INTERNATIONAL ACADEMY OF ASTRONAUTICS

COMMISSION III

Spring Meeting	-	18th March 2013
Venue	-	IAA HQ Office, Paris
Open Session	-	(14.30 hrs. to 16.45 hrs)

PARTICIPANTS

1	Giuseppe Reibaldi	IAA	-	Chair
2	LuYu	CAST	-	Co-Chair
3	S Ramakrishnan	ISRO	-	Secretary
4	Roger Lenard	LPS	-	Member
5	Valery Korepanov	Ukraine	-	Member
6	Christophe Bonnal	CNES	-	Member
7	Russel Dula		-	Invitee
8	Peter Swan		-	Invitee
9	Tetsuo Yasaka		-	Invitee
10	Art Dula		-	Invitee
11	V Adimurthy ISRO		-	Invitee
12	Seishiro Kibe JAXA		-	Invitee
13	Walter Peeters	ISU	-	Invitee
14	Ken Davidian, FAA		-	Invitee
15	Simonetta Di Pippo ASI		-	Invitee
16	Giancarlo Genta		-	Invitee
17	Andreas Rittweger, ASTRIUM		-	Invitee
18	Wanz Xiaowari		-	Invitee
19	Shen Lin		-	Invitee
20	Richard Bonnevill, CNES		-	Invitee
21	Junichiro Kawaguchi, JAXA		-	Invitee
22	Peter Bainum		-	Invitee
23	Alain Dupas		-	Invitee
24	Nicolas Berend, ONERA		-	Invitee
25	Tanja Massonzwaan, IISL		-	Invitee
26	Pavel Trivailo, RMIT		-	Invitee
27	Andrea Jaime Albalat, SGAC		-	Invitee
28	Rauck Horst		-	Invitee

AGENDA FOR MEETING

OPEN SESSION (14.30 Hrs – 16.45 Hrs)

1 Welcome & Introduction to Commission III
2 Salient Updates since September '12 meeting at Naples - Actions
3 Co-operation Established / New Initiatives
4 Feedback on completed studies

- # SG 3.10 Interstellar Precursor Mission – Technologies

5 Status presentation on current studies in progress

- # SG 3.9 - Private Human Access to Space Vol.I suborbital
- # SG 3.13 - Space Elevators
- # SG 3.14 - Private Human Access to Space – Vol II Orbital
- # SG 3.15 - Space Propellant Depot
- # SG 3.16 - Global Human Mission to Mars
- # SS 3.17 - Space Mineral Resources

6 New Study proposals from Human Spaceflight Co-ordination Group:

SG 3.18 Feasibility study of standardized career radiation dose limit in LEO & outlook for BLEO

SG 3.19 study of possible international protocol to handle crisis / emergency of Astronauts in LEO

SG 3.20 Expanding Options for implementing Planetary Protection During Human Space Exploration.

7 Space Generation Advisory Council Presentation

8 Symposia Status IAC 2013 / 2014

9 Report to SAC

Any other Business

MINUTES

1 Chairman, Commission III welcomed the members and invitees for the 2013 spring meeting, and thanked them for their response and participation in the Commission III meeting. Commission III Members were introduced to the forum and the Agenda for the meeting was displayed.

2 Actions from Naples meeting have since been followed up and they will be covered under # 4 and # 5 as study status presentations.

3 It was noted that IAA / IAF / IISL interface Task Force team has been constituted to co-ordinate the activities and bring synergy in their functioning.

4 **Completed studies**

 # SG 3.11 Space Solar Power

This study report was published by IAA in 2011 and an International working Group has been formed to take forward the initiative.

5 **# SG 3.10 Interstellar Precursor Mission Technologies.**

This study is complete and the report is yet to be published by IAA.

6 **Studies in Progress**
 # SG 3.9 Private Human Access to Space = Vol I (Suborbital)

The status of this study Report was presented by Walter Peeters of ISU (Annexure I)

The contents of this report of 55 to 60 pages were reviewed. It was noted that 75% of the report is ready and the first draft report will be available to commission by end of May 2013.

(Action: Walter Peeters)

SG 3.13 Space Elevators – Technological Feasibility.

Dr Peter Swan presented the status of this study report (Annexure II). It was noted that the study is complete and the draft report for review by commission is ready. The study concludes that realization of Space Elevator is technically feasible. The advancement of material sciences is the key factor in constructing the tether of required strength to sustain the Elevator operation. At the present rate of growth in specific strength of potential tether material, accomplishing a practical SE system by 2025 is feasible.

The study report addresses comprehensively all the aspects of SE operation including financial and legal perspectives and proposes a roadmap for way forward.

The members complimented the study lead Dr Swan and the team for the exhaustive coverage of all aspects of Space Elevators technology and operations.

The draft report will be made available by end March to Commission III members for their review and comments.

(Action: Dr Peter Swan)

SG 3.14 Public / Private Human Access to Space - Vol II (Orbital)

It was noted that this new study project was approved in August 2012 and is being lead by Simonetta DI Pippo (ASI) with Ken DAVIDIAN (FAA AST) as Co-Chair.

Ken presented the status of this study (Annexure – III). It was noted that Phase – I will be completed and the Report will be available by Oct / Nov.2013, in time for the Heads of Agencies summit scheduled by end 2013.
The final full report may take two more years, considering the scope and complexity of subject with emerging changes in this area.

SG 3.15 Long Team Space Propellant Depot

Prof. LuYu presented the progress made on this study. (Annexure IV). It was noted that the study team with Giorgio Saccoccia ESA as Co-chair has Members from USA, Germany and France. Members from Japan and India are solicited to be part of this study.

The report contents have been identified and the first draft report will be presented in the next Commission III meeting to be held at Beijing, China in September 2013.

SG 3.16 Global Human Mars Mission.

Prof. Genta briefed the status of this study (Annexure V). Draft table of contents with lead authors was presented.

It was noted that a draft report will be presented to Commission III in September 2013 at IAC, Beijing, after which the final draft will be made available for Heads of Space Agencies meeting in January 2014.

(Action: Prof. Giancarlo Genta)

3.17 Space Mineral Resources – challenges and opportunities.

It was noted that this new study Group under the Chairmanship of Prof Art Dula, had its first meeting that morning. Members from Europe and India are invited to join this study. The draft report is expected to be ready in 2014.

3.18 International Protocol to handle crisis / emergency of Astronauts in Low Earth Orbit.

This new study team under the Chairmanship of Shri S Ramakrishnan has just started the work. The current status of the Study Group and the proposed contents of this study report was presented (Annexure VI).

It was noted that nomination of additional members from Russia, and Japan is solicited.

SG 3.19 Feasibility study of standardized career radiation close limits in LEO & BLEO.

Prof.Mc Kenna,the lead for this Study Group made a presentation (Annexure VII) on the progress.

In this Study Group also, members from ESA, Russia and India are invited to join.

The draft report outline was presented and is expected to be ready by September 2013.

SG 3.20 Expanding options for implementing Planetary protection during Human Space Exploration.

This new study proposal is approved by SAC and the study team is being assembled.

6 **New Study Proposals**

Commission III received three new study proposals from Valery Korepanov (Ukraine).

(i) Space disposal of radioactive wastes

(ii) Global Satellite System to predict earth quakes.

(iii) Satellite remote sensing of Aerosols in Earths' atmosphere.

Commission III accepted the proposal on Space disposal of radioactive waste for submission to IAA. The other two proposals may be referred to Commission I.(Chairman Commission III to inform the SAC and IAA)

7 **Space Generation Advisory Council (SGAC)**

A presentation on SGAC was made by M/s Andrea Jaime, Executive Director (Annexure VIII).

8 **IAC - 2013 Symposia status.**

The status of abstract submission in Commission III managed sessions viz., A5, C3.1, D3 & D4 were presented (Annexure IX). It was noted that there is good response.

9 **Report TO SAC**

Given in Annexure X.

Annexures

Annexure	-	I	Status of SG 3.9
Annexure	-	II	Status of SG 3.13
Annexure	-	III	Status of SG 3.14
Annexure	-	IV	Status of SG 3.15
Annexure	-	V	Status of SG 3.16
Annexure	-	VI	Status of SG 3.18
Annexure	-	VII	Status of SG 3.19
Annexure	-	VIII	Status of SGAC Presentation
Annexure	-	IX	IAC 2013 Symposia Status
Annexure	-	X	Report to SAC

INTERNATIONAL INSTITUTE OF SPACE COMMERCE

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Annexure - I

SG 3.9

Private Human Access to Space Vol. I suborbital

W. Peeters

International Institute for Space Commerce (IISC)

IAA, Paris, February 2013

Status Overview

- **Objectives of the report**
- **Draft Table of Contents**
- **Status and outlook**
- **Preliminary SWOT analysis**
- **Q&A**

Objectives

- Collect various opinions on different subtopics related to Private Human Access to Space
- Build upon outline proposed by C. Bonnal
- Try to come to an objective SWOT analysis summarizing the topics
- List a number of tangible recommendations

Draft Table of content (1)

Draft Table of content (2)

(55-60 p)

Progress tracker (1)

Topic	Author	Inputs lacking	In progress	completed
Intro	WP		X	
Historical	WP			X
Technical	C. Bonnal	X		
Interior design	WP			X
Spaceports	D. Webber			X
Payloads	A. Bukley		X	
Motivation	P. Eymar			X

Progress Tracker (2)

Topic	Author	Inputs lacking	In progress	completed
Market demand	WP			X
Medical	M. Antuñano, and R. Gerzer			X
Legal	R. Jakhu		X	
Regulatory	J. Pelton			X
SWOT	WP		X	
Recommendation	WP	X		

Timeline Outlook

Event	Proposed date	Remarks
Present status	18 March 2013	70% material available
All basic material available	29 April 2013	
Compilation and editing	10 May 2013	
Draft report submittal to IAA commission	24 May 2013	Not IAA formatted
Assist with publishing	21 June 2013	Action WP

Preliminary SWOT Analysis

	Helpful to achieving the objective	**Harmful** to achieving the objective
Internal Origin (attributes of the	➢ Potential demonstrated market ➢ Tourism sector in search of new adventure tourism products ➢ Attracts business angels as financers ➢Relatively off-the-shelf technologies ➢ New activities and employment effect (in particular spaceports) **S**	➢ Increasing TTM (Time To Market) ➢ Accidents during first flights ➢ Emergency landings/ rescue actions away from spaceport ➢ Unexpected medical risks and claims ➢ Liability issues with consent forms ➢ respect of safety standards **W**
External Origin (attributes of the environment)	➢ Possible support from Agencies (payload) ➢ Incentive trips (AXE) ➢ New Space trend (cfr. SpaceX) ➢ Interest on medical experience ➢ Experimenting with green propulsion ➢ May create innovative approaches and spin-off **O**	➢ Lack of clear regulations ➢ Export Control influences ➢ Technology transfer from agencies ➢ Lack of experience with medical support for average health passengers ➢ Loss of motivation after pioneering effect decreases ➢ Market competition and price war **T**

Annexure-II

Space Elevators: An Assessment of the Technological Feasibility and the Way Forward -- Commission III Study 3-13

Peter A. Swan, Ph.D.
Vice President, Member BofD's
International Space Elevator Consortium
Industry Professor
Technical University of Delft and
Stevens Institute of Technology
TSTI Emeritus Professor

David Raitt, Ph.D.
European Space Agency Retired
Past Chair of Commission VI

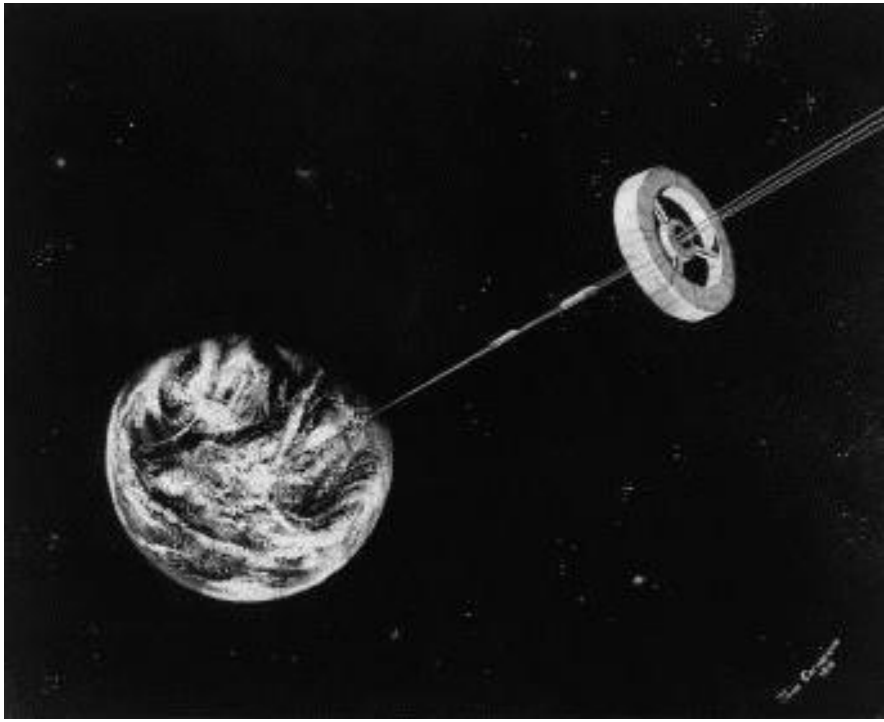


Image from Jerome Pearson's orginal work, also shown in *Chapter 2 of* Space Elevator Systems Architecture*, Swan, Peter & Cathy Swan, Lulu.com publishers, 2007.*

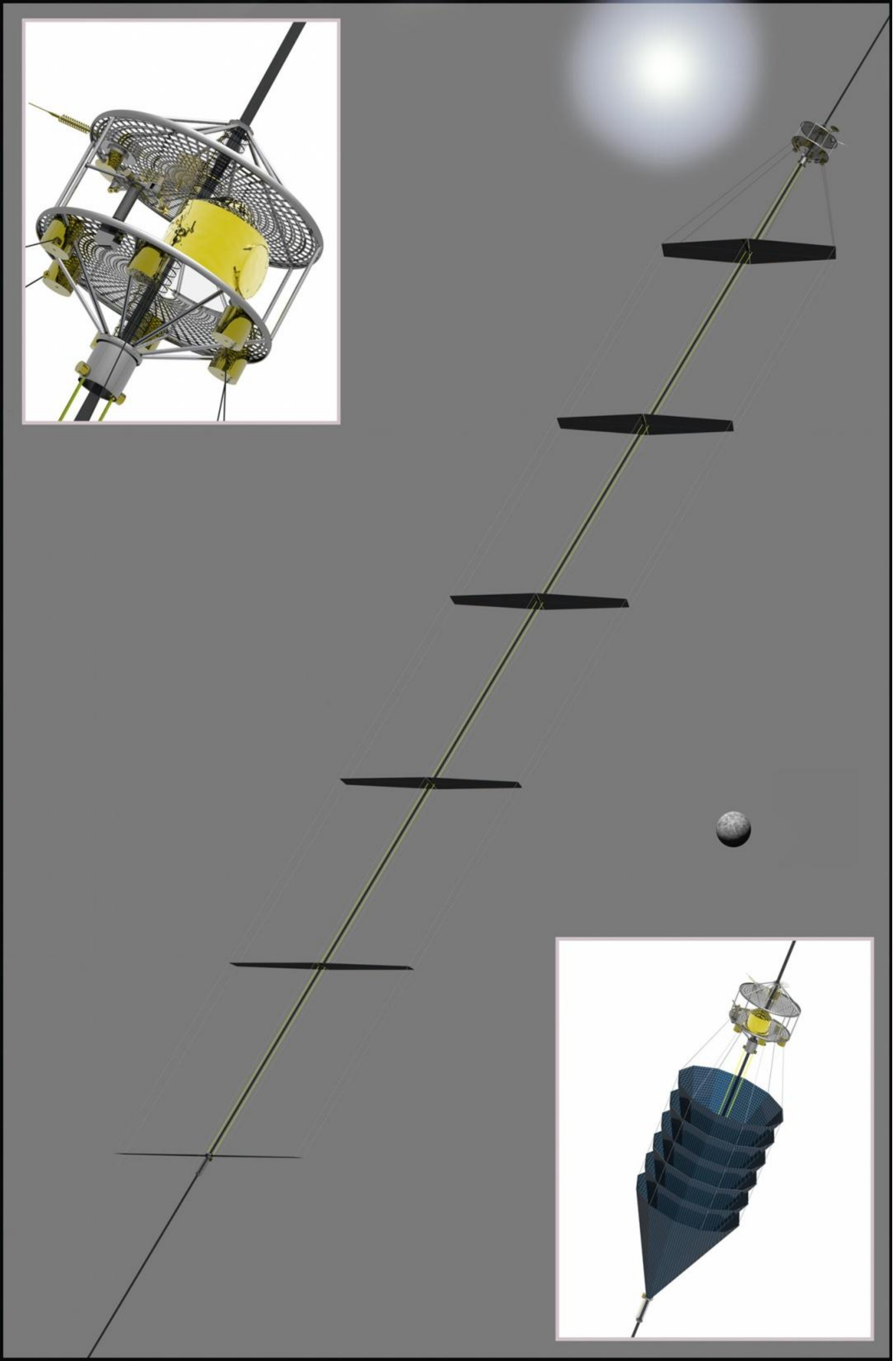
Name		Nation	Role-chapter	Organization
Swan	Peter	USA	Editor	IAA Commission III & VI, ISEC
Raitt	David	UK	Editor	IAA Commission VI
Penny	Skip	USA	Ed. 8, 9	Cholla Space Systems, ISEC
Swan	Cathy	USA	Editor	IAA Commission VI
Knapman	John	UK	Ed. 5, 7	Independent Researcher, ISEC, ESwA
Semon	Ted	USA	4	President ISEC
Shelef	Ben	USA	4	Independent Researcher, ISEC
Gassend	Blaise	USA	6	Independent Researcher
Laubscher	Bryan	USA	3	Independent Researcher, ISEC
Lades	Martin	Germany	review	ISEC, ESwA
Fujii	Hironori	Japan	6	Kanagawa Institute of Technology
Uchiyama	Kenji	Japan	6	Nihon University
Takeichi	Noboru	Japan	6	Nagoya University
Watanabe	Takeo	Japan	6	Teikyo University
Perek	Lubos	Czech R.	review	Astronomical Inst. Czech Acad. Sci.
Mashayekhi	Mohammad	Iran	6	McGill University
Misra	Arun	Canada	6	McGill University
Williams	Paul	Australia	6	BAE Systems Australia
Laine	Michael	USA	11	LiftPort, ISEC
Cohen!	Stephen!	Canada	6	Vanier College
Kai	Sunao	Japan	12	Nihon University, College of Law
Lofstrom	Keith	USA	5	Independent Researcher
Kruijff	Michiel	Netherlands	6	Delta-Utec Space
Brambilla	Gilberto	Italy	3	University of Southampton
Tsuchida!	Akira!	Japan	10, 11	Earth-Track Corporation
Aoki!	Yoshio!	Japan	10, 11	Nihon University
Sato!	Minoru!	Japan	10, 11	Tokai University
Saito!	Shigeo!	Japan	10, 11	JSEA
Matsumoto!	Takane!	Japan	10, 11	JSEA
Nakadai!	Kohei!	Japan	10, 11	Nihon University
Takezawa!	Yoshinori!	Japan	10, 11	Nihon University
Natsume!	Hideyuki!	Japan	10, 11	JSEA
Ishimaru!	Osamu!	Japan	10, 11	JSEA
Hara!	Emiko!	Japan	10, 11	Nihon University
Sannomiya!	Kotaro!	Japan	10, 11	Nihon University
Yoshino!	Nobuto!	Japan	10, 11	Nihon University
Sasaki!	Fumiki!	Japan	10, 11	JSEA
Hanada!	Takaki!	Japan	10, 11	JSEA, kikyu.org
Akiyama!	Ayano!	Japan	10, 11	JSEA
Mimura!	Kunihiko!	Japan	10, 11	JSEA

IAA - International Academy of Astronautics; **ISEC** – International Space Elevator Consortium;
JSEA - Japanese Space Elevator Association, **ESwA** - European Spaceward Association

Study Participants

Cosmic Study Outline

Figure 4-1. Climber as Spacecraft [chasedesignstudios.com]



Executive Summary

“Don’t undertake a project unless it is manifestly important and nearly impossible.”

Edwin Land, quoted in the Coral Reef Alliance letter, March 30, 2011. www.coral.org

Major Questions:

Why a space elevator?
Can it be done?
How would all the elements fit together to create a system of systems?
What are the technical feasibilities of each major space elevator element?

