
April 3-4
Virtual Conference
A Ribbon to the Stars
—Uniting Earth and Space with Gravity and Grace
Space Elevator
Zoom Link
Meeting ID: 284 702 0609
Passcode: 167882
April 3
9:00
Peter A. Swan
Modern-Day Space Elevators Define Permanent Space Access Transportation Infrastructures
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Dennis Wright
Constraints placed on the tether material by a tether climber
10:00
Larry Bartoszek
A possible Space Elevator climber
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Stephen Cohen
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17:00
Adrian Nixon
Space Elevator Tether Materials
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John Knapman
Research into the Space Elevator
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Nicola Pugno
Design of space elevator cables
19:30
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Modern-Day Space Elevators Define Permanent Space Access Transportation Infrastructures

Peter A. Swan

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Chief Architect, ISEC | Board Member, Space Elevator Development Corporation

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Research into modern-day space elevators has revealed transformational capabilities that could establish a permanent space transportation infrastructure. Unlike traditional space access methods, space elevators offer routine, large-scale, and environmentally friendly transport to geostationary orbit (GEO) and beyond, with potential capacities ranging from 30,000 to 170,000 tonnes per year. The space elevator system, featuring electric tether climbers instead of rocket propulsion, aims to eliminate space debris in low Earth orbit (LEO) while providing sustainable access to the Moon, Mars, and the broader solar system. This presentation will explore the architectural evolution of space elevators, their commercial and governmental applications, and the emerging competitive ecosystem that could redefine space logistics.

BIOGRAPHY. Dr. Peter A. Swan has been a leading figure in the advancement of space elevator technology for over two decades. As Past President and Chief Architect of the International Space Elevator Consortium (ISEC), he has played a key role in conceptual studies, technology roadmaps, and international collaboration. He has authored, co-authored, and edited numerous books and research papers on the subject.
Dr. Swan earned his Ph.D. in Mechanical Engineering from the University of California, Los Angeles (UCLA). He is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA) and the British Interplanetary Society (BIS) and is a full member of the International Academy of Astronautics (IAA). His work continues to shape the vision for space elevators as a transformative infrastructure for future space exploration and commercial space activities.

Constraints placed on the tether material by a tether climber

Dennis H. Wright

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A friction-based space elevator climber of 20 tons imposes several constraints on the material used to build the tether. This study focused on the 2D materials graphene and hexagonal boron nitride. While the tensile strength of the single-crystal materials appears sufficient, the coefficient of friction of graphene is deficient, as is the shear strength of both materials. Enhancing these properties may be possible either during material production or through post-processing. Many other bulk material parameters remain unknown and require further measurement.

BIOGRAPHY. Dennis Wright retired in 2020 as a physicist in the Elementary Particle Physics Department at SLAC National Accelerator Laboratory, Stanford. He earned his Ph.D. in nuclear physics from the University of Illinois at Urbana-Champaign and has contributed to over 20 experiments, including low-energy photo-nuclear reactions, strong interaction studies at Los Alamos, the ATLAS experiment at CERN, and the SuperCDMS dark matter search.
As Vice President of ISEC, Dennis focuses on simulating the physics of the space elevator, including its dynamics, electrodynamics, and radiation effects. He is also a member of the International Academy of Astronautics and the National Space Society.
He and his wife, Linda, live in Santa Fe, New Mexico.

A Possible Space Elevator Climber

Larry Bartoszek

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This talk describes a reference conceptual design (RCD) for a 20-tonne commercial climber for a space elevator. Starting with fundamental principles, I will develop a mathematical model for the climber drive train, followed by a CAD model using commercially available components where possible. I will also highlight areas where these assumptions break down, particularly concerning high-torque, low-mass motors. The project exemplifies the relationship between project requirements and the resulting machine design.

BIOGRAPHY. Larry Bartoszek holds a dual degree in Mechanical Engineering and Physics from the University of Illinois and is a Licensed Professional Engineer in Illinois. He is Vice President of the International Space Elevator Consortium (ISEC) and a Space Ambassador for the National Space Society (NSS). He is also a member of ASME, AWS, ASM International, the Chicago Society for Space Studies, and NSS.

As the owner of Bartoszek Engineering, Larry specializes in mechanical designs for nuclear and high-energy physics research worldwide, working with national laboratories, universities, and governments. His work ranges from table-top devices to machines up to 120 tons. A history of his projects is available here.

Larry began working on the Space Elevator as a hobby in 2004, developing conceptual designs for climbers based on "The Space Elevator" by Edwards and Westling. He has presented at multiple Space Elevator Conferences, including Washington, DC (2004), Seattle (2013), and ISEC Annual Conferences in Chicago (2023, 2024). His original climber designs have been published in ISEC study reports. In April 2021, he joined the ISEC Board of Directors and was elected Vice President in July 2024.

