same point in an non-rotating reference frame, the original elevator will not be there, having rotated T / 24 of a cycle to the East for an orbital period of T hours. If there is a second elevator in the right location (i.e., T / 24 of the Earth's circumference from the first elevator), then the material dropped from the first elevator will appear at the second elevator one orbit later, rising nearly vertically to be stationary at the release altitude. For ZRVTO transfers the co-moving accelerations are very small at the destination, giving a reasonable time to catch an incoming transfer vehicle. All that is necessary for a transfer between elevator pairs is a release at the right altitude; cross-track velocities as small as a few meters / second at the release will ensure that transferred material misses other elevators in its path.

Transfer orbits and the corresponding release altitudes are found for any pair of space elevators for the Earth. Eastward transfers require release at altitudes below the radius of a geostationary orbit, and thus will take less than one day, while westward transfers require release at altitudes higher than a geostationary orbit, with the transfers taking longer than one day. For a system of 3 space elevators separated by 120° of longitude, Eastward transfers between adjacent pairs take 15.99 hours, while Westward ones between adjacent pairs take 31.91 hours. Local accelerations at the transfer station are small, 5.5 and -2.8 cm sec^{-2} , respectively, providing a reasonable amount of time to secure a transfer vehicle to the transfer station on the elevator.

We also find ZRVTOs for transfers between Terrestrial and Lunar space elevators. The lunar case (presented in brief at the 2008 Space Elevator conference) is of particular interest for Lunar exploration and exploitation as material from the Lunar surface could be transfered to the Earth, and supplies could be shipped to the Moon, with very little expenditure of energy. In general, ZRVTO's between elevators of different bodies require the transfer to occur when the Moon is at zero inclination, and the ZRVTO transfers will take ~ 3.55 days.

Presentation Abstracts and Summaries

SATURDAY (cont.):

Space Elevator Construction Issues

Gaylen Hinton (ZQ Tech) gaylenhinton@yahoo.com

The process of building a space elevator (SE) will begin with the placement of an SE construction satellite in geosynchronous orbit (GEO). Once in position, the construction satellite would send out cables both toward and away from earth to start the process of building the SE. However, the mechanics of that process are not as simple as some may have imagined. As soon as any object, section of cable, or counterweight leaves the construction satellite, it is in its own independent orbit, and must obey the laws of celestial mechanics. In addition, the mechanical constraints, the tidal forces from the earth, the conservation of angular momentum, and the total energy of the system would influence the behavior and outcome of the process.

An example is given, using realistic numbers, that shows the process necessary to land the seed cable of an SE on earth. Once the seed cable reached earth, the rest of the SE's construction could be done from the ground.

Presentation Abstracts and Summaries

SATURDAY (cont.):

Lunar Space Elevators: A Strategy for the Human Exploration of the Moon

Thomas Marshall Eubanks (AmericaFree.TV) tme@americafree.tv
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The return of human explorers to the Moon is hampered by the expense of engineering, developing and manufacturing a lunar landing module capable of landing on and returning from the lunar surface. A lunar landing module represents something of a technological dead-end, as the engineering requirements are radically different for lunar landings and either a martian landing or rendezvous with near-Earth asteroids. A Space Elevator rising from the Moon to a counterweight on the other side of the Earth-Moon L1 Lagrange point offers a means of Lunar travel requiring nothing more than the flight technologies needed to send astronauts on missions to Near Earth Asteroids, and thus would fit well with the current direction of the US Manned Space Flight program. Such an Elevator is possible with currently existing materials, could be delivered by existing Heavy Lift Launch Vehicles (HLVs), and would lead to very early science payoff, including the return of material from the equatorial region of the Moon.

We propose a lunar exploration program centered on a Lunar Space Elevator, beginning with an elevator constructed from a single HLV payload. This first elevator would deliver micro-rovers for the lunar surface, and could return kilogram sized samples of the lunar surface back to Earth. This would constitute the first lunar sample return since 1976, and would provide valuable insight into the operation a space elevator.

Subsequent stages of lunar exploration by the LSE would include installing multiple elevator strands, increasing the lift capacity of the LSE, the construction of a robotic base on the lunar equator, and transport and assembly of the infrastructure required for the long term support of human activities on the lunar surface. The development of a lunar module would never be necessary as human transportation to and from the Lunar surface could be accomplished entirely by the LSE. An elevator based lunar exploration program would fit naturally in the plans and technology required for human exploration of the asteroids and Mars, and would enable further exploration of the Moon at a relatively low cost.

Presentation Abstracts and Summaries
SATURDAY (cont.):

The Colonization of Mars via a Martian Space Elevator

Gaylen Hinton (ZQ Tech) gaylenhinton@yahoo.com

An initial colony on Mars could be established through a Martian space elevator (MSE) that was sent from earth along with the colonists. The MSE and the colony could get into areosynchronous orbit (ASO) with the expenditure of less than 600 m/s of delta V.