Conclusions

The conclusions from this study fall into a few distinct categories:

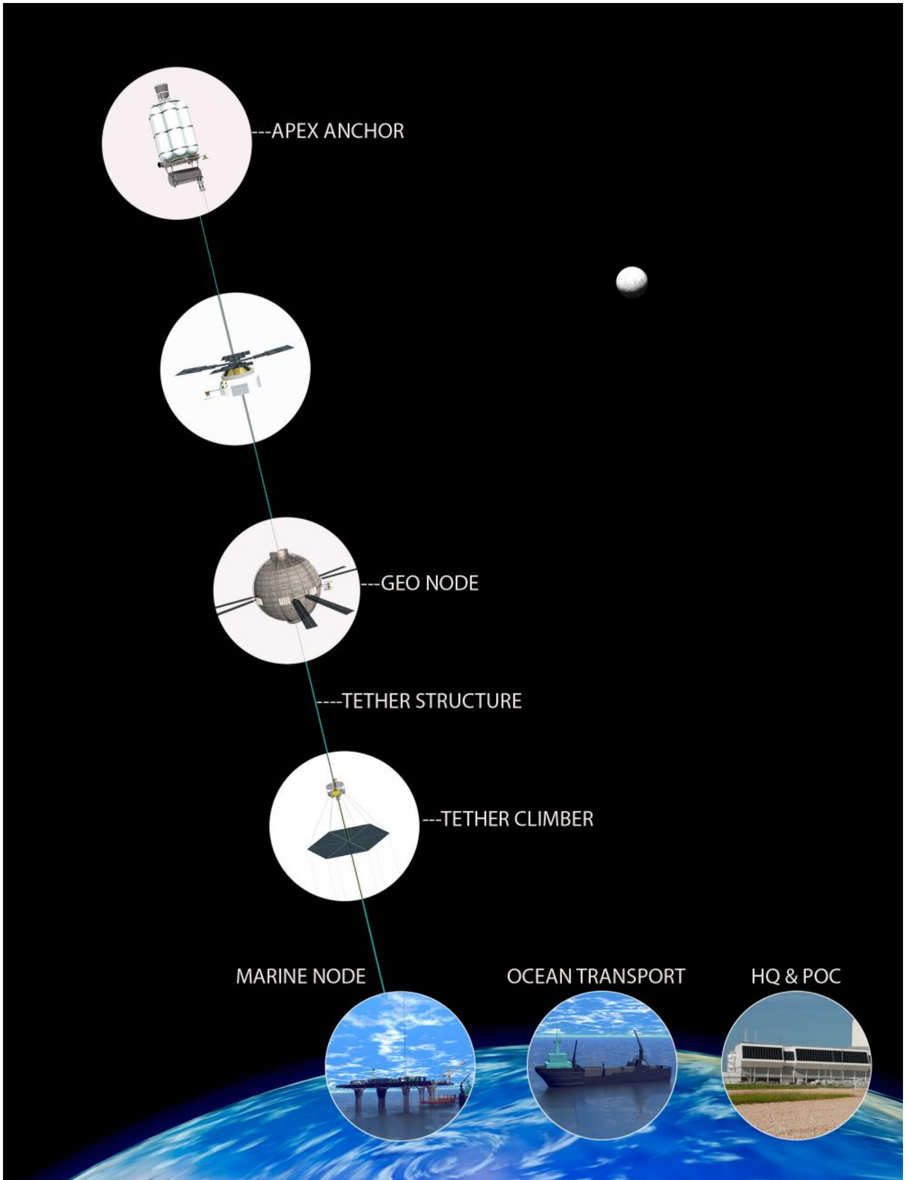
Legal: The space elevator can be accomplished within today's arena!

Technology: It can be accomplished with today's projection of where materials science and solar array efficiencies are headed.

Business: This mega-project will be successful for the investors with a positive return on investment within 10 years after erection is complete.

Cultural: This project will drive a renaissance on the surface of the Earth with its solutions to key problems, stimulation of travel throughout the solar system, and inexpensive and routine access to GEO and beyond.

Cosmic Study Assessment



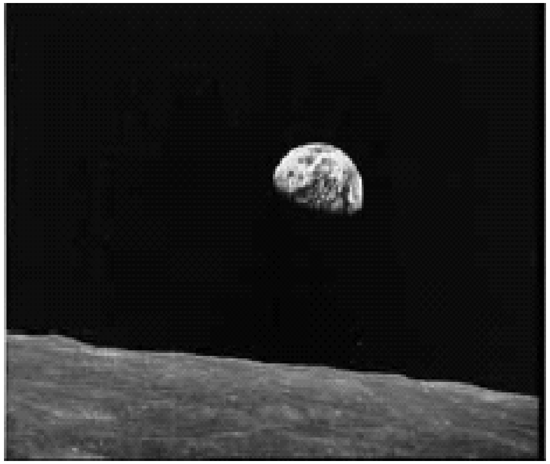
The authors have come to believe that the operation of a space elevator infrastructure will lead to a "game changing" experience in the space world. Each of the authors considers that the space elevator can be developed when the material is mature enough for the demands of the space elevator. Our final assessment is:

A Space Elevator is Eminently Feasible.

Why

Rationale:

- **Routine:** Space will become boring and routine with lift-offs occurring every day with 20 ton tether climbers.
- **Price:** The price for a pound of payload to be delivered to GEO will be below $ 500/kg. This change from $ 20,000/kg will alter the clientele for space liftoff and open businesses that are not even considered today.
- **Safety:** Elevators have inherent safety vs. the dangerous practice of mounting valuable payload on top of huge explosive tanks.
- **Delivery Dynamics:** Space elevators will have vibrations in the region of cycles per day and shock loads of marshmallows dropping into a pool instead of explosive potential and the rock & roll during liftoff of rockets.



Real Reason -- Why

- **The human spirit needs no restrictions:** Once the Apollo 8 picture of the Earthrise from the lunar orbit was broadcast, the world was sensitized to our limitations and the realization that we were on a fragile "Big Blue Marble." We must soar beyond our boundaries and expand into the solar system and beyond.
- **The recognition that the "*Space Option*" will enable solutions to Earth's current limitations:** The space option is an alternative that is now open to humanity with access to space.
- **The realization that chemical rockets can not get us to and beyond Low Earth Orbit economically:** The rocket equation requires that approximately 80% of the mass at the launch pad is fuel and 14% is structure, control equipment and other essential elements of a launch vehicle. This leaves roughly 6% for payload (mission satellite).

Dr. Edwards' Space Elevator

- Length: 100,000 km, anchored on the Earth with a large mass floating in the ocean and a large counterweight
- Width: One meter, curved
- Design: Woven with multiple strands to enable localized damage; and curved to ensure that edge on, small size, hits do not sever the ribbon.
- Cargo: The first few years will enable 25 ton payloads without humans with five concurrent payloads on the ribbon
- Production: The space elevator can, and will, be produced in the near future because the human condition demands it and the materials are almost ready to enable the construction today.
- Construction Strategy: The first space elevator will be built the tough, and only, way – from GEO – then once the gravity well has been overcome it will be replicated from the ground up leading to multiple elevators appearing around the globe. This redundancy will reduce the magnitude of the impact if one is lost.

Dr. Edwards in Space Elevators [*Edwards, Bradley C. and Eric A. Westling, 2003]*
Space Elevator Systems Architecture, [*Swan, Peter A. and Cathy W. Swan, 2007]*

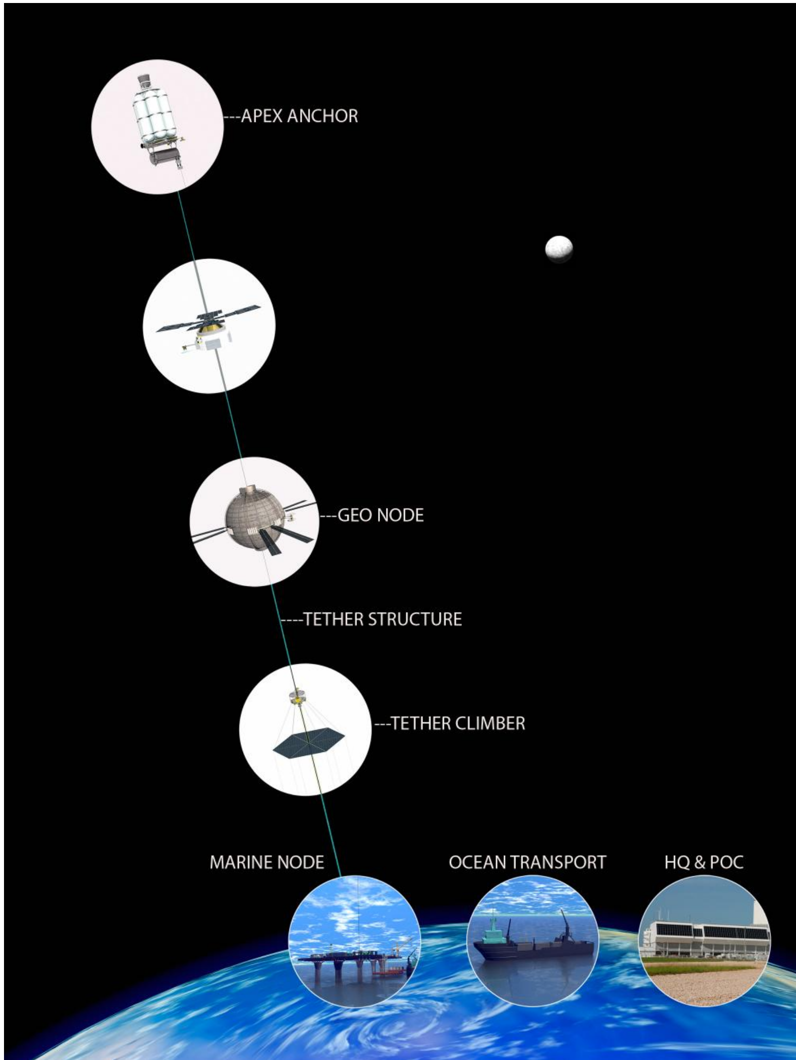
Approach

Routine: Space will be routine with lift-offs every day with 20 ton tether climbers.

Price: The price for a pound of payload to be delivered to GEO will be below $500/kg

Safety: Elevators have inherent safety vs. the dangerous practice of mounting valuable payload on top of huge explosive tanks.

Delivery Dynamics: Space elevators will have vibrations in the region of cycles per day and shock loads of marshmallows dropping into a pool instead of explosive potential and rock and roll during liftoff of rockets.



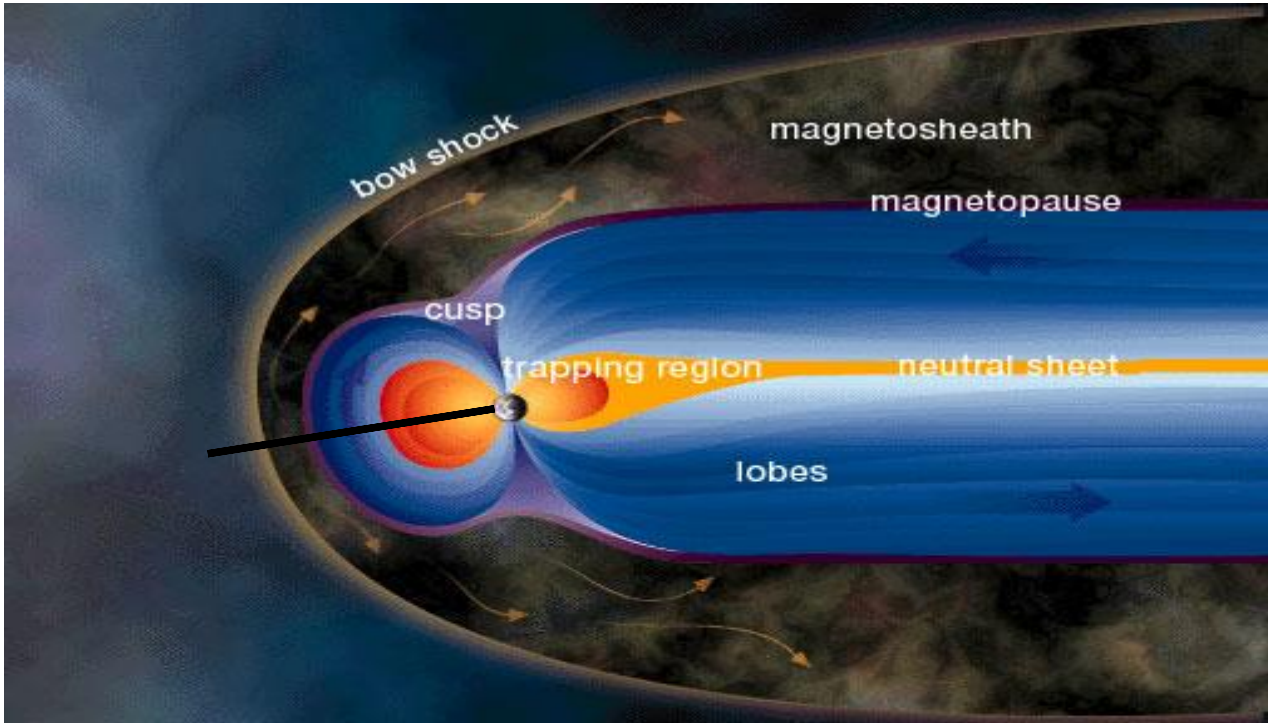
Topics to be discussed

- Policy & Legal
- The Tether
- The Climber
- The System of Systems

- Process for Study
- Next Steps for Study
- The study team needs
- Questions

George Whitesides (Whitesides, 2004) stated:

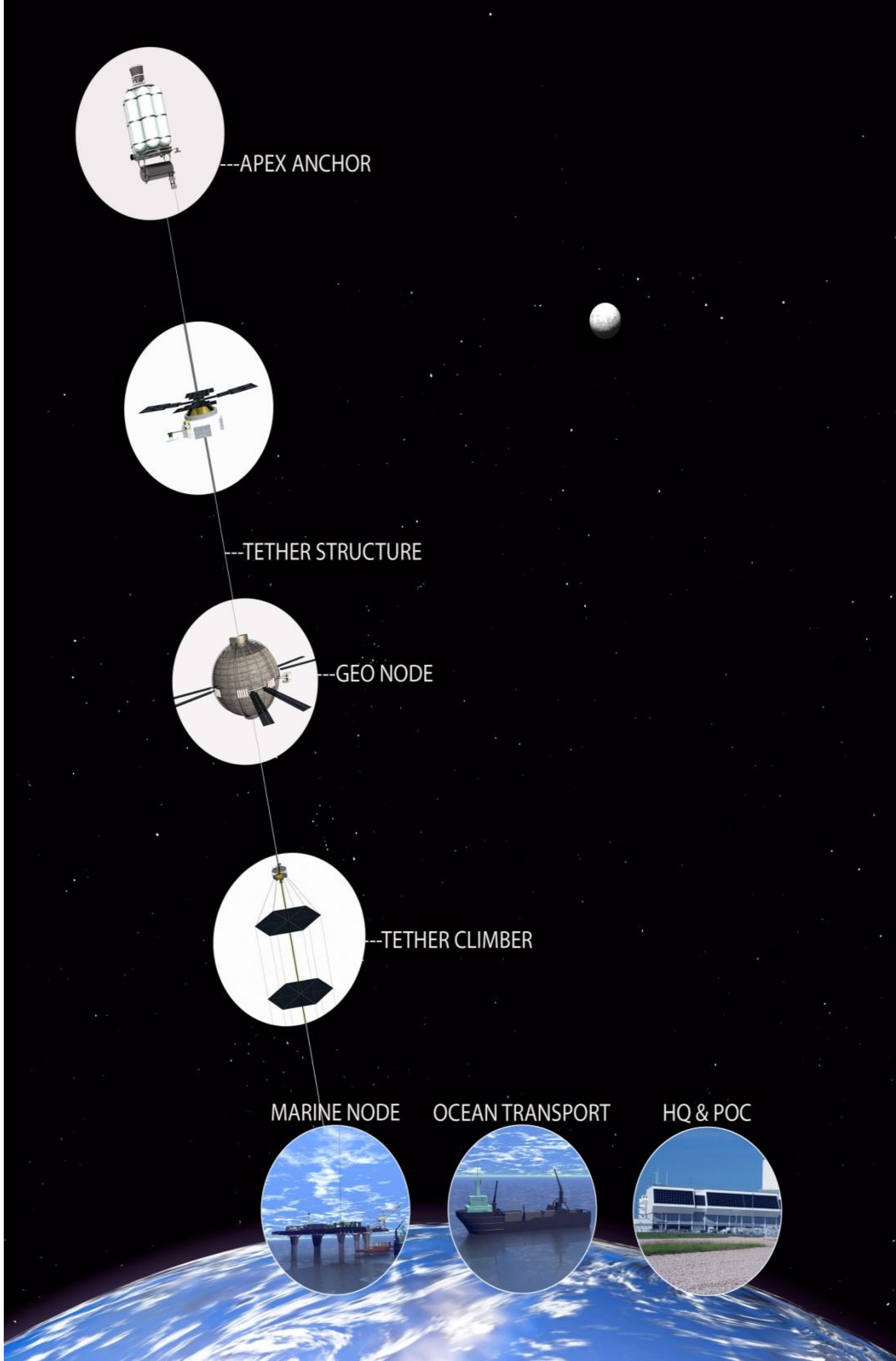
"Until you build an infrastructure, you are not serious."



Policy

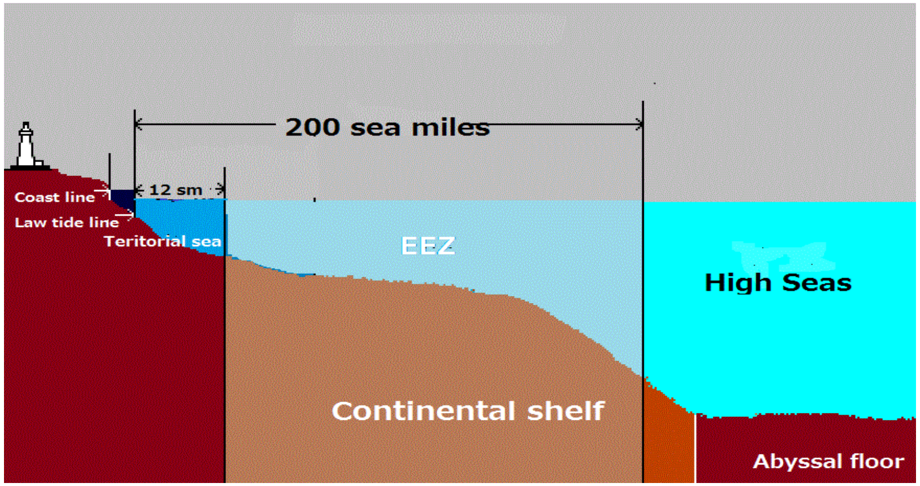
- Commercial or Government
  - MUST have Gov Support
- Stationary or Moving
- UN International Telecommunication Union
  - Allocation of frequency
  - Allocation of GEO Node

- Bottom Line: In today's environment, Space Elevators can fit into the global and governmental policy arenas.



Law

- Law of Land
- Law of Sea
- Law of Air
- Law of Space



- Bottom Line: The Marine Node of the Space Elevator will be in the ocean beyond the continental shelf and any exclusive economic zone (EEZ) of individual countries. In addition, the Marine Node must be flexible enough to not infringe upon other nations rights of movement. Also, there must be allocation for safety of flight.