A webinar he presented for ISEC in April 2022 can be viewed here.

Space Elevator Dynamics

Stephen Cohen

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I will discuss the fundamental dynamic behavior of a space elevator, essential for its design. This presentation will first discuss how the various space elevator components are sized. Then, the natural frequencies and mode shapes of the system will be examined. The effects of a climber on the structure will then be presented. Finally, an overview of the orbits available to satellites launched from the space elevator will be shown.

BIOGRAPHY. Stephen Cohen was the co-recipient of the National Ken Spencer Award for Innovation in Teaching and Learning in 2018. He obtained his bachelor’s and master's degrees in mechanical engineering at McGill University and published the first ever comprehensive analysis of the mechanics of space elevators. He has industry experience designing space payloads and has spent more than a decade teaching the fundamentals of physics. He is the author of *Getting Physics: Nature's Laws as a Guide to Life*.
Further information about Stephen Cohen is available at https://www.vaniercollege.qc.ca/

Space Elevator Tether Materials

Adrian Nixon

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I will discuss the key component of the space elevator—the tether. This continuous material must extend from the Earth's surface to space, supporting the ascent and descent of the climber. The material must be both incredibly strong and lightweight. Until recently, ultra-strong materials were either insufficiently strong or could not be manufactured at the necessary length and speed, stalling progress on the space elevator concept.
This presentation will outline the challenges involved and review recent advancements in one-dimensional (1D) and two-dimensional (2D) materials. Several candidate materials are now being actively considered for the space elevator tether. I will discuss the state of the art in manufacturing these materials, both in laboratory settings and at industrial scale, including production length and speed. The key question will be explored: *Is a tether made from these materials feasible?*

BIOGRAPHY. Adrian Nixon is a founding director of Nixene Publishing Ltd and Editor of the Nixene Journal, a publication that provides insight into graphene and 2D materials. Nixene Publishing is based at the Graphene Engineering Innovation Centre (GEIC), University of Manchester, UK.
He is also a director of the International Space Elevator Consortium (ISEC) and an advisory council member of Stellar Modal, the space transportation association.
A Chartered Chemist and Member of the Royal Society of Chemistry, Adrian has over 20 years of experience in the chemical industry, working in R&D, technical service, and global market information management. After earning an MBA from the University of Bradford, he transitioned to consulting before refocusing on graphene and 2D materials in 2014.
Adrian and his team have contributed to key reports on graphene manufacturing and its economic impact, delivered briefings for NASA, and conducted rare interviews with leading scientists in the field.
He is married and enjoys walking in the countryside.

StellarModal Transportation Association

NixeneJournal

ISEC

Research into Space Elevators

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I will discuss the feasibility of space elevators, focusing on the balance of forces that make them viable, and the challenges posed by Earth's atmosphere, such as winds and other environmental hazards. Additionally, I will explore the opportunities for utilizing space elevators, particularly at geosynchronous altitude (GEO) and the apex, where microgravity conditions enable the construction of large structures, including interstellar spacecraft. The rotational velocity at the apex can facilitate spacecraft launches to Mars, while secondary tether systems may enhance velocity for travel across the solar system and beyond.

BIOGRAPHY. Dr. John Knapman graduated with a first-class degree in Mathematics from the University of Cambridge, England, in 1969. He earned a Ph.D. in Artificial Intelligence from the University of Edinburgh, Scotland, in 1976.

He joined IBM United Kingdom Ltd. in 1969, where he held various roles in customer support, product development, and research, eventually serving as a senior product architect. After taking early retirement in 2003, he focused on refining the Launch Loop concept, originally proposed by Keith Lofstrom. In 2010, he joined the International Space Elevator Consortium (ISEC) and became Director of Research in 2012.

Dr. Knapman has authored 10 refereed journal papers, 15 conference papers, and two book contributions. He has also co-authored five ISEC reports, which are available at www.isec.org. In previous work, he filed 24 patents.

Asteroid Mining

Volodymyr Usov

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BIOGRAPHY. Volodymyr Usov is a tech entrepreneur with a demonstrated history of working in the aerospace industry and additive manufacturing. He is a member of the International Academy of Astronautics, former Chairman of the State Space Agency of Ukraine, and the author of numerous publications covering the latest space technology and on-orbit

Space Elevator Construction Concept – The Future of Transportation

Yoji Ishikawa

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The space elevator is a future transportation system that can carry people and goods into space. I will share Obayashi Corporation's *Space Elevator Construction Concept*. This system consists of a 100,000 km-long cable extending from the equator, with climbers traveling up and down along it. My talk will cover the configuration of the space elevator's elements and its construction process. Once established, this system will enable affordable space travel, accelerate the development of the Moon and Mars, promote Solar System exploration, and expand the space industry.

