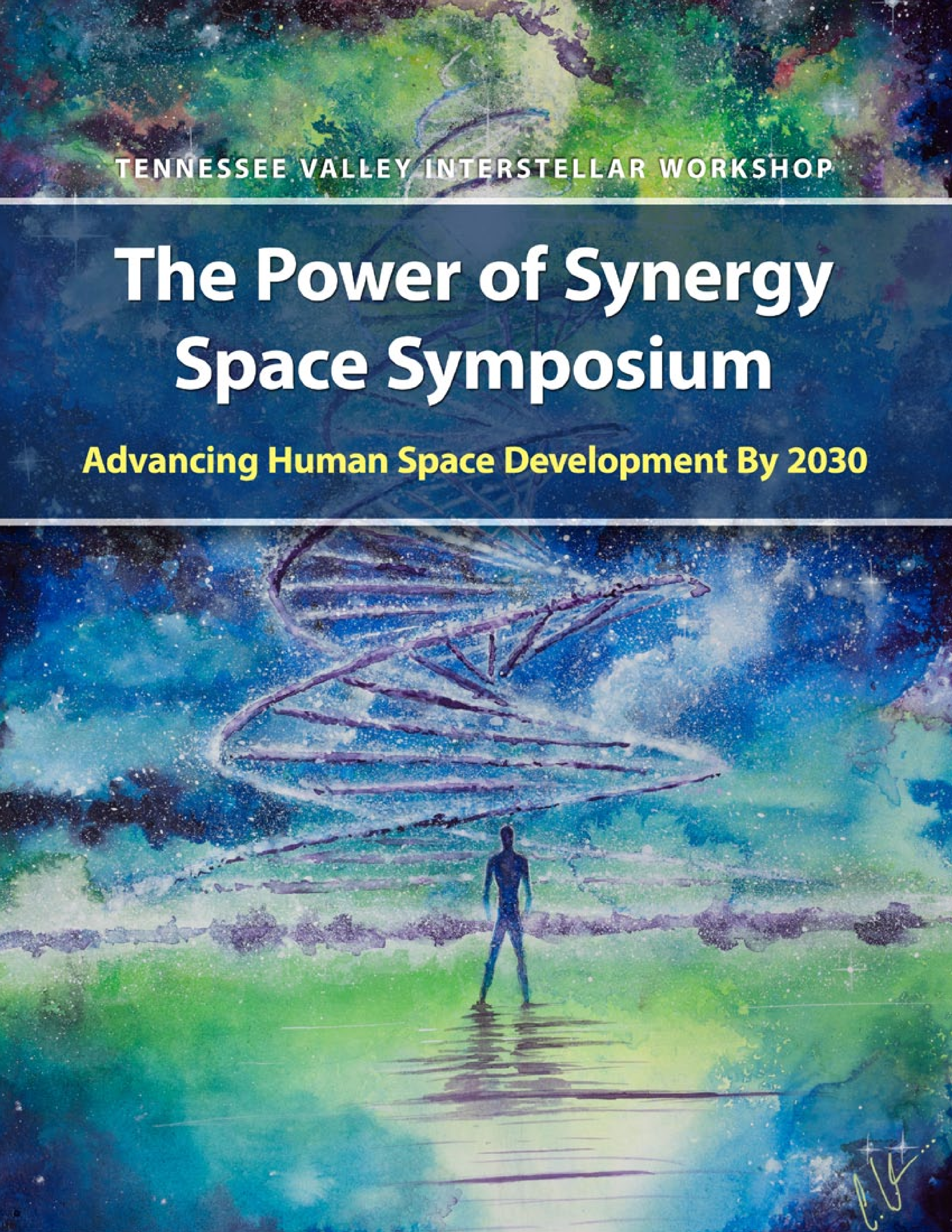
TENNESSEE VALLEY INTERSTELLAR WORKSHOP

The Power of Synergy Space Symposium

Advancing Human Space Development By 2030



❖ *Cover art by Chris Wade* ❖

Summary Final Report

TENNESSEE VALLEY INTERSTELLAR WORKSHOP

The *Power of Synergy* Space Symposium

Advancing Human Space Development by 2030

October 23–25, 2018

RCIG

RATHER CREATIVE INNOVATIONS GROUP, Inc.

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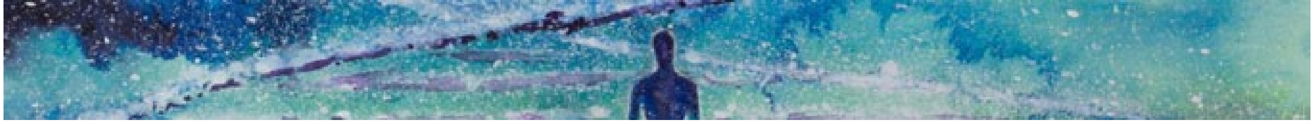

The Power of Synergy Space Symposium
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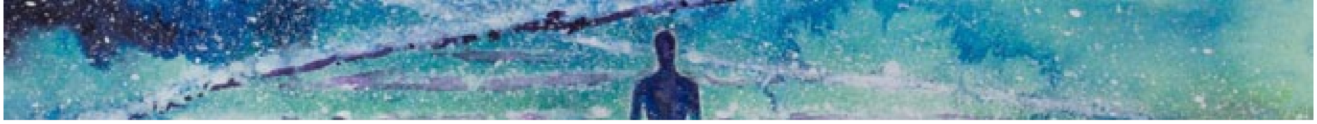


The *Power of Synergy* Symposium

Promoting a Grand Decadal Transformation for US Leadership in Space Development and Commercialization

1.0 Executive Summary: A Sense of Urgency

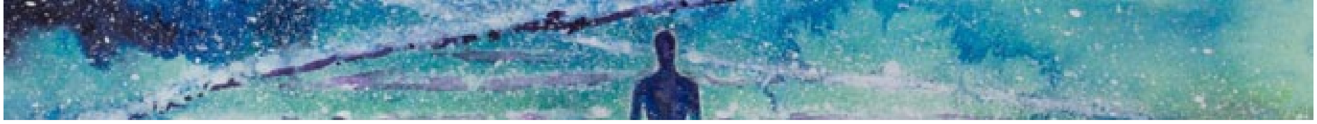
The world has reached a transformative moment having profound implications for the near future. Governments and private enterprises in several of the world's largest economies have realized that new potentials now exist for achieving dominance in both space commercialization and major defense capabilities. Visionary leadership and aggressive "technology push" can establish permanent advantages for nations that seize the opportunities. Strategies are clearly possible that will result in rapid growth of Gross Domestic Products while simultaneously enabling dominant military advantages. ***Traditional leadership roles of the United States are clearly in jeopardy.***

At the time of this writing, numerous technology-driven space development opportunities and motivations are emerging that can be either very dangerous or highly constructive. There are clear lessons from past history: During the first half of the twentieth century, the world suffered through the two worst wars in human history. The future was forever changed, however, when amazing new discoveries from arcane realms of academic physics suddenly gave birth to nuclear weapons that ended World War II in 1945. By 1960, remarkable breakthroughs in rocket engineering enabled rapid deployment of Intercontinental Ballistic Missiles (ICBM). Human annihilation on a global scale had become quite possible. The subsequent forty years of the Cold War became a very expensive international stalemate. Mutual Assured Destruction (MAD) is a real possibility that, fortunately, has held traditional human malevolence in check ever since – but at a tremendous cost. ***Half a century ago, totally unanticipated technology innovations changed the entire future of the world in a decade.***

The Apollo moonshot fifty years ago was an inspired forty-billion dollar triumph for peaceful civilian space exploration that captured worldwide respect for U.S. technology leadership -- also in a decade. This occurred amidst the enormous trillion dollar costs of deploying more than eight thousand ICBMs and numerous nuclear missile submarines. Remarkably, both Apollo and the ICBM deployment led directly to huge growth of the U.S. Gross Domestic Product (GDP). Burgeoning aerospace companies and spinoff technology industries ultimately generated dominant global market advantages for the United States. Similar transformative opportunities now exist in the realm of human and robotic development of outer space based upon synergistic applications of mature, but not fully exploited technologies. ***The logical path forward is to seize presently underestimated opportunities for major space progress to catalyze the traditional U.S. culture of creative innovation and global leadership.***

This report describes the results of the *Power of Synergy space symposium*, held in Oak Ridge, Tennessee October 23–25, 2018. The primary objective of the meeting was to validate highly innovative concepts for accelerating large-scale U.S. development and commercialization of outer space before 2030. Results of the meeting summarized in this report are intended to inspire thoughtful synergistic alignment and prioritization of key transformative elements now being developed in excellent work by multiple government agencies and private industries. ***This is the mission of the synergy concept. With inspired top-down management, it can enable critically important U.S. space development and commercialization before 2030 without vast new fiscal commitments beyond existing plans.***

The eponymous *"Power of Synergy"* describes the vital catalytic element that must be applied. Hugely important but nascent concepts and technologies already exist that can be combined in new ways, where the sum becomes much more than the parts. Diverse not-yet-exploited technologies can be marshaled together serendipitously – enabling greatly enhanced capabilities for national security, fiscal growth,



infrastructure improvement, and human engagement, both simultaneously in space and on Earth. Thus, the October 2018 symposium framed a roadmap for synergy and technology superiority that will sustain U.S. space development as the hallmark of inspired innovation leadership on Earth and beyond.

The symposium findings emphasize that ***inspired multi-agency government collaboration with private industries can greatly accelerate progress***. In March 2018, NASA announced a relatively small new cooperative technology development effort with the U.S. Department of Energy (DOE) and related contractors. Quickly expanding upon this new beginning is fundamentally important to enable major breakthrough strategies for accelerating human space development and industrialization. ***An essential requirement is for clearly defined large-scale programs uniting NASA and the DOE Advanced Research Projects Agency-Energy (ARPA-E) to implement fully operational high-energy Nuclear Thermal Propulsion (NTP), Solar Powered Industrial Robotic Processes, and other game-changing technologies and capabilities made feasible by DOE National Laboratories working jointly with NASA and private industries.***

Major collaboration of government agencies with emerging private space industries is the vital fructifying principle, but this cannot succeed without clearly established specific goals. Defining and justifying highly innovative but logical and affordable candidate goals was thus fundamental to the success of the symposium. Three key Recommendations for Action frame a roadmap to achieve transformative human progress in space before 2030:

RECOMMENDATION 1: A Focused Program. An integrated decade-long systems-level innovative program must be defined and initiated in early 2020. It must be ***focused on the goals of space industrial development, and permanent human space habitats.*** Detailed definition of game-changing synergistic concepts and supporting technology R&D must target resources necessary to rapidly bridge the gap from research to large-scale applications. This must not be random piece-work. ***The objectives must be concisely defined, with performance requirements matched to explicit US mission goals and transformative accomplishments before 2030.***

RECOMMENDATION 2: Transformative Implementation Objectives. ***Abundant, affordable high-energy systems for space propulsion, electric power, and industrial processing are essential to successfully achieve large-scale development and settlement of space.*** High-payoff synergistic R&D investments should address topic areas identified in this report to accomplish the needed objectives in 5 to 7 years maximum. ***Major transformations can be accomplished with reasonable funding provided these decisions are specifically governed to fit the overall systems plan and concise mission objectives.*** Catalytic goals must include (1) Capturing small Near Earth Asteroids and demonstrating use of their materials to enable very safe human habitats and lucrative space industries. (2) Establishing a permanent US base at the Moon's south pole specifically to develop fully autonomous long-term life support from in-situ resources. (3) Making human round trips to Mars's two moons to establish their resources as forward bases for missions to that planet's surface.

RECOMMENDATION 3: Cooperation and Coordination. ***A key element for success is for the government's National Laboratories to transform their policies to bridge the current "valley of death" that is killing a large percentage of creative work proposed by academics, small business founders, and even employees of the National Labs who are highly competent in science and engineering but not experienced in raising several million dollars to bridge to actual game-changing applications. The success of Silicon Valley innovations must guide our strategies to industrialize space and make it profitable before 2030.*** Accelerating essential technology development to realize space industrialization and settlement before 2030 will require novel organizational arrangements, including cooperation and coordination among multiple government agencies and laboratories together with partnerships among government and private sector missions and programs. Ample support must also be given to "garage style" highly innovative startup companies inspired by these challenges.

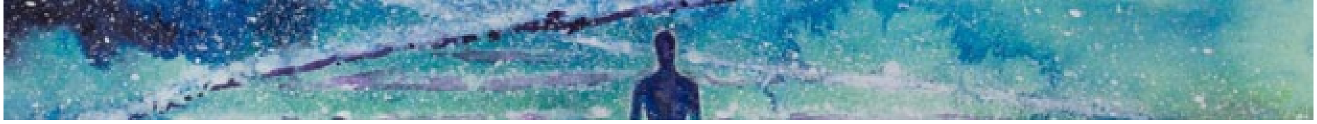
A possible roadmap emerges that can engender exponential fiscal growth while simultaneously providing national security advantages that can stabilize our troubled world during the Twenty-first Century and forever after. The United States can lead the charge again to commercialize space within a decade! Details of the symposium leading to definition of the proposed roadmap will be summarized in the remainder of this report.

1.1 Transformative Technologies and Systems Concepts

Crucial synergistic technologies and concepts evaluated at the symposium are summarized below. **Most have high Technology Readiness Levels (TRLs), not requiring decades to implement.** Mobilizing development of key materials, components, and applications (e.g., involving nuclear fuels, reactor design, and propulsion systems) must necessarily engage rapid coordinated development in existing advanced R&D facilities of DOE, NASA, and private industries.

<u>High Energy Systems for Space, Power, Propulsion, and Industrialization</u>

- **High Impulse Nuclear Propulsion and Bi-modal Power** – ***A huge step forward in compact nuclear reactor design was proved by DOD/ DARPA in the $430 Million Timberwind Particle Bed Reactor Program from 1988 to 1993. It remains the most advanced candidate technology for space propulsion. The reactors can also operate bi-modally to provide both propulsion and large amounts of electric power.*** Upper stage nuclear rockets (i.e. used only in space) can enable human trips to Mars in thirty to sixty days rather than multiple years. Nuclear propulsion is also vital for capture and engineering of small (10-meter diameter) near earth asteroids (NEA) that can facilitate construction in space of habitats safe from solar and cosmic radiation. Space Solar Power (SSP) wireless transmission stations and other major industries will be rapidly enabled by the availability of ample nuclear energy.
- **High Efficiency Wireless Power Transmission** – Efficient and affordable wireless microwave or laser power transmission is broadly applicable for space exploration and development. ***Already proven by DARPA for near-term applications, high-efficiency fiber-optic high-energy lasers (HEL) are now very mature technology that can enable megawatt-class power beaming capabilities for space power and propulsion. Ultimately, Laser Light Sail or plasma-propelled tugboats can enable crucial applications extending to interplanetary propulsion for continuous, very low-cost logistics.***
- **High Temperature Superconductor (HTSC) Applications** – This technology will radically transform all types of electrical applications when fully exploited. It has been developed for thirty years and is ready for many implementations, both on Earth and in space. ***A unique game-changing space application is Magnetically Inflated Cable (MIC) technology that can deploy from compact payloads to form very large but low-weight rigid space structures such as solar concentrators 100 meters in diameter.*** Megawatts of 3000° C solar energy at the focus of such solar concentrators can implement near-term capture of 10-meter diameter near-earth asteroids to lunar orbits, where they can provide millions of kilograms of useful materials. ***Robotic mass-production of low-cost products then becomes feasible to provide completely safe radiation shielding and centrifugal artificial gravity solutions for in-space human habitats and long-duration travel. – HTSC technologies can also be quickly developed for such "Maglev" applications as 95% efficiency surface transportation, centrifugal gravity habitats on the moon and Mars, and surface-to-space electromagnetic launch from the Earth, Moon, or Mars.***
- **Solar Power Satellites (SPS)** – Formerly regarded as "pie in the sky," high-energy space solar power using microwave or laser power beaming is now a very real transformative



possibility. Persuasive concepts already exist for in-space production and deployment of all of the SPS components. ***Combining the notions of small asteroid capture for raw materials with robotic machines for ever-expanding 3D printing production capabilities, near-term concepts are viable for diverse commercial space industries enabled by beaming efficient, totally pollution-free solar energy to Earth and to the Moon and Mars.***

<u>Enabling and Enabled Systems for Manufacturing & Resources</u>

- **Large Scale 3-D Printing for Additive Manufacturing** – The DOE Oak Ridge National Laboratory (ORNL) and its innovative manufacturing spin-offs are world leaders in this vital new technology. ***There are direct links to in-space manufacturing possibilities using readily available regolith materials from asteroids and on the moon. Inexpensive robotic mass production of vast numbers of essential industrial products will lead directly to exponential business growth, finally making space the province of the New Gold Rush!***
- **Space Resources Utilization** – The extraction, processing and utilization of in-situ space resources is both enabled-by, and enabling-for ambitious large-scale but affordable space energy and human habitat systems. The resources from near-earth asteroids (NEAs), the Moon (particularly the detected deposits of volatiles within the permanently shadowed cold-traps at the lunar poles) and beyond (e.g., Mars and its moons) can be utilized only with the availability of large-scale, affordable energy. ***These enabling resources can be readily and economically employed for many vital applications such as food production and waste reprocessing for human habitats, self-sustaining reusable transportation systems, and fabrication of industrial components for Space Solar Power Satellites.***
- **Lightweight Large Aperture Optics** – Various paths lead directly to the possibility of building enormous solar concentrators and optical telescopes in space at vastly lower cost than present comparable ground-based technologies. ***Solar concentrators will enable efficient capture and industrialization of near-earth asteroids. Large aperture optics will lead directly to efficient laser propulsion and power beaming throughout our solar system.*** As capabilities mature, (e.g. see HTSC/MIC above) they will enable kilometer diameter telescopes capable of imaging and diagnosing of earth-like planets around nearby stars. Evaluation of possible life on exo-planets and the Search for Extraterrestrial Intelligence (SETI) will be greatly augmented. Importantly, the science of cosmology will massively advance understanding of the origin and destiny of our universe.
- **Regenerative / Self-Sufficient Habitation Systems** – Affordable and abundant energy, the transformation and utilization of space resources, 3D printing of systems, etc., are essential to enable the permanent expansion of humanity beyond Earth. ***Today's space systems are energy-starved and as a result depend on continuous supply from Earth of consumables such as air, water and food, as well as regular waste removal. All of the systems currently in use must be radically improved to enable humanity to move permanently beyond low Earth orbit. Megawatts of low cost energy provide the key to success in the decade before 2030.***

1.2 Executive Summary General Observations

There was widespread agreement among speakers and participants at the symposium that the world has reached a transformative moment having profound implications for the near future. Governments and private enterprises in several of the world's largest economies have realized that potentials for dominance in both defense and space commercialization are now within reach. Visionary leadership and aggressive technology push can establish permanent advantages for the countries that seize the opportunities. ***Traditional leadership roles of the United States are clearly in jeopardy.***

Realization of even a fraction of the technologies and concepts considered at the meeting will open limitless horizons for breakthrough human accomplishments in space by 2030. ***This promising outcome depends upon rapid exploitation of transformative technologies focused on specific goals for human development of outer-space resources, leading directly to near-term propitious worldwide consequences.***

Historically, the percentage of the US population that left the comforts of the East Coast was very small; but the effects of having an open frontier were practically, psychologically and culturally very significant: The open frontier provided vast new resources and opportunities. ***Historians cite the open frontier as a major factor in US fiscal and cultural development as an adventurous, individualistic, creative society. Opening space for full-scale development will provide the same advantages for our future.***

High Energy synergistic technologies are at the heart of everything we might accomplish. New initiatives to combine the resources of DOE, DOD, NASA, and Private Industries are fundamental requirements for the US to lead the world in space development. Other countries will dominate if near term synergistic capabilities are not vigorously pursued in the decade prior to 2030.

2.0 Motivations and Methodology for the Symposium

The meeting was proposed and managed by astrophysicist entrepreneur Dr. John D.G. Rather, President of RCIG, Inc., who served as General Chair. Dr. Dean S. Hartley III, noted expert in operations research, served as Co-Chair. Speakers and participants included leaders from government agencies, national laboratories, academia, and private space industries, as well as notable visionaries and prominent media enthusiasts involved in transforming the future. ***The entire meeting had a single plenary structure. All speakers were invited experts having well established credentials in their related fields. They were selected and challenged by a common belief that accelerated human and robotic large-scale commercialization of space is both possible and achievable before 2030.***

2.1 The Reality of Decadal Transformations

Oak Ridge, Tennessee is the Secret City that changed the future of the world in three years during World War II—and literally won the war. In 1942 the city was founded in an obscure location that had huge amounts of electric power available from the newly created Tennessee Valley Authority (TVA), which gave birth to the national power grid. The purpose of Oak Ridge was to create and produce essential nuclear materials for the top-secret Manhattan Project. The production processes required more electricity than the city of New York. Building the city and four hundred large industrial buildings in eighteen months required drafting eighty thousand workers to work within the fenced top-secret hundred square miles of the of proto Oak Ridge complex. After the war, the huge technology facilities were transformed into what has become the Department of Energy's Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex—both $1-2 Billion per year research and national security operations.

For 75 years, Oak Ridge has been a hotbed of breakthrough science and engineering creativity. It is now being celebrated as a key part of the Manhattan Project National Historic Park created in 2015. Extending south from Oak Ridge, the Tennessee River valley embraces huge industrial growth in Chattanooga, Tennessee, and burgeoning high-tech development in Huntsville, Alabama. Huntsville hosts NASA Marshall Space Flight Center (MSFC), the birthplace of the Saturn rockets that took us to the moon in 1968, as well as the U.S. Army Aviation & Missile Command and many supporting industries.

Implementation of the Apollo moonshot in only seven years from 1962 to '69 depended upon creation of a new Government administrative Agency, support from many government branches and laboratories, and integration with the most advanced capabilities of U.S aerospace industries. Hundreds of thousands of people were employed nationwide in the most exciting project in human history. In the 1960s, the newly formed National Aeronautics and Space Administration unified the best elements of existing government and business functions; and NASA still enjoys the greatest popularity of any government agency.