Topics to be covered

- Policy & Legal
- The Tether
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- Next Steps for Study
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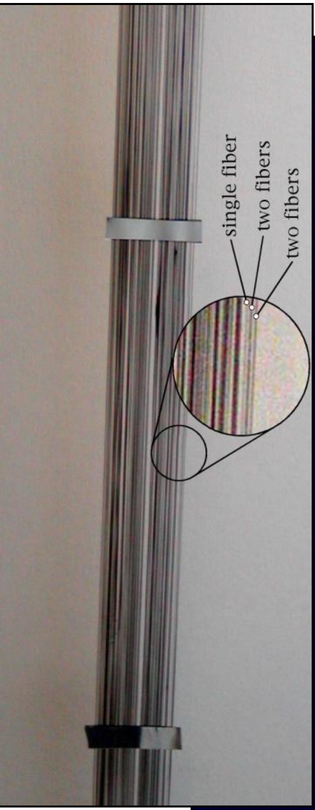
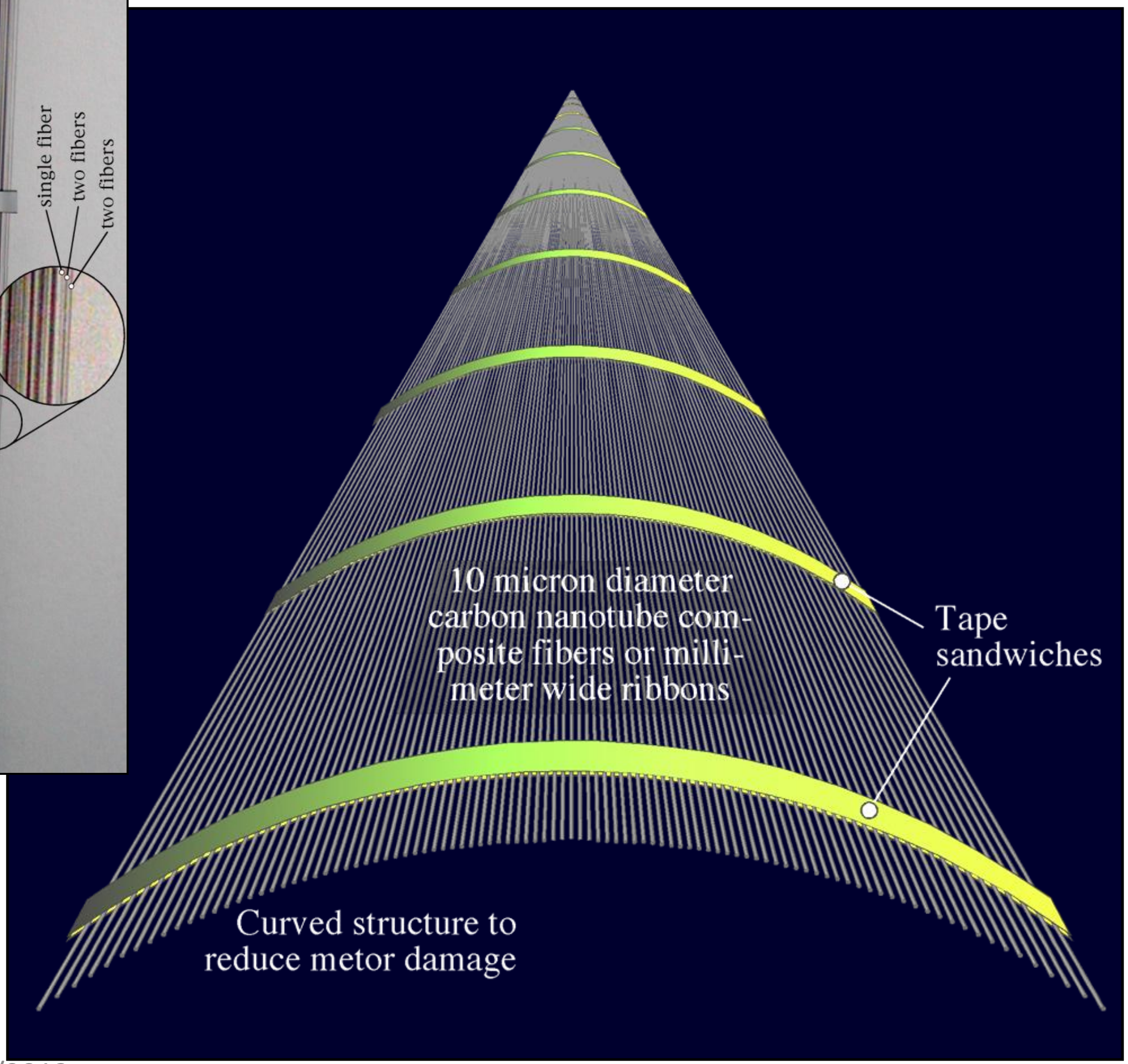
Tether Characteristics

Rated Tether: 38 Myuri [49.4 GPa @ 1.3 gm/cm^3]
Density of Material: 1.3 gm/cm^3
Operational capacity: 35.2 GPa or 27 MYuri [maximum]
Taper Ratio: 6
Safety Factor: 1.4 or 40%
Cross Section:62.8 mm^2 - GEO node -1m x 62.8mirometers
10.5 mm^2 - Earth terminus -1m x 10.5micrometers
Standard Climber:20 Metric ton
[6MT structure + 14 MT payload]
Number of Climbers: 7
Equivalent mass of 29 metric tons
Tether Mass: 6,300 metric tons
Apex Anchor: 1,900 metric tons [30% of tether mass]
Tether Length: 100,000 km radius

Ribbon Design





- The final ribbon is one-meter wide and composed of parallel high-strength fibers
- Interconnects maintain structure and allow the ribbon to survive small impacts
- Initial, low-strength ribbon segments have been built and tested

Ribbon Status - Materials

- Professor Nicola Pugno recently presented a paper entitled "Towards the Artsutanov's dream of the space elevator: the ultimate design of a 35 MYuri strong tether." In the discussion, he lays out the failure modes and calculates the stress levels to be expected, the flaw methodologies, and predicts the expected levels of stress in a tolerant design. His conclusions are:
  - "The corresponding maximum achievable fracture specific strength is thus predicted to be: … approximately 35 MYuri." [reference fracture strength]
  - "… the predicted maximum sliding specific strength for a single walled nanotube cable is: … approximately 37 MYuri."
  - "… the corresponding flaw-tolerant taper-ratio to be: … approximately 5."

  Pugano, Nicola, "towards the Artsutanov's dream of the space elevator: the ultimate design of a 35 MYuri strong tether," Acta Astronomica [details to be supplied].
- Yarns longer than 40m with σ ~ 1.7 MYuri have been reported in 2010 [40].
- Indeed, with better manufacturing techniques σρ has increased from a fraction of MYuri (σ ~ 0.7 GPa and ρ ~ 800 kg/m3) in 2004 [32] to 10 – 16 MYuri (σ ~ 3.3 GPa and ρ ~ 200 kg/m3) in 2007
- CNTs have been identified as the ideal candidate because of their astonishing strength [1,2]: σρ > 60 MYuri has been recorded for CNTs manufactured by chemical vapour deposition (CVD) with radii in the region of r ~ 50nm (Fig. 1).
- 46MYuri - Mechanical properties of carbon nanotubes: theoretical predictions and experimental measurements" Ruoff et al., C. R. Physique 4 [2003] - Summary of experimental results and modeled prediction

Ribbon Status [SEFC]

	TSL	A/A_0	TMR	P_{REQ}
	Tether specific loading	Taper ratio	Tether mass ratio	Required mass throughput
	MYuri			STU
(optimistic)	50	2.6	50	50 – 75
	40	3.4	77	77 – 116
CNT	30	5.0	144	144 – 216
CNT	25	7.0	228	228 – 342
	20	11.3	433	433 – 650
(pessimistic)	17	17.30	739	739 –1109

<

P_{POS}	PD	
Possible mass throughput	Power density	
STU	kWatt/kg	
100 – 115	0.5	(pessimistic)
135 – 155	0.7	
170 – 210	1.0	Thin-film PV + motors
200 – 275	1.5	Thin-film PV + motors
230 – 340	2.5	
250 – 370	3.5	(optimistic)

- The space elevator feasibility condition [SEFC] has shown that if the Carbon Nanotube material can be manufactured in long lengths to a specific loading [which includes safety and degrading factors], then the required power density can be reached at about 1.0 – 1.5 kWatt/kg. These two enabling physical characteristic lead to the potential design meeting or exceeding the feasibility condition.

Tether material findings

- ***Finding 3-1:*** Space elevators can be developed with 30 MYuri tethers, as explained in the feasibility condition.
- ***Finding 3-2:*** If growth in specific strength continues at the current pace, it is possible that yarns with specific strengths in the range of 20 MYuri can be demonstrated as early as 2015. Scaling up the process to lengths in excess of 1000km might take a couple of years, meaning that a space elevator tether could be available before 2025.
- ***Finding 3-3:*** CNTs are not the only available materials. A range of alternatives exist, ranging from polymers (polyethylene, polyborazylene) to boron nitride nanotubes and diamond.
- ***Finding 3-4:*** The design of the tether has a taper ratio to compensate for the greater tensions near the GEO node. With the current strength projections, the expected taper ratio will be less than eight.
- ***Finding 3.5:*** The macro design of the space elevator tether is a sparsely filled, one-meter wide, curved, woven tether that is designed for winds under 100kms altitude and space debris between 200 and 2000kms altitude.

Topics to be covered

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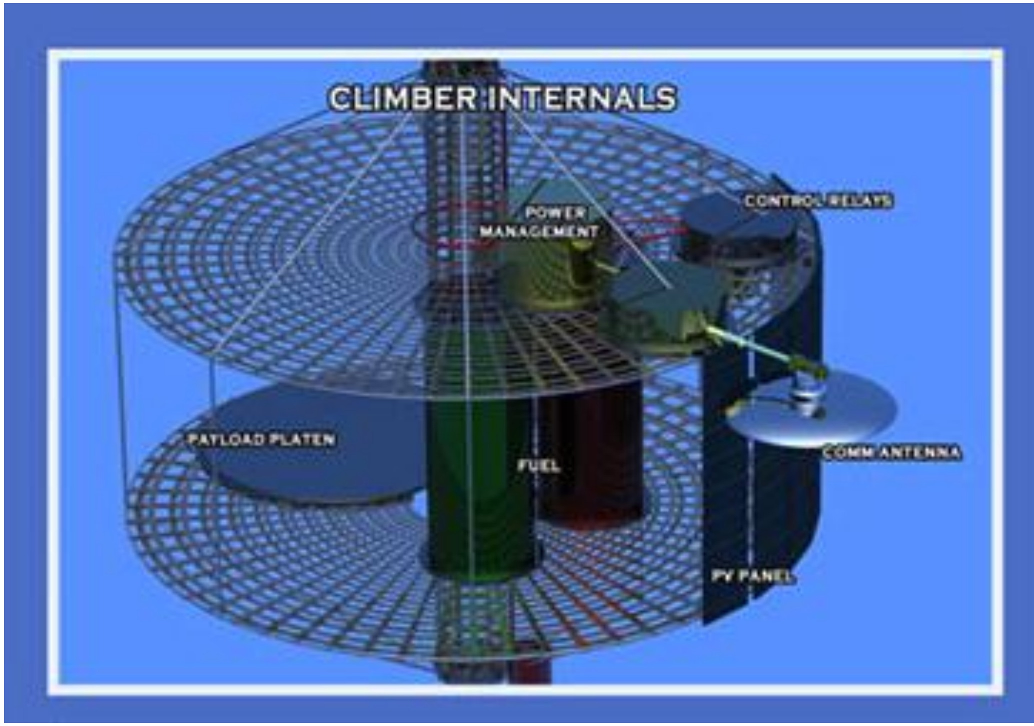
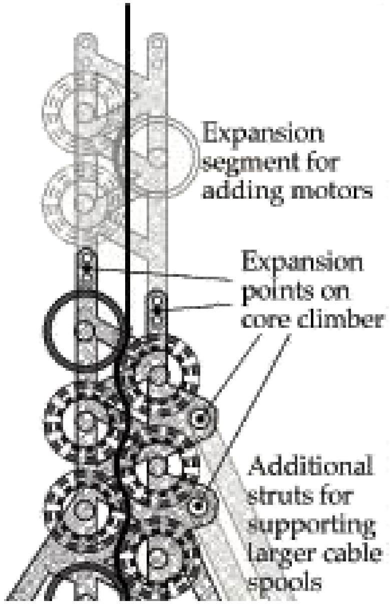
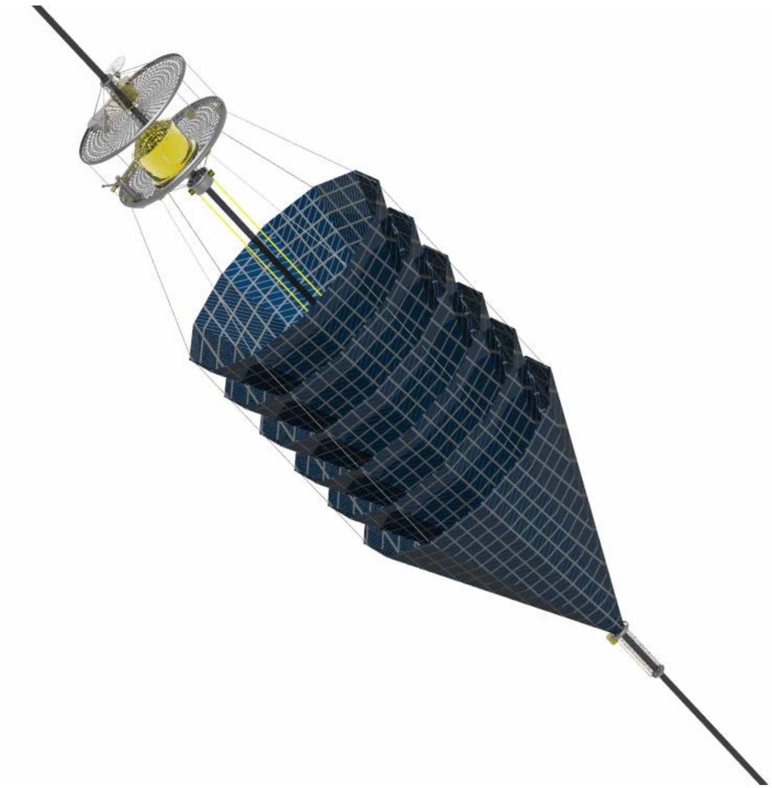


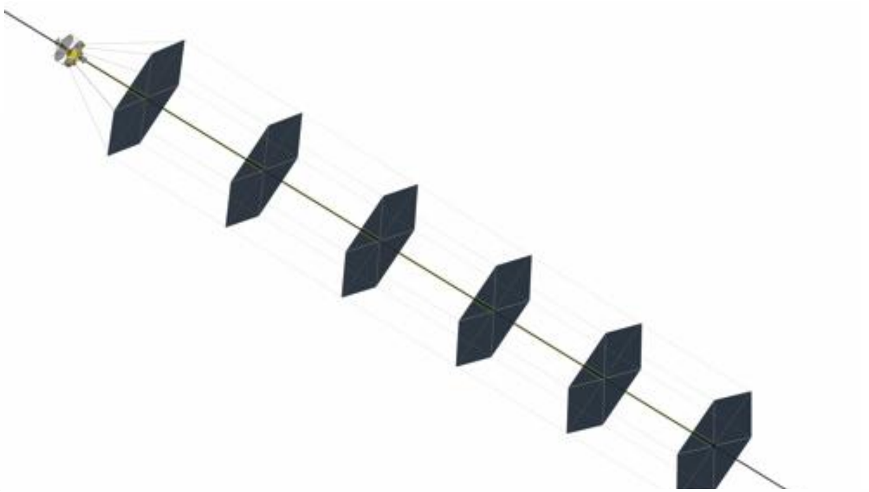


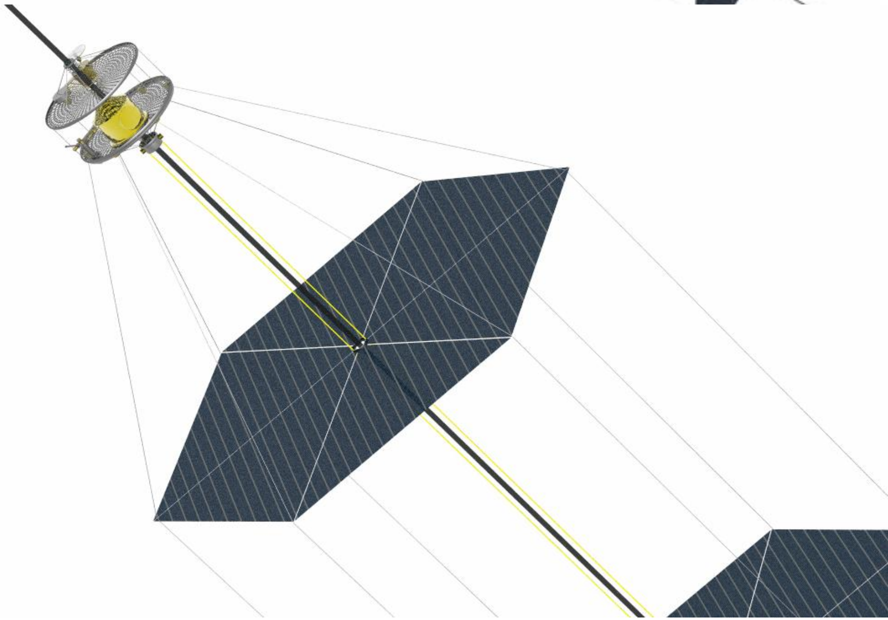
20 Metric Ton Tether Climber
6 MT Spacecraft
14 MT Payload Capability

Tether Climber

First 40 kms by one of 3 approaches
Above 40 kms, solar arrays for power



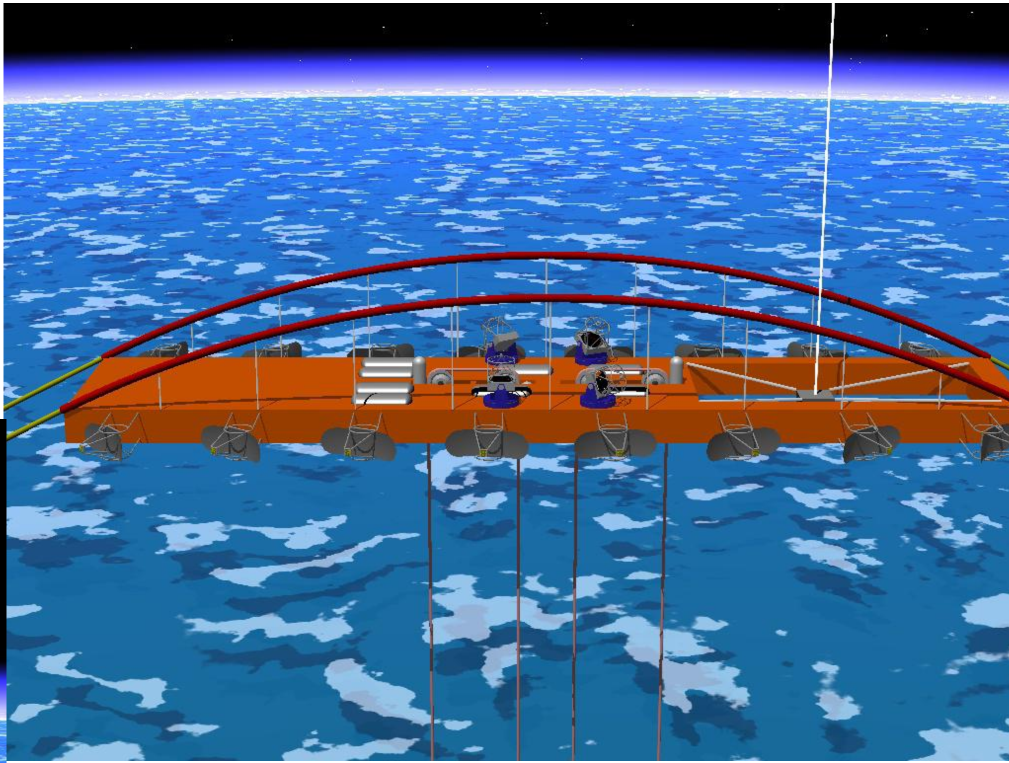


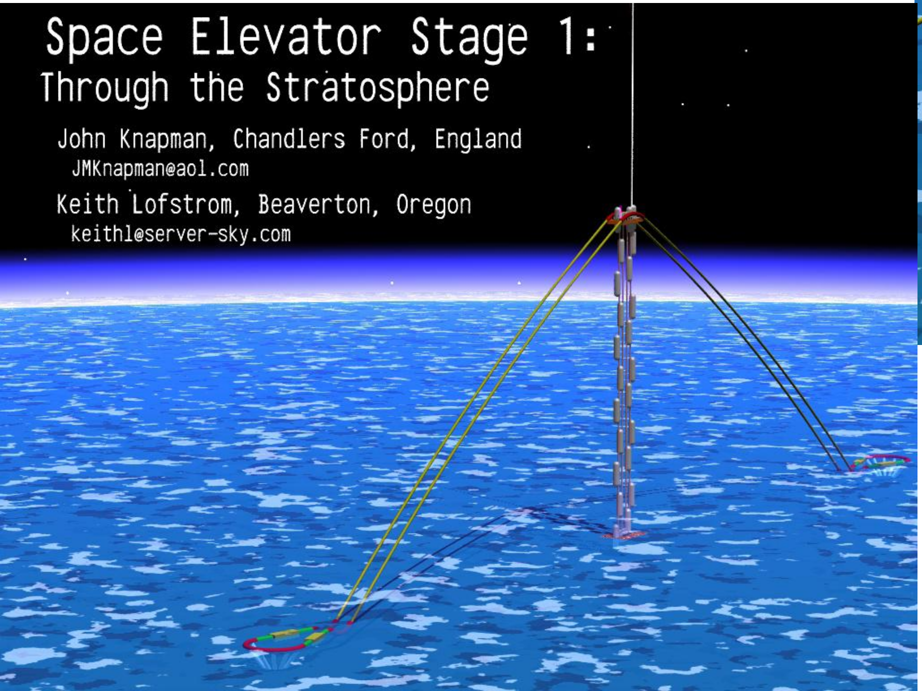


Images by chasedesignstudios.com

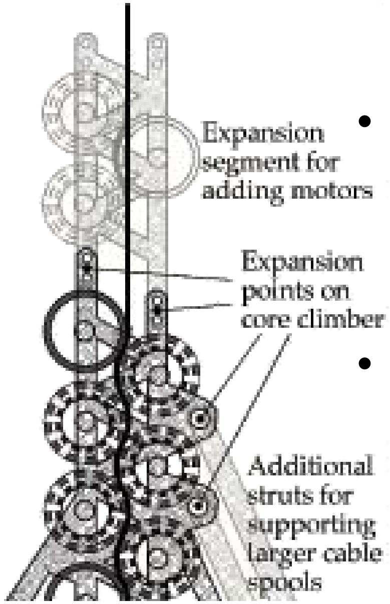
Three Options to Reach 40 Km Altitude

- Option One: Marine Stage One
  - MSO – Box Protection
  - MSO – Spring Forward
- Option Two: High Stage One





Tether Climber Findings



- ***Finding 4-1:*** CNT materials will be incorporated into the structural design and will substantially lessen the mass of components and structures through-out future space elevator satellites, including all varieties of tether climbers.
- ***Finding 4-2:*** The strongest concept for tether climbers is solar only from 40km altitude based upon projection of technology. There are three viable concepts to move the climber from the Marine Node to the appropriate starting altitude: box satellite with extension cord, spring forward, and High Stage One.