BIOGRAPHY. Dr. Yoji Ishikawa has made significant contributions to space engineering and science, focusing on "space" and "life." After earning his Ph.D., M.S., and B.S. in aerospace engineering from The University of Tokyo, he conducted postdoctoral research in astrobiology at Rensselaer Polytechnic Institute and NASA Ames Research Center in the U.S.

At Obayashi Corporation, one of Japan’s largest construction firms, Dr. Ishikawa has worked on space-related research, including Lunar and Mars bases, life support systems, space agriculture, and the space elevator. He is a member of the International Academy of Astronautics (IAA).

Design of space elevator cables

Nicola Maria Pugno

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In this talk I will review our proposals [1-10] for the flaw tolerant design of a real thus defective space elevator cable, suggesting potential applications with advanced materials (see prof. Ruoff's talk) and also for asteroid mining (see Dr. Usov's talk).

10 Selected References

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BIOGRAPHY. Nicola Maria Pugno (born 4 January 1972) is a mechanical engineer, and physicist, with PhDs in fracture mechanics and biology. He is a professor of solid and structural mechanics at the University of Trento and of materials science at the Queen Mary University of London (part-time). He has been selected as member of several committees such as the technical and scientific committee of the Italian Space Agency and as plenary speaker in several international workshops, events, and conferences, such as at Falling Walls, at the World Economic Forum, and at the European Parliament invited by the European Research Council as well as –as opening plenary speaker– at the quadrennial International Conference of Theoretical and Applied Mechanics. Since 2011, he has received several grants also from the European Union within the Excellent Science pillars for both fundamental science and high-tech transfer, that he is developing for several high-tech industries. He has received the A. A. Griffith Medal and Prize in 2017 and the Humboldt Research Award in 2022.

Can the Space Elevator Tether be made (now?)

Rodney S. Ruoff

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The *specific tensile strength* of the space elevator tether (as provided to me by colleagues and thus through discussions with them) has me finding that these (and only these) materials (all must be single crystal, SC)) with each being essentially free of defects or flaws, **could *in principle* be used in a <u>1-meter wide, 100,000 kilometer long, and multi-micron thick tether</u>**: diamond (SCD), cubic boron nitride(SCcBN), and layers of graphene (SCG) and/or hexagonal boron nitride (SChBN), single crystal graphite (SCgraphite) or single crystal hexagonal boron nitride (SC-hboronnitride). If it were possible (*it has not been reported, to date*) to synthesize large area and 'proper geometry' SCD, SCcBN, SCgraphite, SChboronnitride, they would be of *great interest*—this could include as ultralong fibers/filaments that are woven or stacked to achieve the tether geometry. Alas, these options do not now exist.

Two options are available <u>now</u>: *layers* of SCG *and/or* of SChBN. I briefly describe 'large area' SCG grown on Cu(111) [1], Ni(111) [2], and Cu-Ni(111) [3] foil substrates in our group, and of multilayer SChBN through collaboration of our group with Prof. Hyeon Suk Shin's group [4]; and I briefly describe growth of SCG and SChBN on ~500-nm thick M(111) (M=Cu or Ni) films on 'c-cut sapphire', i.e., $Al_2O3(0001)$ wafers—by others.
Pondering the extraordinary size scale of the tether led me to several schemes to produce SCG (SChBN) at such scales. I present several production methods and what I perceive as likely to be the *bottleneck(s)* to producing the tether material (to a physical chemist—'bottlenecks' or 'chokepoints' in my manufacturing schemes for the tether are akin to 'rate determining step(s) in chemical reactions). *Support by the IBS is appreciated.*

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BIOGRAPHY. Rodney S. Ruoff, UNIST Distinguished Professor (The Departments of Chemistry and Materials Science, and The School of Energy Science and Chemical Engineering), directs the *Center for Multidimensional Carbon Materials* (CMCM), an Institute for Basic Science Center (IBS Center) located at the Ulsan National Institute of Science and Technology (UNIST) campus. Prior to joining UNIST in 2014, he was the Cockrell Family Regents Endowed Chair Professor at the University of Texas at Austin from September, 2007. He earned his Ph.D. in Chemical Physics from the University of Illinois-Urbana in 1988, and was a Fulbright Fellow in 1988-89 at the Max Planck Institute für Strömungsforschung in Göttingen, Germany. He was at Northwestern University from January 2000 to August 2007, where he was the John Evans Professor of Nanoengineering and director of NU's *Biologically Inspired Materials Institute*, and did research at the Molecular Physical Laboratory, SRI International for 6 years after being a postdoctoral fellow at IBM TJ Watson Research Center. Further information about Rod is at https://en.wikipedia.org/wiki/Rodney_S._Ruoff and http://cmcm.ibs.re.kr/ .