As we celebrate the 85^{th} anniversary of the creation of TVA, the 75^{th} of the Manhattan Project, and the 50^{th} of the Apollo Moonshot, it is inspiring to consider how all three of these amazing decadal transformations were born in the Tennessee Valley and flourished beyond all historical precedents. ***All three examples paid for themselves hundreds of times over within two decades by catalyzing industrial and fiscal growth opportunities that had never been anticipated.*** Now, half a century later, our *Power of Synergy* symposium was created by a group of experienced forward-thinking innovators in Oak Ridge to make the case for inspired cooperation among multiple government agencies and private industries to greatly accelerate space exploration before the year 2030. ***The United States can lead the charge again to commercialize space within a decade!***

"The Power of Synergy" ***describes the vital catalytic element that must be applied to realize a new Transformative Decade. Hugely important concepts and technologies already exist that can be combined in new ways, where the sum becomes much more than the parts. Diverse under-exploited technologies can be marshaled together to greatly accelerate human progress in space while—serendipitously—promoting on Earth greatly enhanced national security, fiscal growth, infrastructure improvement, and human engagement.*** Thus our October 2018 symposium endeavored to generate a roadmap for synergy and technology superiority that will once again make U.S. space development the hallmark of inspired innovative leadership. ***Specific precisely goal-oriented collaboration between government agencies and private space industries is the vital necessity.***

2.2 Symposium Structure

The Tennessee Valley Interstellar Workshop (TVIW), a tax-exempt educational corporation, is the creation of highly motivated people in Oak Ridge and Huntsville who are inspired to develop meaningful steps toward a space-faring civilization. At the request of Dr. John Rather, General Chair of our symposium, TVIW hosted the meeting in Oak Ridge October 23–25, 2018 at the Y-12 National Security Complex *New Hope Center* (Figure 1). Rather's company, RCIG, Inc., and its symposium Executive Committee greatly appreciate the expert help of TVIW to make the meeting a major success.

Figure 1. Y-12 National Security Complex *New Hope Center*

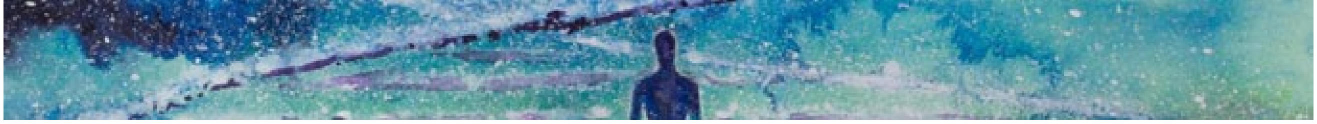
In keeping with TVIW's traditional zest for promoting cross-cultural understanding of the vision of space development, the speakers and Theme leaders in the symposium included well-known scientists, engineers, inventors, astronautics experts, government administrators, and private entrepreneurs from space-faring industries. Several notable science fiction authors and prominent media enthusiasts also participated in panel discussions of great interest to attendees and the post-symposium web audience.

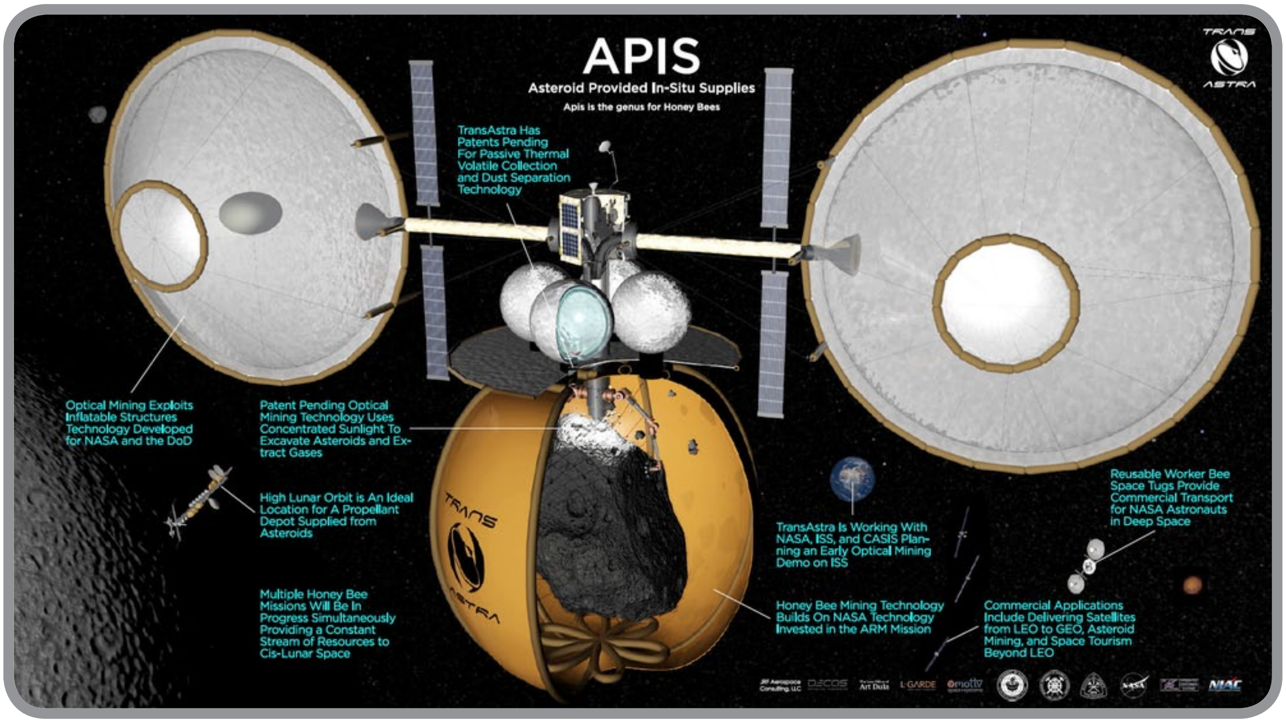
The three-day meeting presentations included four distinguished keynote lecturers and thirty plenary talks. Over a hundred participants from many related fields provided a rich backbone for the overall discussions. At breaks and lunch hours, a novel arrangement used ten Topical Tables with changing posted subjects to attract and encourage all participants to move about and exchange ideas with diverse new friends and colleagues. Questions for the experts were submitted in writing and discussed openly by the Synthesis Panels at the end of each of the four main Themes. Figure 2 shows a group photo of many of the participants.

Figure 2. Participants in the 2018 *Power of Synergy* Symposium

The next section of this report provides a chronicle of all of the talks in the order of their presentation. Speakers and subject titles are shown together with page references to more detailed biographical information provided in a subsequent section. TVIW website YouTube link, https://tviw.us/tviw-symposium-on-the-power-of-synergy/, provide very important understanding of the detailed case for accelerated decadal progress developed throughout the meeting. ***The videos of all talks, with their excellent supporting slides, comprise a vitally important record that we hope will be widely referenced by interested readers***. You will note that in the chronicle list of talks, individual links and QR patterns are provided for each talk that enable immediate audio and video review.

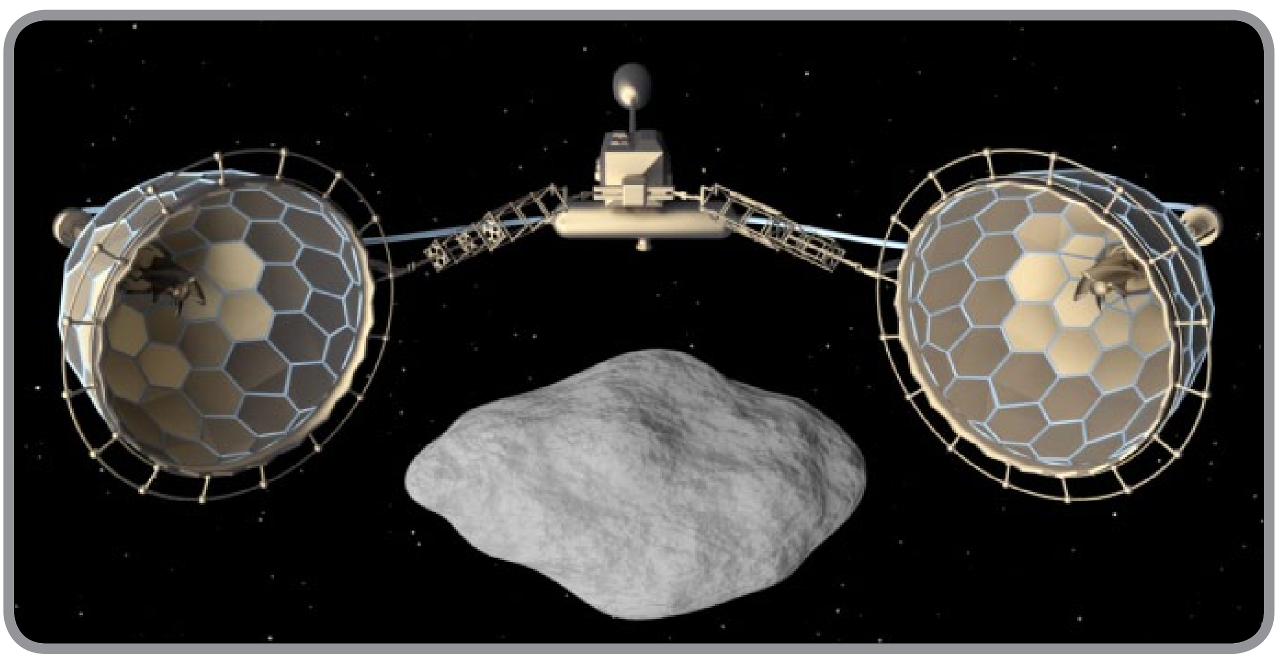
The primary goal of our TVIW symposium, The* Power of Synergy*, is to generate a new vision and integrated plan for development and economic use of outer space within a decade. Courageous leadership with an inspired national team is the vital key. The resulting new jobs, infrastructure industries, and major fiscal growth will insure that the United States continues and expands its traditional roles of creating great innovative futures for the world.





Solar powered NEA capture and harvesting concept by Joel Sercel, Trans Astronautica Corporation.

Small Near-Earth Astoroids:
Key to Fast Decadal Commercialization



Nuclear PBR NEA capture and harvesting concept by John DG Rather, RCIG, Inc.© *Art by John Lane*

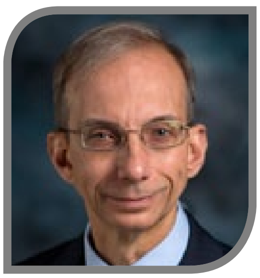
DAY 1 | Welcome and Introduction Keynotes

Administrivia—Dean S. Hartley

Symposium Welcome—John D. G. Rather—https://youtu.be/zKazdKMg3GE

TVIW Welcome—Edward "Sandy" Montgomery

Keynote Addresses:



The Reality of Decadal Transformations

Morgan Smith (bio pg.30)

CEO Y-12 National Security Complex

https://youtu.be/WGEAAv2Gzwo

ARPA-E Roles in Transformative Progress

John Vonglis (bio pg. 31)

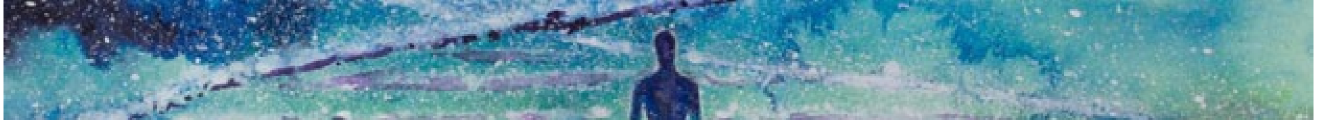
DOE CFO and Acting Director, ARPA-E

https://youtu.be/CFvvy7CBSss

The Power of Synergy Symposium Challenge: Human Commercial Development of Space Before 2030

John D. G. Rather (bio pg. 51)

https://youtu.be/5CUP8Jg6AK4



THEME 1: Large-Scale Space Development and Human Expansion

Eminent authority on space technology, John Mankins, chaired the first topical theme.

Large-Scale Space Development, The Moon is a Stepping Stone

John Mankins, Chair (bio pg. 34)
Founder and President, Mankins Space Technology, Inc
President, Artemis Innovation Management Solutions LLC
https://youtu.be/kk24GA8EEB0

Living and Working in Space, an Astronaut's Perspective from Seven Missions and Sixty-Six Days in Space

Franklin Chang Diaz (bio pg. 35)
Chairman & CEO, Ad Astra Rocket Company
https://youtu.be/7gwk-zyqU5Y

John Mankins' Tribute to Dr. James Powell, Creator of Particle Bed Reactors and Superconducting MagLev for Space Development

In memorium James Powell, 1934-2019 (bio pg. 36)
https://youtu.be/SXEBimJvN-E

Advanced Exploration with Nuclear Thermal Propulsion

Michael Houts (bio pg. 37)
Nuclear Research Manager,
Marshall Space Flight Center, NASA
https://youtu.be/1CTTOTDlg4M

Capture and Game-Changing Development of Small Asteroids

Joel Sercel (bio pg. 38)
Founder, Trans Astronautica Corporation (TransAstra)
https://youtu.be/yGkHM3umMYU
animation https://youtu.be/yGkHM3umMYU?t=2097

Theme 1 Summary Findings

Following are high-level findings from Theme 1 presentations and subsequent discussions:

- The Moon is the primary stepping-stone for America's (and humanity's) expansion into Space.
- Abundant and Affordable Energy for Propulsion and Power is essential for large-scale exploration, development and settlement of space.
- Advanced Propulsion Systems are essential (e.g., high-energy, high-efficiency, refuelable, reusable Nuclear Thermal, Solar Thermal, Plasma, Beamed Power).
- Large scale use of space resources (from the Moon and small near-Earth asteroids) is both possible and essential for affordability and commercialization.
- High-Temperature Superconductors – particularly employed in electromagnetic systems – enable a variety of transformative future breakthroughs.
- Exceptionally-Large Optical Systems – for example, employing the concept of Magnetically Inflated Cables (MIC) – would enable a wide range of prospective applications.
- Prospects for much lower cost launch from earth are possible. (MagLifter and StarTram)
- Development and settlement of space requires a variety of novel organizational arrangements: Cooperation and Coordination among Government Agencies, and Partnerships with Private Sector players.

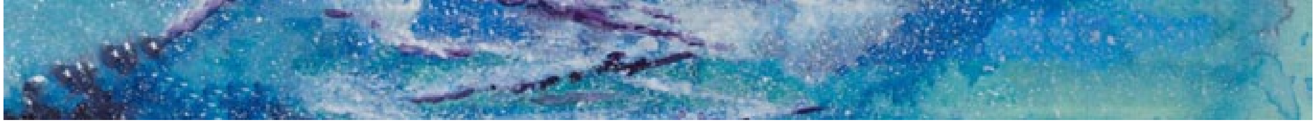
High Energy synergistic technologies are at the heart of everything. New initiatives to combine the resources of DOE, DOD, NASA, and Private Industries are fundamental requirements for US world leadership in space development. Other countries will dominate if near term synergistic capabilities are not vigorously pursued by the US.

THEME 2: Catalytic and Affordable Synergistic Breakthrough Concepts and Technologies

Figure 3. Jason Derleth Introducing a Speaker

The second theme of the symposium discussed identification of breakthrough candidate technologies. Topics were highly diverse, including both innovative enabling technologies and prospective applications. Topics included an overview of the NASA Innovative Advanced Concepts Program (NIAC); Particle Bed Reactor Nuclear Thermal Propulsion & Power; Directed Energy Propulsion & Power Beaming; Environmental Control & Life Support; Large-scale 3D Printing & Complex Structures; Persistent Space Platforms; Advanced Plasma Propulsion; A Possible Solution to the Problem of Low-Gravity Health Threats; and highly innovative Small Satellite Concepts.

The following pages summarize sequentially the presentations made to support this theme.



NASA HQ Director Innovative Advanced Concepts Program (NAIC): Breakthrough Objectives and Examples

Jason Derleth, Chair (bio pg. 39)
https://youtu.be/qe0POqb1FIk

Particle Bed Reactor Nuclear Thermal Propulsion and Power

Jonathan K. Witter (bio pg. 40)
Advanced Technology Programs, BWXT
https://youtu.be/TierVQMkXN8

Appraisal: Advanced PB Reactors and Space Power Systems

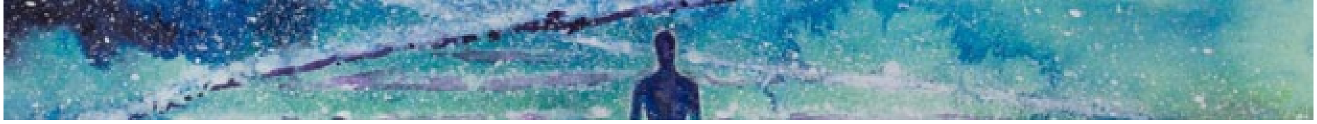
Roger Lenard (bio pg. 41)
Former DARPA PBR Program Manager
https://youtu.be/NAqYnSrYRiw

Directed Energy Propulsion and Power Beaming: Mature Technology Now Ready for Game-Changing Exploitation

Phillip Lubin (bio pg. 42)
University of California, Santa Barbara
https://youtu.be/LXti61oIhzQ

Environment Control and Life Support Major Challenges

Robert Bagdigian (bio pg. 43)
Marshall Space Flight Center, NASA
https://youtu.be/XwpiJkdCd9Y



DAY 2 | Keynote and Theme 2 continued

KEYNOTE

Oak Ridge National Laboratory

Alan Icenhour, PhD, (bio pg. 32)
Associate Laboratory Director (ALD)
for the Nuclear Science and Engineering Directorate
https://youtu.be/wEoEjX45T8s

Large-scale 3D Printing and Complex Structures

William Peter (bio pg. 44)
Director, Manufacturing Demonstration Facility
Oak Ridge National Laboratory
https://youtu.be/svbj7nw7dIc

Persistent Space Platforms and Bootstrapping an In-Space Economy

Jeffrey Slostad (bio pg. 45)
Director, Strategic Missions
Tethers Unlimited Inc
https://youtu.be/m8lu-1Gk5qI

VASIMR Plasma Propulsion

Mark D. Carter (bio pg. 46)
Senior Vice President,
Ad Astra Rocket Company
https://youtu.be/RuqsdVI2SGI

Problem of Low-Gravity and Physiology: A Possible Solution

Ken Roy (bio pg. 47)
Y-12 National Security Complex
https://youtu.be/E5CFJRP6Mes

Small Satellite Concepts at The Aerospace Corporation

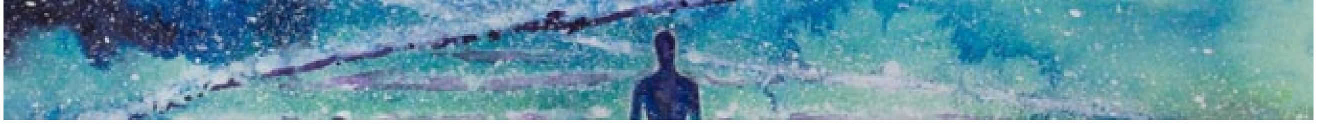
Siegfried Janson (bio pg. 48)
The Aerospace Corporation
https://youtu.be/9i6wDdRBl3g

Figure 4: Theme 2 Panel, from left: Ken Roy, Sieg Janson, Bob Bagdigian, Phil Lubin, Jason Derleth, Jeff Slostad, Roger Lenard and Rick Rather at the podium.

Theme 2 Summary Findings

The following are some notable high-level findings resulting from Theme 2 presentations and subsequent discussions:

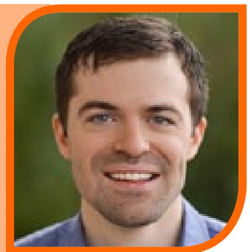
- Defining novel concepts and supporting technology R&D can result in dramatic and rapid advances in capabilities – and even organizational goals.
- Advanced in-space propulsion is critically needed and can be realized rapidly – particularly in the areas of Nuclear Thermal Propulsion (nearer term), and Plasma Propulsion (longer term).
- Wireless power transmission (WPT) is needed and doable. Laser-based wireless power transmission is perhaps the only solution in the foreseeable future to the visionary goal of sending fast probes to our outer solar system and beyond. It also can deliver logistics to humans in transit.
- Advanced environmental control and life support systems (ECLSS) are crucial to human space exploration.
- Superconductor systems (e.g., MagLev) may provide a novel solution to major challenges of mitigating human physiological responses to low gravity.
- Advanced in-space manufacturing – particularly employing 3D printing – will have diverse important applications in future space systems and major commercial product development.
- Numerous innovative spacecraft and space systems concepts should be pursued in parallel– including novel applications of nano- and thin-membrane satellites.



THEME 3: Transformative Decadal Plan

The third symposium Theme (Theme 3) discussed the question of how to pursue a transformational decadal plan for space systems and technologies. Topics discussed included: Making Big Ideas a Reality; Putting together a Transformative Decadal Plan; Thoughts on the *Power of Synergy*; An Example Decadal Plan for Affordable, Abundant Solar Energy; and How to Integrate a Decadal Plan.

The following paragraphs briefly summarize the several presentations made as a part of this theme.



Making Big Ideas Into Realities

Matt Hollingsworth, Chair (bio pg. 49)

CEO, Carta Healthcare
Founder, Nucleation Labs
https://youtu.be/HrDc4bQ5jPo

Transformative Decadal Plan Near Term Synthesis Solutions

James T. Early (bio pg. 50)

Lawerence Livermore National Lab, ret
https://youtu.be/YoOinZbvE8s Decadal Plan

Examples of Powerful Synergistic Technological Concepts

John D. G. Rather (bio pg. 51)

Founder, President RCIG, Inc.
Sisyphus Energy Inc.
https://youtu.be/816qPE-4Low

The Critical Importance of Affordable and Abundant Solar Energy

John Mankins (bio pg. 52)

President, Artemis Innovation Management Solutions LLC
Founder and President, Mankins Space Technology, Inc.
https://youtu.be/KLway0Pd2xc

How To Integrate It?

Dean S. Hartley III (bio pg. 53)

Hartley Consulting
Military Operations Research Society
https://youtu.be/zMNLDPRZcos

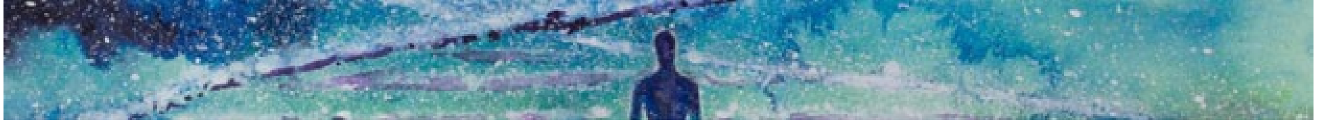
Theme 3 Synthesis—https://youtu.be/oFe3mOB6C-0

Figure 5: Theme 3 Panel from left, John Mankins, Jim Early, Matt Hollingsworth, John Rather and Dean Hartley.

Theme 3 Synthesis Panel Findings

The following are some high-level findings resulting from Theme 3 presentations and subsequent discussions:

- Innovations in planning, management and applications of novel technologies and solutions are needed as much as new concepts. Bridging the "gap" in programs / funding from research to large scale applications is especially crucial.
- Focusing a decadal plan on the goals of human exploration, commercial development and long-term settlement is essential to achieving the timely transformation of America's capabilities in space.
- A prime example where transformation within a decade can be realized is that of Solar Power Satellites – bringing together synergistically wireless power beaming, space resources utilization, modular "von Neumann-type" construction, and other catalytic technologies to enable affordable and abundant energy for use in space and for terrestrial markets.
- Effective integration of R&D activities, design studies, engineering, ongoing programs and projects, etc. will be essential to realize the transformation in capabilities and the visionary goals that can be achieved within a decade – such as a settlement on the Moon, a human Mission to Mars and the large-scale commercial development of space.