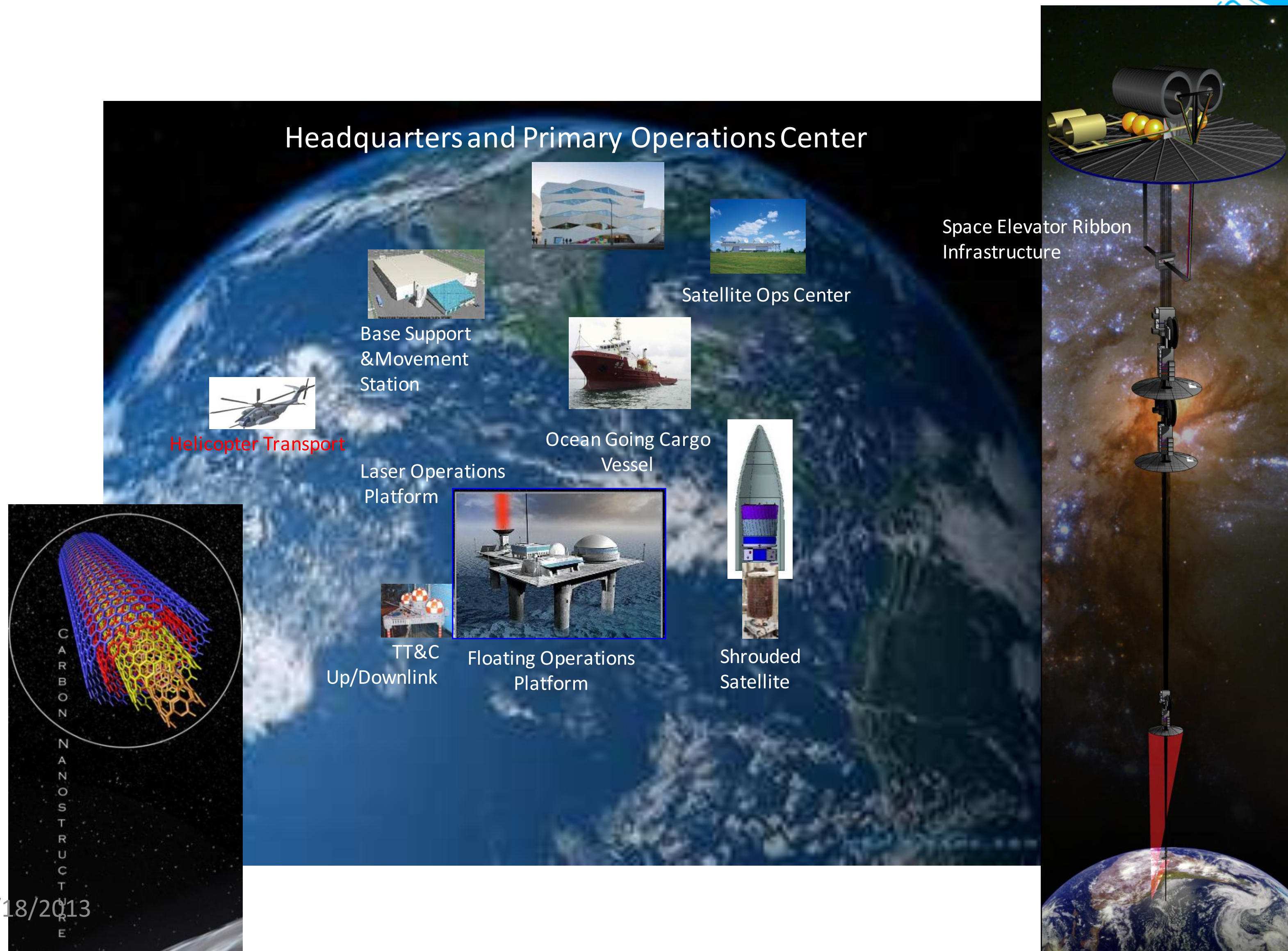
Finding 4-3: Large, light-weight, deployable, advanced solar arrays will power the tether climbers above 40km altitude.
Finding 4-4: Operations are to launch at daybreak from above the atmosphere, climb using solar during the first day, rest during the first night, and then solar during the rest of the trip [with small outage eclipses]
Finding 4-5: Although massive at 86.5 metric tons, the movement from LEO to the GEO node of the deployment satellite is not technologically challenging. Improvements in mass to GEO could be gained with significant improvement in thruster performance by demanding development of massive ion engines or equivalent efficiency improvements.

Topics to be discussed

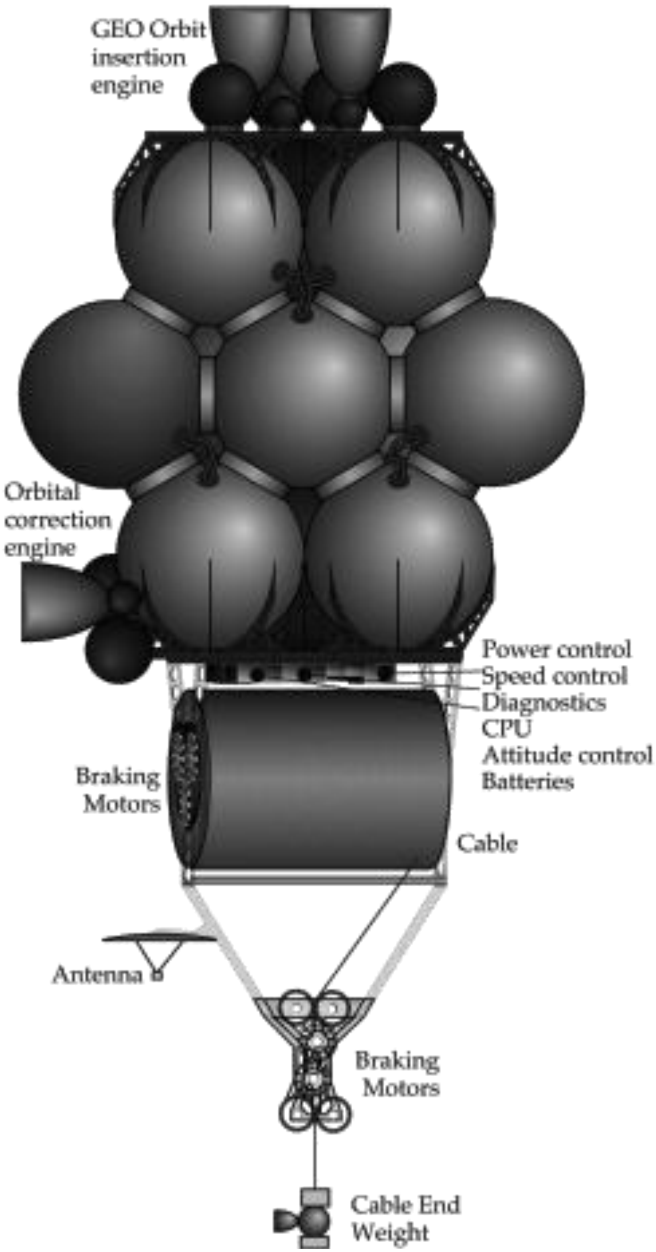
- Policy & Legal
- The Tether
- The Climber
- The System of Systems
- Process for Study
- Next Steps for Study
- The study team needs
- Questions

Function	Location
Enterprise Operations Center	HQ & Primary Ops Center
Transportation Operations Center	HQ & POC
Climber Operations Center	HQ & POC
Tether Operations Center	HQ & POC
GEO Node Operations Center	HQ & POC
Marine Node Operations Center	Marine Node
Payload (Satellite) Operations Center	Owner’s Ops Center

Operational View – 1 (OV-1)

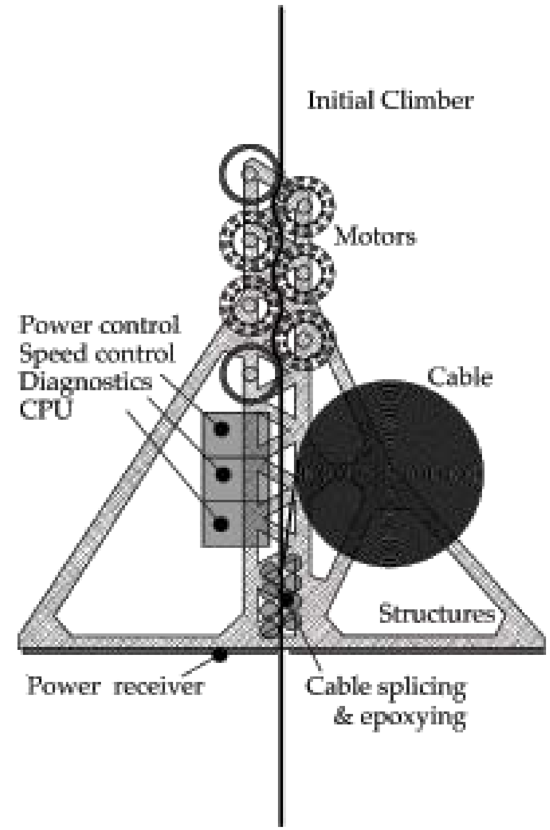


Spacecraft for Space Elevator



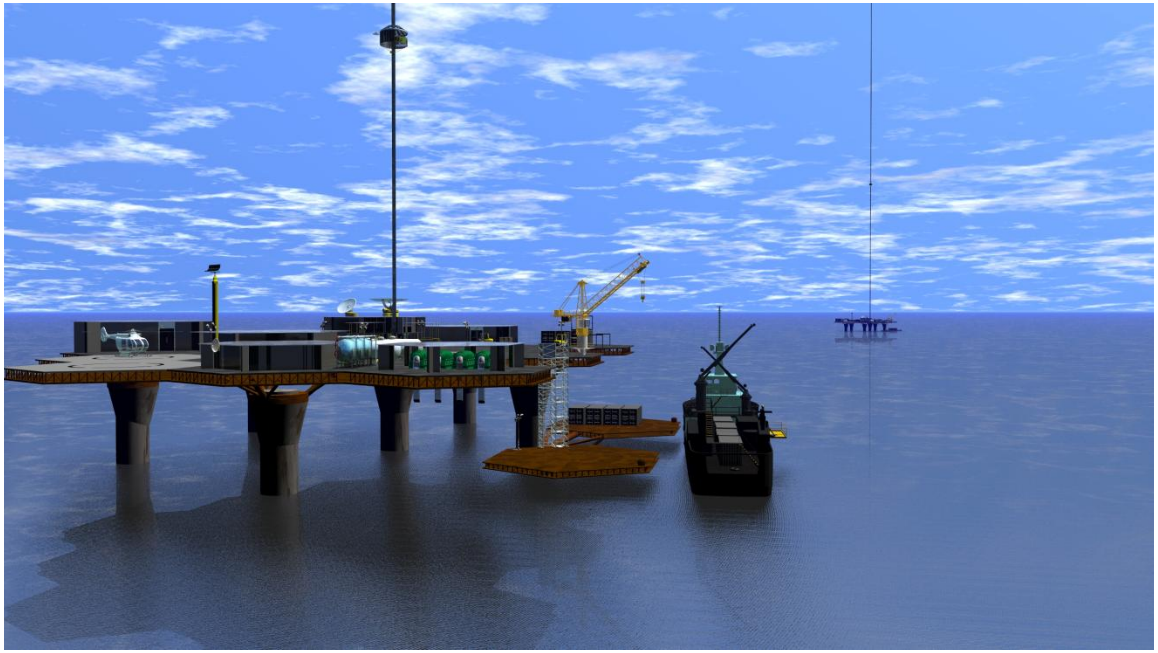
Deployment Spacecraft
& Future Apex Anchor

Buildup Climber with Cable



Tether Terminus Anchor

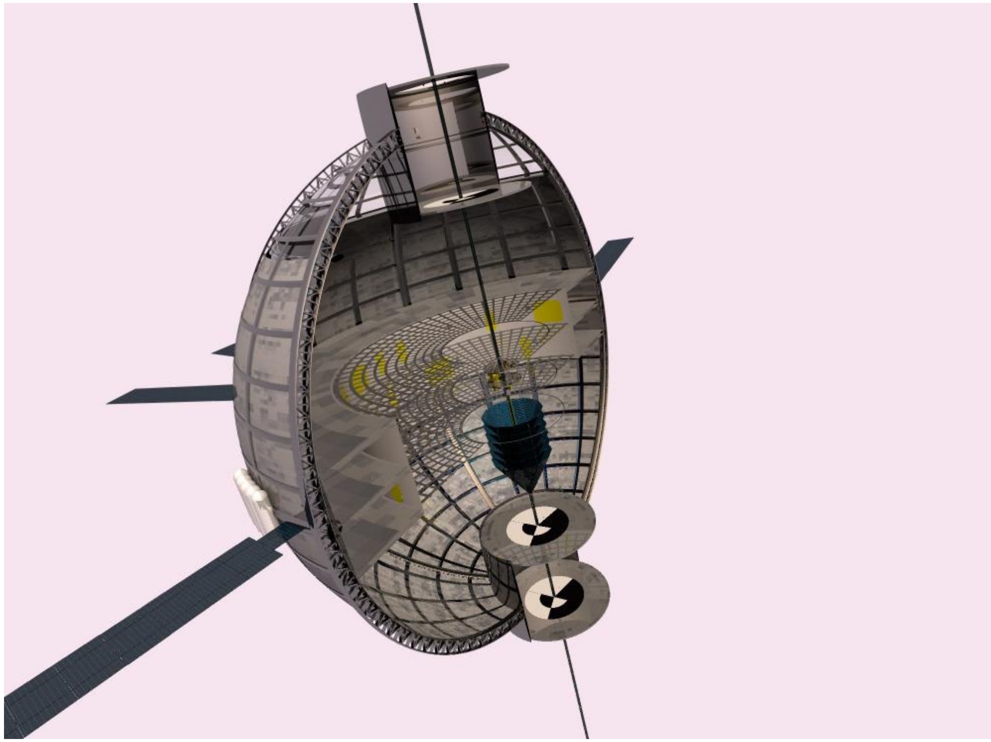
- Marine Node is a mobile, ocean-going platform identical to ones used in oil drilling
- Marine Node is located in eastern equatorial pacific, weather and mobility are primary factors



Geosynchronous Operations Complex

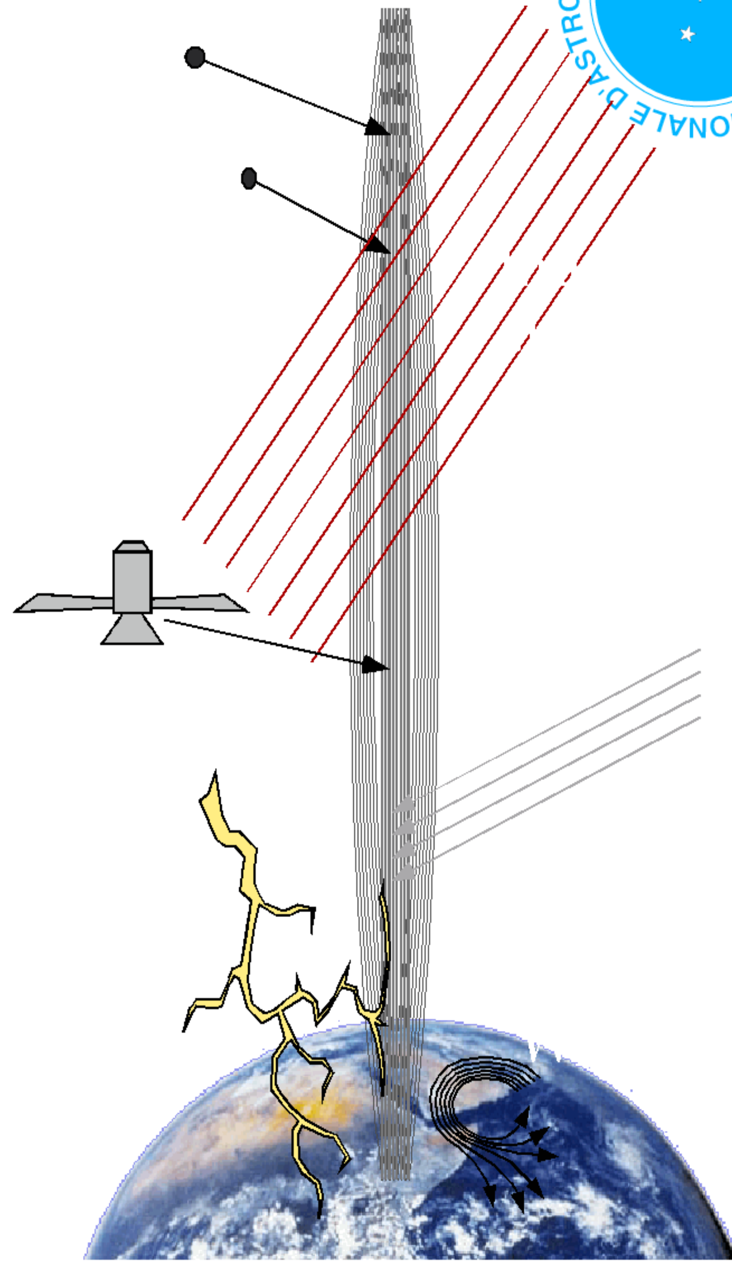
- Infrastructure at GEO: along the ribbon, where most payloads will be destined. There will be autonomous operations to off-load, adjust, and monitor satellites that are designed for GEO arc mission locations. In the future, this operations center could become a manufacturing / assembly location as well as a location for human habitat.

- GEO Station:. Autonomous operations will ensure that the satellite is healthy and then assist in the release of the system. In addition, this location will be where returning GEO payloads are collected and prepared for the trip back to the Earth's surface. Also, it will be a location for refueling spacecraft.



Challenges

- Magnetosphere
- Induced oscillations
- Radiation
- Atomic oxygen in Earth's upper atmosphere
- Environmental Impact: Ionosphere
- Malfunctioning climbers
- Lightning, wind, clouds
- Meteors and space debris
- Satellites
- Health considerations



Altitude Breakout

Super GEO: This region has very little human-created debris, so the major threat consists of meteors and micro-meteorites.