Once in ASO, the MSE would be made operational by simultaneously lowering a base station to Mars and extending the counterweight. The base station would be mobile in order to maneuver it to the right location. The colony would be based about 10° off of the equator in order to position the MSE where the Martian moons would not affect it.

After the base station was anchored and the proper tension provided by the counterweight, the supplies, equipment, habitats and colonists would be lowered down to the surface. Everything could come down with little or no concern for aerodynamics.

Once the colony was in place, the MSE would provide the means for easily and cheaply sending materials back to earth. Essentially the only cost would be a container capable of surviving earth reentry.

It would probably not be practical to send an MSE to Mars unless there was a space elevator (SE) on earth first, due to the mass involved. In order for an earth-based SE to give a craft the delta V necessary to get to Mars, the craft would have to be released about 25,000 km past geosynchronous orbit (GSO). At that point the net force is only about 1/40g. Therefore huge loads, assembled at GSO, could be sent to Mars with minimal loading on the cable. Also, multiple loads could be sent and collected together in transit. Therefore, the initial colony could be composed of hundreds of people, the MSE, and all their supplies and equipment.

Presentation Abstracts and Summaries
SATURDAY (cont.):

Space Elevator technologies for Mars Exploration
Ben Shelef (The Spaceward Foundation) ben@spaceward.org

The paper surveys several techniques for using Space Elevator technologies for Mars Exploration, including a Phobos-based tether capture and descent system for reducing the costs associated with Mars entry, descent, and landing (EDL), and a power beaming architecture that allows for fast, more powerful surface rovers.

The International Space Elevator Consortium (ISEC)
Ted Semon (ISEC) ted.semon@isec.info

ISEC is now approaching its second birthday. How did it come about? What has it accomplished? How is it promoting the idea of a Space Elevator? What are its future plans?

ISEC now operates according to a Strategic Plan, created by the President and approved by the Board of Directors. This plan includes the following:

• Defining a theme that all major activities of ISEC revolve around – for 2010, this theme is Space Debris Mitigation.

• Establish and award the Pearson and Artsutanov prizes for papers that 'increase our understanding' of the Space Elevator.

• Compile, print and distribute the ISEC Technical Journal.

• Create the ISEC Library – a reference of published articles centered around the 2010 theme.

• Create the 2009 and 2010 ISEC Posters.

• Create a Press Kit and active Technical, Business, Legal and Outreach committees.

This presentation will give a brief history of ISEC, will explain the rationale and progress for each of its goals and will explain to the audience why they should consider joining ISEC (or renewing their membership if already a member).

Presentation Abstracts and Summaries

SUNDAY:

Space Elevator in 7

Keith Curtis keithcu@gmail.com

The conventional wisdom, amongst those who think it is even possible, is that it will take between 20 and 50 years to build a space elevator. However, anyone who makes such predictions doesn't understand that engineering is a fungible commodity. Two people will, in general, accomplish something twice as fast as one person. How can you say something will unequivocally take a certain amount of time when you don't specify how many resources it will require or how many people you plan to assign to the task?

Furthermore, predictions are usually way off. If you asked someone how long it would take unpaid volunteers to make Wikipedia as big as the Encyclopedia Britannica, no one would have guessed the correct answer of two and a half years. From creating a space elevator to world domination by Linux, anything can happen in far less time than we think is possible if everyone simply steps up to play their part. The way to be a part of the future is to invent it, by unleashing our scientific and creative energy towards big, shared goals. Wikipedia, as our encyclopedia, was an inspiration to millions of people, and so the resources have come piling in. The way to get help is to create a vision that inspires people.

In a period of 75 years, man went from using horses and wagons to landing on the moon. Why should it take 30 years to build something that is 99% doable today?

Many of the components of a space elevator are simple enough that college kids are building prototype elevators in their free time. The Elevator:2010 contest is sponsored by NASA, but while these contests have generated excitement and interest in the press, they are building toys, much like a radio-controlled airplane is a toy compared to a Boeing airliner.

I believe we could have a space elevator built in 7 years. If you divvy up three to four years of work per person, and add in some time to ramp up and test, you can see how seven years is quite reasonable. Man landed on the moon 7 years after Kennedy's speech, exactly as he ordained, because dates can be self-fulfilling prophecies. It allows everyone to measure themselves against their goals, and determine if they need additional resources.

If the design of the hardware and the software were done in a public fashion, others could take the intermediate efforts and test them and improve them, therefore saving further engineering time. Perhaps NASA could come up with hundreds of truly useful research projects for college kids to help out on instead of encouraging them to build toys.