DAY 3 | Theme 4 and Wrap Up

Theme 4: Ultimate Paths to the Future—Science Fiction to Fact Relationships

Figure 6. Catherine Asaro Introduces Theme 4

The final theme, “Ultimate Paths to the Future,” stepped back from detailed discussions of specific technologies and missions to consider the broad question of how our current visions of the future have been framed and where future visions might spring. Topics discussed included: Plausible Approaches for Enabling Human Population of Our Solar System; Sustaining Progress Beyond the Obvious; What is meant by “Human”; Repurposing Asteroids; Thoughts on the History of the StarShip Concept; Quantum Universe Properties; and, Faster than Light Synergies.

The following lists briefly summarize the speakers and presentations for this theme.

KEYNOTE

Enabling the Future of Human Space Flight

Mark Uhran (bio pg. 33)

Former Director/Assistant Associate Administrator,
International Space Station Division, NASA Headquarters
https://youtu.be/l52PfE90Rsc

Ultimate Paths to the Future (Science Fiction to Fact Relationships)

Catherine Asaro, Chair (bio pg. 54)

https://youtu.be/1BGp3u3fgSw

Sustaining Progress Beyond the Obvious

Marc G Millis (bio pg. 55)

https://youtu.be/5OPHjO9tKxE

What We Mean by "Human"

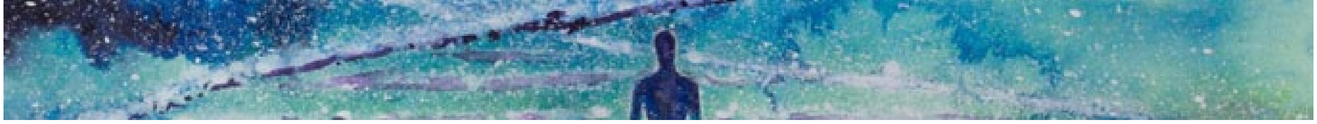
David Brin (bio pg. 56)

https://youtu.be/vfOLBxJh15c

CARPE:DIEM (Captured Asteroid Re-Purposing Experiment)

Arlan Andrews, Sr. (bio pg. 57)

https://youtu.be/F8ycA2gevTI



Quantum Universe Properties?

Ruth Kastner (bio pg. 58)

https://youtu.be/pVx6kFW26m4

Synergies to Faster than Light

Buck Field (bio pg. 59)

https://youtu.be/p0BDETDY77g

Thoughts on the History of the StarShip

Allen M. Steele (bio pg. 60)

https://youtu.be/HgThhrBbpuQ

Theme 4 Synthesis Findings

The following are some of the findings resulting from the Theme 4 presentations and discussion:

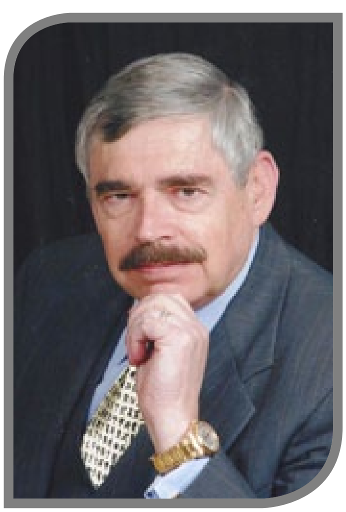
- Many of the ideas discussed during the *Power of Synergy* symposium began as science fiction.
- Science Fiction authors nurture visions of humanity's future in space. This resonates with the importance of imagining scientific and technological advances.
- A prime example is the long-term history of spaceships and how they influence our visions of what is possible now, and what might be our dreams.
- Although still speculative, research continues into new understanding of quantum physics that may someday find applications in future space systems.

Overall Symposium Summary Findings and Recommendations

Figure 7. Dean Hartley Closing the Symposium

Both in preparation for, and during the three days of the *Power of Synergy* symposium, many hundreds of hours of time from leading experts and organizations from across the US came together to consider the central question: "how can we realize a fundamental transformation in American space capabilities and enable within a decade humanity's permanent expansion beyond the boundaries of Earth?"

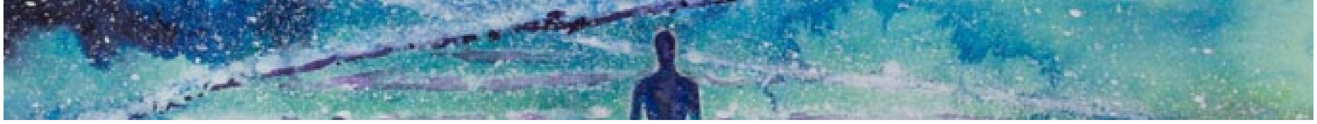
During the course of the symposium, there were numerous opportunities for discussion and "synthesis" of the information presented. (Findings from each Theme were summarized previously.) The following is the integrated set of Key Findings from the October 2018 *Power of Synergy* symposium.



A Preliminary Synthesis Report

Dean S. Hartley, PhD

Symposium Co-Chair Dean Hartley closed the symposium with a review of the presentations and preliminary results of these synthesis discussions. He noted that each presenter was passionate about his or her presentation, yet still the science and engineering need to be tested, the results compared with others for cost, efficiency, synergy, etc. He also noted that the technologies presented in the symposium were not exhaustive, that other technologies are relevant and must be considered as we go forward. Hartley described the scientific functions of science fiction (in addition to the entertainment function) as the search for novel technologies, the exploration of concepts, examination of ramifications, performance of gedanken experiments, and the search for loopholes in physics. He restated our goal of broadening the option space for technologies and synergies.



Overarching Findings

- ***Abundant, affordable high-energy systems are essential (including both power and propulsion) to the large-scale exploration, development and settlement of space***.

Key Areas of Technology and Systems

- Advanced propulsion (e.g., high-energy, high-efficiency, refuelable, reusable) is essential to the large-scale exploration, development and settlement of space; including nuclear thermal propulsion (nearer term), and plasma propulsion (longer term). (Themes 1, 2)
- Affordable high-energy nuclear and solar power systems are essential.
- Wireless power transmission (WPT) is needed and feasible for a range of applications in space and for clean energy to Earth. Laser-based wireless power transmission is perhaps the only solution in the foreseeable future to the visionary goal of sending probes beyond our solar system. (Theme 2, 3)
- High-temperature superconductor systems – particularly employed in electromagnetic systems – can enable a variety of future systems, including artificial gravity and exceptionally low-cost launch from Earth. Such innovations are needed to realize permanent human settlement. (Theme 1, 2)
- Solar Power Satellites provide one example where transformation within a decade can be realized – bringing together synergistic wireless power beaming, modular "von Neumann-type" production systems, space resources utilization, and other technologies to enable affordable and abundant energy for use in space and for terrestrial markets. (Theme 3)

Enabled and Enabling Technologies and Systems

- Use of natural space resources from the moon and small NEAs is both feasible and necessary for space exploration, development and settlement. (Theme 1, 3)
- Advanced in-space manufacturing – particularly employing 3D printing – will have diverse applications in future space systems. (Theme 2)
- Modular "von Neumann-type" systems enable novel space applications of hierarchal 3D advanced manufacturing such as large Space Power Systems. (Theme 2, 3)
- Advanced environmental control and life support systems (ECLSS) will be crucial to human space exploration in the future. (Theme 2)
- Exceptionally-large optical systems – for example employing the concept of Magnetically Inflated Cables (MIC) – would be enabling for a wide range of prospective applications. (Theme 1)

Programmatic Considerations

- The Moon is the primary stepping stone for America's (and humanity's) expansion into Space. The United States must accept the leadership challenge. (Theme 1)
- Focusing a decadal plan on the goals of exploration, development and settlement is essential to achieving the timely transformation of America's capabilities in space. (Theme 3)
- Focused investment in identifying and defining novel concepts and supporting technology R&D can result in dramatic and rapid advances in capability – and even organizational goals. (Theme 2)
- Many of the ideas discussed during the *Power of Synergy* symposium began as science fiction. Science fiction is very important for developing visions of humanities future in space. This is illustrated effectively by the long-term history of the concept of the spaceship – and how these visions influenced our concepts of what is possible and what should be our dreams. (Theme 4)
- Innovations in planning, management and applications of novel technologies solutions are needed as much as new concepts. Bridging the "gap" in programs / funding from research to applications is especially crucial. (Theme 3)

- Accomplishing essential technology developments and demonstrations to realize space exploration, development and settlement will require a variety of novel organizational arrangements – including cooperation and coordination among government agencies, partnerships among government programs and private sector missions and programs, and engagement with international players.
- Effective integration of R&D activities, design studies, engineering, ongoing programs and projects, etc. will be essential to realize the transformation in capabilities and the visionary goals that can be achieved within a decade – such as a settlement on the Moon, a human Mission to Mars and the large-scale development of space. (Theme 3)

Recommendations for Action

Based on the findings above, the following recommendations for action are offered.

Recommendation 1: A Focused Program
An integrated decadal systems and technology program should be undertaken -- focused on the goals of exploration, development and settlement, including the identification and definition of novel concepts and supporting technology R&D, and including resources necessary to "bridge the gap" from research to applications.

Recommendation 2: Essential Technology Area(s)
Abundant, affordable ***high-energy systems are essential*** to the large-scale exploration, development and settlement of space (including both power and propulsion); the above investment should address the topic areas identified above.

Recommendation 3: Cooperation & Coordination
Accomplishing essential technology developments and demonstrations to realize space exploration, development and settlement will require a variety of novel organizational arrangements – including cooperation and coordination among government agencies, partnerships among government programs and private sector missions and programs, and engagement with international players.

Closing Thoughts

"*There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy*"—
Hamlet I.5: 159-167

The 2018 TVIW *Power of Synergy* symposium has advocated strongly for focused, synergistic technology developments that can dramatically expand the options for America's future in space. By pursuing the synergies, and preserving a sense of wonder about the opportunities accomplishments like those of the Apollo era are still possible. Realization of even a fraction of the technologies and concepts discussed here by 2030 will open limitless horizons for human enterprise and accomplishment in space. This promising outcome depends upon rapid exploitation of transformative technologies focused on human development of outer-space resources, actually having near-term propitious consequences for worldwide stabilization.

Naysayers contend that no significant fraction of the population will leave the Earth, so that claims that this is an important effort are specious. The history of the growth of the US refutes this contention by analogy. The percentage of the US population that left the comforts of the East Coast was very small; but the effects of having an open frontier were practically, psychologically and culturally very significant: The open frontier provided vast new resources and opportunities. Historians cite the open frontier as a major factor in US cultural development as an adventurous, individualistic, creative society. Opening space for full-scale development will provide the same advantages for our future.

Energy is at the heart of everything we might accomplish.

The Power of Synergy — Roadmap to 2030

Expand Cooperation of NASA, DOE, DOD, and Private Industry to Expedite:

High Energy Propulsion and Power

There is now well-documented understanding that nuclear Thermal Propulsion is essential for safe human exploration of Mars. Less appreciated is the game-changing importance of NTP for developing and commercializing Cis-Lunar space. Similarly, solar electric power is taken for granted, but the huge benefits of very high energy solar power are not fully understood.

The synergies advocated in our decadal transformation plan will enable

- Powerful, reusable, fast, and safe transportation;
- Immense free solar energy;
- Power Beaming to deliver large amounts of energy where needed;
- Hyper-efficient super-conducting magnetic systems.

This program can yield crucial, affordable commercial opportunities with huge implications for evaluating large-scale space development.

- **In-Space Testing:** Robust facilities must be created on Earth and in space to develop, test, and refine the technologies.
- **Operational:** Emergent Commercial opportunites include space tourism, jobs, robotic production, deliveries of goods to and from the Earth, and exponential business growth. All will lead to economic growth that will exponentiate rapidly.

In-Situ Space Manufacturing

Requires true "Moonshot" fast development of (1) Additive (and subtractive) 3D manufacturing capabilities on-and-off-Earth; (2) AI Robotics to handle difficult and/or dangerous processes such as rapid capture and mining of small Near Earth Asteroids; (3) Self-Replicating Solar Powered Machines to massively proliferate identical component elements, for example to build Space Solar Power to sell affordable clean energy to Earth.

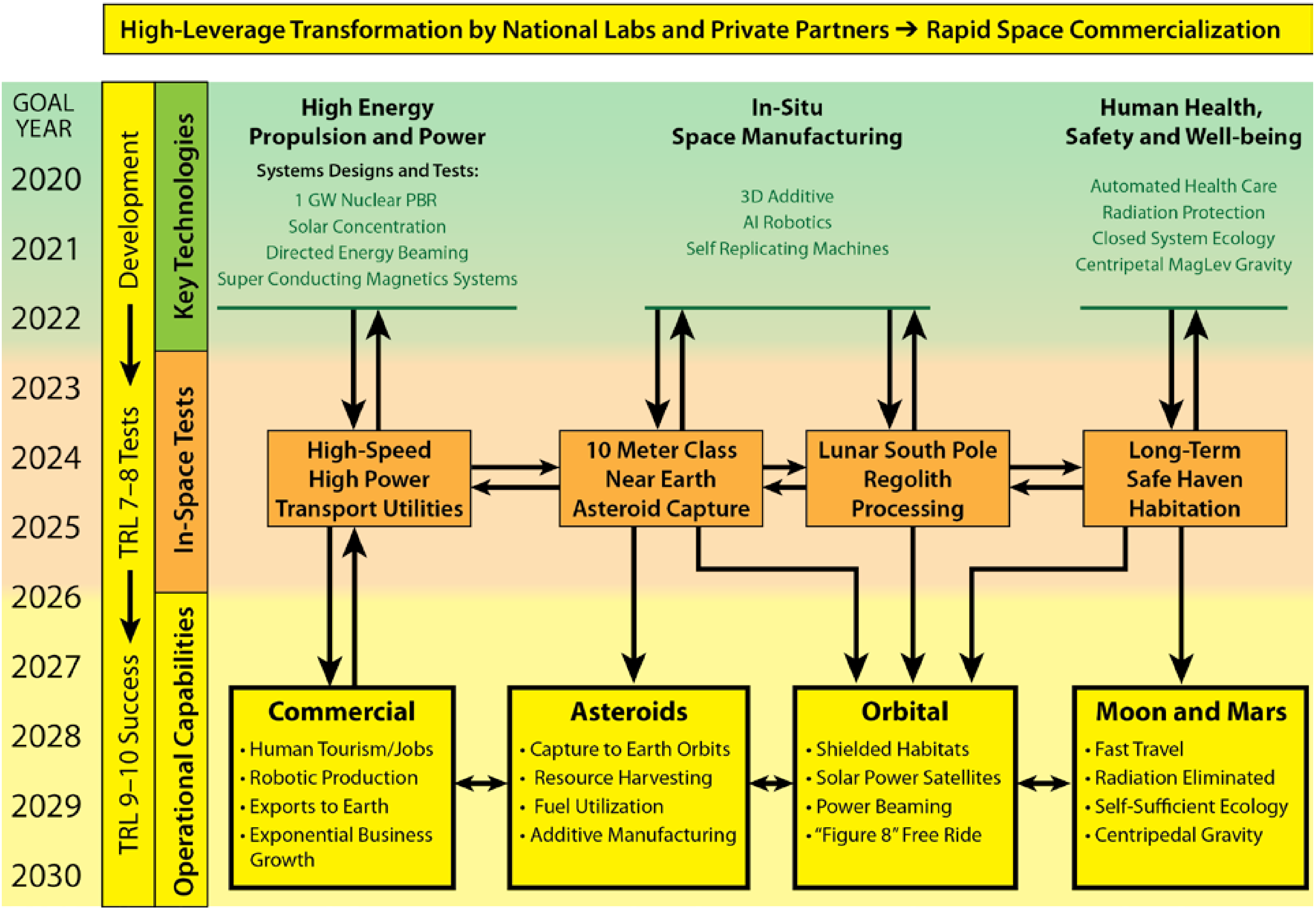
- **In-Space Production:** Fast development to capture, harvest and exploit materials in small, Near Earth Asteroids (NEA).
- **Robotic Operations:** Ten-meter diameter NEAs can be captured to Lunar orbits. Resources provide thousands of tons of fuel and materials for manufacturing.
- **Lunar Surface:** Fast development of methods for processing lunar regolith, including high energy solar beamed power.
- **Operational:** Simple production of fully shielded orbital habitats for human occupation enables creation of "Figure-8 Free Ride" regular, inexpensive transportation modes from Low Earth Orbit to Lunar Gateway.
- **Powerful Synergies:** Near-Earth asteroid and lunar regolith processing will provide cross-learning opportunities. Asteroid materials enable commercial development and the basis for long-term, completely safe habitats having radiation shielding and centripetal artificial gravity. Also "Figure 8 Free Rides" with no hazards from Van Allan and Solar radiation.

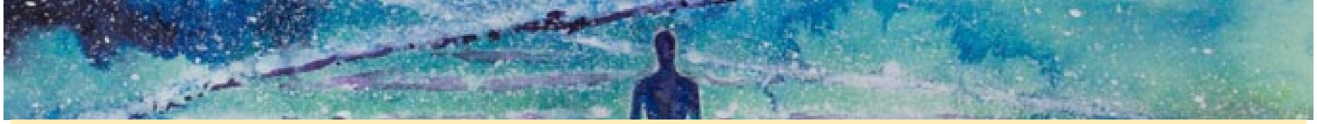
Human Health, Safety and Well-being

Automated medical diagnostics and health care can definitely be developed in a decade. Highly-efficient, completely closed-cycle human habitat ecologies are difficult but feasible with ample sources of energy. Centripetal artificial gravity for prolonged human residence is likely to be essential. Highly efficient radiation protection using materials harvested from small NEAs is self evident.

- **In-Space Testing:** Major priority must be given to technologies enabling long-term safe haven human habitation.
- **Operational:** For travel to the Moon and *especially* to Mars, we need fast travel to reduce radiation exposure and mitigate closed-system ecology problems. We need centripetal gravity to reduce health hazards both for the Mars trip and for lunar habitats.
- **Powerful Synergies:** The issues of health, safety and well-being are crucial for orbital and lunar habitats, but even more so for lengthy human space travel. Highest priority must be given to R&D and FDA-level testing of the multiplicity of challenges that must be adequately solved in the decade before 2030. Let's remember the Manhattan Project and Apollo and **JUST DO IT!**

Focused Synergistic Goals — Roadmap Summary





Power of Synergy 2030 Goals

Nuclear Thermal Propulsion

Large Aperture Optics

Large Scale 3-D Printing

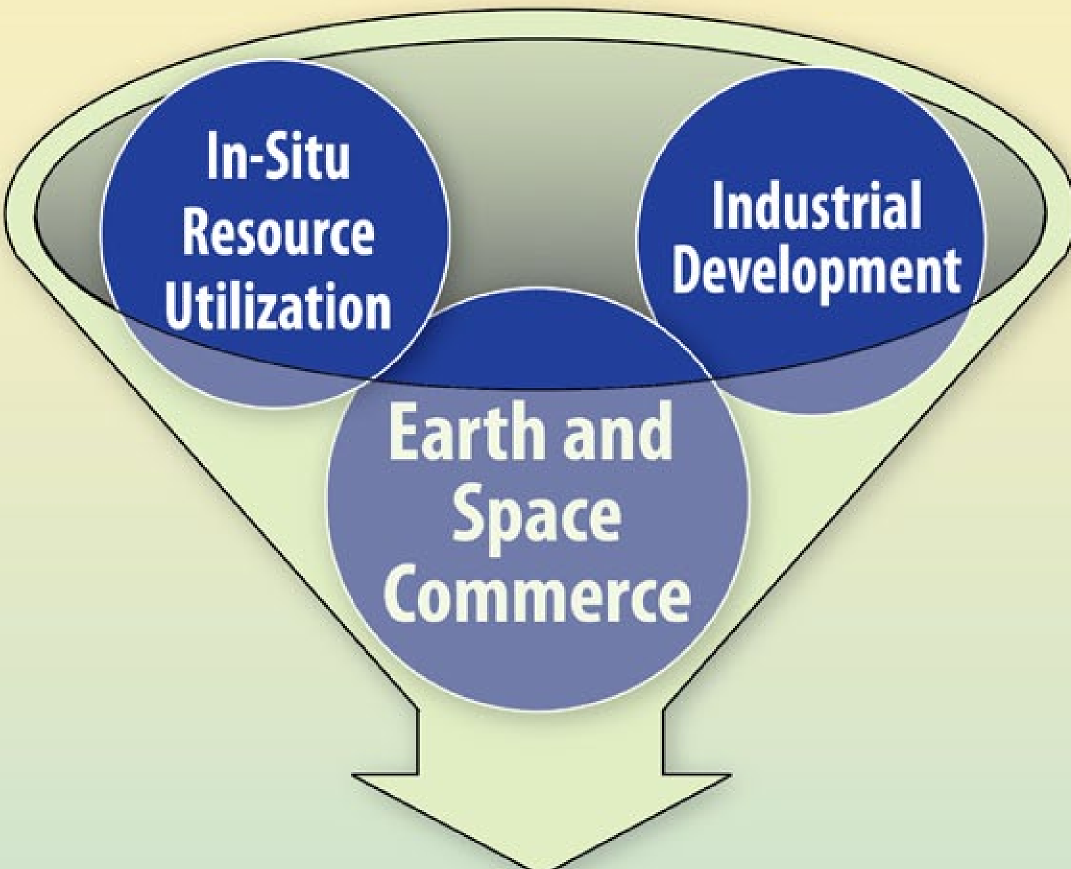
High Energy Lasers

High Energy Solar

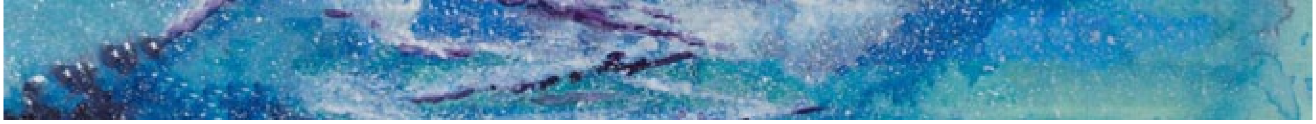
Superconducting Technology

Self-Replicating Machines

Solar Power Satellites

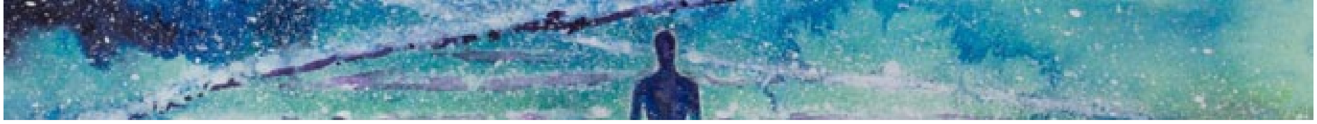


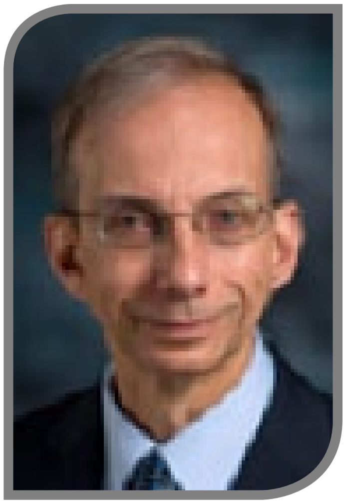
GDP Growth
Asteriod Industrialization
Moon Base Technologies
Mars Exploration



BIOGRAPHIES | ABSTRACTS

Speakers and Participants





Morgan Smith

President and CEO,
Consolidated Nuclear
Security, LLC
CEO Y-12 National
Security Complex

KEYNOTE

The Reality of Decadal Transformations

Mr. Morgan Smith, President and CEO of Consolidated Nuclear Security: Y-12 and Pantex, presented the first keynote address on Tuesday, October 23rd. His career included many years as Captain of nuclear submarines, the most advanced integrated technology systems in the history of the world. Since retiring from the Navy, he has become senior manager of the two facilities that lead the world in the production of the most advanced materials for all things nuclear.—He began by discussing three major national programs that transformed the entire future of the world: the Tennessee Valley Authority (TVA) project 85 years ago that built the national power grid, the Manhattan Project 75 years ago that won World War II, and the Apollo Program 50 years ago that got humanity to the moon. These hugely successful projects were all accomplished within a decade, and they provide powerful evidence that accelerated human development of space is possible before 2030. Morgan Smith zealously supports such projects as catalysts for across-the-board human progress while continuing to expand US leadership on Earth and in space. The YouTube link to his stirring talk is https://www.youtube.com/watch?v=IsKpcqm5Lv0

Morgan Smith is the president and the chief executive officer of Consolidated Nuclear Security, LLC, which is responsible for the management and operation of the Pantex Plant in Amarillo, Texas, and the Y-12 National Security Complex in Oak Ridge, Tennessee. A Bechtel executive, Smith joined CNS in 2014 to serve as the CNS chief operating officer and manage the operations of both sites. Smith has more than 36 years of prior technical and managerial leadership experience within the Naval Nuclear Propulsion Program. He planned and implemented the consolidation of the Bettis Atomic Power Laboratory and Knolls Atomic Power Laboratory into a single organization and, in 2014, applied that experience to initiate the consolidation of Pantex and Y-12 under one U.S. Department of Energy contract.