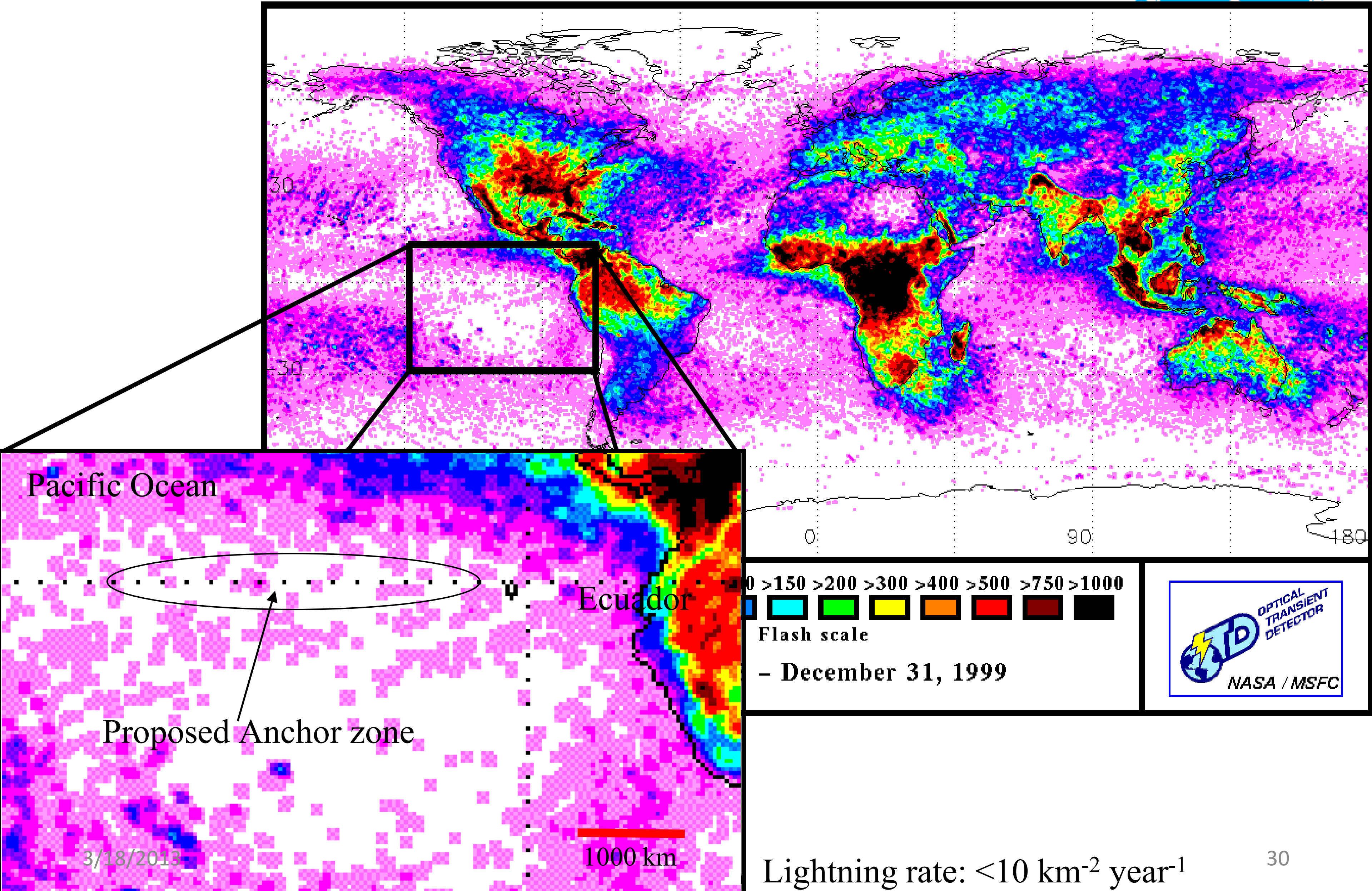
GEO Region: This region has the micrometeorite issue and human hardware intersection. The advantage is that debris are mostly large and moving slowly when at, or close to, the “Geo Belt.” The relative velocities are usually less than 10s of meters per second.

MA Region: This region is huge and mostly resembles the GEO region in that only a few man-made objects reside at this altitude. This includes a small number of objects right above the lower limit of 2,000 km altitude and around the 12 hour orbit populated by navigation constellations (GPS with more than 36 satellites; GLONAS with more than 20 satellites; and the future Galileo with more than 24 satellites). In addition, the Geosynchronous Transfer Orbit (12 hour, highly elliptical) leaves rocket bodies after payloads are “kicked” into GEO orbit. The velocity differences between a space elevator and orbiting objects for the 12-hour region debris presents a serious threat for a space elevator. In addition, the lower portion of this region contains the radiation belts.

LEO Region: This region has a problem with space debris, a modest problem with operational satellites, and a smaller problem with micrometeorites. Most space debris have been created in this region filling all altitudes and inclinations, which results in equatorial crossing near a space elevator. Of the 15,000 objects tracked daily, approximately 12,000 are located in this region.

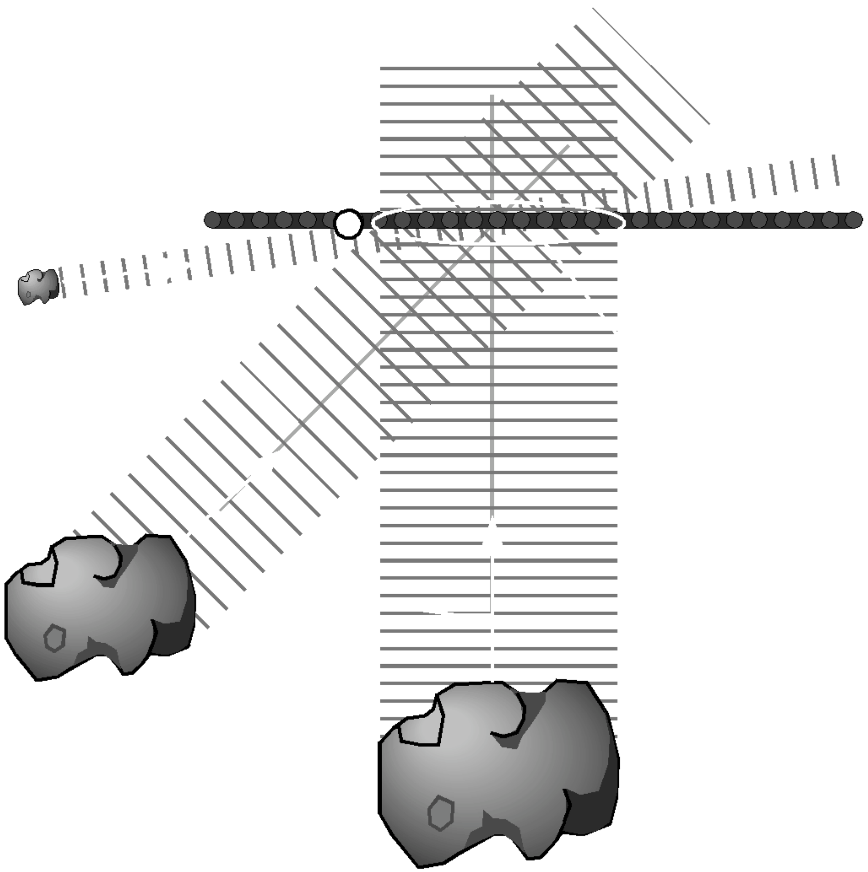
Aero Lift Region: The concern in this region deals with the dangerous aspects of the atmosphere that will threaten the ribbon and integrity of the space elevator. The dangers of concern are: winds aloft, hurricanes, tornados, lightening, and human interference (aircraft, ships, and terrorism).

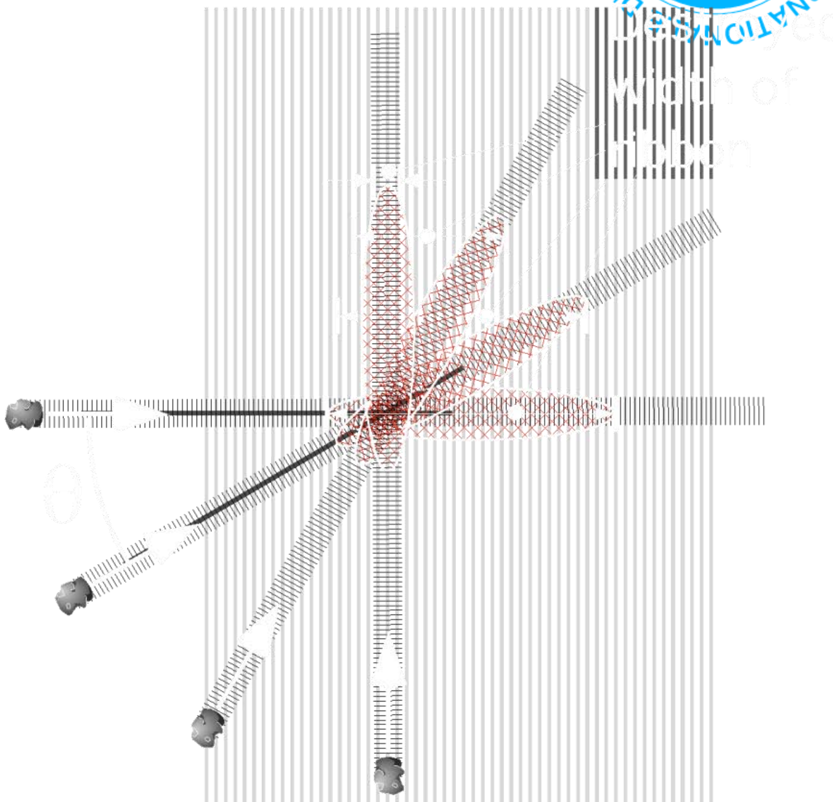
Lightning



Lightning rate: <10 km^{-2} $year^{-1}$

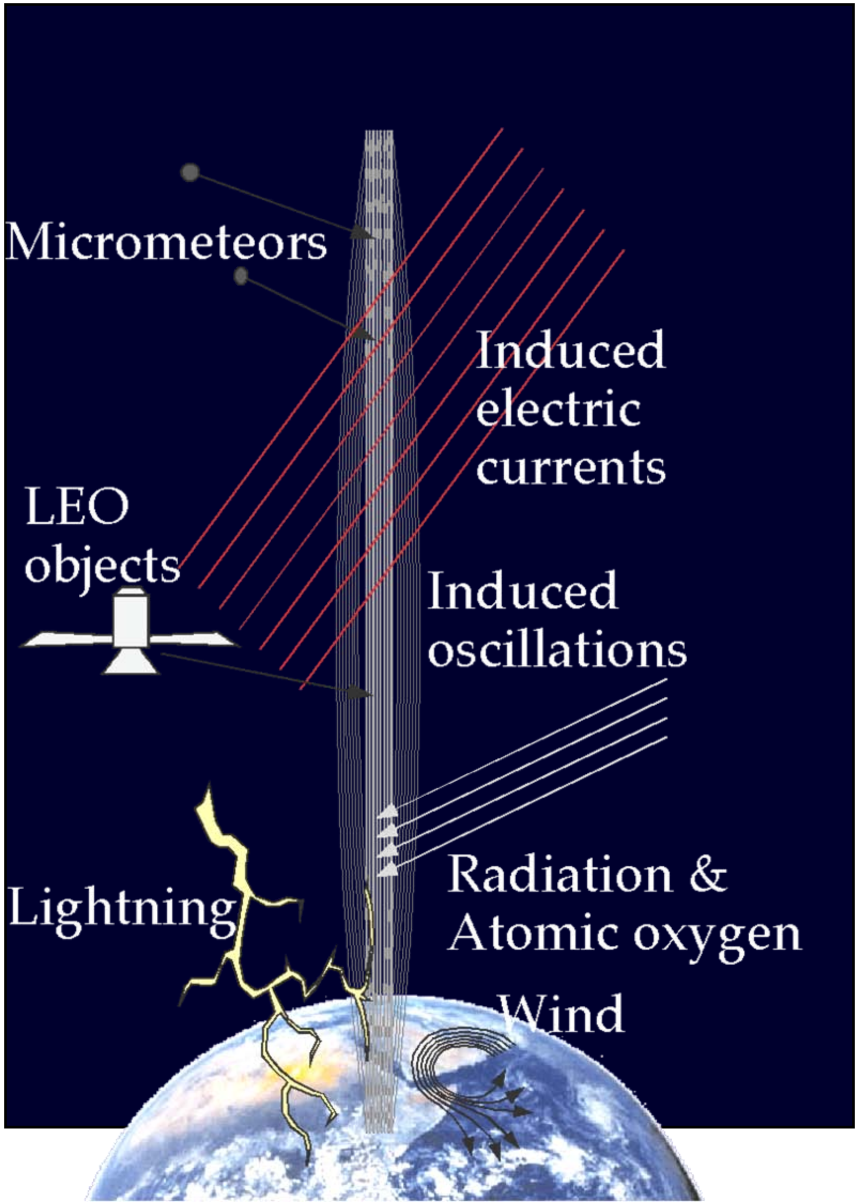
Meteors and Debris





- 3d, spherical integration is used to determine the impact flux
- A critical dimension of 30 cm is found

Proposed Solutions to Challenges



- Induced Currents: milliwatts and not a problem
- Induced oscillations: 7 hour natural frequency couples poorly with moon and sun, active damping with anchor
- Radiation: carbon fiber composites good for 1000 years in Earth orbit (LDEF)
- Atomic oxygen: <25 micron Nickel coating between 60 and 800 km (LDEF)
- Environmental Impact: Ionosphere discharging not an issue
- Malfunctioning climbers: up to 3000 km reel in the cable, above 2600 km send up an empty climber to retrieve the first
- Lightning, wind, clouds: avoid through proper anchor location selection
- Meteors: ribbon design allows for 200 year probability-based life
- LEOs: active avoidance requires movement every 14 hours on average to avoid debris down to 1 cm
- Health hazards: under investigation but initial tests indicate minimal problem
- Damaged or severed ribbons: collatoral damage is minimal due to mass and distribution

Topics to be covered

- Policy & Legal
- The Tether
- The Climber
- The System of Systems
- Process for Study
- Next Steps for Study
- The study team needs
- Questions

Finding 3-2: If growth in specific strength continues at the current pace, it is possible that yarns with specific strengths in the range of 20 MYuri can be demonstrated as early as 2015. Scaling up the process to lengths in excess of 1000km might take a couple of years, meaning that a space elevator tether could be available before 2025.

Roadmap A: Assumption [based upon chapter 3] is that the tether material matures rapidly and supports a 2036 space elevator deployment.

Roadmap B: Assumptions support a space elevator deployment in the 2050s.

Technology Assessment

	Expected year for Space Elevator System	TRL Level	TRL Level by 2030	Remarks
The Tether	2035+ with estimates varying to 2060 (JSTM, 2010)	2	7	Major development funding required. Terrestrial version will be available by 2030 in greater than 1,000 km lengths with appropriate strength
Apex Anchor	2025	5	8	Reel-out in vacuum of long material will require design and testing of components in orbit.
Geosynchronous Station	today	6	9	routine
Tether Climber	2025	4	8	Major design effort, however, not out of the knowledge of current satellite designers
Marine Node	2015	8	9	Deep Ocean Drilling Platforms and Sea Launch platform can be a models.
High Stage One	2025-30	3	6	Major design and development effort. Major breakthroughs needed in timely manner for many of its major components.
Ocean Going cargo Vessel	today	9	9	Routine
Helicopter Transport	today	9	9	Routine
Operations Centers	today	9	9	Routine

Table 10-XVI. Integrated System Realizable Time and TRLs

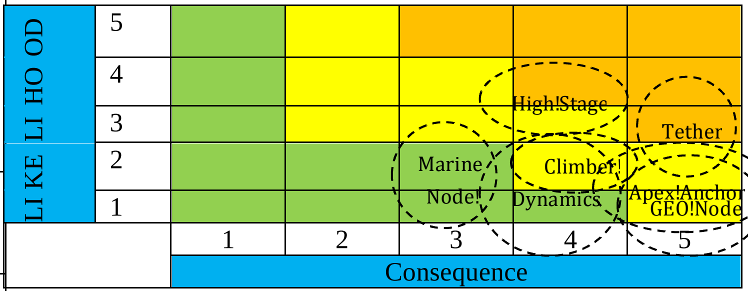


Figure 10-8 Project Risk Position Reporting !

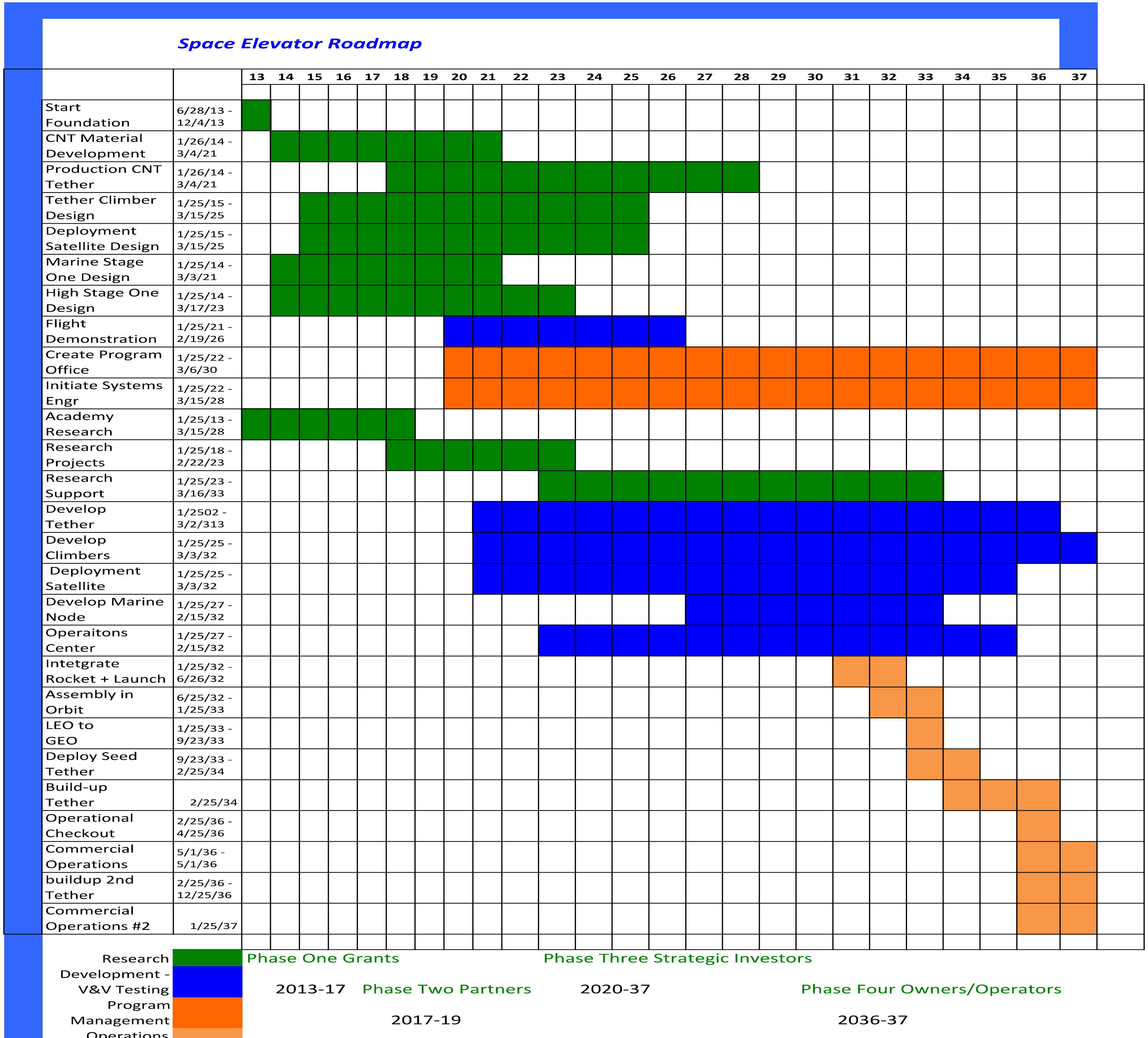


Figure 11- 1. Space Elevator Roadmap A

Roadmap A: Assumption [based upon chapter 3] is that the tether material matures rapidly and supports a 2036 space elevator deployment.

Roadmap B: Assumptions support a space elevator deployment in the 2050s.