The Unknown Unknown is the nanotubes, but nearly all the other pieces can be built without having any access to them. We will only need them wound into a big spool on the launch date.

Presentation Abstracts and Summaries

SUNDAY (cont.):

The SkyLift Project: Paradigm Shifts and Sustainable Development

Bryan Laubscher (Odysseus Technologies, LLC) skyhookbel@hotmail.com

The Space Elevator is a paradigm shift in space access. In this paper, the many challenges facing individuals committed to developing the Space Elevator are discussed. To sustain the development, especially the long-term development, requires an understanding of the magnitude of the paradigm shift that the Space Elevator represents. We need to develop a story of the "reason for being" of the Space Elevator as well as the value/benefit of the Space Elevator. Above all we must examine our ideas and concepts of value and relevance for circular thinking. I propose a goal of developing a single consistent story of the Space Elevator and to name this concept The SkyLift Project at this conference.

Presentation Abstracts and Summaries

SUNDAY (cont.):

Who Can Establish The Space Elevator?

Sunao Kai (Nihon University) kaisunao@mpd.biglobe.ne.jp

I would like to discuss about the establishing/management institution of 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 about the Military Balance between the strong states. Until now, the only mean of international attack is Missile. But when the SE comes real, the state that controls the SE has the absolute military Power. If he only drops big Masses (for example sea water) from this absolute Altitude, he can easily give the damage on the ground of earth like Nuclear weapons. There are no effective defense methods. So, when the technology for the SE comes true, there shall be the serious confrontation between strong states. They shall interfere with each other for establishing SE. Hence, we need to explore other possibilities before the Technology development enables to establish the SE. Tack on this; state cannot build the SE from the view point of the Outer Space Treaty. Art. 2 of the treaty freeze the occupation of outer space, and SE has the character of occupation of the space of its own.

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 say, the Location is a Common heritage of mankind. Because of such a scarcity value, we cannot expect free competition between private enterprises. The SE is the Star-Gate for all mankind. SE is an important business in the near future directly linked to the survival of all earthlings'kind. So we cannot endure the commercialism.

3 Possibility of establishing SE by International organization

Hence, I believe, the only one Possibility to establish the SE is by International Organization, if it possible, as a UN special agency. I suppose, the best form of SE organization (SEO) is the organization like the International Bank for Reconstruction and Development (IBRD).

If we take the form like IBRD for the SEO, we need only background contributions from the each state instead of real money. SEO 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.

If I have a enough time, I would like to discuss about two more problems.

II SE Defense Facilities and the Outer Space Treaties

III The Anchor station of SE and the United Nations Convention on the Law of the Sea

Presentation Abstracts and Summaries

SUNDAY (cont.):

Ensuring the Safety of Commercial Human Spaceflights

Shane Chaddha (PhD Candidate) shane.chaddha@postgrad.manchester.ac.uk

The private space industry is to offer national governments and the paying public commercial human spaceflights and other services on a regular and flexible basis, and at costs lower than those charged by government agencies carrying out the same services. An unavoidable issue which shall challenge every commercial actor must reasonably discharge is the safety and reliability of their space vehicles. Assuring the safety of their spacecrafts is such a critical component to preserve the future existence and maturity of the private space sector. This paper shall identify and discuss the safety requirements designed and implemented by the National Administrative Space Agency (NASA) which potentially could apply to selected commercial actors to take over the Agency's operations in Low Earth Orbit (LEO). Commentary on federal regulations, the Commercial Space Launch Amendment Act of 2004 (CSLAA) as promulgated by the US Federal Aviation Agency's (FAA's) measures, which govern commercial space travel being offered to the public shall follow. This paper shall evaluate the adequacy of these legal regimes to address and mitigate the concerns about the safety and reliability about forthcoming commercial human spaceflights, and yet nurture the infant growth of that market. It shall be demonstrated that NASA's safety measures build a relationship based on cooperation between itself and the commercial sector. The Agency, developing safety standards from knowledge and experience inside and outside itself, is helping the private sector to design safe and reliable space systems which are capable of undertaking space-related activities in LEO as well as carry human passengers to the International Space Station (ISS) without compromising their health and safety. In return, commercial orbital transportation providers selected under NASA's Commercial Orbital Transportation Services (COTS) project and alike programmes sustain America's independent access into outer space and its capabilities to launch humans to LEO. The CSLAA, on the other hand, adopt an 'informed consent' regime to ensure the safety of crew and space flight participants on board space vehicle. The 'informed consent' prescribes an irreducible minimum of information which must be disclosed, in writing, to every potential passenger before that person agrees to board the launching spacecraft. The FAA's rules are then relied upon to substantiate those federal requirements. Together, the CSLAA and FAA's safety standards promote self-regulation in order to foster the infant development of commercial human orbital flights.