Smith's career has been focused on leading disciplined nuclear operations and improving performance in high-risk environments. His technical background includes design; development; and fabrication of reactor control drive mechanisms, steam generators and refueling equipment. Smith holds a BS in civil engineering from The Pennsylvania State University and has completed various project management and leadership development programs with Westinghouse, Bechtel and the University of Michigan.

New Hope Center borders Y-12 Security Complex

Hon. John Vonglis

Acting Director,
ARPA-E, DOE
Chief Financial Officer, DOE

KEYNOTE

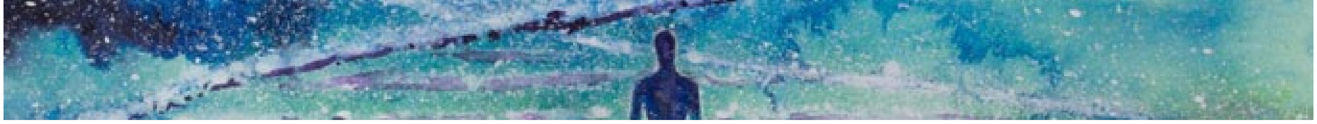
ARPA-E Role in Transformative Progress

Hon. John Vonglis, Chief Financial Officer of the U.S. Department of Energy, and Acting Director of the DOE Advanced Research Projects Agency for Energy, presented the second keynote address, also on Tuesday morning. He described the technology development mission of ARPA-E and how it fits with our symposium efforts. ARPA-E was created by the US Congress to keep America safe, secure, and competitive. Its mission is to fund energy technology research that may be early-stage, high risk, and/or ready for advancement, with broad relevance to energy generation, utilization and storage. Criteria for project selection include potentials for transforming the status quo beyond the scope of other DOE programs, with good scientific basis backed by experienced teams having diverse backgrounds, and having potentials for market commercialization. Since the potentials of such projects can and should transform the US energy landscape, project success is expected to spillover to other sectors of the government and private business working toward common goals. This aspect leads directly to high probability that broadened participation of ARPA-E in space-related technology development can lead to major positive fiscal and strategic advantages for the United States, both on Earth and in space. The YouTube link to his insightful talk is https://www.youtube.com/watch?v=OLoJr8Fk42w

Confirmed by the U.S. Senate in December 2017, John G. Vonglis serves as the Chief Financial Officer of the Department of Energy (DOE). As CFO, he is responsible for all matters financial of the department. Additionally, John serves as acting Director of the department's transformative Advanced Research Projects Agency-Energy. The mission of ARPA-E is to advance innovative early-stage high-potential, high-impact technologies, while minimizing risk to the taxpayer.

Prior to joining DOE, Mr. Vonglis was a senior advisor to Cross Range Capital LLC, a boutique private equity firm. Before Cross Range Capital, he was Senior Vice President of Finance at Red Apple Group, Inc., a $5B diversified business where he served simultaneously as CFO of its second largest portfolio company. Before this, he was a practice area leader with IBM. From 2002 – 2009 he served at the Department of Defense. Initially, he was Director of Management Initiatives for the Under Secretary of Defense for Personnel and Readiness, and later served as Principal Deputy, acting Assistant Secretary (Financial Management and Comptroller), and as the first Chief Management Officer of the U.S. Air Force. In 2000, he was a candidate for the U.S. House of Representatives from his native New York.

His private sector experiences include senior financial and operational positions within advisory, aerospace/defense, financial services, and high-technology firms. John also is a Colonel in the U.S. Army Reserve and advises the Army Cyber Institute at West Point. He is a published writer, has appeared on radio and television, lectured at the U.S. Military Academy, and served on various boards. As a former Eagle Scout, he is active with the Boy Scouts of America. He holds BS and MBA degrees from Fordham University, and a Masters in International Public Policy degree from The Johns Hopkins University.



Alan Icenhour

Associate Laboratory Director (ALD) for the Nuclear Science and Engineering Directorate Oak Ridge National Laboratory

KEYNOTE

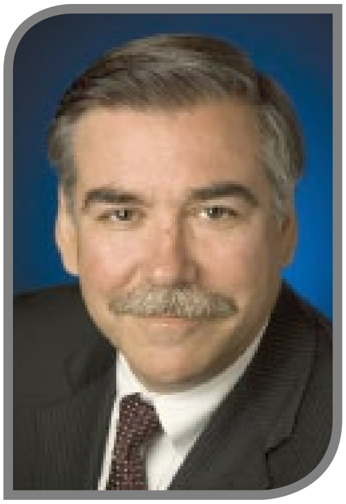
Introduction Keynote Address

Alan Icenhour, PhD, ORNL Associate Lab Director for the Nuclear Science and Engineering Directorate, presented the third keynote address on Wednesday morning, October 24, 2018. He discussed the Oak Ridge National Laboratory (ORNL) and the many synergies it provides with our symposium efforts. The YouTube link to his talk is https://www.youtube.com/watch?v=nMzGaZwZTNE

Dr. Alan Icenhour is the Oak Ridge National Laboratory (ORNL) Associate Laboratory Director for the Nuclear Science and Engineering Directorate (NSED), which operates state-of-the-art nuclear facilities and conducts technology research, development, and application programs that impact a large range of fields from basic science to reactor development, and to national security. NSED mission areas include R&D for both fission and fusion technologies; advanced modeling and simulation; stable and radioactive isotope R&D and production; R&D and deployment of technologies to address nuclear security challenges globally; and safe and efficient operation of ORNL's nuclear facilities. His experience has included a range of fuel cycle topics such as enrichment, radiochemical processing, stable and radioisotope production, nuclear fuels, radiation effects on materials, radioactive waste management, and nuclear security.

Before joining ORNL, he served as a commissioned officer in the U.S. Navy on a nuclear- powered submarine. After leaving active duty, he continued his service with the Navy as an active reservist, retiring in August 2010 at the rank of Captain (O-6). He received his BS degree in nuclear engineering from North Carolina State University, and his MS and PhD degrees in nuclear engineering from the University of Tennessee. He is an Adjunct Professor of Nuclear Engineering at the University of Tennessee. He is a fellow of the American Nuclear Society and a member of the Institute for Nuclear Materials Management.

Oak Ridge National Laboratory main campus.



Mark Uhran

Former Director/Assistant Associate Administrator, International Space Station Division, NASA Headquarters

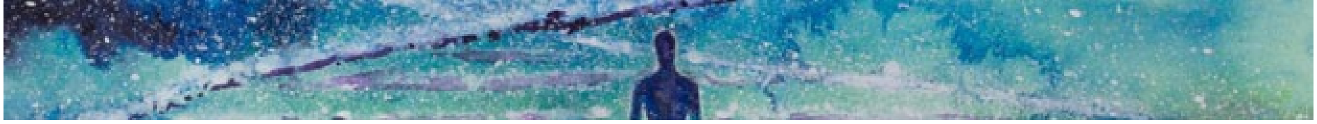
Enabling the Future of Human Space Flight

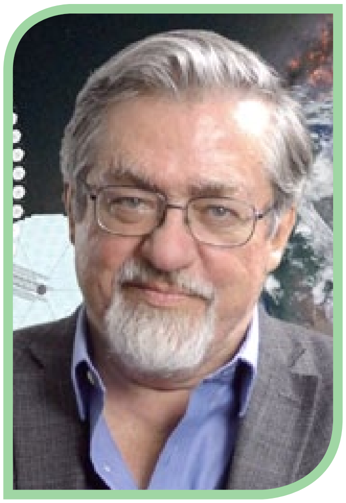
Mark Uhran was Director of the International Space Station Division at NASA Headquarters in Washington, DC, where he spent 28 years working with international partners in Canada, Europe, Russia and Japan on the design, development, and operation of the approximately 500 metric ton, full-service, crewed space station currently on orbit. In 2012, Mark Uhran joined the Oak Ridge National Laboratory to participate in the International Thermonuclear Experimental Reactor (ITER) Project – a partnership among China, Europe, India, Japan, Korea, Russia and the United States to build a 500 Megawatt-thermal, industrial-scale, nuclear fusion reactor in southern France. The ITER mission is to demonstrate sustained burning plasma of hydrogen isotopes, so that the process can be used for practical, safe and carbon-free electric power generation in the future.

At our *Power of Synergy* symposium, he presented the fourth keynote address on Thursday morning, October 25th. He discussed key enablers for expanding human spaceflight, both technical and political. They include: a focused singular mission objective; robust and sustained public support; multi-sectoral international technology alliances; sound and disciplined systems engineering and integration; intellectually objective technology selection; minimized O&M cost proving grounds, and; exhaustive teamwork on design reference missions.

Mr. Uhran holds a BS in Natural Resources from Cornell University, a MS in Technology Management from the University of Maryland, and a Master of Public Administration from Harvard University.

KEYNOTE





John Mankins

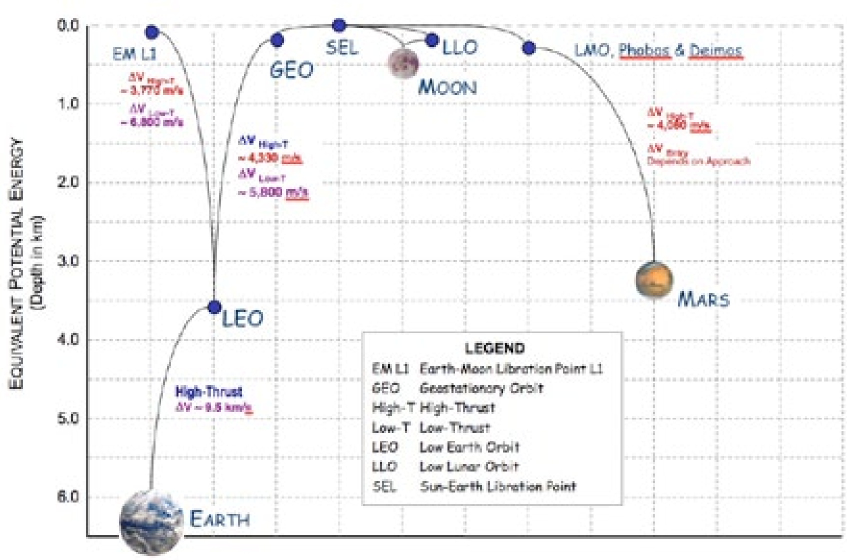
Founder and President,
Mankins Space Technology, Inc
President, Artemis Innovation
Management Solutions LLC

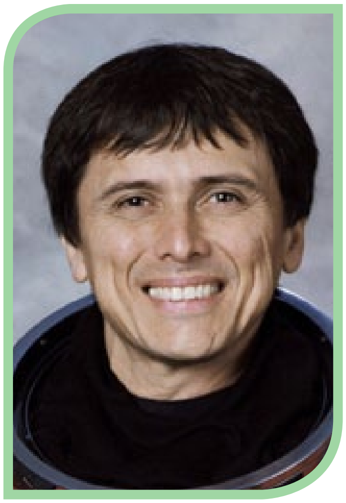
THEME 1

Realizing the Development and Settlement of Space: the Moon as the Stepping Stone

John C. Mankins is President of Artemis Innovation Management Solutions LLC and the Founder & President of Mankins Space Technology, Inc. He is also Vice President of the Board for the Moon Village Association, and a member of the Board for the National Space Society and SPACE Canada. Mankins was formerly Chief Technologist for Human Exploration and Development of Space at NASA HQ. His 25-year career at NASA and the Jet Propulsion Laboratory ranged from flight projects and space mission operations, to systems-level innovation and technology management. He planned, proposed, and managed the Exploration Systems Research & Technology program with a roughly $5B budget ($1B per year). He is recognized as the leading expert in the field of Space Solar Power (SSP), and is the author of "The Case for Space Solar Power" (2014). He created NASA's Integrated Technology Readiness and Risk Assessment methodology for managing advanced technology projects. Mankins holds B.S. and M.S. degrees in Physics and an MBA in Public Policy Analysis. His numerous honors include the NASA Exceptional Technology Achievement Medal and the National Space Society (NSS) "Space Pioneer" Award. He Chaired the International Space Development Conference (ISDC 2018), which had highest attendance (more than 1,200) and highest revenues of any ISDC in the 30-plus years of the event. He lives on a family Ranch on the California Central Coast.

ABSTRACT: The Moon is the stepping stone for the development and settlement of space; as Krafft Ehricke once said: "If God had intended for humanity to be a space-faring species, he would have given Earth a Moon." The concepts and core technologies already exist that would enable us to rapidly and affordably develop the resources of the Moon, establish bases for science and exploration, and establish permanent settlements. This paper explores (1) plans for lunar exploration, (2) critical technologies that can enable dramatic progress to be made rapidly, and (3) a road map forward for space exploration and development, in which the Moon plays a critical role. In keeping with the *Power of Synergy* symposium's prime motives of developing the case for a breakthrough decadal plan, I will show the crucial linkage from the elements of my Theme 1 to the technologies and concepts to be presented in Themes 2, 3 and 4.





Franklin Chang Diaz

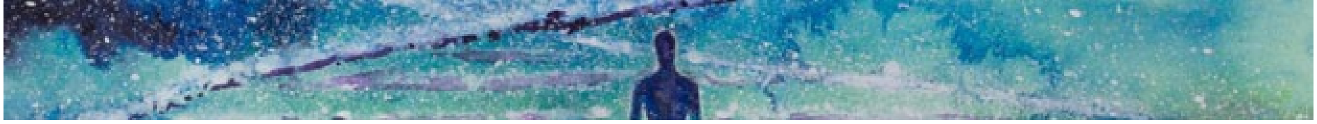
Chairman and CEO,
Ad Astra Rocket Company

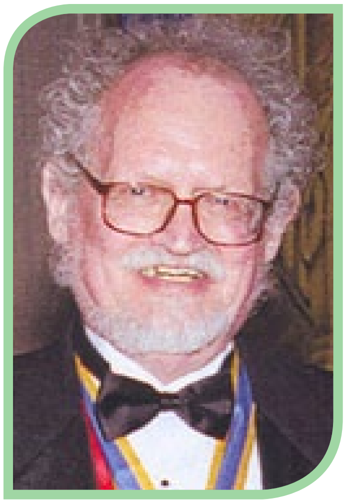
THEME 1

Living and Working in Space, an Astronaut's Perspective

Dr. Franklin R. Chang Díaz is Chairman & CEO of Ad Astra Rocket Company. At the age of 18, having completed high-school in Costa Rica, he left his family for the United States to pursue his dream of becoming a rocket scientist and an astronaut. He arrived in the fall of 1968 with $50 dollars in his pocket and speaking no English. In a Hartford CT Public High School, he learned English and graduated again in the spring of 1969. That year he also earned a scholarship to the University of Connecticut, where he obtained a BS in Mechanical Engineering. Physics and engineering were the correct skill mix for his chosen career in space. He entered graduate school at MIT in the field of plasma physics and controlled fusion, where he completed his doctorate in 1977. In that same year, he became a US citizen. In 1980, when NASA sought new astronauts for the Space Shuttle Program having advanced degrees, he was ready. As one of 19 astronauts selected by NASA from 3,000 applicants, he became the first naturalized citizen from Latin America to be so chosen. Dr. Chang Díaz achieved his dream of space flight on January 12, 1986 on board the Space Shuttle Columbia mission STS 61-C. The 6-day mission deployed a communications satellite and conducted multiple scientific experiments. After 96 orbits of the Earth, Columbia made a successful night landing at Edwards Air Force Base in California. Dr. Chang Díaz flew a (world) record of 6 more space missions, which contributed to major US space accomplishments. On three separate space walks, totaling more than 19 hours, Dr. Chang Díaz led the installation of major components of the International Space Station (ISS). In his seven space missions, he logged over 1,600 hours in space.—Alongside astronaut duties, Dr. Chang Díaz continued his research in applied plasma physics. His 1979 concept of a plasma rocket became the VASIMR® plasma engine, with 3 NASA patents to his name. In 2005, after 25 years with NASA, he retired from government service to continue his work on VASIMR® through the private sector.

ABSTRACT: In the late twentieth century, Mother Earth gave birth to a new space-faring species: humans. As with any birth, the process is fundamentally irreversible; an evolutionary step, intrinsically driven by our self-preservation instinct. We are soon to outgrow our home planet and must now look at the universe before us as a place to grow and prosper. Humans are in space to stay. Treacherous and unforgiving, space is also wonderful, with resources and opportunities on a cosmic scale. It holds the keys to our survival. But, more than survive, we must learn to live and work in our new realm. Two technologies are essential for success: Abundant electric power and a paradigm shift in propulsion. Human physiology, language, beliefs and culture are also important, as are crew-interdependence and autonomy from Earth. In this session, I plan to share my perspective from seven space missions and 25 years as a NASA astronaut.





James Powell

Brookhaven National Laboratory, Retired
Founder, MagLev2000

A Celebration of James Powell – 1934-2019

Creator of Particle Bed Reactors and Superconducting MagLev

(presented by John Mankins and John Rather)

James R. Powell, PhD was a senior scientist at Brookhaven National Laboratory (BNL) from 1956 through 1996. His creative work led to significant advances in the design and analysis of advanced reactor systems, cryogenic and super conducting power transmission, plasma physics, mine safety, fusion reactor technology, electro-nuclear (accelerator) breeder systems, transmutation of nuclear wastes, space nuclear thermal propulsion, electromagnetic hypervelocity guns, hydrogen and synthetic fuels, and transportation infrastructure. Dr. Powell and his colleague, Dr. Gordon Danby received the 2000 Benjamin Franklin Medal in Engineering "for their invention of a magnetically levitated transport system using super conducting magnets and subsequent work in the field." The Franklin Institute awards medals annually in recognition of the recipients' genius and civic spirit and in memory of the Institute's namesake, Benjamin Franklin, who exhibited those same qualities. Some noted past recipients of the Franklin Institute medals include Alexander Graham Bell, Thomas Edison, Neils Bohr, Max Planck, Albert Einstein and Stephen Hawking. Dr. Powell and Dr. Danby won the first patent for superconducting MagLev in 1968, as well as many recent patents on their 2nd generation advanced MagLev system. Their designs are now realized in the Japanese MagLev trains – the world's fastest. – Dr. Powell invented and patented the Particle Bed Reactor (PBR) for nuclear rocket propulsion, and he was program manager for its development and proof of principle at Sandia and Los Alamos National Labs. He has many other patents related to the use of aluminum structure in fusion reactors; blankets employing solid lithium ceramics and alloys for tritium breeding; demountable super conducting magnet systems; and the Advanced Vitrification System (AVS) for high-level nuclear and toxic wastes. Dr. Powell held a Bachelor of Science in Chemical Engineering from the Carnegie Institute of Technology and a Doctor of Science in nuclear engineering earned in 1958 from the Massachusetts Institute of Technology. Dr. Powell published almost 500 professional papers and reports and four books. He was a member of the American Nuclear Society.

Historic models from James Powell's invention of Particle Bed Reactor.

Michael Houts

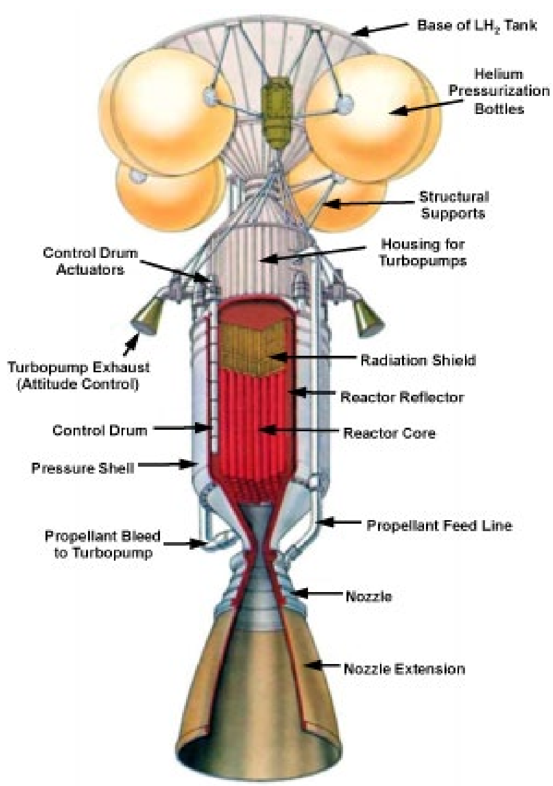
NASA MSFC

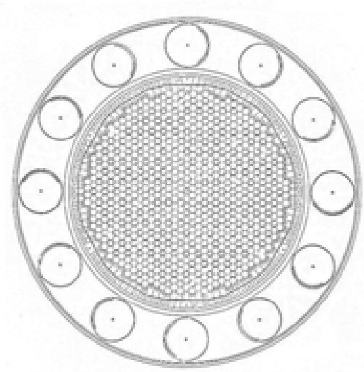
THEME 1

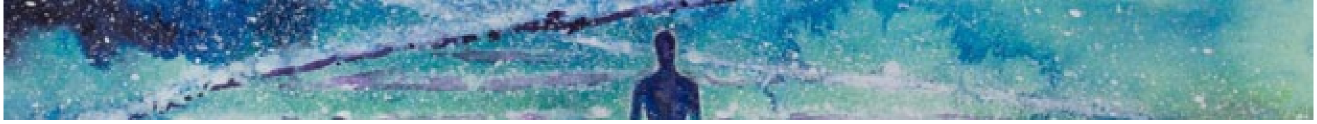
Enabling Advanced Exploration with Nuclear Thermal Propulsion (NTP)

Dr. Michael Houts obtained his PhD in Nuclear Engineering from the Massachusetts Institute of Technology. He was employed at Los Alamos National Laboratory for 11 years where he served in various positions including Team Leader for Criticality, Reactor, and Radiation Physics and Deputy Group Leader of the 70-person Nuclear Design and Risk Analysis group. Dr. Houts currently serves as Nuclear Research Manager for NASA's Marshall Space Flight Center, and is also the principal investigator for NASA's Nuclear Thermal Propulsion (NTP) project. Recent awards include a NASA Exceptional Service Medal, a NASA Exceptional Engineering Achievement Medal, and being selected as an Associate Fellow of the American Institute of Aeronautics and Astronautics.