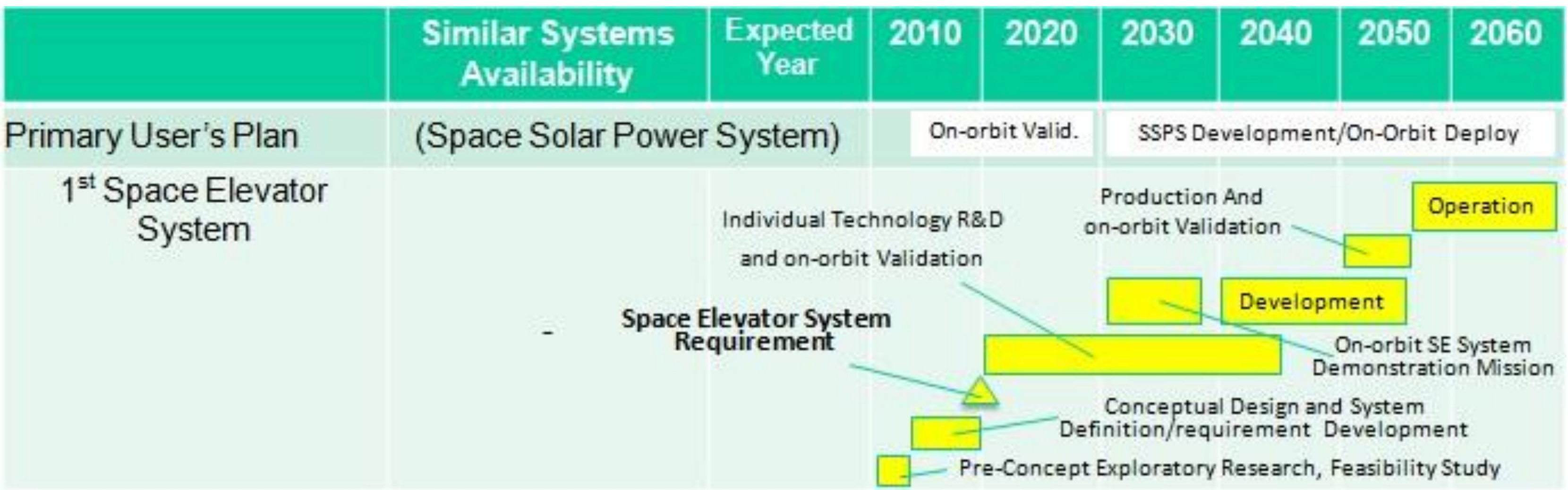


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Figure 11.2. Summarized Space Elevator Roadmap B (Tsuchida, 2011)

Topics to be covered

- Policy & Legal
- The Tether
- The Climber
- The System of Systems
- Process for Study
- Next Steps for Study
- The study team needs
- Questions

Findings and Conclusions with recommendations and next steps.

Findings - 1

- ***Finding 1-1:*** The space elevator will improve the human environment. The characteristics of a routine, on schedule (7 times a week), $500/kg fee, non-explosive service, without major pollution or shake-rattle-roll, and without major restrictions on packaging of the payload will lead to robust demand for space elevators.
- ***Finding 3-1:*** Space elevators can be developed with 30 MYuri tethers, as explained in the feasibility condition.
- ***Finding 3-2:*** If growth in specific strength continues at the current pace, it is possible that yarns with specific strengths in the range of 20 MYuri can be demonstrated as early as 2015. Scaling up the process to lengths in excess of 1000km might take a couple of years, meaning that a space elevator tether could be available before 2025.
- ***Finding 6.2:*** The nominal space elevator system consisting of a deployed tether and Apex Anchor is a stable one for linearized stationary vibrational modes.
- ***Finding 7-1:*** The environmental threats to a space elevator are not significantly different from historical threats to orbiting spacecraft, reflecting the differences in motion – orbiting around the Earth vs. rotating with the Earth.

Findings - 2

- **Finding 8-6:** The threat from LEO space debris is manageable with relatively modest design and operational procedures. For small debris, tether design will enable survivability while for tracked debris, movement will prevent collision.
- ***Finding 9-1:*** Operation of the space elevator will leverage over 50 years of experience in operating satellite systems. Operations centers will look very much like today's satellite operations centers.
- ***Finding 10.1:*** In all technological endeavors there are projections into the future. In the case of the space elevator, this study has recognized that there are two thrusts that must be taken:

  Thrust ONE: Assume tether material is space qualified by 2030.

  Thrust TWO: Assume tether material is available two decades later.
- ***Finding 11-2:*** Parallel prototype developmental programs must be established to lower risk and raise technology readiness levels (TRLs). The successful program will then enable a construction company to initiate development of a space elevator infrastructure in the 2035 time frame.

Findings - 3

- ***Finding 12-1:*** The risk to the space elevator infrastructure from placing the base station inside a nation state's territory is too high to be acceptable.
- ***Finding 12-2:*** The Marine Node of the Space Elevator will be in the ocean beyond the continental shelf and beyond any exclusive economic zone (EEZ) of individual countries. In addition, the Marine Node must be flexible enough to not infringe upon any nation's rights of movement.
- ***Finding 13-1:*** Market projections show robust customer demand for multiple space elevators as soon as they are available. This is not surprising as the expected fee is $500 per kg or three orders of magnitude less than today's fees.
- ***Finding 14-1:*** Space elevators will make major profits in the long run. As in most transportation infrastructures, the initial investments are massive and will require flexibility and creative funding; however, as the profit potential is so great, there will be money to be invested.

Cosmic Study Conclusions

- The conclusions from this study fall into a few distinct categories:

- **Legal:** The space elevator can be accomplished in todays arena!
- **Technology:** It can be accomplished with today's projection of where materials science and solar array efficiencies are headed.
- **Business:** This mega-project will be successful for the investors
- **Culturally:** This project will drive a renaissance on the surface of the Earth with its solution to key problems, stimulation of travel throughout the solar system, and inexpensive and routine access to GEO and beyond.

Cosmic Study Next Steps

1. Publish and distribute this International Academy of Astronautics Study Report.
2. Establish a Space Elevator Foundation during 2013.
3. Assist in funding the Space Elevator Foundation to the level required to conduct the early activities and then transition to the technological prototype developments.
4. Support the "Next Steps" shown earlier in this chapter.
   - Step ONE: Create a foundation
   - Step TWO: Initiate research with hardware prototypes as objectives
   - Step THREE: Initiate a "Program Office".

Space Elevator Roadmap

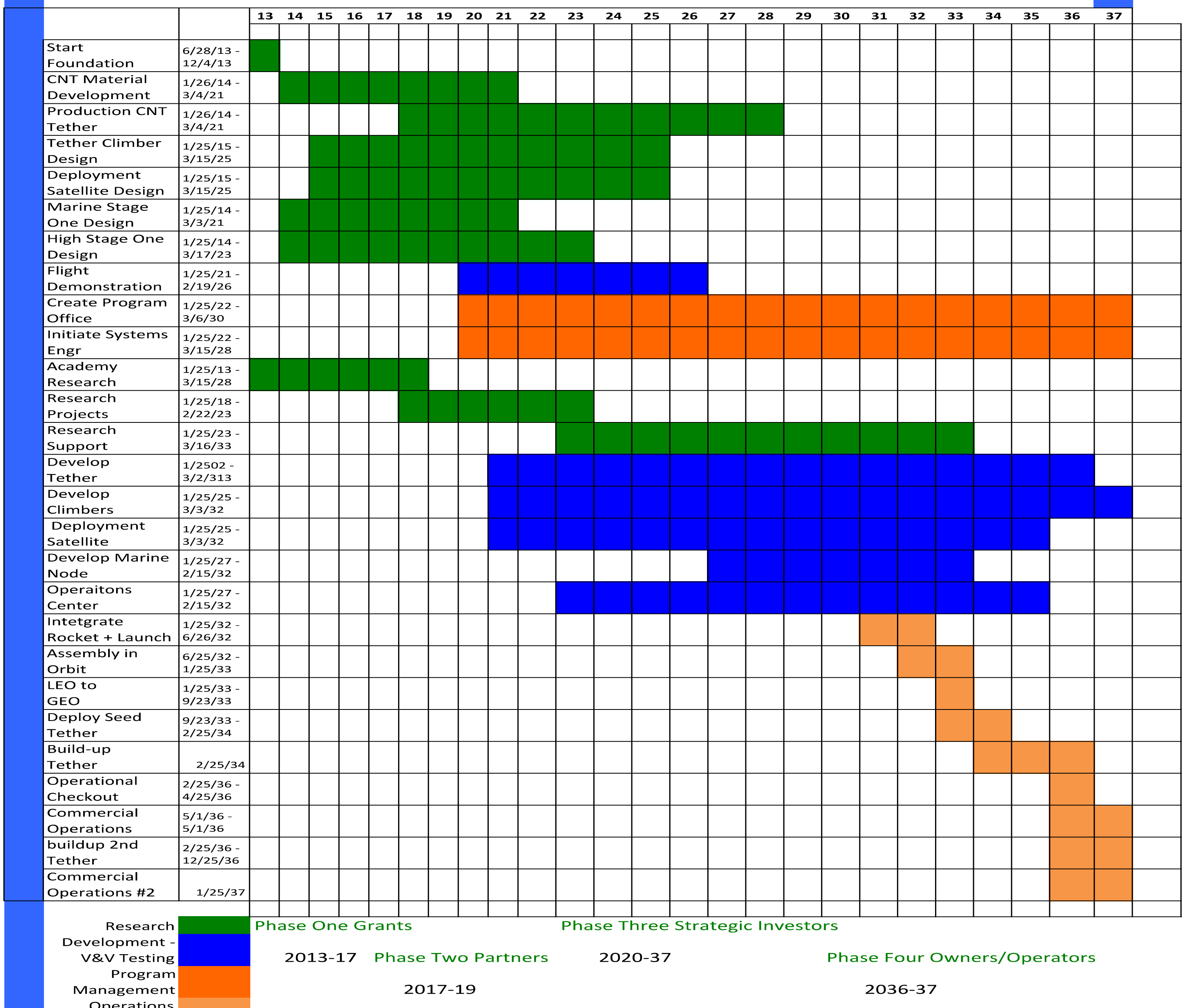


Figure 11- 1. Space Elevator Roadmap A

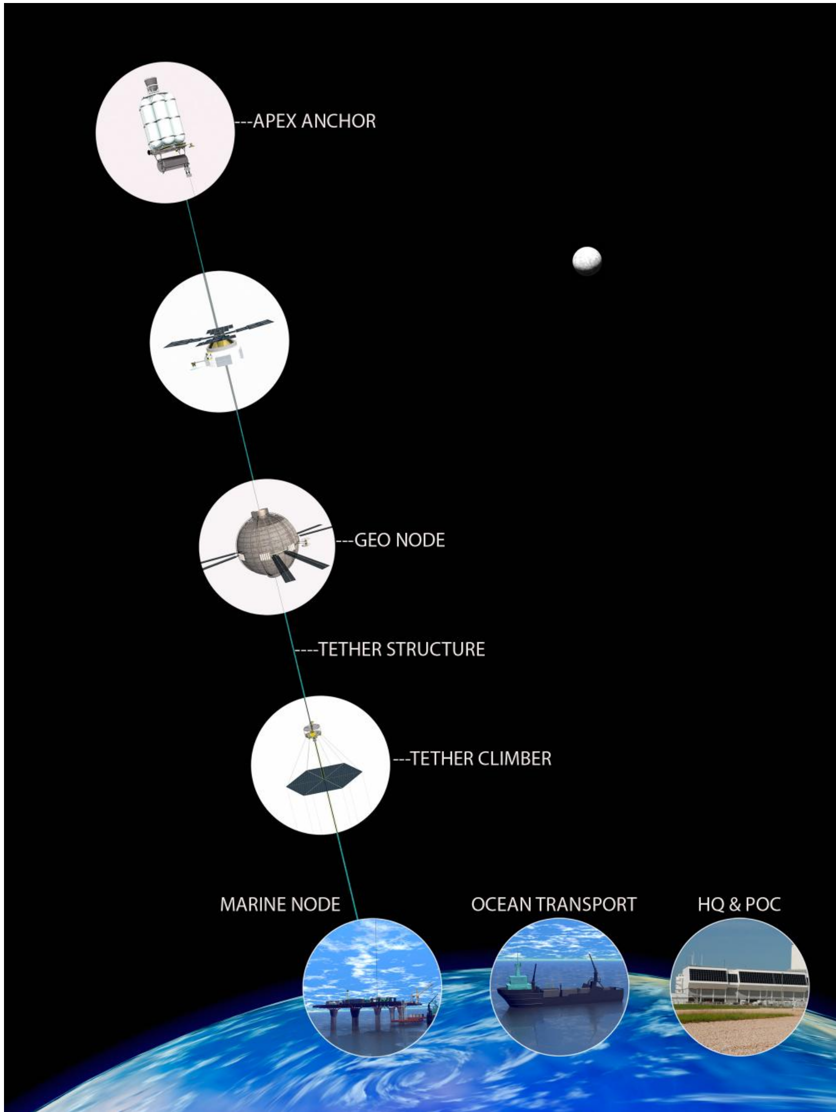
Topics to be covered

- Policy & Legal
- The Tether
- The Climber
- The System of Systems
- Process for Study
- Next Steps for Study
- The study team needs
- Questions

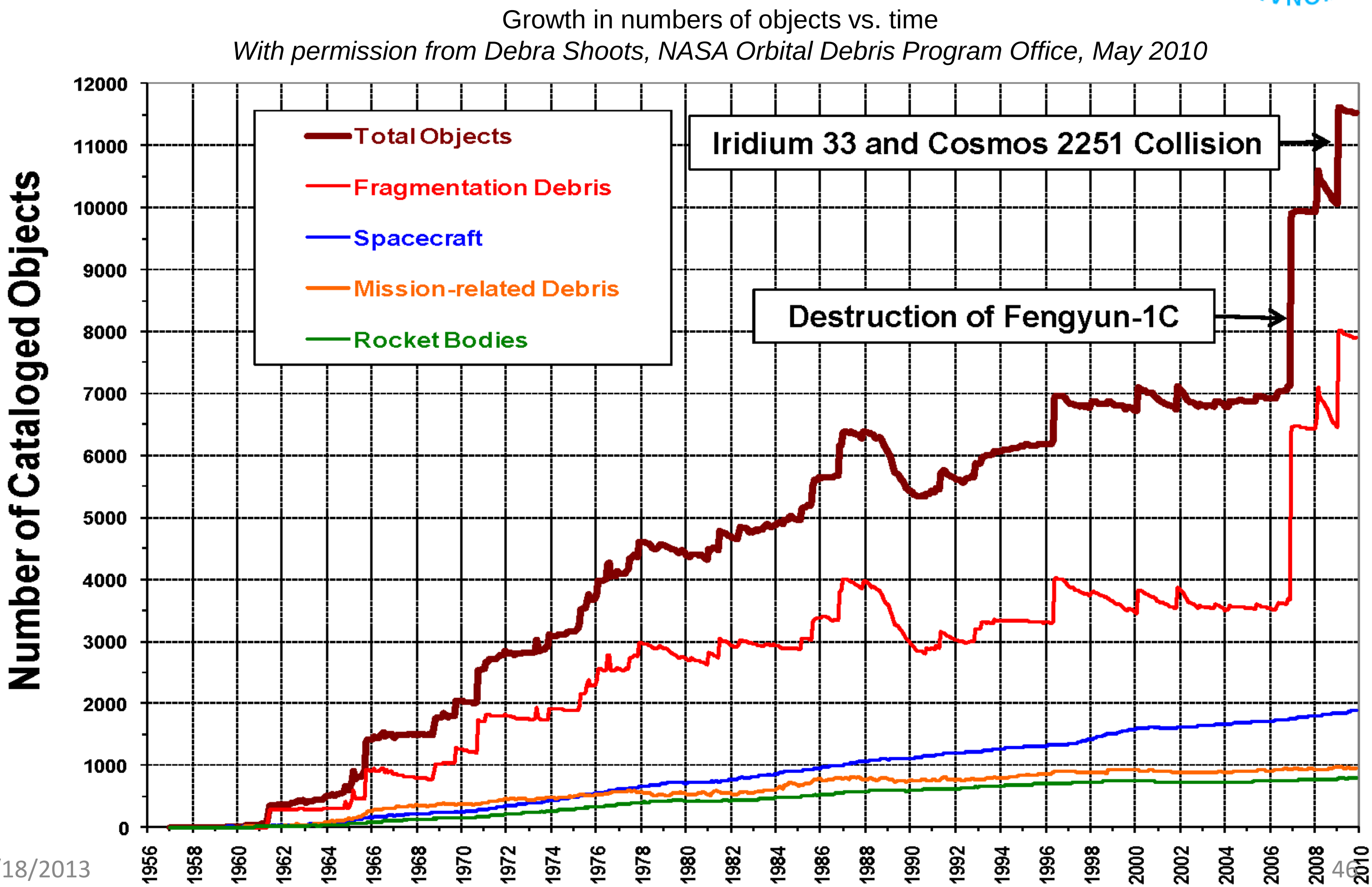
Commission III Review
with Peer Review Following
Need website support
Need rapid review
Need printing – publishing path

Topics to be covered

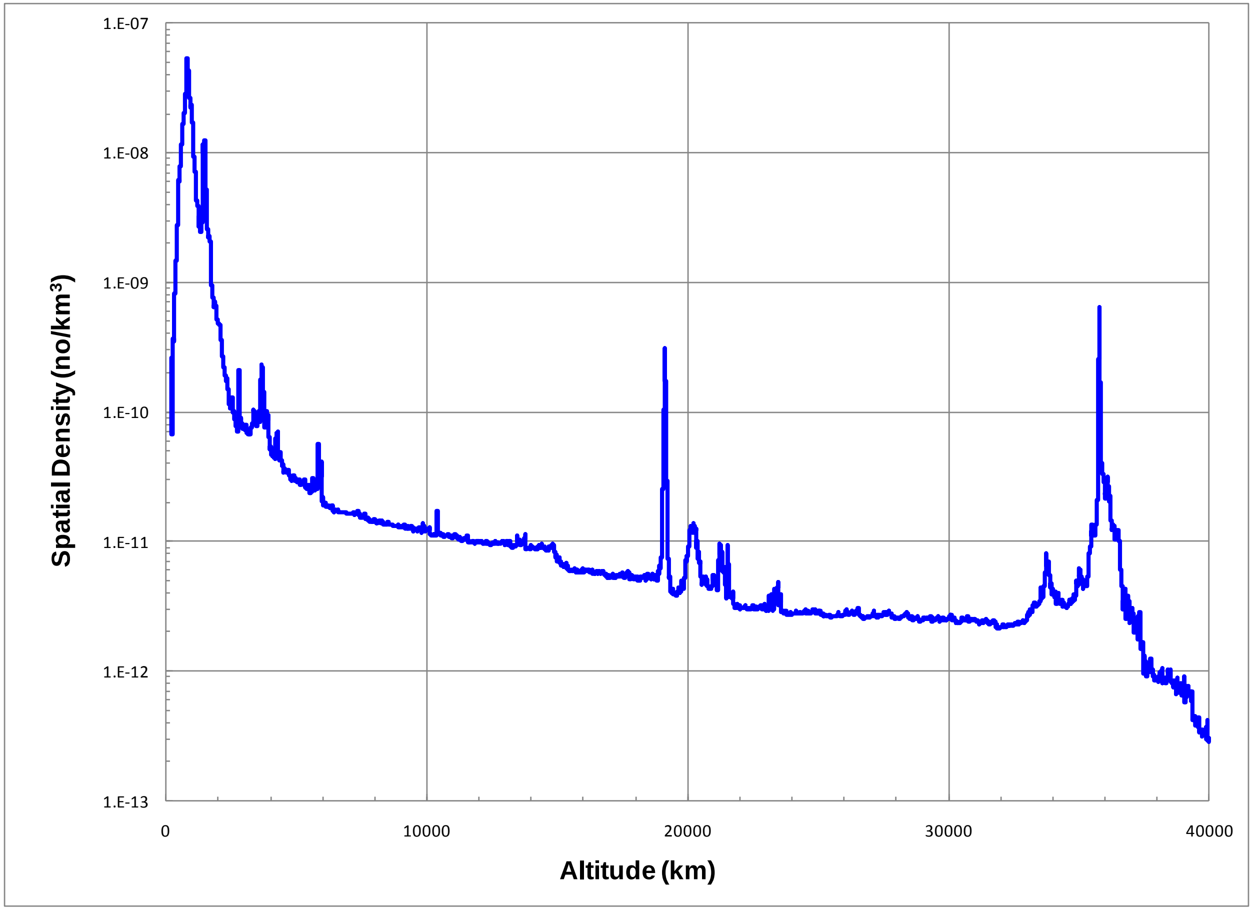
- Policy & Legal
- The Tether
- The Climber
- The System of Systems
- Process for Study
- Next Steps for Study
- The study team needs
- Questions



Space Debris Analysis



Density vs. Altitude



With permission from Debra Shoots, NASA Orbital Debris Program Office, May 2010

Probability of Collision

$$PC = 1 - e^{(-VR \times SPD \times XC \times T)}$$

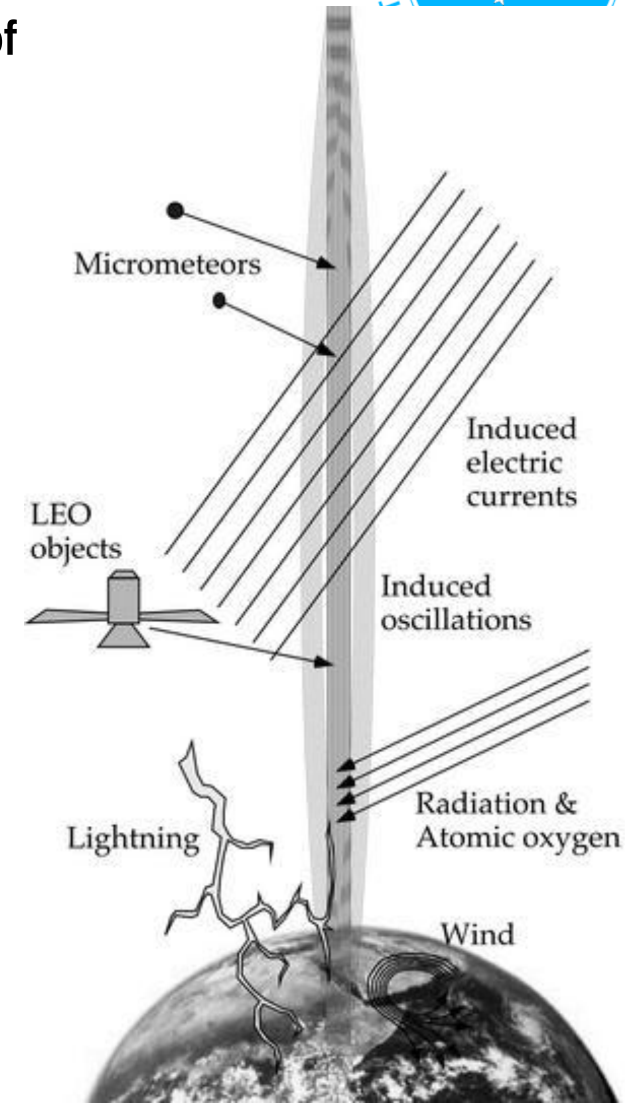
V relative velocity, SPD spatial density,
XC cross section, T time

Low Earth Orbit (9 cases)

- **Case A**: 60 km ribbon segment (740-800 km altitude) representing the peak debris density – highest risk case
- **Case B**: 60 km ribbon segment (1340-1400 km altitude) representing an average debris density in LEO
- **Case C**: 1800 km ribbon segment (200-2000 km altitude) representing the LEO environment
- **Case A-u, B-u, C-u:** represent the untracked items in above described segments [factor of 10 in numbers; < 10 cm's]
- **Case A-c, B-c, C-c:** represent the controlled satellites in above segments [only 6% of tracked objects]

PC for 3 Cases*

Types of Debris	Case	Probability of Collision
Untrackable Debris < 10 cm		PC per **day**
50 km stretch - peak	A	0.70%
50 km stretch - average	B	0.17%
LEO 200 - 2000 km	C	7.41%
Trackable Debris > 10 cm		PC per **year**
50 km stretch - peak	A	24.00%
50 km stretch - average	B	6.10%
LEO 200 - 2000 km	C	93.97%
Cooperative Debris		PC per **year**
50 km stretch - peak	A	1.60%
50 km stretch - average	B	0.50%
LEO 200 - 2000 km	C	15.51%



Used with permission Dr. Edwards

*2010 ISEC Study Report, “Space Elevator Survivability – Space Debris Mitigation”

Tentative Conclusions for Debris Mitigation

- GEO is not a problem
- MEO is not a problem
- Untrackable, small (<10 cm) will impact the Space Elevator in (LEO 200-2000 Kms) once every 10 days on the average and therefore must be designed for impact velocities and energies.
- Trackable debris will impact the total LEO segment (200 – 2000 kms) once per 100 days or multiple times a year if not accounted for.
- Trackable debris will only impact a single 60 km stretch of LEO space elevator every 18 years on the average and every 5 years in the peak regions.

Engineering Summary: Good Design will Ensure Space Elevator Survivability from Space Debris

ANNEXURE - III

IAA Commission 3.4 Study Group: Status Report

"Public/Private Human Access to Space"

March 4, 2013
IAC 2013 Planning Meetings
in Paris, France

Agenda

- Why: Goals
- When: Schedule
- Who: Leads & Current/Invited Contributors
- How: Approach (October 2012 to March 2013)
- What: Current Status: Country/Region Assignments

Goals

- This study group will create a report that assesses the cultural, economic and political environments affecting the creation and sustainability of global public and private orbital space activities and beyond.
- Two primary activities:
  - A collection of past works.
  - A series of separate but coordinated activities, including research studies, participant workshops and academic forums.
- Phase I Report: 25 Pages by October 2013.
- FINAL REPORT: 100 Pages.

Schedule

- Initial Results
  - Form the basis of discussion at the next Heads of Agency Summit scheduled for late-2013/early-2014.
    - Phase 1 Report delivered by October-November 2013.
  - Constrains the initial timeline.
- Subsequent Results
  - Will require two to three years.
  - Report depth of complexity and breadth of scope will likely require subsequent bi-annual updates to reflect changes in emerging or temporal subject-matter facets.

Leads & Current/Invited Contributors

LEADS

- Simonetta DI PIPPO (ASI)
- Ken DAVIDIAN (FAA AST)

CURRENT CONTRIBUTORS

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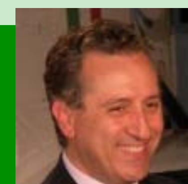
- John CULTON (US Embassy Denmark)
- Allen HERBERT (USA/Africa)
- Jie "Jay" HOU (Dresden Univ of Tech)
- Zhuoyen "Joy-yen" LU (Univ of Lapland)
- Philipp MAIER (Dresden Univ of Tech)
- Gennaro RUSSO (AIDAA)
- Khurana SHASHANK (SGAC CSPG)
- Randy SWEET (Lockheed Martin)
- Marco VILLA (SpaceX)
- Vikram UDYAWER (Univ of Sydney)
- Jose Mariano Lopez URDIALES










INVITED CONTRIBUTORS

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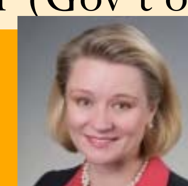
- Alan BOND (Reaction Engines)
- Claire JOLLY (OECD)
- Dmitry PAYSON (Skolkovo Space-Telecomm)
- Annalisa WEIGEL (Consultant)
- Anthony WICHT (Gov't of Australia)






Major Approaches (October 2012)

1. Fundamentals
- Definitions
- Analyses and Models
- Integration of Studies
- Target Sectors

2. Historical and Cultural Contexts
- Transportation Sectors
- Precursor Industries
- Geo-Political, Legal

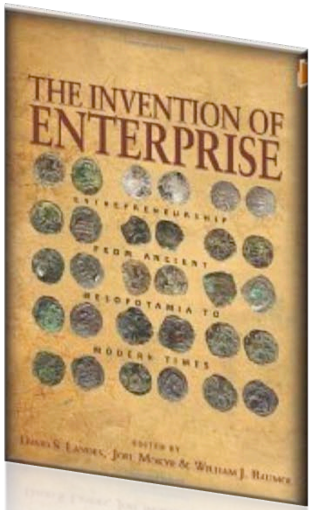
3. Theoretical Models
- Industry Structures
- Innovation Models
- Diffusion

4. Analytical Reports
- Current Industry
- Forecasts
- Rankings and Indices

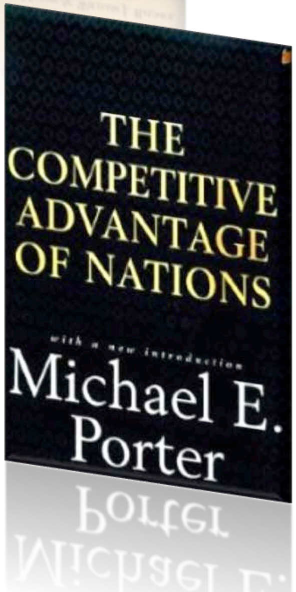
5. Policy Implications
- Space Industrial Base
- Strategic Industry Development
- Collaboration & Diffusion Approaches

Current Approach (March 2013)

1. **Literature Search**
   - Compile publicly available reports that provide data and/or analysis of the space industry for a given country or region.
2. **Historical & Cultural Assessment**
   - Based on historical and cultural information from "Invention of Enterprise" for select countries, provide a "compare and contrast" analysis based on your personal experiences and assess the applicability and relevance to your country's space industry and the viability of a human orbital commercial market.



3. **Initial Industry Cluster Assessment**
   - Based on "The Competitive Advantage of Nations" notes for select countries, provide a "compare and contrast" analysis based on your personal experience and assess the applicability and relevance of the given industry cluster analysis to your country's space industry and the viability of a human orbital commercial market.



Preliminary Analysis Presentations at IAA C3.4 SG March Meeting

Current Status: Country/Region Assignments

Country/ Region	Name	Lit Search	Cultural Analysis	Industry Cluster	Country/ Region	Name	Lit Search	Cultural Analysis	Industry Cluster
Africa	Allen Herbert	🟢		🟠	India	Khurana Shashank	🟢		🟢
Australia	Vik Udyawer				Indonesia	Bustanul Arifin	🟢	🟢	🟢
Canada					Italy	Gennaro Russo	🟢		🟢
China	Zhuoyan Lu	🟢	🟢🟢		Japan				
China	Xiaohui Cao	🟠		🟠	Russia	Dmitry Payson	🟡	🟡	🟡
Denmark	John Culton	🟠		🟠	Spain	Jose Mariano Lopez Urdiales	🟢		🟢
Europe	Simonetta di Pippo	🔴	🔴	🔴	UK	Alan Bond	🟡	🟡	🟡
Europe	Claire Jolly	🟡		🟡	US	Ken Davidian	🔴	🔴	🔴
France					US	Marco Villa	🟠		🟠
Germany	Philipp Maier	🟢	🟢🟢	🟢	US	Randy Sweet	🟠		🟠
Germany	Jie Hou	🟢	🟢	🟢					

🔴 Lead Activity 🟢 Current Activity 🟢🟢 2013 IAC Abstract Submitted 🟡 Invited Act.

Phase I Report Content

- Introduction
  - Scope of Report (Cultural, Theoretical, Analytical)
  - Definitions
  - Target Market Sectors
  - Introduction of Case Study Companies/Agencies
- Past Analytical Studies – Overview & Initial Results (O&IR)
  - Select Countries/Regions
- Cultural Context of Human Orbital Enterprise – O&IR
  - Select Countries/Regions
- Industry Cluster Analyses – O&IR
  - Select Countries/Regions
- Introduction to Policy Implications
  - Strategic Space Industrial Base Development
  - Collaboration & Diffusion Approaches

IAA Study Next Moves

- October 2012 – March 2013
  - ✓ Establish list of interested members, potential contributors.
  - ✓ Identify leads and contributors for study approach areas
  - ✓ Conduct Meeting with Space Generation Contributors
  - ✓ Interim Results at March Meeting (lit review, assignments)
- April – December 2013
  - ❑ Conduct 3-4 Meetings of major groups
  - ❑ Conduct Public Workshop #1 of Relevant Studies
  - ❑ IAC 2013: Face-to-Face Meeting of Group
    - Interim Results, Updated Schedule
  - ❑ Delivery of Phase I Report
- January 2014 – April 2014
  - ❑ Heads of Agencies Meeting
  - ❑ Conduct Public Workshop #2 of Relevant Studies

Annexure - IV

IAA SG3.15

Long Term Space Propellant Depot

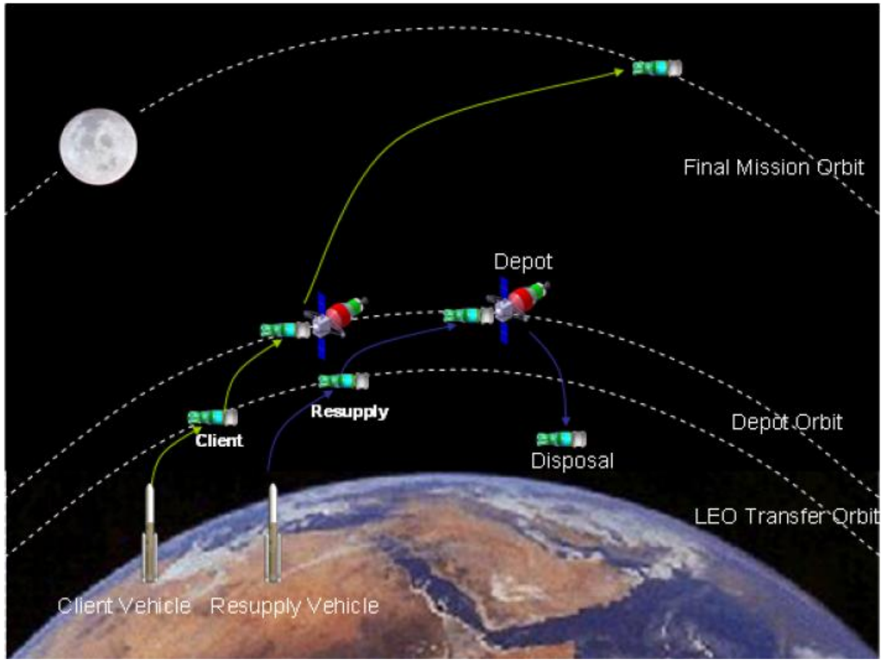
Yu Lu

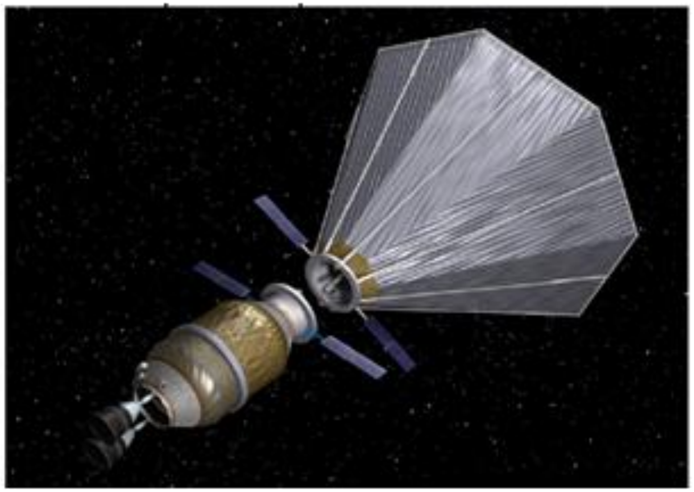
IAA Spring Meeting, Paris

Mar. 18th, 2013

Goals

- **Identify requirements, concepts and opportunities for future high energy propellant space depots, identify required key technologies and define the road map for this new capability.**





The 1st Meeting

1st Meeting, 30-9-2012, Naples

Minutes of Meeting:

- **Only in-orbit depot will be addressed and not surface infrastructures.**
- **A "macro" structure for the study had been discussed and the following 3 blocks had been identified (each of them might include several chapters):**
  - Missions, "business cases, architectures, etc.: Why these concepts?"
  - Technologies: background (previous missions addressing some of the challenges), needs, status, challenges, schedules and costs
  - Implementation: private vs. institutional initiatives, international collaboration, etc.
- **Proposed way forward:**
  - Build a study team by proposing new members and contacting them. Deadline: End 2012
  - Definition of the Study Structure: Each member should reflect on the 3 blocks above and propose a chapter structure with a few lines of content per each chapter. Deadline: End January 2013. Consolidation by G.Saccoccia by mid February. Last iteration and study structure completed by March 2013.

Current Status

- **Group Composition:**

Chairs:

Giorgio Saccoccia
ESA – The Netherlands

Yu Lu
China Academy of Laucnh Vehicle Technology (CALT)-China

Secretary:

Xiaowei Wang
CALT – China

Members:

Dallas Bienhoff
Boeing – USA

Davina Di Cara
ESA – The Netherlands

Christophe Bonhomme
CNES – France

James Free
NASA (Glenn Research Center) – USA

Philippe Caisso
SNECMA – France

Jim Keravala
Shackleton Energy – USA

Current Status

- **Group Composition:**

Members:

Guenter Langel
EADS/ASTRIUM – Germany

Jerrol Littles
Pratt & Withney – USA

Kevin Miller
Ball Aerospace – USA

Robert Mueller
NASA (Kennedy Space Center) – USA

Bill Smith
Aerojet Corp. – USA

Wei Liu
CALT – China

Jim Keravala
Shackleton Energy – USA

Current Status

Table of contents:

Current Status

- **Schedule:**

June 2013:

- **Completion of the Preliminary Draft report for discussion**

July 2013:

- **Discussion of the Preliminary Draft**
- **3-5 July, IAA "The Future of Space Exploration" Conference in Turin, possibility to held another SG meeting**

September 2013:

- **Consolidation of the complete Draft Report**
- **23-27 September IAC 2013 in Beijing: Present the status of SG at the Commission III meeting**

Current Status

- **Schedule:**

October 2013:

- 25th October: Finalization of the Draft Report including all deliverables
- Send the Report to IAA

November 2013:

- IAA will synthesize the main part/recommendation of the report for inclusion in the HoA report
- IAA discuss HoA report with Space Agencies

Taking into account the feedback from the event in Washington, the Study Report will then be finalized in 2014-15.

Thanks!

ANNEXURE - V

IAA COMMISSION -3 MEETING

SG 3.16 - Global Human Mars System Missions Exploration - Goals, Requirements and Technologies

CHAIR

Giancarlo Genta

CO-CHAIR

Hideto Yamazaki

SECRETARY

Jean-Marc Salotti

SG MEMBERS

Mauro Augelli
Andrew Aldrin
Nicolas Bérend
Giovanni Bignami
C. Bonnal
Claudio Bruno
John B. Charles
Lin Chen
Elisa Cliquet Moreno
Gabriel G. De la Torre
Alain Dupas
Nadeem Ghafoor
Richard. Heidmann
Bernhard Hufenbach
Les Johnson
Nick Kanas
David Kendall
Julien-Alexandre Lamamy
John Logsdon
Chris McKay
Susan Mc Kenna
Ernst Messerschmid
Gian Gabriele Ori
Maria Antonietta Perino
Pascal Renten
Stephen C. Ringler
Andreas Rittweger
Christian Sallaberger
Klaus Schilling
Carol R.Stoker
Lin Wei
Luo Wencheng
Alan Wilhite
Cao Xiaohui
Lu Yu

DEADLINE

A draft is scheduled to be available for the next Heads of Space Agencies Summit.

The Study will be completed for the 65th IAC in Sept. 2015

GOAL

Identify, assess and synthesize a global set of goals with its related criteria requirements for future human exploration of the Mars system and establish technology opportunities and roadmaps in the context of promising cooperative exploration scenarios. The Study should aim to identify means to minimize the risks at global level

SG 3.16 - Global Human Mars System Missions Exploration - Goals, Requirements and Technologies

SCHEDULE

- Early drafts by March 18, 2013 meeting,
- A paper presented at the 8th IAA Symposium on the Future of Space Exploration: Towards the Stars, Turin , Italy, 03-05 July 2013
- A paper presented at the 64th IAC, Beijing, 23-27 Sept. 2013
- A draft presented at the meeting in Beijing during the 64th IAC
- A final draft prepared for the Heads of Space Agencies Summit in Washington, January 2014
- The Study will be completed for the 65th IAC in Sept. 2015

SG 3.16 - **Global Human Mars System Missions Exploration - Goals, Requirements and Technologies**

DRAFT TABLE OF CONTENTS

ANNEXURE - VI

Study group on

Feasibility Study of Possible International Protocol to handle crisis / emergency to Astronauts in LEO

Status as on 14 March 2013

STUDY GROUP MEMBERS

- S Ramakrishnan, VSSC, ISRO, India – Chair
- Bernhard Hufenbach, ESA /ESTEC, The Netherlands
- Mike Hawes, Lockheed Martin, USA
- ZHANG Shu, CALT, China
- Prof . Irmgard Marboe, University of Vienna, Vienna
- Unnikrishnan Nair S., VSSC/ISRO, India – Secretary

OVERALL GOAL

- The Study will assess the feasibility to establish a protocol, restricted to rescue of crew from LEO, who got marooned or have lost de-orbit burn capability or are left with intolerably damaged thermal protection system and is not considering Moon, trans-lunar, Mars or other interplanetary missions.

- Rescuing from orbit is a critical operation and may not always result in success. It may also subject another set of crew to the uncertainties of rescue operations. Therefore the design of space vehicle shall take care of all conceivable failure modes and make the space vehicle reliable to the extent possible. In the unlikely event of crisis/emergencies, the space vehicle design shall be capable enough to achieve the objective of alleviating the immediate danger to the crew without any external assistance.

- Rescue in the context of this protocol is considered to be those cases where external assistance is mandatory to rescue the lives of the crew.