ABSTRACT: First generation Nuclear Thermal Propulsion (NTP) offers significant advantages for operations in cis-lunar space and for human Mars missions. For cis-lunar operations, NTP enables rapid plane changes and other high delta-V maneuvers. NTP also increases flexibility, enables faster response times, and can reduce cost if re-used. For human Mars missions, NTP can reduce crew time away from earth from >900 days to <500 days while still allowing adequate time for Mars surface exploration. NTP can reduce crew exposure to space radiation, microgravity, and other hazards, and enables numerous abort modes not available with other architectures. A stage/habitat optimized for use with NTP could further reduce crew exposure to cosmic rays and provide shielding against any conceivable solar flare. Systems derived from NTP could enable a power-rich environment anywhere in space. First generation NTP systems are a stepping stone to highly advanced nuclear propulsion systems that could help enable detailed exploration and utilization of the solar system and beyond.







Joel Sercel

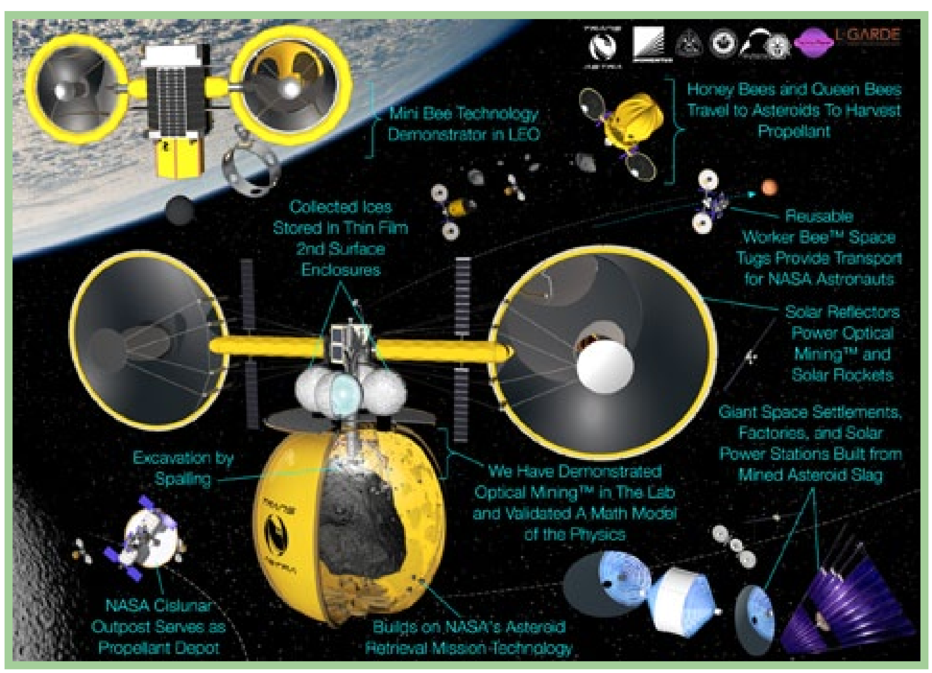
Founder, Trans Astronautica Corporation

THEME 1

Capture and Uses of Small Asteroids

Joel C. Sercel, PhD, is the Founder of Trans Astronautica Corporation (TransAstra). Dr. Sercel has three decades of experience developing advanced technology and innovative products in fields ranging from aerospace and defense to software and robotics. Joel spent 14 years at JPL and taught systems engineering and space mission and satellite design at the graduate level at Caltech. Sercel led the conception and definition of the NSTAR ion propulsion system currently in use on the Dawn spacecraft in orbit around the asteroid Ceres. Sercel is a three time NIAC fellow for his work in asteroid prospecting and asteroid mining and is the inventor of Optical Mining (patent pending). NASA funded TransAstra studies show that asteroid mining for rocket propellant can reduce the cost of human exploration by a factor of three and make lunar tourism affordable. Sercel received his PhD and master's degrees in Mechanical Engineering from the California Institute of Technology with a doctoral dissertation in plasma physics as applied to space propulsion.

ABSTRACT: Since 2015 TransAstra corporation has been conducting a multidisciplinary research and development program centering on enabling practical harvesting of the ingredients in rocket propellant from Near Earth Objects (NEOs). This work, which has been conducted with support from NASA and private sector investors has been done in collaboration of partners at the University of Hawaii's Institute for Astronomy (IfA); the University of Central Florida's Center for Lunar and Asteroid Surface Science (CLASS); and the Colorado School of Mines Center for Space Resources. In this presentation Dr. Joel Sercel will provide highlights of these research efforts focusing on work related to telescopic prospecting; mission design for asteroid mining; economic benefits; and experimental work in our Patent Pending method of Optical Mining™. In this presentation Dr. Sercel will describe past and on-going experiments and demonstrations of Optical Mining technology and will relate TransAstra's work to the prospect of robotic 3D manufacturing of large structures and components in space using the power of sunlight.



Sercel Honeybee concept harvesting asteroid resources.

Jason Derleth

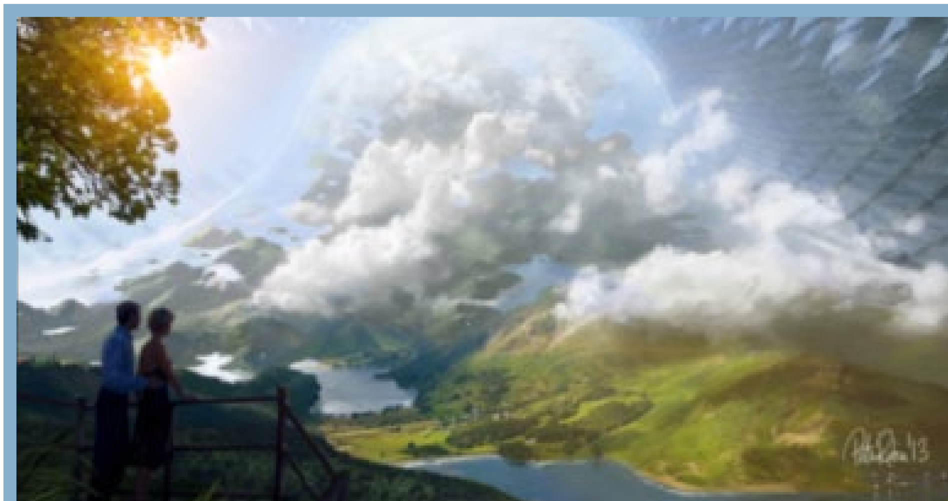
NASA

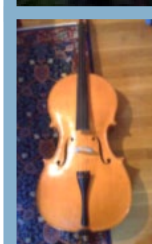
THEME 2

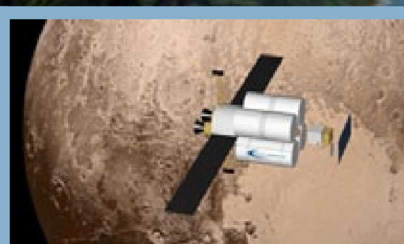
NASA Innovative Advanced Concepts Program (NAIC)

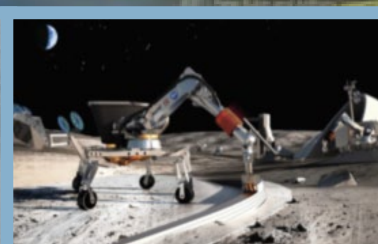
Jason Derleth obtained a B.A. in Liberal Arts from St. John's College, Annapolis, and an S.M. in Aero/Astro Engineering from MIT. He was employed at the Jet Propulsion Laboratory for five years, where he worked as a systems engineer on the Curiosity rover, and performed Technology Portfolio Optimization for various NASA programs. It was the latter that got him invited to NASA HQ, where he was awarded in 2005 the Exceptional Public Service medal for his work co-leading the Exploration Systems Architecture Study technology portfolio work needed to return to the Moon. Mr. Derleth currently serves as the Program Executive in charge of the NASA Innovative Advanced Concepts program. Additional awards include the Space Flight Awareness Honoree award, numerous Group Achievement Awards, and the Baird Prize for Excellence in the Arts and Sciences for his creation of a hand-carved cello.

ABSTRACT: The NASA Innovative Advanced Concepts (NIAC) program is the most advanced technology development program at NASA. Importantly, it is open to proposals from all technology areas, and holds an annual Symposium, open to the public, where all current projects report their progress to the Program Office. The *Power of Synergy* is clearly visible in the results of the NIAC Program, which has inspired hundreds of millions of dollars of follow-on work from NASA, other government agencies, and private industry. Mr. Derleth explains what NIAC is and why its multidisciplinary community is so active in creating the future of aerospace. Additionally, Mr. Derleth looks at the philosophy of exploration, art, and science, and why such things are important to the NIAC community. He explains the basics of NIAC and how to propose to this unique program. Finally, Mr. Derleth will introduce the concepts and technology topics presented in the TVIW *Power of Synergy* symposium, showing how they support the overall motives of the meeting to catalyze a decade of major breakthroughs before 2030.









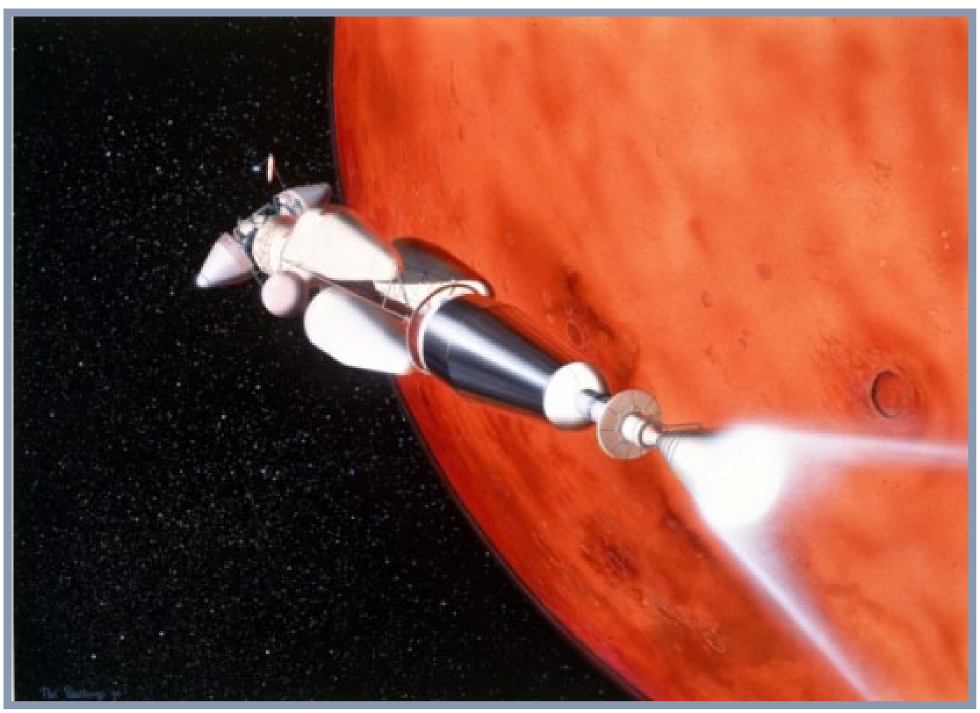
Jonathan K. Witter

Chief Engineer,
BWXT Corp

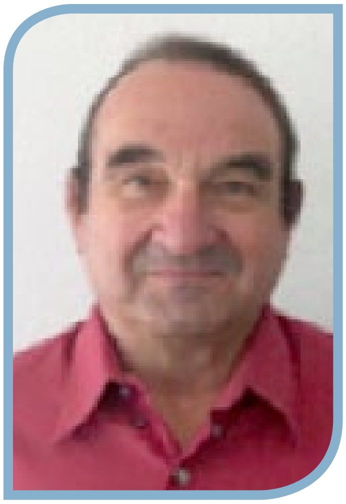
Particle Bed Reactor Nuclear Thermal Propulsion & Power

Jonathan Witter is the Chief Engineer for BWXT's Advance Technology Programs. In this role, he currently serves as the technical engineering lead for the NASA GCD Nuclear Thermal Propulsion (NTP) project with a focus on the reactor core design and analysis and the fuel mechanical development and testing. Dr. Witter's past experience spans space nuclear programs, reactor physics design, leader for the Project Prometheus/Jupiter Icy Moon Orbiter fission power system at the Knolls Atomic Power Laboratory, and his PhD research at MIT under a NASA Space Grant for nuclear thermal propulsion under the Space Exploration Initiative.

ABSTRACT: I am a long time enthusiast for applying fission nuclear power for space propulsion. I'm confident that the team NASA has assembled will finally realize the dreams of predecessors and finally fly a nuclear rocket engine in space and have it as the reference architecture for getting humans to Mars in a shorter and safer timeframe than chemical propulsion. BWXT was a key contractor in the very successful DOD DARPA R&D SNTP program that proved feasibility of particle bed reactors (PBR) in the 1990s. This technology is the leading candidate for rapid development of lighter and smaller second-generation nuclear rockets. The PBR was extensively tested and validated, signaling a giant leap forward in the size reduction of Nuclear Thermal Propulsion engines.



Particle Bed Nuclear thermal Propulsion and power



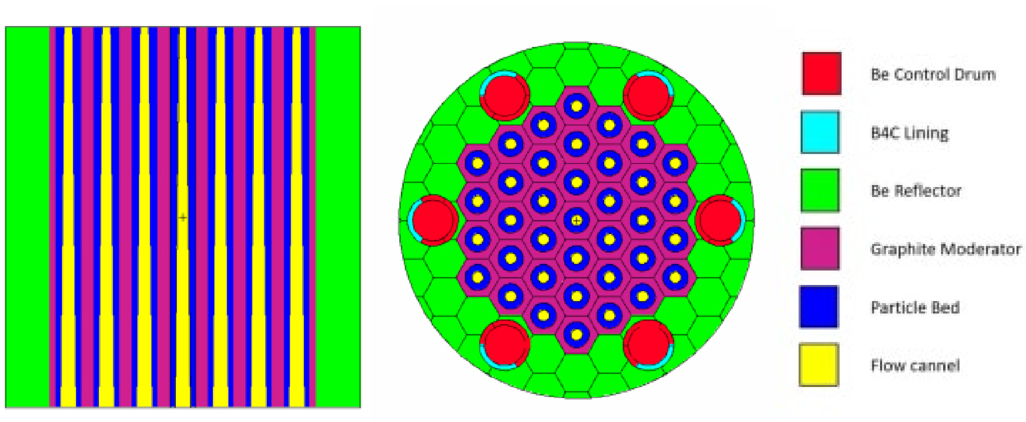
Roger Lenard

Col. U.S.A.F., Retired

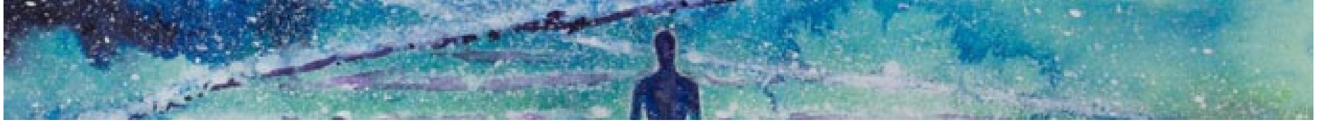
Timberwind Program History and Future Portents Remarks

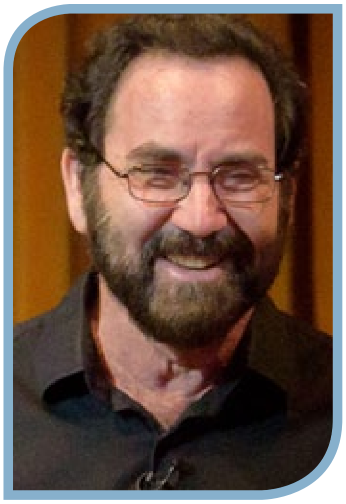
As Col.in the U.S. Air Force, Roger Lenard served as DoD/DARPA Timberwind project manager for the breakthrough Particle Bed Reactor research and development program. The work was performed at Los Alamos and Sandia National Labs, with Grumman and BWXT as contractors from 1988–1993. Lenard presented some concepts allowing the use of Low Enriched Uranium and possibilities for incorporating uranium metal operating in the molten state to achieve gas temperatures ~3300K. This research indicates that concepts using LEU can be compact and exhibit high specific impulse and thrust-to-weight ratios. He also presented some concepts for a nuclear power system that would be suitable in space as well as for lunar and Martian surface power generation.

THEME 2



- This concept has higher specific impulse (Isp) than all other Nuclear Thermal Reactor designs
- Five years of design and testing successfully validated required performance
- Specific impulse Isp = 1,082 seconds
- Nozzle exit velocity = operational speed 10.6 km/s
- Reactor Core outlet temperature and pressure 3300K at 1000psi





Phil Lubin

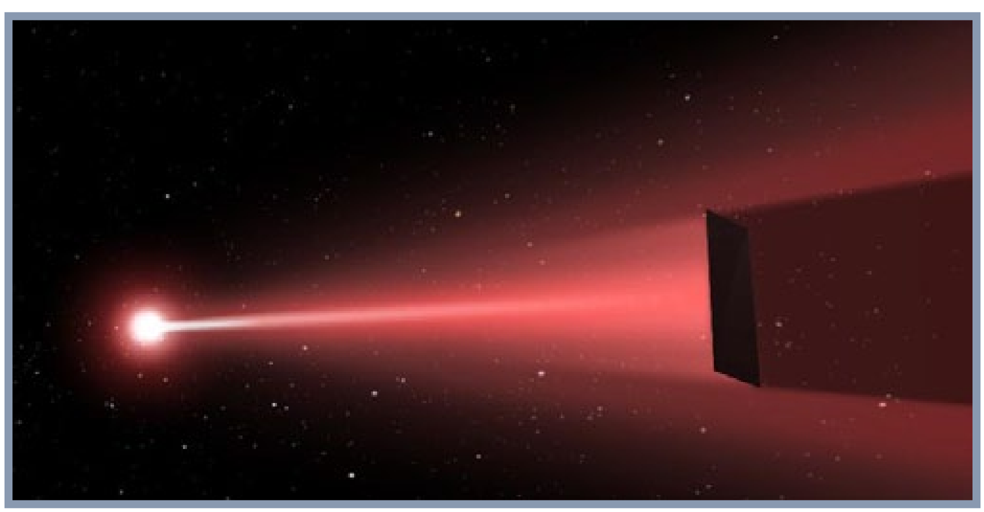
Professor, UC Santa Barbara

THEME 2

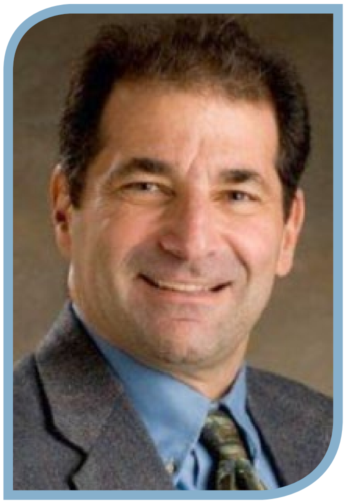
Directed Energy Propulsion & Power Beaming

Dr. Philip Lubin obtained his PhDin Physics at UC Berkeley, and is now a professor of Physics at UC Santa Barbara. His primary research has been focused on astrophysics of the early universe and also, quite differently, applications of directed energy for planetary defense and relativistic propulsion. His group first detected the horizon scale fluctuations in the Cosmic Microwave Background radiation that are fundamentally important to cosmological theory. He was a co-investigator on the Planck cosmology mission, which mapped in exquisite detail the structures of the early universe.—Relevant to the present symposium on synergistic technologies to advance progress in space development, Lubin's group has worked on applications of directed energy systems for both small-scale single launcher solutions as well as large standoff systems for planetary defense and on applications to allow small interstellar probes to achieve relativistic speeds for the first interstellar missions. He is director of the NASA Starlight program, currently in Phase II, whose goal is to use directed energy for humanity's first interstellar missions. He is also concept director for the Breakthrough Starshot program whose goals are to achieve relativistic flight with miniature spacecraft. He has published more than 400 papers.

ABSTRACT: All current propulsion systems that leave the Earth are based on chemical reactions. While chemistry will get us to Mars, it will not allow large-scale solar system nor interstellar capabilities in any reasonable mission times. Nuclear propulsion can shorten solar system missions by a factor of 5, but none of our current propulsion systems, including nuclear, are capable of extremely rapid solar system missions, and certainly not the relativistic speeds needed for exploring the many nearby stellar systems and exo-planets. Barring new physics we are left with few realistic solutions. However, recent advances in photonics and directed energy systems now allow us to realize the ability to develop systems capable of very rapid high mass solar system missions and low mass relativistic flight. Large-scale missions are possible for rapid interplanetary transit capable of supporting human life.—Photonics, like electronics and unlike chemical propulsion, is an exponential technology with a current double time of about 20 months. This can enable profound changes in human capability. We will discuss the many technical challenges ahead, our current laboratory prototypes and recent data on kilometer baseline arrays as well as the many transformative implications of this program.



Lasers will enable hypervelocity payload delivery within a decade.