PROPOSED CONTENTS OF STUDY REPORT

- Introduction/Preamble
- Objectives/scope of study
- Possible crisis situations/emergency scenario of Crew in LEO
- Crew Rescue Methodologies/Mechanisms under study – Hardware, operations and logistics
- Current International Treaties/Protocol in the area of Outer Space & Space Travel/Space systems and their implementation status
- Impediments/hurdles foreseen in evolving an international protocol on Crew rescue from space and approach to overcome them
- Proposed draft protocol to handle crisis/emergency of astronauts in LEO
- Conclusion & way forward
- Annexures:
    - Index of International agreements/MoU/Protocol governing activities in outer space
    - Bibliography

DELIVERABLES

- Report between 20-25 pages (minimum, annexes can be added) including:
  - Discussion of the Objectives, subject matter and critical issues
  - Executive Summary, (2 pages)
  - Recommendations (5-10). These should include specific recommendations in order to engage, the Space Agencies attending the HoA
  - Topics to be analyzed further, if any

SCHEDULE

- Project team finalization – **February,2013** ***(completed)***
- Detailed Content List definition with assignment of the specific tasks to the Project Team members - **March, 2013** ***(completed)***
- Completion of the Draft for discussion within the Project Team – **June, 2013**
- Discussion of the Project Draft to be held within a dedicated project meting or virtual forum. – **July, 2013**
- Consolidation of the complete Draft report within the Project Team – **Sept, 2013**
- Finalization of the Draft Report including all deliverables and send the Report to Chair of the HSFCG – **October, 2013**

STATUS OF STUDY GROUP

- Letter requesting nominations to Study group sent to space agencies
- Extensive collection of literature and applicable UN treaties on Space
- Study group formed with members from ESA, CALT, Lockheed, University of Vienna and ISRO with a total strength of six. Mr Ramakrishnan, ISRO is the Chair and Dr Unnikrishnan ISRO is the Secretary
- Proposed Contents of report prepared and endorsed by members through telecom
- First Telecon held on 15 February 2013 at 13.00 hrs GMT
- A draft on International Protocol to handle crisis / emergency to Astronauts in LEO is made and ready for discussion among group

IMMEDIATE PLAN

- Draft Protocol – circulation among group members and refinement – April, 10
- Second Telecon – Second half of April, 2013
- Preparation of draft for discussion among group members – June, 2013

ANNEXURE - VII

Space Technology Ireland

Status Report on Study 1.2.3

"Feasibility Study of Astronaut Standardized Career Dose Limits in LEO and the outlook for BLEO"

Susan McKenna-Lawlor

Space Technology Ireland,

National University of Ireland,

Maynooth, Co. Kildare

Historical Background

In 2012 the International Academy of Astronautics (IAA) issued an invitation to certain of its members to form part of a Group that would provide a focal point for coordinating information concerning Human Spaceflight activities. The information thus gathered and its related recommendations will be presented at the next Heads of Space Agencies (HoSA) Summit in January, 2014.

A starting point for consideration by the group was a set of topics already selected by the IAA as priorities for consideration at the next HoSA Summit.

Topic Selection

Space Technology Ireland

My personal suggestion for a topic was "Definition of Standardized Career dose limits in LEO and outlook for BLEO" ⌈(BLEO - Beyond Low Earth Orbit⌋. This was based on my observation, in the course of preparing a book for the Academy on "The energetic particle radiation hazard en route to and at Mars", that different Agencies currently adopt different values for career dose limits in LEO. These differences require to be investigated and the present differences justified. Alternatively a consensus of standardization might be adopted.

Also, no Career Dose Limits are as yet assigned for BLEO.

The Academy approved the topic and I was appointed *Project Manager* for this study (Proposal No. 1.2.3). The title was later changed by the HSFCG to:

“Feasibility Study of Astronaut Standardized Career Dose Limits in LEO and the outlook for BLEO”

Studies on other topics selected by the Academy run in parallel to this one and each has been assigned its own Project Manager.

Organization of the present study

Space Technology Ireland

Since at the heart of the Career Dose Limit Study lie the different limits currently adopted within some individual space agencies, I assembled an international group that could articulate the national viewpoints of the major space faring nations in the matter of setting career dose limits for LEO.

The names of those already appointed are listed below. Discussions are ongoing in obtaining recommendations from a few space agencies for contributors (ESA, India, Russia).

Prof. S. McKenna-Lawlor (Project Manager)

Space Technology Ireland

Canadian Space Agency	**Dr. Leena Tomi**
Astronaut Research and Training Center of China /ACC	**Prof. Li Yinghui**
German Space Agency/DLR	**Dr. G. Reitz**
Japanese Space Agency/JAXA	**Dr. A. Nagamatsu**
USA (Univ. Tennessee, Knoxville)	**Prof. L. Townsend**

Ongoing Steps

Everyone in the group was initially requested to prepare a document indicating what exactly are the career dose limits adopted for space personnel in the particular Agency with which they are associated. The limits should have reference to gender, age, previous irradiation and any other factors deemed to be relevant.

Although some updates are still needed a lot of information has already been assembled.

NASA Norms

NASA bases its limits in LEO on the recommendations of the *National Council on Radiation Protection and Measurements* (NCRP 132, 2000);

NASA and JAXA have age dependant limits,

The other agencies have adapted a recommendation of the *International Commission on Radiological Protection* (ICRP) which calls for a general life time limit of 1 Sv (ICRP, 60, 1990; MED, Vol. A 2010).

Radiation Protection at NASA

A candidate for a specific flight is not eligible for selection if the sum of the astronaut's career occupational exposure to date, plus the projected mission exposure associated with the proposed new flight, exceeds the lifetime career limits adopted by the agency.

Radiation Protection at NASA Contd.

Career Limits

Occupationally related sources of exposure throughout the career of any USA crewmember shall result in no more than a 3% probability of lifetime excess cancer mortality risk. NASA assures that these limits are not exceeded at a 95% confidence level based on a statistical assessment of the uncertainties that enter into the National Council on Radiation Protection cancer risk projection model (NCRP Report-132). The corresponding career dose limits are determined using age and gender dependent risk coefficients as also provided by the NCRP.

NASA Radiation Protection Requirements

Space Technology Ireland

The following Table lists examples of dose limits for 10-year NASA careers. (For career lengths of other durations or other age-at-first-exposure situations, dose limits corresponding to 3% excess cancer mortality are determined by the Radiation Health Officer through interpolation of the age and gender dependent risk coefficients).

The NASA list is compared with a corresponding list from JAXA.

NASA *CAREER EFFECTIVE DOSE LIMITS FOR AGE AND SEX SPECIFIC IONIZING RADIATION EXPOSURE FOR 10-YEAR CAREERS*

Space Technology Ireland

Career Effective Dose Limits Example for 10-Year Career (Sv)				
	Age at First Exposure			
Gender	**25**	**35**	**45**	**55**
Female	**0.40**	**0.60**	**0.90**	**1.70**
Male	**0.70**	**1.00**	**1.50**	**3.0**

JAXA *CAREER IONIZING RADIATION EXPOSURE LIMITS*

Current Career Exposure Limits By Age And Gender Effective Dose Equivalent (Sv)				
	Age			
Gender	**27 – 29**	**30 - 35**	**36 - 39**	**> 40**
Female	**0.6**	**0.8**	**0.9**	**1.1**
Male	**0.6**	**0.9**	**1.0**	**1.2**

Ongoing Steps *continued*

Space Technology Ireland

It is now necessary to discuss within the Team differences between the limits adopted in different agencies and this will be accomplished through a telecon that will take place through the Academy hub in early April, 2013.

The results of these discussions will be prepared for presentation at forthcoming meetings:

3-5 July 2013, Presentation of a status report at Torino

16-20 Sept. 2013, Presentation of a status report at a UN/China workshop in Beijing, (possibly also at the following IAC).

Also, a Draft Report/associated recommendations will be provided to the Chair of the HSFCG. 25 October, 2013.

Draft Report Outline

1. **Goals of the project (short term and long term)**
2. **The energetic particle environment in LEO and beyond.**
3. **Career dose limits for crews in LEO provided by:**
    a) **Canadian Space Agency**
    b) **Chinese Space Agency**
    c) **European Space Agency**
    d) **Indian Space Agency**
    e) **Japanese Space Agency**
    f) **Russian Space Agency**
    g) **NASA**

Report Outline *Continued*

Space Technology Ireland

4. **Discussion of the limits adopted by different space agencies and arguments as to whether these differences should be retained or excised.**
5. **Construction of a procedure that will allow new knowledge to be introduced regarding internationally agreed dose limits in future.**
6. **Issues that presently impede further progress (e.g., the requirement for enabling technologies including: shielding; propulsion; radiation experiments under micro-gravity conditions; etc.).**
7. **Recommendations**

spais teicneolaíocht éire teoranta
Space Technology Ireland

Go raibh maith agaibh go léir

ANNEXURE - VIII

SPACE GENERATION
ADVISORY COUNCIL

SGAC: BEYOND A NETWORK

IN SUPPORT OF THE UNITED NATIONS PROGRAMME ON SPACE APPLICATIONS

Andrea Jaime, Executive Director
Andrea.Jaime@spacegeneration.org

CONTENT

- Basic Facts to SGAC
- SGAC Products
- Current projects and endeavours

SPACE GENERATION ADVISORY COUNCIL

BASIC FACTS ABOUT SGAC

Space Generation Advisory Council

SGAC is a non-profit organisation that represents 18-35 year olds in international space policy at the United Nations, at agencies, in industry, and in academia

- Founded as a result of the 1999 UNISPACE III conference
- SGAC has had permanent observer status in the UN COPUOS since 2001 and has been a member of the UN Economic and Social Council since 2003
- SGAC has a volunteer network of more than 4,000 members in over 90 countries

SGAC Products

Example SGAC Products

- Conferences
  - Space Generation Congress (SGC)
  - Space Generation Fusion Forum
- Year-round Projects
- Pragmatic Policy Suggestions
  - Reports to United Nations Committee on the Peaceful Uses of Outer Space
  - Recommendations from Space Generation Congresses
- Scholarships
- Special Projects
  - ISECG-NASA Videos
  - IAA Study Groups
  - European Space Expo
  - Other

Space Generation Congress

- The Congress is held annually in conjunction with the International Astronautical Congress
- Allows up to 130 of our top, selected members to congregate and network with each other and top space professionals
- Delegates work together on projects
- Speakers from the world's top space organisations and companies address the Congress

Space Generation Congress

- Projects are worked on by the attendees on some of the most relevant and up and coming space topics
- 2012's themes: Agency, Industry, Society, Exploration, & Outreach
- Products are presented at the International Astronautical Congress as well as throughout the year at conferences
- SGC 2013 in Beijing, China

Space Generation Fusion Forum

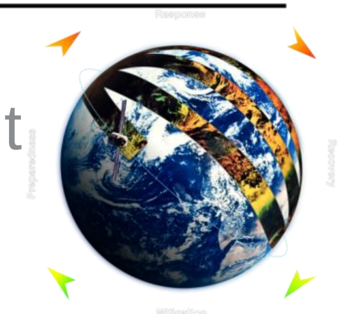
- US space event highlighting international thinking geared towards university students and young professionals
- Held in conjunction with the National Space Symposium
- 50 top young adults from 20 countries from various areas of space – government, industry, & academia
- Panel discussions moderated by top international space sector leaders
- Output reported at the AIAA's Space 2012 and at the National Space Symposium
- Over $20,000 in scholarships awarded

SPACE GENERATION ADVISORY COUNCIL

Current Projects and Endeavours

Current Projects

- Near Earth Objects (NEO)
- Space Safety & Sustainability (SSS)
- Youth for GNSS (YGNSS)
- Space Technology and Disaster Management (STDM)



Current projects

- Small Satellites
- Commercial Space
- Space Law

SPACE LAW
PROJECT
GROUP

Voice in Policy

- SGAC working groups support UN Action Teams (e.g., Action Team 14 on NEOs)
- SGAC produces space policy papers and advice – (e.g., Recommendations from the Space Generation Congress and Youth Space Vision Report)
- SGAC informs UN COPUOS and UN Office of Outer Space Affairs of its activities and ideas

Benefits to Members

- Becoming involved in and apply their work towards today's top space issues in a broader setting
- Voicing their opinions
- Access to **scholarships**
- Building leadership skills
- Connecting with current and future international space leaders

THANK YOU!

www.spacegeneration.org

twitter.com/sgac

www.facebook.com/spacegeneration

www.youtube.com/spacegeneration

IAC 2013 ANNEXURE - IX
SYMPOSIA UNDER COMMISSION III

- **Commission III responsible, for the following Symposia:**
  - **A5 "Human Exploration of the Moon and Mars" (4 Sessions)**
  - **C3.1 "Space Based Solar Power Architecture.." (1 Session)**
  - **D3 "Building Blocks for Future Space Exploration.." (4 Sessions)**
  - **D4 "Vision and Strategies for the Far Future" (4 Sessions)**
- **Average 10 papers for 13 sessions.**

IAC 2013 SYMPOSIA

A5. HUMAN EXPLORATION OF SOLAR SYSTEM

A5.1	HUMAN LUNAR EXPLORATION	15 Abstracts
A5.2	HUMAN MARS EXPLORATION	11 Abstracts
A 5.3 B 3.6	HUMAN & ROBOTIC EXPLORATION	16 Abstracts
A 5.4 D2.8	BEYON EARTH – MOON SYSTEM	11 Abstracts
C 3.1	SPACE BASED S OLAR POWER	16 Abstracts

IAC 2013 SYMPOSIA

D3 BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION

- **D3.1 STRATEGIES & ARCHITECTURE - 13 Abstracts**
- **D3.2 SYSTEMS & INFRASTRUCTURE - 11 Abstracts**
- **D3.3 NOVEL CONCEPTS & TECHNOLOGIES - 22 Abstracts**
- **D3.4 SPACE TECHNOLOGY & SYSTEM MGT - 13 Abstracts**

IAC 2013 SYMPOSIA

D4 VISIONS & STRATEGIES FOR FAR FUTURE

- **D4.1 NOVEL CONCEPTS & TECHNOLOGIES - 26 Abstracts**
- **D4.2**
- **E6.4 GLOBAL PUBLIC / PRIVATE INITIATIVES - 2 Abstracts**
- **D4.3 SPACE ELEVATOR DESIGN - 8 Abstracts**
- **D4.4 SPACE ACTIVITIES TO SOLVE GLOBAL SOCIETAL CHALLENGES - 9 Abstracts**

IAC SYMPOSIA 2014

- New Criteria and rule for Commission Membership applied
- Change of Coordinators / Session Chairs implemented, if required
- Symposia consolidated to be complementary to past/future studies carried out by the commission
- Main changes to be confirmed after Commission meetings
- A5 focused on Human Mars Mission and Cislunar Space
- D3 not changed with emphasis on Nuclear Propulsion
- D4, New session on Space Natural resources created
- C 3.1 not changed

ANNEXURE - X

IAA COMMISSION III

REPORT TO SAC

Paris, 18 March 2013

Content List

Commission Proceedings

- 2 Commission meetings held on the 18th March:

  -> Restricted, to discuss Commission internal issues

  -> Open, to discuss all Commission issues
- Leadership discussed regularly the status of the actions to insure completion
- Co-operation to foster involvement of Young professional in the Academy achieved in December 2012: The Commission established an agreement with the Space Generation Advisory Council (SGAC) selecting 3 members of SGAC for participating in 3 Study Groups.

  (ei.3.14,3.15, 3.16)

  -> SGAC News from SGAC web-site
- **The International Academy of Astronautics (IAA) has selected nine SGAC members to join their Study Groups**
- 8 February, 2013

Status of On-going Studies (1/3)

- **SG 3.10 “Technologies for Interstellar Precursor Missions”**
  -> SAC/BoT Approval, December 2012
  -> Publication by IAA, TBC
- **SG 3.9 “Private Human Access, Vol I: Sub-Orbital”**
  -> Two IAA Symposia organized 2008,2011
  (proceedings published in Acta Astronautica)
  -> New Co-Chair identified for the report finalization
  -> Draft completed , end May 2013,
  -> VC Study Review, June/July 2013
  -> SAC/BoT Approval, August 2013
  -> Publication by IAA, Oct./Nov. 2013

Status of On-going Studies (2/3)

- **SG 3.13 “Assessment of the Technology Feasibility and Challenges of the Space Elevator Concept”**
  - -> Final Draft to the Commission, March 2013
  - -> VC Study Review, May/June 2013
  - -> SAC/BoT Approval, August/Sep. 2013
  - -> Publication by IAA, Dec. 2013
- **SG3.14 “Private Human Access to Space – Vol. 2: Orbital”**
  - -> Study Approved, August 2012
  - -> Meeting to be held on the 20th March at IAA HO
  - -> First Draft available for next HoA Summit, October 2013
  - -> Publication, 2014/15

Status of On-going Studies (3/3)

- **SG3.15 "Long Term Space Propellant Depot"**
  -> Study Approved, August 2012
  -> Meeting to be held on the 21st March in ESA HO
  -> First Draft available for next HoA Summit, End 2013
  -> Publication, 2015

- **SG3.16 "Global Human Mars Reference Mission and Technologies"**
  -> Study Approved, August 2012
  -> Meeting to be held on the 19th March
  -> First Draft available for next HoA Summit, October 2013
  -> Completion, 2014/15

- **SG3.17 "Space Mineral Resources – Challenges and Opportunities"**
  -> Study approved in November 2012
  -> Team to be completed
  -> Draft to be completed in 2014

New Studies

- Proposals generated by the Human Spaceflight Coordinating Group and attached to the Commission III:
  - **SG3.18 "Possible International Protocol to handle Crisis/Emergency of Astronauts in Low Earth Orbit"**
  - **SG3.19 "Feasibility study of Standardized Career Dose Limits in LEO and outlook for BLEO"**
  - **SG3.20 "Expanding Options for Implementing Planetary Protection during Human Space Exploration"**

-> Study approved by SAC in March 2013

-> Teams under completion

-> Drafts to be completed by October 2013

-> Final Report by 2014

Symposia organized by the Commission

IAC 2013

- Commission III responsible, within IAC12, for the following Symposia:

-> A5 “Human Exploration of the Moon and Mars”(4 Sessions)

-> C3.1 “Space Based Solar Power Architecture..” (1 Session)

-> D3 “Building Blocks for Future Space Exploration..”(4 Sessions)

-> D4 “Vision and Strategies for the Far Future” (4 Sessions)

- Average is 6 papers for 13 sessions to be presented

Symposia organized by the Commission

IAC 2014

- New Criteria and rule for Commission Membership applied
- Change of Coordinators/Session Chairs implemented, if required
- Symposia consolidated to be complementary to past/future Studies carried out by the Commission
- Main Changes to be confirmed after Commission meetings:
  - A5 focused on Human Mars Mission and Cislunar Space
  - D3 not changed with emphasis on Nuclear Propulsion
  - D4, new session on Space Natural resources created
  - C3.1 not changed
- Details of the 2014 Symposia are in Annex 1

Scientific Activity Plan 2013/15

- Cosmic Studies to be published:
  - SG3.9, SG3.10, SG3.13 in 2013
  - SG 3.14, SG3.16 in 2014
  - SG 3.15, SG 3.17, 3.18, 3.19, 3.20 in 2015
- Draft of SG 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 3.20 available in support of HoA Summit

- IAA Conferences will be used to present preliminary SG status and reccomendations

- Thematic Symposia will be proposed for 2013/14, after discussion within the Commission, ei. Space Mineral Resources, Interstellar Technologies

Increased support to Commission Activities

- Participation to the activities is open to all technical professional world wide especially for the Study Groups just initiated.
- Young Professionals are welcome since there is a need of fresh “blood” to bring new ideas to the Studies and prepare the future Academicians.
- Beside the 10 official Members of the Commission, the position of Expert should be created, by IAA, for internationally recognized professionals participating in the Commission activities but not yet appointed Academician.

Future Trends

- Commission III is planning to create new opportunity for Members, Experts and Young professionals by the creation of virtual forum.
- The virtual forum would be created, first, at the level of the Study Groups just initiated in order to allow interaction of the participants during all year.
- The possibility to join the Commission face--to-face meetings, in a virtual fashion, will be also investigated

Annex I (1/2)

IAC 2013 Symposia

- A5 “Human Exploration of the Moon and Mars”

  Coordinators: C.Sallaberger, W.Mendell (To be replaced)

  - A5.1 “Near Term Strategies for Cislunar/ Lunar Surface Infrastructures” (Change)
  - A5.2 “Human Mission to Mars, Reference mission/technologies” (NEW)
  - A5.3 Joint session on Human and Robotic Partnership (No Change)
  - A5.4 “Going Beyond the Cislunar System:Libtation Point, NEOs (Change)

Annex I (2/2)

IAC 2013

- C3.1 “Space Based Solar Power Architetture…” (No change)

- D3”Building Blocks for Future Space Exploration and development”   (No change)
- D4”Visions and Strategies for the far future”
  - D4.1 “Novel Concept and Technologies” (No change)
  - D4.2”Space Mineral Resources” (new)
  - D4.3 ‘’Space Elevator Feasibility and Technologies” (No change)
  - D4.4 ‘”Contribution of Space Activities to Solving Global Societal Challenges” (No change)