Robert Bagdigian

NASA MSFC

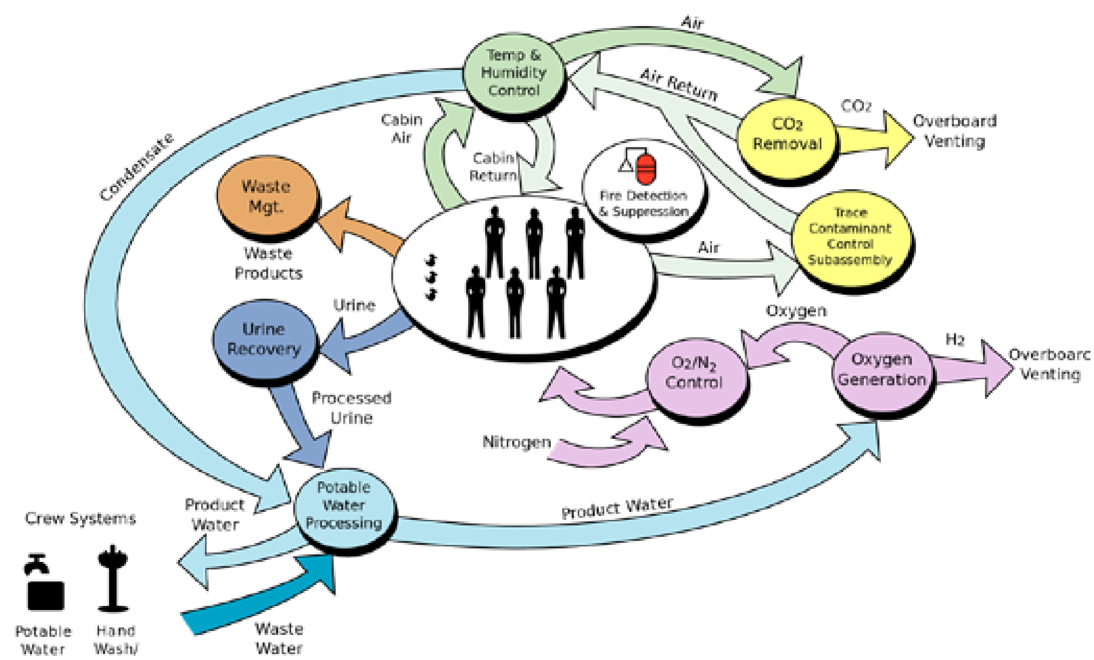
THEME 2

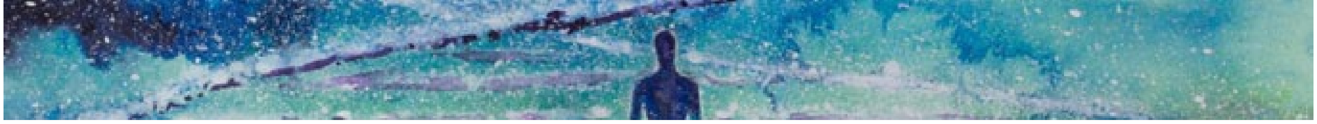
Environmental Control and Life Support Challenges

Robert Bagdigian has been an engineer with NASA's Marshall Space Flight Center for over 30 years. He spent much of his career developing environmental control and life support (ECLS) systems for human spaceflight for the Space Station Freedom and later for the International Space Station programs. As a member of engineering teams, Mr. Bagdigian planned and conducted comparative technology demonstration tests and integrated system tests that contributed to the baselining of subsystems and ECLS system architectures that are operating on-board the ISS today. Mr. Bagdigian served as the project manager responsible for the design, development, test, and evaluation of the ISS Regenerative ECLS systems and later as the chief of MSFC's Environmental Control and Life Support Development Branch. Mr. Bagdigian is currently assigned to NASA's Office of the Chief Engineer where he is serving as the Deputy Chief Engineer for the Human Exploration and Operations Mission Directorate.

ABSTRACT: In accordance with the United States Space Policy Directive -1, the National Aeronautics and Space Administration is leading an innovative and sustainable program with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Enabling this endeavor are the experiences and lessons that are being learned about keeping humans alive, well, and productive in space aboard the *International Space Station*. Some of these experiences and their high level implications to human space exploration planning are discussed.

Creating completely closed life support





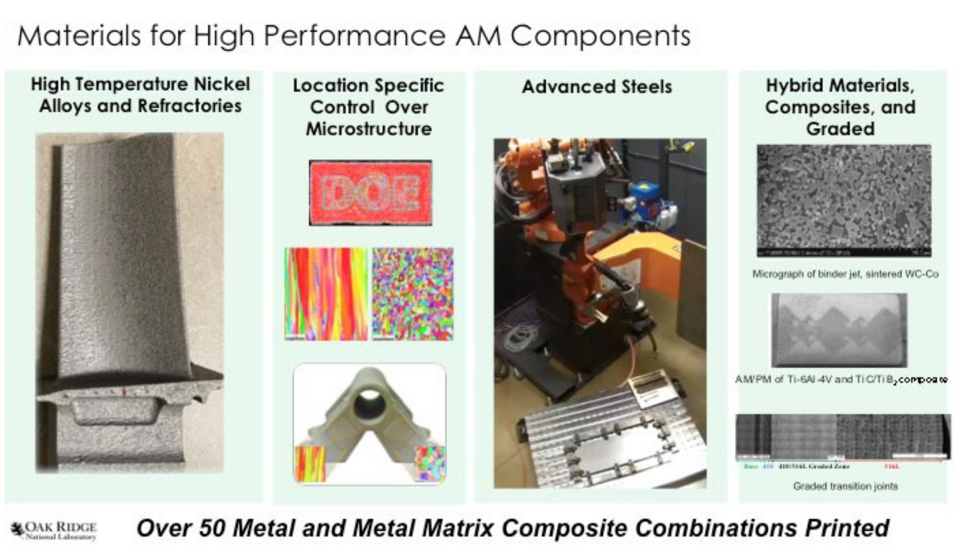
Large-scale 3D Printing & Complex Structures

William Peter

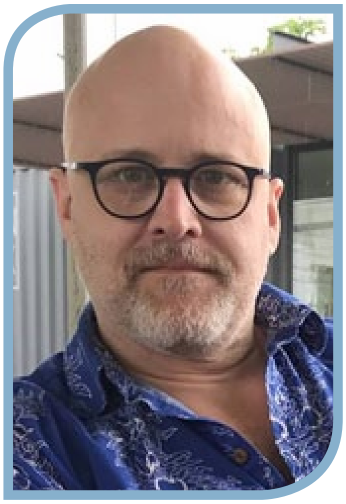
Director, Manufacturing Demonstration Facility
Oak Ridge National Laboratory

Dr. William Peter is the Director of Department of Energy's first Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory (ORNL). The MDF was established to provide industry with affordable and convenient access to infrastructure, tools and expertise to facilitate rapid adoption of advanced manufacturing with its current focus in Additive Manufacturing and Carbon Fiber/Composites. Dr. Peter has led groups of greater than 80 people in joining research, metal and ceramic processing, carbon fiber and composites, energy storage, separations, and additive 3D printing manufacturing. He has been the principal investigator for over 20 R&D projects including research in the areas of powder metallurgy of titanium powders, the fabrication of amorphous/nanocrystalline materials, the processing of Al, Mg, and Fe-based alloys, and additive manufacturing. Dr. Peter has been author or co-author for 40 articles and has won 4 R&D 100 Magazine awards for research in consolidation of new titanium powders, additive manufacturing of prosthetics, development of a roll mill technology, and the development of laser-fused NanoSHIELD coatings. Dr. Peter received his B.E. from Vanderbilt University, and his M.S. and PhD from the University of Tennessee.

ABSTRACT: Large Scale Additive Manufacturing, New Materials and Technology "Moonshots" at Oak Ridge National Laboratory (Bill Peter) -The Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory (ORNL) performs early stage research in additive manufacturing and composites, sponsored by Department of Energy's Advanced Manufacturing Office. Current research areas include materials for enhanced performance, new additive technology development including large-scale systems, and simulation and data analytics for qualification. In addition, ORNL has collaborated on over 140 projects cost shared with industry. This presentation will discuss the fundamental research performed by the MDF along with the impacts with industry and academia. The applications range from the evaluation of new energy generation concepts to transportation components. New material combinations, materials designed for additive deposition and the systems used to deposit will be discussed. The presentation will end with discussion on how these new advanced manufacturing technologies could be used for and during space exploration.



Persistent Space Platforms and Bootstrapping an In-Space Economy



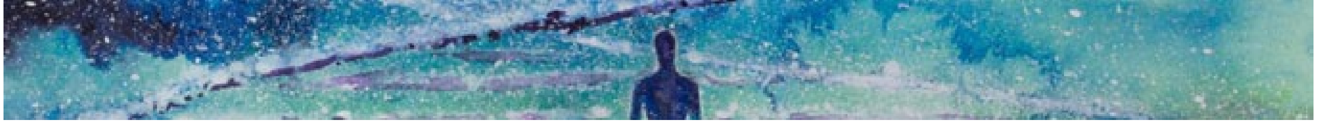
Jeffrey Slostad

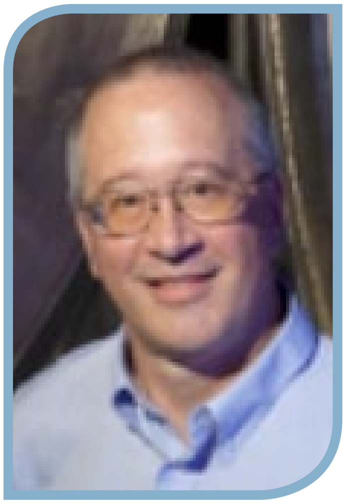
Tethers Unlimited Inc.

Jeff Slostad currently serves as Director of Strategic Missions at Tethers Unlimited Inc. He joined TUI in 2001, and since then has led planning, design, and testing efforts on a number of efforts, including several DoD and NASA contracts as well as contracted development efforts in support of aerospace primes. From 2000 to 2001 Mr. Slostad was Chief Engineer at BlastOff! Inc., a commercial entertainment venture developing a lunar rover mission with multiple rovers. From 1993 to 2000 Mr. Slostad worked at the NASA Jet Propulsion Laboratory. From 1995 to 2000 he was responsible for the design, development, testing, and operations of the Robotic Arm on the Mars Polar Lander. He also led the assembly, test, and launch operations for the remainder of the science instruments on the lander.— Mr. Slostad holds M.S. and B.S. degrees in Aeronautics and Astronautics from the University of Washington.

ABSTRACT: Tethers Unlimited is developing a spectrum of advanced technologies intended to kick-start the development of a robust in-space economy. The keystones of this economy are an in-space manufacturing supply chain and a service chain built around water as a critical resource. We will describe our vision for this in-space economy, and discuss recent progress on developing and maturing the critical technical elements, including in-space recycling and manufacturing systems, low-cost robotic servicing and assembly technologies, water-based propulsion thrusters, and modular space platforms.

THEME 2





Mark D. Carter

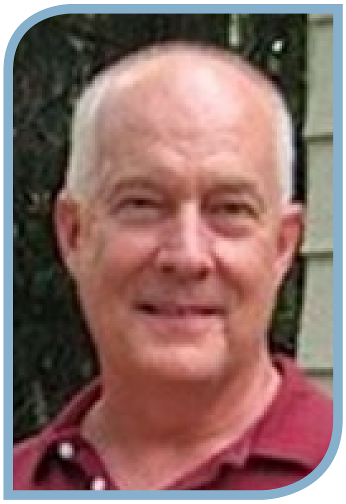
Senior Vice President,
Ad Astra Rocket Company

VASIMR Plasma Propulsion

Dr. Mark D. Carter is the Senior Vice President of Technology Development for Ad Astra Rocket Company. He is a co-inventor of the VASIMR® engine and the principle investigator for testing the engine in thermal steady-state conditions under Ad Astra's NextSTEP contract with NASA, authorized in August 2015. Dr. Carter began working for Ad Astra Rocket Company in 2006 and has been associated with VASIMR® development since the late 1990s under interagency agreements between NASA and Oak Ridge National Laboratory in Oak Ridge, TN. Dr. Carter spent over 23 years as part of the research staff at Oak Ridge specializing in the application of radio frequency (RF) power to heat plasmas in fusion experiments around the world. Dr. Carter received his PhD in Nuclear Engineering with a minor in Physics in 1985 from the University of Wisconsin at Madison.

ABSTRACT: Synergy, re-usability, scalability and plenty of power are necessary for the future of space industrialization and exploration. Chemical propulsion systems are good for initial launch, but higher specific impulse will ultimately be needed for a sustainable deep-space architecture. The exponential advantage of high specific impulse reduces the propellant mass needed to complete the mission, dramatically lowering the initial cost to orbit. Electric propulsion (EP) systems with specific impulse above ~2000s are already playing a logistic role. Solar photovoltaic arrays with a few kilowatts of power have already allowed EP to make otherwise-impossible-missions to comets and asteroids possible, and EP is now widely used commercially to raise large satellites from their geo-transfer launch orbit to their operational geo-stationary position. Photovoltaic arrays are now envisioned with power levels of hundreds of kilowatts for cis-lunar cargo missions, but multi-megawatt nuclear power levels will ultimately be needed for sustainable deep space exploration. The Variable Specific Impulse Magneto Plasma Rocket (VASIMR®) technology is an EP system scalable from 40 kWe per thruster using solar arrays to multi-megawatts per thruster using nuclear electric power. The VX-200SS VASIMR test article is now being matured to a technical readiness level of 5 by Ad Astra Rocket Company in partnership with NASA under the NextSTEP program. The trade-space for power, specific impulse, and propellants will be presented for VASIMR engines along with other nuclear-capable high specific impulse technologies operating from low earth orbit to Mars and beyond.

- Space station re-boost
- Orbital debris mitigation
- Satellite servicing
- In-space logistics
- Space resources mining/recovery
- Fast interplanetary human transport



Ken Roy

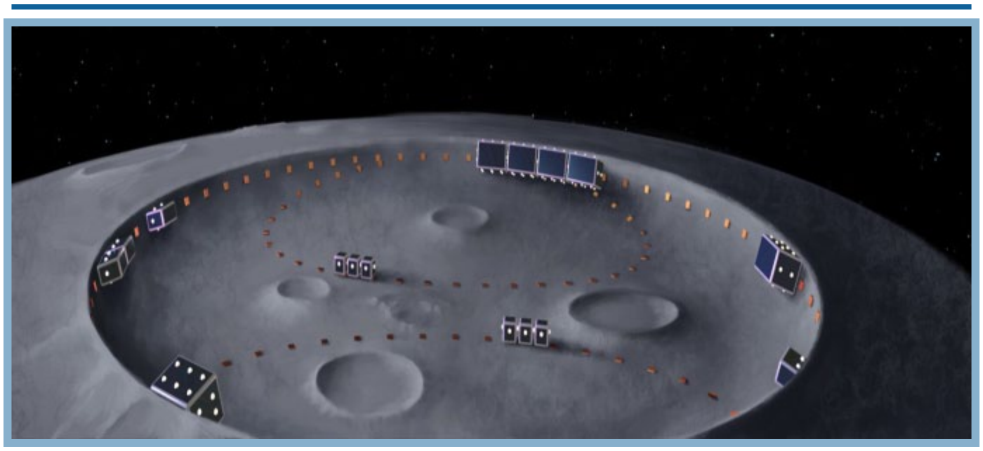
Y-12 National Security Complex

THEME 2

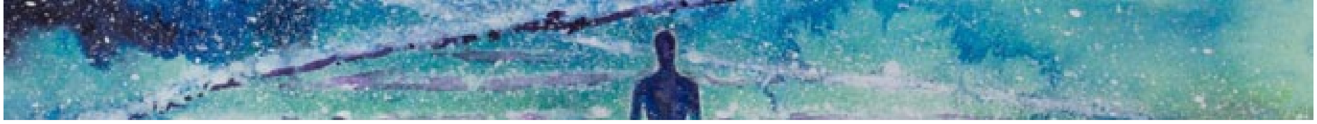
The Problem of Low Gravity and Human Physiology: One Possible Solution

Ken Roy is an engineer living and working amidst the relics of the Manhattan Project in Oak Ridge, Tennessee. In 1997, he made the cover of the prestigious Proceedings of the U.S. Naval Institute for his forecast of anti-ship, space-based, kinetic energy weapons. Roy's work has appeared multiple times in the Journal of the British Interplanetary Society and Acta Astronautica with papers on terraforming and space colonization. He invented the "Shell Worlds" concept. He is a graduate of the Illinois Institute of Technology and the University of Tennessee at Knoxville in engineering. He enjoys reading science fiction and books on terraforming.

ABSTRACT: The International Space Station and earlier space flight activities in Earth orbit have provided extensive opportunities to study human biology in a micro-g environment, and the conclusions are not positive. However, there is no real experience with humans in low-g environments. There are many open questions relating to how much gravity human beings need to survive, grow, and reproduce. Developing children seem to need Earth level gravity to develop bone, muscle, and balance abilities. Even healthy adults, after some extended period of exposure to lunar-type gravity, might not be able to return to Earth.—For a long-term human settlement on a low-gravity body such as the Moon or Mars, some form of artificial gravity may be required. The only known way to achieve this is by using revolving structures to create centripetal acceleration. Combining centripetal acceleration and the body's natural inertial mass allows creation of the equivalent force of an Earth-normal gravitational field that can be sustained for long periods of time.—We have experience with magnetically levitated trains on Earth used in Japan to achieve efficient high-speed travel. That same superconducting technology offers the prospect of individual magnetically levitated habitats or other structures, moving at feasible speeds in a circular pattern to provide any degree of gravity required. This approach eliminates the potential problem of low gravity on human physiology, allowing for long-term human settlements on low-gravity moons and planets. The prevalence of large circular craters on the moon and Mars can expedite creation of synergistic gravitational environments to enable safe colonization.



Superconducting MagLev provides artificial gravity centripetal solution. Shielded vehicles of many sizes can independently orbit safely. They can exit and enter orbit as required.



Siegfried Janson

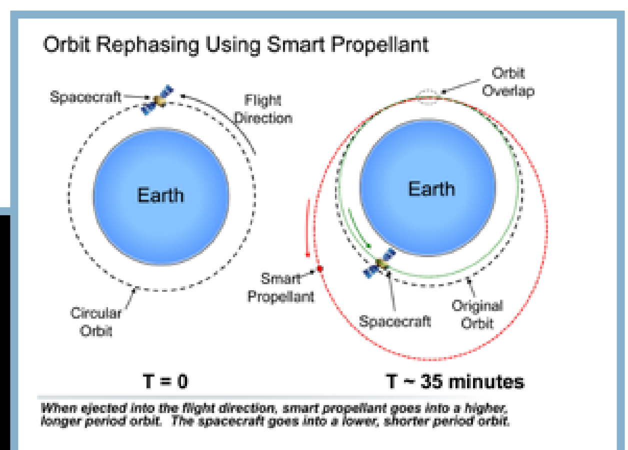
The Aerospace Corporation

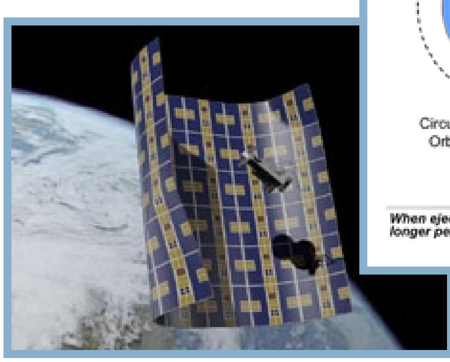
THEME 2

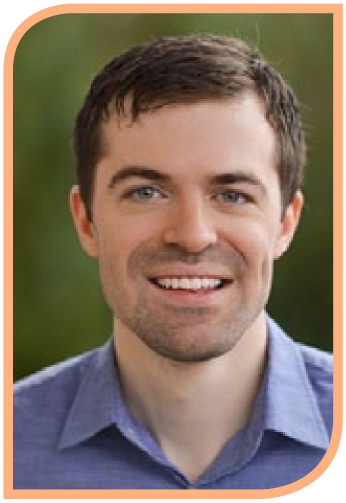
Small Satellite Concepts at The Aerospace Corporation

Dr. Siegfried Janson is a senior scientist in the Small Satellite Concepts group at The Aerospace Corporation. He obtained a PhD in aerospace engineering from Cornell University in 1984, was a post-doctoral associate at Cornell from 1984 to 1987, and joined the Aerospace Corporation in 1987 to pursue experimental research in advanced electric thrusters for spacecraft. Dr. Janson's current research interests are nano/pico/femtosatellites, membrane spacecraft for orbital debris removal, spacecraft optical communications, microthrusters, formation flying, microelectromechanical systems, and distributed space systems. He started investigating sub-kilogram mass spacecraft in 1989 and has published over 50 papers on small satellite propulsion requirements, basic design issues, MEMS for space applications, all-silicon satellites, and small satellite orbital architectures. Dr. Janson has flown MEMS experiments on sounding rockets, nanosatellites, CubeSats, the Space Shuttle, and the International Space Station. He served on the National Research Council (NRC) Committee on Implications of Emerging Micro and Nano Technologies, and on the NRC Committee on Nanotechnology for the Intelligence Community. Dr. Janson chaired the SPIE "MEMS Components and Applications" conference in 2001, 2003, and 2004, and is co-editor of the book "Small Satellites: Past, Present and Future." He is currently the principal investigator on the NIAC Brane Craft Phase II effort and co-principal investigator on the NASA-sponsored Optical Communications and Sensor Demonstration CubeSat program.

ABSTRACT: NASA's Innovative and Advanced Concepts (NIAC) group funded a 9-month long Phase I study on active membrane spacecraft, called Brane Craft, in early 2016. This concept uses ~10-micron thick Kapton sheets as the basic spacecraft structure, with a 10 to 30-micron wide gap between the sheets serving as a propellant tank. The propellant is an ionic liquid and the Brane Craft uses distributed nano-electrospray thrusters for propulsion. The current 1-meter square design has a total thickness of 50 microns, and a mass of only 81 grams, wet. Thin film solar cells provide up to 180 W of power to the 4000-s specific impulse electric thrusters, resulting in 8.2 mN of thrust for an unprecedented acceleration of up to 0.1 m/s2 at this high specific impulse. Total delta-V is 16 km/s, enabling a Brane Craft to visit most bodies in the solar system, and return. Total operating time for the thrusters, under full power, is only 36 hours.







Matt Hollingsworth

Co-founder and CEO,
Carta Healthcare
Creator of Nucleation Labs

THEME 3

Making Big Ideas a Reality

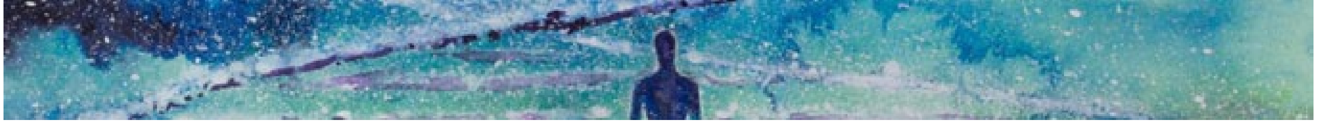
Matt Hollingsworth is a data scientist and entrepreneur who began his career as a high-energy physicist working at CERN on the search for the Higgs Boson. The immense, untapped potential of applying CERN's technology in other domains inspired Matt to devote his career to taking transformative ideas out of the lab into the wider world. During that time, he has started a couple of companies, attended Stanford's business school, and worked with the government to transition projects into commercial applications. He is now the co-founder and CEO of Carta Healthcare, a healthcare analytics company focused on using the latest advances in data science research to improve healthcare operations. Additionally, he is launching his Nucleation Labs concept for breakthrough technology commercialization.

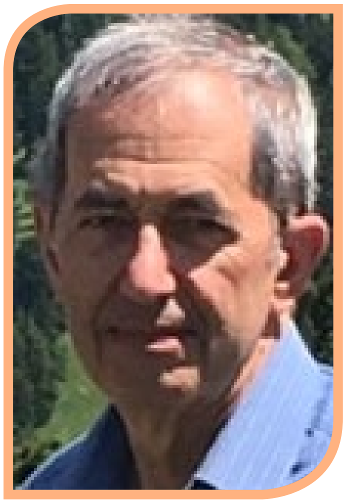
ABSTRACT: The journey of an idea from the lab into the wider world, known as technology transfer, is fraught with peril. Most revolutionary ideas never make it out of their birthplace. Universities—the bastions of academic research—are rarely incentivized to do anything but publish their ideas, and businesses often cannot finance the R&D necessary to morph an early stage prototype into a sustainable product. In the past, organizations like Bell Labs and DARPA were highly effective at bridging this gap, but today, there are few institutions that can help. Gone are the days of decades-long government programs with billion dollar budgets as a solution for technology transfer. Yet all is not lost. Newer, leaner ways of completing technology transfers have begun to show great success. We are at the cusp of a new age of sustainable, high velocity, and effective technology transfer. These new developments and thoughts for the future will be discussed.

NUCLEATION LABS

Intellectual freedom	IP protection	Resources
Members choose research projects to work on	Labs provide legal structure to protect ideas	Lab equipment, grant writing, recruiting, etc.

Nucleation Labs will Transform Innovation





James T. Early

LLNL, Retired

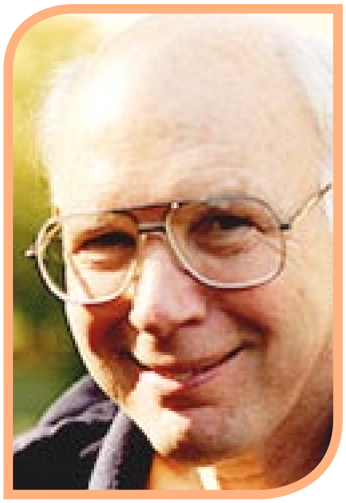
THEME 3

Transformative Decadal Plan

James Early obtained his BS in Aeronautics & Astronautics at MIT. He followed with an MS in Mechanical Engineering (Propulsion) at Caltech, and a PhD in Aeronautics & Astronautics (Physics minor) at Stanford University. Early in his career (pun intended), he worked at NASA-Greenbelt, Douglas Aircraft- Culver City, Lockheed Missiles & Space-Sunnyvale, and Hughes Aircraft-Culver City. Subsequently for thirty years, Dr. Early worked at Lawrence Livermore National Laboratory in activities primarily related to lasers, optics and systems design. He made major contributions to the Atomic Vapor Laser Isotope Separation Program. Some of his important papers include “Twenty meter space telescope based on diffractive Fresnel lens,” 2003; “Space debris de-orbiting by vaporization impulse using short pulse laser,” 2003; “Use of a solar sail as a zone plate lens to enable fly-by missions with large telescope capabilities,” 2002; “Dust grain damage to interstellar laser pushed lightsail,” 2000; and “Space based shield to offset greenhouse effect,” 1989.

ABSTRACT: The objective of the *Power of Synergy* symposium is to propose a plan that enables a major change in the level of space accomplishments. We are not seeking to map out the next logical evolutionary steps, which is the usual objective of the standard institutional “Decadal Plan.”—We will first review a similar forward-reaching transformative effort made in 1991. We must clearly identify the circumstances that are necessary to allow us to achieve more success. New missions have usually motivated past-technology upgrades, or they might finally enable an old objective. We seek a breakthrough plan that can enable manned exploration of Mars and the moon, promote major expansion of activities in cislunar space, and allow serious exploration of the outer planets and beyond.

At LLNL, Dr. Early pioneered Laser Guide Star Adaptive Optics that now enables high resolution photography for all major telescopes of the world.



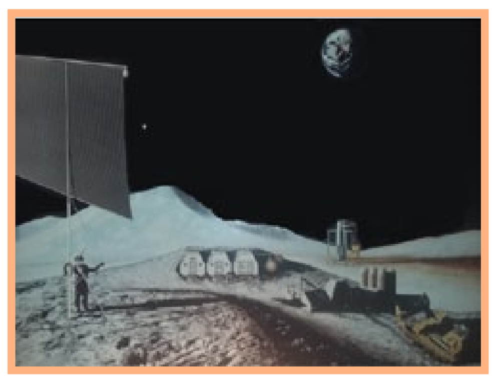
John D. G. Rather

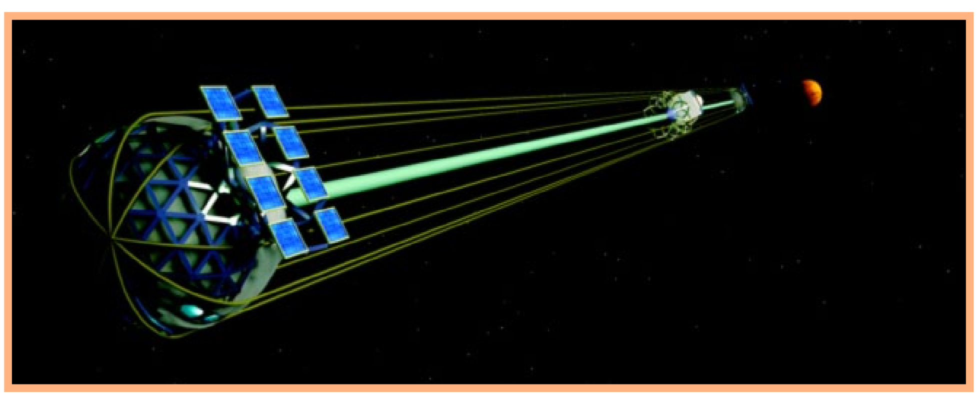
THEME 3

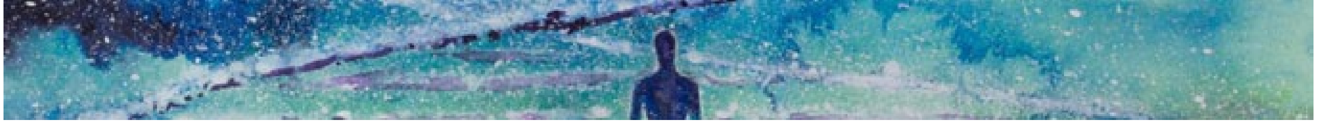
Examples of Powerful Synergistic Technological Concepts

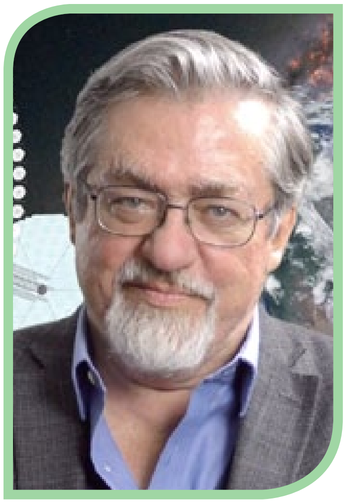
Dr. John D.G. Rather obtained his BS in Physics from the University of Tennessee, Knoxville, and his MS and PhD in Astronomy from The University of California, Berkeley. He worked in physics, astronomy, and space research at three National Laboratories before moving into the business sector to create and manage large applied research and development initiatives. This led to high-level involvement with the U.S. Government, where he frequently provided invited expert testimony to the U.S. House, Senate, and White House concerning issues of technology and science policy. After his role as VP of an aerospace company, he was recruited to serve in the Senior Executive Service at NASA HQ in Washington DC. Mandated by the U.S. Congress, he chaired the NASA Near-Earth-Object Interception Workshop to recommend impact prevention methods. ***Asteroid 7290 was named "Johnrather" in his honor on his sixtieth birthday***. Dr. Rather moved to Oak Ridge, Tennessee in 2006 and founded Rather Creative Innovations Group, Inc. (RCIG, Inc.) to create new opportunities for economic and societal growth and to engender focused revolutionary technology breakthroughs. The present *Power of Synergy* Symposium is an example of his efforts. The RCIG website is www.RCIGinc.com.

ABSTRACT: This talk describes how synergistic combining of Nuclear Propulsion, large Solar Concentrators, and Robotic 3D printing can enable transformative factories in space before 2030. The required key technologies are already at NASA Technology Readiness Levels greater than 4 for earth-based applications, and they can be readily developed for space. This also catalyzes rapid exploitation of other synergistic technologies such as Laser Power Beaming, Space Power Satellites, and Superconducting Magnetic Structures. Robotic capturing and industrializing small Near Earth Asteroids (NEAs) will enable many human jobs to build habitats and infrastructure for permanent human expansion to the moon and Mars.









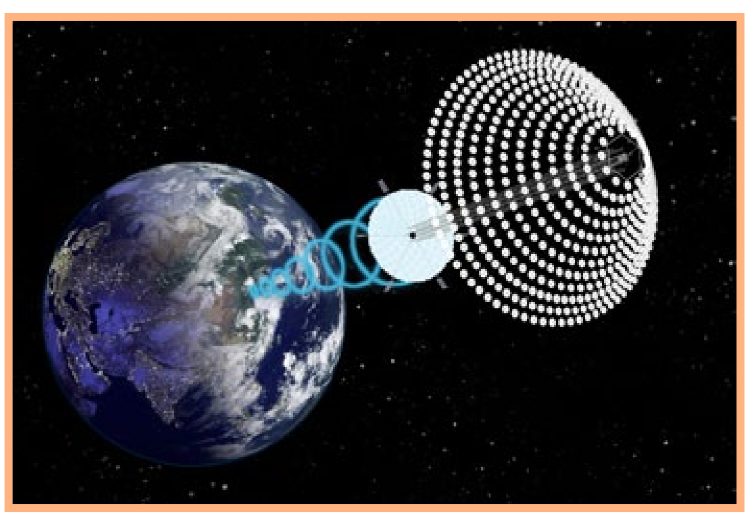
The Critical Importance of Affordable and Abundant Solar Energy

John Mankins

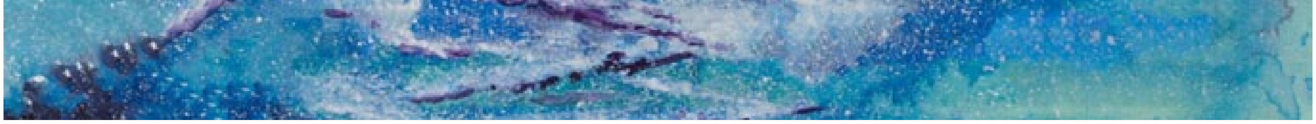
President, Artemis Innovation Management Solutions LLC
Founder and President, Mankins Space Technology, Inc

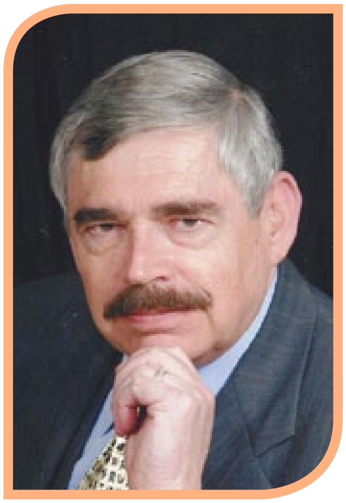
John C. Mankins is President of Artemis Innovation Management Solutions LLC and the Founder & President of Mankins Space Technology, Inc. He is also Vice President of the Board for the Moon Village Association, and a member of the Board for the National Space Society and SPACE Canada. Mankins was formerly Chief Technologist for Human Exploration and Development of Space at NASA HQ. His 25-year career at NASA and the Jet Propulsion Laboratory ranged from flight projects and space mission operations, to systems-level innovation and technology management. He planned, proposed, and managed the Exploration Systems Research & Technology program with a roughly $5B budget ($1B per year). He is recognized as the leading expert in the field of Space Solar Power (SSP), and is the author of "The Case for Space Solar Power" (2014). He created NASA's Integrated Technology Readiness and Risk Assessment methodology for managing advanced technology projects. Mankins holds B.S. and M.S. degrees in Physics and an MBA in Public Policy Analysis. His numerous honors include the NASA Exceptional Technology Achievement Medal and the National Space Society (NSS) "Space Pioneer" Award. He Chaired the International Space Development Conference (ISDC 2018), which had highest attendance (more than 1,200) and highest revenues of any ISDC in the 30-plus years of the event. He lives on a family Ranch on the California Central Coast.

ABSTRACT: Space solar power (SSP) is often discussed only in the context of its prospective use for markets on Earth; however, there is no single more important source of energy for use elsewhere in our Solar System than the Sun itself. Nuclear power systems are typically discussed for mission applications on the Moon or Mars, or in space beyond the asteroids; but freely available sunlight is one valuable synergistic resource that all missions have in common (admittedly at decreasing intensity with increasing distance). At an entirely greater order of difficulty, several strategic programs are now seriously considering the challenge of transportation beyond our solar system. This presentation reviews ambitious energy requirements for a variety of candidate missions and markets across the solar system – including power for Earth, but focusing on the Moon, the Mars system, the asteroids and targets beyond. It examines the potential for SSP systems to meet those energy requirements and compare this potential with other options, including a variety of nuclear approaches. The paper concludes with a roadmap forward, setting into an integrated framework the potential for SSP to truly "Power Space" during the coming century.



Solar energy power beaming hive.





Dean S. Hartley III

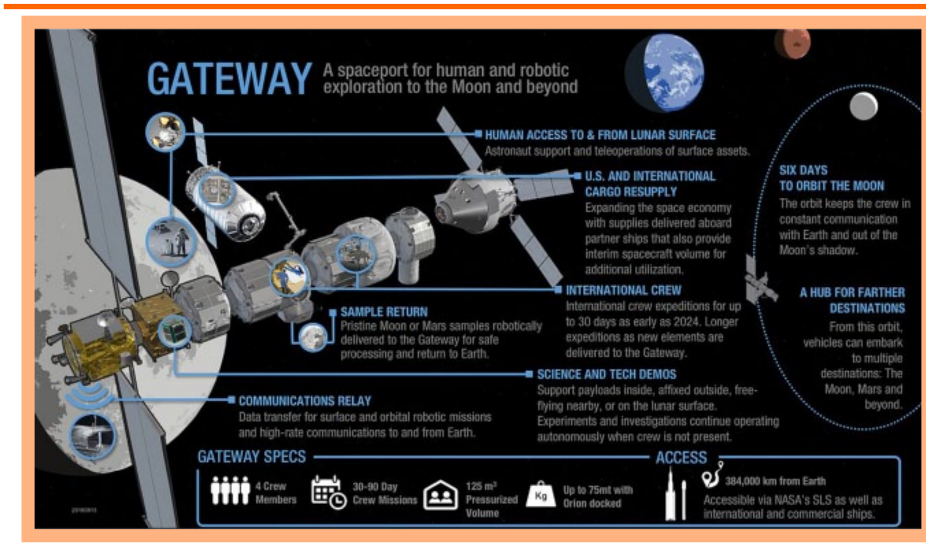
Hartley Consulting
Military Operations
Research Society

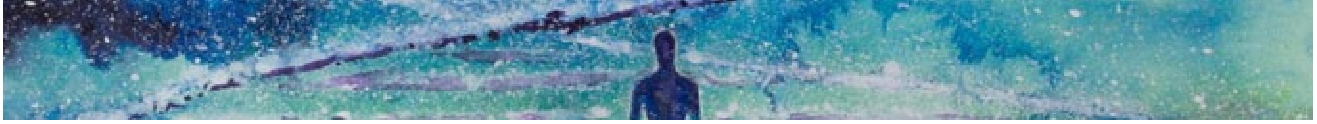
THEME 3

How To Integrate It?

Dr. Hartley is known internationally as a problem solver and expert in operations research (OR). Operations Research is the "Science of Better," the discipline of modeling complex problems to make better decisions. He has been solving problems for customers for almost fifty years: two years while in graduate school, four years while on active duty in the Army, nine years in private industry, fifteen years at the Oak Ridge Federal Facilities, and seventeen years as Principal of Hartley Consulting. The Hartley Consulting website is http://DrDeanHartley.com is a Director of the Military Operations Research Society (MORS), a past Vice President of the Institute for Operations Research and Management Science (INFORMS), past President of the Military Applications Society (MAS), and a member of the INFORMS Simulation Society (ISIM). He also serves as the Technical Advisor for Operations Research and Modeling to the International Psychopharmacology Algorithm Project (IPAP). Hartley is a Senior Fellow with the George Mason University School of Public Policy, a consulting resource for the Naval Postgraduate School (NPS), MOVES Institute, and a Research Fellow with the University of Alabama in Huntsville, CMOST. Hartley has published *An Ontology for Unconventional Conflict, Unconventional Conflict: A Modeling Perspective, Predicting Combat Effects*, co-authored two other books, contributed numerous chapters to other books, and written more than 150 articles and technical documents. In 1994 he was awarded the Koopman Prize for best publication in military operations research and in 2013 he was awarded the Steinhardt Prize for lifetime achievement in operations research. His expertise includes modeling and simulation of combat, irregular warfare (IW) operations, verification, validation, and accreditation (VV&A) of models, and psychopharmacology modeling.

ABSTRACT: Describing the integration requirements for a decadal plan takes more than 25 minutes. (The integration requirements also depend on having the plans for the parts, which are only sketched in preceding presentations.) Instead I will describe some of the characteristics of the integration requirements. Naturally, there will be hardware and software integration between and among the systems that will be part of the decadal plan. However, a large part of the integration will involve deconfliction. Part of that deconfliction is conceptual deconfliction – competition versus complementarity. Part of the deconfliction will involve such things as trajectories and activities. Within all of this there will be integration of infrastructure, testing regimes, technologies, and computational systems. The integration activities are needed to ensure that we get to Mars within 10 years of the start date.





Catherine Asaro

THEME 4

Ultimate Paths to the Future (Science Fiction to Fact Relationships)

Catherine Asaro obtained a B.S. with highest honors in chemistry from UCLA, followed by a Masters in physics and a PhD in chemical physics from Harvard University. She is also a science fiction author, two time winner of Nebula Award. She served two terms as president of Science Fiction and Fantasy Writers of America. When not writing, Asaro teaches math, physics, and chemistry and has coached various nationally ranked teams for tournaments such as the Princeton and Harvard-MIT competitions. Her students have placed at the top levels in the USA Mathematical Olympiad and the US Mathematical Talent Search. Asaro is also a member of SIGMA, a think tank of speculative writers that advises the government on future trends affecting national security. She is also known for her advocacy of bringing girls and women into STEM fields and for challenging gender roles in her fiction. She has been an invited speaker or visiting professor for many institutions, including the National Academy of Sciences, Harvard, Georgetown University, NASA, the AAAS, the University of Maryland, and the US Naval Academy. She is the daughter of Frank Asaro, the nuclear chemist who discovered the iridium anomaly proving that an asteroid collided with the Earth 66 million years ago and caused the demise of the dinosaurs.—Asaro is noted for including sophisticated mathematical concepts in her fiction. The method of space travel used in the Skolian Empire books comes from a paper she wrote on complex variables and special relativity that appeared in the American Journal of Physics. The novel Spherical Harmonic involves an imagined universe based on the Hilbert space described by the spherical harmonic eigenfunctions that solve the Laplace Equation, and some prose in the book is written in the shape of the sinusoidal waves found in the spherical harmonics. Her novel The Quantum Rose is an allegory to quantum scattering theory and is dedicated to her doctoral advisors and mentors in the subject, Alex Dalgarno, Kate Kirby, and Eric J. Heller. The novella "Aurora in Four Voices" includes topics ranging from Fourier series to integration problems in calculus. In essays in the back of some of her novels, Asaro explains the mathematical and physics basis of the ideas used in the books, in particular Spherical Harmonic, The Quantum Rose, and The Moon's Shadow. In the anthology Aurora in Four Voices (which includes the novella of the same name), she describes the mathematical basis of several stories in the anthology, including the use of Fourier transforms, Riemann sheets, and complex numbers in "The SpaceTime Pool."

ABSTRACT: What are some plausible approaches to extend human populations into the solar system and beyond? What game-changing breakthroughs might happen that make what seems impossible today a potential reality tomorrow? Hard science fiction authors extrapolate current science into the future, asking the question "What if?" to see where it can lead us. These are flights of fancy, yes, but they can also inspire scientists and students alike to think outside the box, perhaps leading us to new forms of science that let us explore beyond the confines of Earth. Such ideas are often purely theoretical; no known method for applying them yet exists. However, if we can propose the ideas, we may someday be able to propose a method for testing the extrapolation. It is worth talking about such ideas to see where we might go. The best answer to our aspirations may be realms of physics yet to be discovered. Let's find out what my Theme team thinks.

The Skolian Saga

Marc G Millis

THEME 4

Sustaining Progress Beyond the Obvious

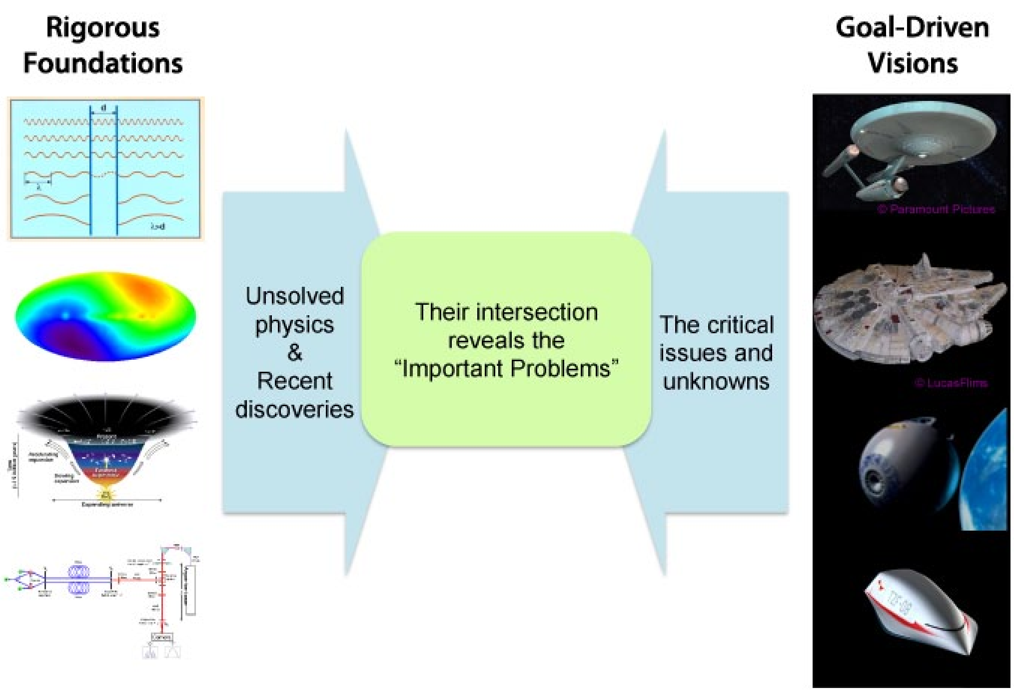
Marc Millis is best known for leading NASA's Breakthrough Propulsion Physics project (1996-2002) and the 2009 book, Frontiers of Propulsion Science – advancing physics to answer the challenges of breakthrough spaceflight. In 2010 Millis took an early retirement to continue these pursuits via the nonprofit Tau Zero Foundation. His expertise spans physics, electronic engineering, cryogenic propellants, and electric space propulsion. [BS Physics Georgia Tech (1982), International Space University Summer Session (1998), MS Physics Entrepreneurship from Case Western Reserve University (2006)]

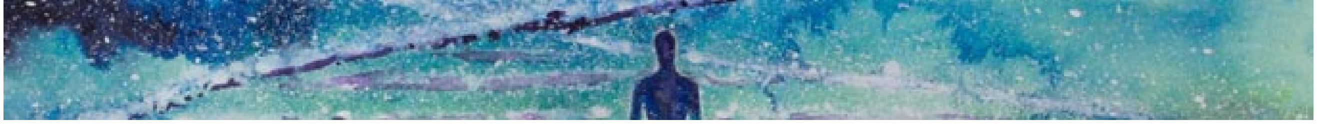
ABSTRACT: The history of scientific and technical progress is a combination of incremental innovations and moments of revolutionary change. A major lesson is that preeminence is not sustained by only working on the next improvement or application. Transistors were not created by improving vacuum tubes, and rockets were not created by improving aircraft. Fortunately, history reveals patterns than can be applied to deliberately seek what comes next. The barriers to progress include the obvious technical challenges, but also predictable human behavior.

Those lessons were applied when creating NASA's Breakthrough Propulsion Physics project, whose goal was to explore open questions in physics that might one day lead to Star Trek like technology. That project took what was once a disparate collection of lone (and often loony) ideas to create a strategically comprehensive process to identify the most impactful goals and the work that could commence, today, to make progress. These lessons and how they apply to "what comes next" will be shared.

From "Grand Challenges" to "Important Problems"

Contrast Now to Wow



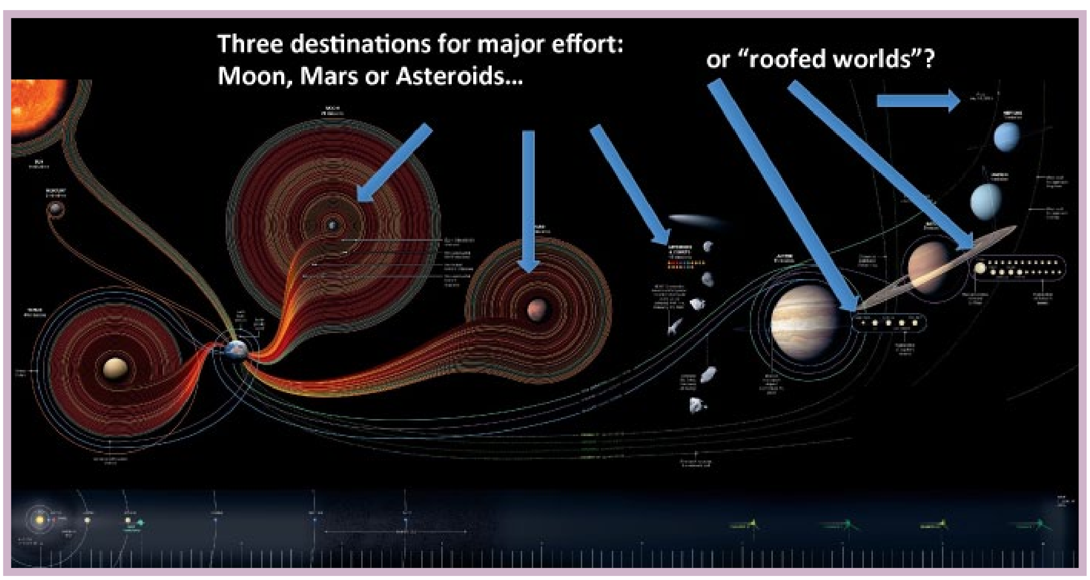


David Brin

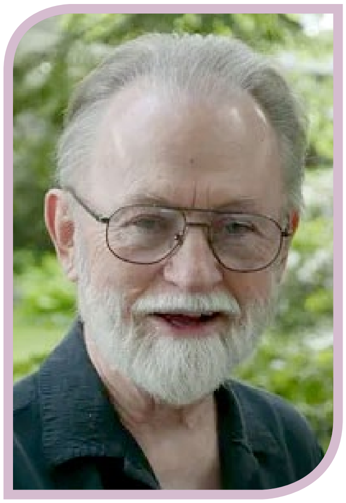
What we mean by "Human"

David Brin is a scientist, inventor, and New York Times bestselling author. With books translated into 25 languages, he has won multiple Hugo, Nebula, and other awards. A film directed by Kevin Costner was based on David's novel The Postman, with other works under option. In EARTH and EXISTENCE he explores near future trends that may transform our world. With degrees from Caltech and the University of California-San Diego, Dr. Brin serves on advisory panels ranging from astronomy and NASA's Innovative & Advanced Concepts program (NIAC) to others dealing with artificial intelligence, nanotech, SETI, national defense, and to technological ethics. He has keynoted scores of major events hosted by the likes of IBM, GE, Google, Boeing and the Institute for Ethics in Emerging Technologies. As a speaker and on television, David Brin shares unique insights—serious and humorous—about ways that changing technology may affect our future lives.

ABSTRACT: While we develop new ways for human crews or settlers to cross the vast distances and harshness of space, we must also expect unfriendly conditions at our destinations. This will not be as simple as the Mayflower survivors learning to plant corn at Plymouth colony. If our aim is to kick-start permanently sustainable human development and expansion beyond the Earth, to the asteroids, Mars and beyond, then we may face daunting obstacles in adapting to permanent low gravity, radiation, closed-ecosystems, long term separation from Mother Earth and susceptibility to toxins. One solution may be to alter the settlers or crew, either through bio modification or else by redefining what we mean by "Human." Indeed, there are reasons to expect that the galaxy may be inherited by descendants made of silicon. A scan of the so-called "Fermi Paradox" shows that we have barely a glimmer about galactic conditions, and should stay agile, ready for anything.



THEME 4



Arlan Andrews, Sr.

THEME 4

CARPE:DIEM (Captured Asteroid Re-Purposing Experiment—Developing Interior Environmental Modules)

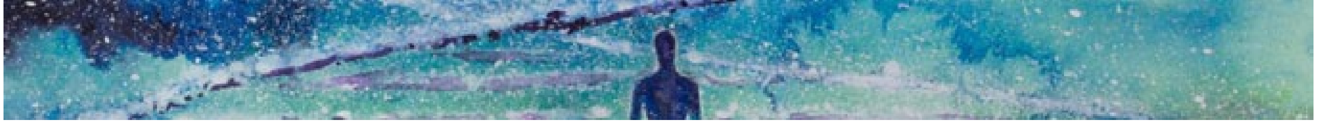
Dr. Arlan Andrews, Sr., has published over 500 publications in more than 100 venues worldwide. After an engineering career with AT&T Bell Labs, Sandia National Lab, and other ventures, he retired as Environmental Director at Naval Air Station Corpus Christi, Texas, in 2013. In 1992, while working as a Fellow in the White House Science Office (OSTP), he founded SIGMA, the science fiction think tank, which provides pro bono science fictional futurism for the Federal Government. SIGMA work continues now with the Unified Futures Forum of the US Army Special Forces Command and with the Science and Technology Directorate of the Department of Homeland Security. In addition to writing the first article about 3D printing in Analog Magazine in 1992 ("Manufacturing Magic"), Arlan coined the terms "nanobots" and "microbots" in a series of 1992 articles in Science Fiction Age Magazine, and wrote the first White House endorsement of molecular nanotechnology (in The President's Report to Congress on Science and Technology, April 1993). In a June 1993 article, "Single Stage to Infinity!" he coined the immortal phrase, "A spaceship that that takes off and lands the way God and Robert Heinlein intended." (PS: Dr. Catherine Asaro and Arlan have recently released a song on iTunes, "Ancient Ages", which relates to a distant past and lost civilizations—quite the opposite of the symposium theme this week.)

ABSTRACT: As proposed by Robert A. Heinlein in a 1939 story, "Misfit", converting existing asteroids for human habitation may be an optimum solution for constructing large-scale space stations. Given that asteroids can be characterized for their mineral resources, then captured and maneuvered into desired orbits, the requisite skills and processes for converting them into human habitats already exist on Earth. Once adapted for low- to zero-gravity environments, the equipment and techniques now used for drilling tunnels and excavating underground structures should be directly applicable to asteroid conversion. Automated 3D printers and support systems could be deployed remotely to initiate projects by fabricating the required conversion machinery on site. For some asteroids, chemical conversion systems for in situ oxygen and water production may be possible. Goals for the re-purposing of asteroids may include (1) lunar-orbiting stations, (2) new moons for Mars, (3) way stations en route to Mars (Heinlein's original story idea), (4) eventual large-population space habitats or spaceships. The scope of the engineering projects, the physics of the orbital transfers, and the economics of the resource expenditures involved, need to be addressed for feasibility.

Annual Global Volumes of Commodities Mined
(Year 2013, *Business Insider Magazine*)

- Platinum = 8 cubic meters
- Gold = 154 cubic meters
- Silver = 2,406 cubic meters
- Uranium = 3,043 cubic meters
- Nickel = 214,000 cubic meters
- Copper = 2,010,000 cubic meters
- Iron = 375,000,000 cubic meters

--Just one asteroid about 4 miles in diameter could potentially contain all of these metals and more, considering only 0.3% ore yields



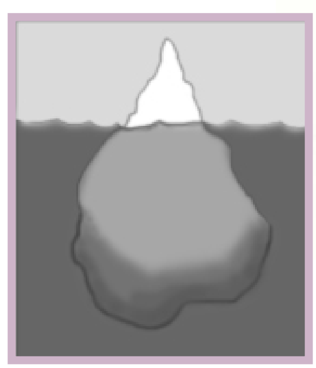
Ruth Kastner

University of Maryland,
College Park (UMCP)
State University of New York
(SUNY)

Quantum Universe Properties?

Ruth E. Kastner earned her M.S. in Physics and PhD in Philosophy (History and Philosophy of Science) at the University of Maryland, College Park. She is a member of the Foundations of Physics group at UMCP. She is also an Affiliate of the physics department at the SUNY Albany campus. She specializes in time-symmetry and the Transactional Interpretation (TI) of quantum mechanics, and has extended the original TI of John Cramer to the relativistic domain. Her interests and publications include topics in thermodynamics and statistical mechanics, quantum ontology, counterfactuals, spacetime emergence, and free will. In addition to a volume in print, "Adventures In Quantumland: Exploring Our Unseen Reality, she has authored two previous books: The Transactional Interpretation of Quantum Mechanics: The Reality of Possibility (Cambridge, 2012) and Understanding Our Unseen Reality: Solving Quantum Riddles (Imperial College Press, 2015). She is also a contributing Editor of a collection of essays by researchers in the field: Quantum Structural Studies (World Scientific, 2016)."

ABSTRACT: In this talk, I introduce the latest version of the Transactional Interpretation of quantum mechanics (TIQM), which describes a dynamic universe in which quantum possibilities are actualized as spacetime events. Though it agrees with known empirical predictions of standard quantum theory, TIQM involves new physics that allows it to solve the 'measurement problem' of standard quantum theory. TIQM involves a subtle form of nonlocality that breaks with the standard paradigm of the behavior of quantum forces and fields. In this regard, it promises the breaking of new ground in understanding the physical world and our place within it.



Buck Field

MBA, PMP, CPM, PBA

Synergies to Faster Than Light

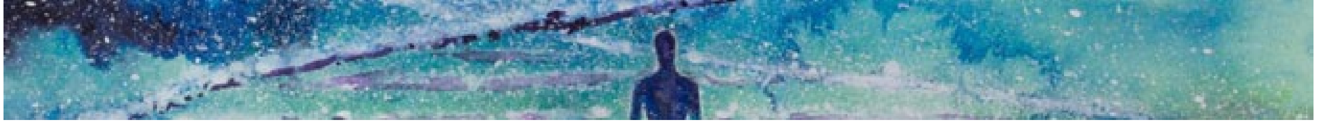
Professional Ethics and Information System consultant John C. "Buck" Field began university undergraduate computer science studies at age 12 and shortly thereafter was hired by IBM, where he found a synergy in application of the ideas of co-worker Benoit Mandelbrot to network traffic datasets, creating a new class of fractal-based predictive systems. He architected the largest financial system in the world via synergy between reductive and emergent perspectives, and created the first project management certification training program to win official approval by the Chinese government. In 2017, his update to the Project Management Institute's guidelines for quantitative decision making became the new global standard for risk analysis. He has a passionate interest in philosophy of science, the demarcation problem, and how scientific revolutions and paradigm shifts relate to humor.

ABSTRACT: This session spans the history of revolutionary advances from our earliest cosmologies to the plethora of quantum interpretations today. We will review the synergies that made each revolutionary idea possible, and the synergistic conditions that helped each of the scientific frameworks built from them ultimately become a successful paradigm change – and the dominant cognitive scientific framework of its day. Out tour concludes with what these commonalities can tell us about how to maximize success, minimize risk, and create new resource allocation strategies that might one day realize our science fiction visions of a truly inter-stellar future.

John Field advocates proven practices for successful tranformative space synergies.

Space progress involves high risk. Success requires expert management to stay agile and achieve more with less.

THEME 4



Allen M. Steele

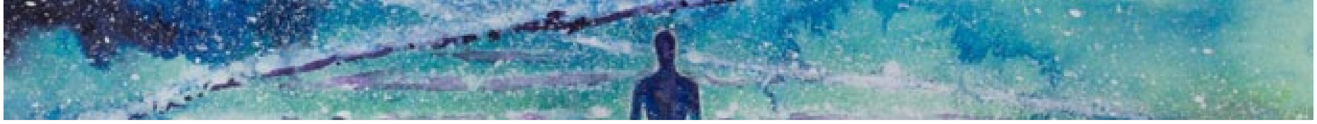
THEME 4

Thoughts on the History of the StarShip

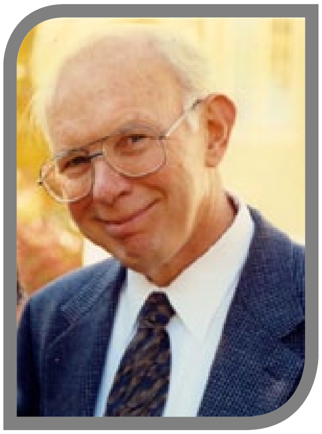
Allen Steele is a former journalist who'd worked for newspapers and magazines in Massachusetts, New Hampshire, Missouri, and his home state of Tennessee. Science fiction was his first love, though, so he eventually ditched journalism and instead began producing that which made him decide to be a writer in the first place. He has been a full-time SF writer since 1988. In that time, Allen has published twenty-one novels and about one hundred short stories. His work has received numerous awards, including three Hugos and the Robert A. Heinlein Award, and has been translated worldwide. He is a former member of the Board of Advisors for the Space Frontier Foundation and the Board of Directors for the Science Fiction and Fantasy Writers of America. He also belongs to SIGMA, a group of SF writers who frequently serve as unpaid consultants on matters regarding technology and security. Allen lives in western Massachusetts with his wife Linda and a procession of adopted dogs.

Virtual Presentation via Skype: Due to illness, noted science fiction author Allen Steele presented by video-conference a brief history of the concept of the "star ship" – beginning with the earliest concepts of space ships and space travel. He discussed tubular-shaped space ships, space ships embedded in asteroids, and spherical space ships. He also included "generation" space ships and photon-powered spacecraft.

Figure 8. Symposium Chair Dr. John Rather (L) discusses transportation technologies with Co-Chair Dr. Dean Hartley (R) regarding travel on the Earth, Moon and Mars (globes shown to scale). John holds a model of the nuclear particle bed propulsion reactor invented by Dr. James Powell at Brookhaven National Lab and Dean considers more typical possibilities.



Profiles of Symposium Creators

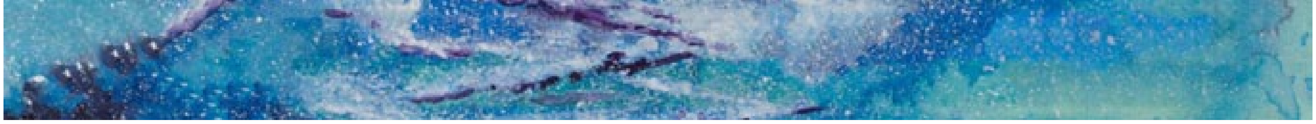


John D.G. Rather, PhD

Dr. John D.G. Rather, General Chair of the *Power of Synergy* Symposium, is known internationally as a scientific innovator and creator of major technology programs. He obtained his BS in Physics at the University of Tennessee, Knoxville, and his MS and PhD in Astronomy at the University of California, Berkeley. His experience in business and government spans defense, space, medical, and industrial communities. Dr. Rather worked in physics and space research at Oak Ridge National Lab, Lawrence Livermore National Lab and the National Radio Astronomy Observatory before moving into private business and US government senior appointments. As VP of Kaman Aerospace Corporation, he created *StarLab*, which with co-contractors became the largest R&D program of the Strategic Defense Initiative with total funding of $630 Million. In 1990, Dr. Rather was recruited to NASA HQ to accelerate space systems development. In 1992, he served as Chairman of the NASA/DOE study of asteroid impact prevention mandated by the U.S. House of Representatives. Asteroid 7290 is named “Johnrather” in his honor. For more than twenty years he was also a contributor at the D.I.A. and the C.I.A. Dr. Rather moved back to Oak Ridge, Tennessee in 2006 and founded RCIG Inc. and Sisyphus Energy Inc. to create and develop focused revolutionary technology breakthroughs. The *Power of Synergy* Symposium is the latest example. His websites are www.RCIGinc.com and www.sisyphusenergy.com . Contacts are jrather@RCIGinc.com.

Dean S. Hartley III, PhD

Dr. Dean Hartley, Co-Chair of The *Power of Synergy* Symposium, is known internationally as a problem solver and expert in operations research (OR). He has been solving problems for customers for almost fifty years: two years while obtaining his PhD in Mathematics, four years while on active duty in the Army, nine years in private industry, fifteen years at the Oak Ridge Federal Facilities, and seventeen years as Principal of Hartley Consulting. Hartley is a Director of the Military Operations Research Society (MORS), a past Vice President of the Institute for Operations Research and Management Science (INFORMS), and past President of the Military Applications Society (MAS). Hartley has published *An Ontology for Unconventional Conflict, Unconventional Conflict: A Modeling Perspective, Predicting Combat Effects*, co-authored two other books, contributed numerous chapters to other books, and written more than 150 articles and technical documents. In 1994 he was awarded the Koopman Prize for best publication in military operations research and in 2013 he was awarded the Steinhardt Prize for lifetime achievement in operations research. The Hartley Consulting website is http://drdeanhartley.com/HartleyConsulting/index.htm



APPRECIATIONS

Symposium Executive Committee

(with John D. G. Rather and Dean Hartley III)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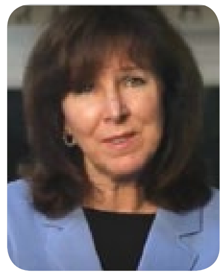
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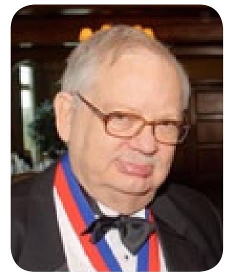
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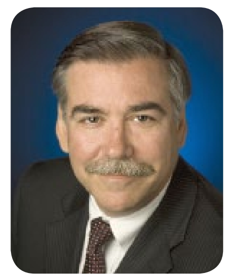
Mark Uhran

Major Symposium Facilitators


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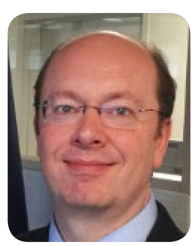
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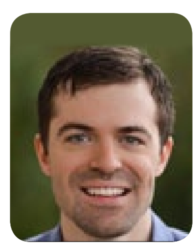
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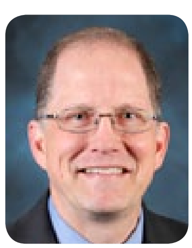
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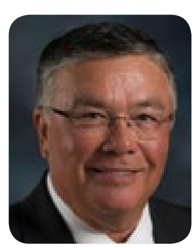
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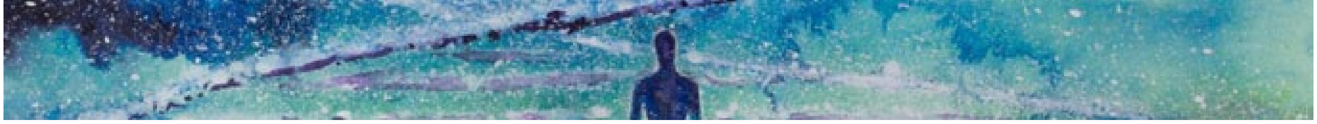
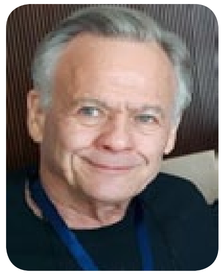


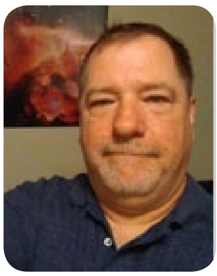
Planning and Production Committee

John C. “Buck” Field



David Fields, PhD

Linda Fippin



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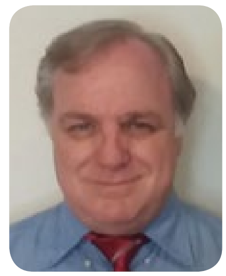

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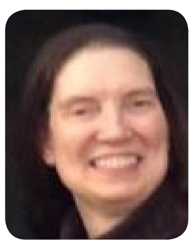
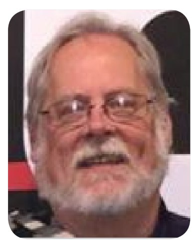


Martha Knowles



Edward “Sandy” Montgomery

Ken Roy

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